ORIGINAL

The correlation between anthropometric variables and body fat percentage in military young adults at the Brazilian Air Force

La correlación entre las variables antropométricas y el porcentaje de grasa corporal en los adultos jóvenes de la Fuerza Aérea Brasileña

Correlação entre variáveis antropométricas e o percentual de gordura em militares adultos jovens da Aeronáutica

Ten Cel Inf Pedro Celso Gagliardi Palermo, Mestre
Comissão de Desportos da Aeronáutica - CDA
Rio de Janeiro/RJ - Brasil
pcgagliardi@gmail. com

ABSTRACT

This work aims to investigate to what extent the variables related to weight, height and waist circumference (WC) of the Brazilian Air Force Command Militaries (COMAER) between 20 and 30 years old, assessed by the Physical Fitness Assessment Test (PFAT) in 2012, correlate with body fat percentage (%BF). The research group consisted of 986 men and 196 women from 10 different Military Organizations from the COMAER. The body mass index (BMI), the waist circumference, the waist-to-height ratio (WtHR), and the waist product -BMI (WPBMI) were the independent variables and the %BF estimated by skinfold, was the dependent variable. The highest values for men, found for the Pearson correlation coefficient (r), were 0.709, when combined with WPBMI, and 0.624 for women, when associated with BMI. The regressions of %BF had coefficients of determination (R^2) of 59.6% for CC and 64.2% for WPBMI, when taking into account gender and age. In conclusion, the correlations must be used with caution in determining %BF. Nevertheless, this research revealed that the WPBMI, because it is an index linked to the amount and distribution of body fat, has the potential to be a new indicator in the clinical evaluation of body composition. It is suggested the execution of new research to clinical validation of WPBMI, and the adoption of other sites for the determination of %BF using anthropometric variables.

Keywords: Percentage of fat. Anthropometry. Body mass index. Waist circumference.

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RESUMEN

Este trabajo tuvo como objetivo investigar en qué medida las variables relacionadas con el peso, estatura y circunferencia de cintura (CC) de los militares del Comando da Aeronáutica (COMAER) entre 20 y 30 años, evaluados por la prueba de evaluación de la condición física (PECF) en 2012, se correlacionaron con el porcentaje de grasa corporal (% GC). El grupo de investigación ha sido formado por 986 hombres y 196 mujeres de 10 organizaciones militares del COMAER. El índice de masa corporal (IMC), la CC, relación cintura-estatura (RCE), y el producto de la cintura IMC (PCIMC) fueron las variables independientes y % GC, estimado por los pliegues cutáneos, la dependiente. Los mayores valores para el coeficiente de correlación de Pearson (r) encontrados fueron de 0,709 para los hombres, cuando se combina con PCIMC, y 0.624 para las mujeres, cuando se asocian con el IMC. Las regresiones de % GC tuvieron coeficientes de determinación (R^2) de 59,6 % para CC y el 64,2 % para PCIMC cuando se consideró el sexo y la edad. En conclusión, las correlaciones se deben utilizar con precaución en la determinación de % GC. Sin embargo, esta investigación mostró que el PCIMC, ya que es un índice relacionado con la cantidad y distribución de la grasa corporal, tiene el potencial de ser un nuevo indicador en la evaluación clínica de la composición corporal. Se sugiere la necesidad de nuevas investigaciones para la validación clínica de PCIMC, y la adopción de otros sitios para la determinación del % GC utilizando variables antropométricas.

Palabras-clave: *Porcentaje de grasa. Antropometría. Índice de masa corporal. Circunferencia de la cintura.*

RESUMO

Este trabalho teve por objetivo investigar em que medida as variáveis relacionadas ao peso, à estatura e à circunferência da cintura (CC) de militares do Comando da Aeronáutica (COMAER) entre 20 e 30 anos, avaliados pelo Teste de Avaliação do Condicionamento Físico (TACF) em 2012, se correlacionam com o percentual de gordura (%GC). O grupo de pesquisa foi composto de 986 homens e 196 mulheres de 10 Organizações Militares do COMAER. O índice de massa corporal (IMC), a CC, a razão cintura-estatura (RCE), e o produto cintura - IMC (PCIMC) foram as variáveis independentes e o %GC, estimado por meio de dobras cutâneas, a dependente. Os maiores valores para o coeficiente de correlação de Pearson (r) encontrados foram de 0,709 para homens, quando associados ao PCIMC, e 0,624 para mulheres, quando associados ao IMC. As regressões do %GC apresentaram coeficientes de determinação (R^2) de 59,6% para a CC, e de 64,2% para o PCIMC, quando considerados o sexo e a idade. Como conclusão, as correlações devem ser empregadas com cuidado na determinação do %GC. Apesar disso, esta pesquisa apresentou o PCIMC que, por se tratar de um índice associado à quantidade e à distribuição da gordura corporal, tem potencial para ser um novo indicador na avaliação clínica da composição corporal. Sugere-se a realização de novos trabalhos para validação clínica do PCIMC, bem como a adoção de outros sítios para a determinação do %GC por meio de variáveis antropométricas.

Palavras-chave: *Percentual de gordura. Antropometria. Índice de massa corporal. Circunferência da cintura.*

1 INTRODUCTION

The Brazilian Air Force Command (COMAER) uses several criteria for evaluating the performance of its staff and among them is the Physical Fitness Assessment Test (PFAT) regulated by the instruction of the Brazilian Air Force Command (ICA) 54-1 (BRAZIL, 2011).

This instrument was designed to measure the minimum physical conditions that all active duty military of the Brazilian Air Force must have, considering their age and gender. Their results imply conceptual classifications; ultimately will result in points in the Assessment of the Military Merit of each member of the contingent.

The PFAT is composed by a list of tests that measure aerobic capacity, muscular strength, flexibility and body fat percentage, which are the components of health-related physical conditioning. Regarding the assessment of the body fat percentage, the method used is the measurement of skinfolds. Once carried out the measurements at specific sites in the human body, the sum of skinfolds is used in regression equations that calculate body density and percentage of adipose tissue present in the body.

Each military member is still subjected to the measurement of height, body mass (weight) and waist circumference. The combination of these three variables has a good relationship with blood laboratory data and, depending on the combination, they provide useful and low cost clinical information about the health status assessed, especially those related to obesity and metabolic disorders associated with it (AMERICAN COLLEGE OF SPORTS MEDICINE, 2003).

In addition to providing important information about the physical condition of each military, PFAT still has another purpose: provide data to the Commissions of Officers Promotions and Graduated for conceptual classification of military merit of each member of the contingent. In this sense, the tests for PFAT must use methods and insightful, accurate and equitable procedures in order to avoid the occurrence of measurement errors that surely would have impact on the classification of the relative merit of each military member tested.

The most critical assessment for accuracy in the collection of data is referred to by way of the body fat percentage through the skinfolds. There are several potential errors that can result in incorrect assessments of the body fat percentage when the skinfolds are used as a method of measurement. The intra- and inter-evaluator errors stand out, the difference in the use of different instruments and the use of regression equations are not compatible with the population evaluated (POLLOCK; WILMORE, 1993; HEYWARD; STOLARCZYK, 2000; AMERICAN COLLEGE OF SPORTS MEDICINE, 2003).

Heinrich *et al.* (2008) and Flegal *et al.* (2009) suggest that waist circumference (WC) and body mass index (BMI), in turn, are easier to measure, because they involve simpler procedures and use equipment whose handling is easier than the skinfold caliper, thereby reducing the probability of error of the evaluators.

Deurenberg, Weststrate and Seidell (1991) demonstrated that it is possible to predict the body fat percentage using simple anthropometric measures such as BMI and WC. Some studies with Brazilians also demonstrate a correlation between anthropometric indicators such as the body fat percentage, but they were performed with samples restricted in size (DUMITH *et al.*, 2009).

The anxiety came when they visualized the possibility to follow the recommendations of Dumith *et al.* (2009) for studies with larger populations, which would be made possible by taking as basis the database available on the Sports Commission of the Brazilian Air Force (CDA), since there are a lot of PFAT results made on military members throughout Brazil.

In this context, this study aimed to investigate to what extent the variables related to weight, height and waist circumference of the military of COMAER, between 20 and 30 years old, who were valued by PFAT in 2012, correlated with the body fat percentage.

Research shows it is relevant as it seeks to deepen the knowledge on the prediction of body fat percentage using methods that have a lower probability of error on the part of the evaluators, in order to maintain equitable conditions for measuring this important physical quality in military members of COMAER for the age group in question.

2 THEORETICAL FOUNDATIONS

In order to establish the relationships between the variables under study, it is important to understand the concepts of each one of them, their interactions with the professional military fitness and health, as well as identifying potential errors in data collection that may impact the assessment and interpretation of their meanings.

According to the manual of the International Society for the Advancement of Kinanthropometry - ISAK, published by Stewart *et al.* (2011), the waist circumference (WC) is the measure of the abdominal perimeter at its narrowest point.

BMI is the ratio of body mass (weight) expressed in kilograms divided by the squared height in meters, being represented by the equation BMI = weight/height^2, and its measure unit is kg/m^2 (HEYWARD; STOLARCZYK, 2000). The Waist-to-Height Ratio (WtHR) is the ratio of the measure of WC divided by the height, although less used; it has been demonstrated as an important predictor of cardiovascular risk in adults (DUMITH *et al.*, 2009).

The waist product-BMI (WPBMI) deals with the relationship between the distributions of fat in the human body with the body mass index. Studies show that many health problems are related to waist circumference and increased BMI, especially when it is greater than 25 kg/m^2 and greater than 102 cm in men and 88 cm in women (WEI *et al.*, 1996; JANSSEN *et al.*, 2002). However, there is a standard error when using BMI to classify obesity because individuals with high muscle mass are strong and heavy and do not necessarily present the same risks as obese people, although the absolute value of BMI is also high (AMERICAN COLLEGE OF SPORTS MEDICINE, 2003).

The distribution of fat in the body got from the waist circumference is also recognized as an important indicator of the risks of obesity on health. Individuals with more fat in their torso, especially abdominal fat, are at increased risk of hypertension, Type 2 diabetes, hyperlipidemia, coronary artery disease and premature death compared with equally fat individuals, but with most of fat localized in the extremities (WEI *et al.*, 1996; AMERICAN COLLEGE OF SPORTS MEDICINE, 2003; JANSSEN; KATZMARZYK; ROSS, 2004;). For this reason, researchers have tried to associate waist circumference with BMI and its relationship with the body fat percentage in the prediction of health risks.

The body fat percentage, or relative body fat (%BF), is defined as fat mass (FM), expressed as percentage of the body mass and total body weight (BW), where %BF = (FM/BW) x 100. Fat mass is composed of all the lipids extracted from adipose tissue and other body tissues (HEYWARD; STOLARCZYK, 2000).

The most accurate assessment method for measurement of body fat is the body dissection. However, as it may not be applied to living beings, several indirect ways to estimate %BF were developed, such as: the analysis of bioelectric impedance, plethysmography, dual energy X-ray radiological absorptiometry, magnetic resonance imaging, hydrostatic weighing, infrared interactance, among others. Such methods, however, involve high costs and judicious methodological details to be administered so as to not compromise its applicability in large scale (DUMITH *et al.*, 2009).

Given this situation, and considering the logistical and operational costs are greatly reduced, the scientific community has been developing and improving anthropometric methods in order to estimate body fat percentage that, despite being less precise, can offer an important information about body composition (HEYWARD; STOLARCZYK, 2000).

Stewart *et al.* (2011) defines anthropometry as the scientific procedures and processes of acquiring the dimensional measurements of the anatomical surfaces such as lengths, widths, circumferences (perimeters) and skinfolds of the human body through the use of specific equipment.

Following this global trend, COMAER has been seeking ways to enhance the professional military physical fitness assessment, in order to provide subsidies to improve the physical fitness of its contingent.

According to the ICA 54-1, regardless of the role they play in COMAER, all military members are obligated to achieve the Minimum Performance Standard (MPS) for their age and gender.

The instrument for assessment of MPS is the Physical Fitness Assessment Test (PFAT), which follows the guidelines of the American College of Sports Medicine (ACSM) and assesses cardiorespiratory fitness, body composition, muscular strength and flexibility (AMERICAN COLLEGE OF SPORTS MEDICINE, 2003).

In terms of body composition, the American College of Sports Medicine (2003) reiterates that the anthropometric methods are an alternative to other indirect methods described. However, because of the relatively large standard error of the estimate of the body fat percentage solely from BMI (± 5% fat), this should not be used in isolation to determine the body fat of the individual during a physical fitness assessment, and one should therefore include other variables in order to determine this component of the physical fitness.

The skinfold method (SF), although more difficult to apply, provides better estimates of %BF than the one based only on BMI and, for this reason, the COMAER, through the CDA, has adopted this practice since 2000 when the first version of the ICA 54-1 was published.

The CDA, in its annual work program, has sought to standardize procedures, train applicators of PFAT and inspect the various OM of COMAER about the quality of the tests throughout the country. Nevertheless, increasing difficulties have been reported with regard to inspecting the collection quality of the skinfold data in all OM of COMAER.

In a recent study, Lopes Júnior (2013) found that only 10 out of more than 300 OM of COMAER followed all procedures for collecting anthropometric data provided by ICA 54-1 when applying the TACF in 2012.

Ignoring the need for methods of measurement of skinfolds can lead to intra and inter-evaluators errors that turn out to be as significant as those described for the estimation of the BMI. On this issue, Lohman *et al.* (1984) point out that the validity and reliability of skinfold measurement are affected by the ability of the evaluator, the type of instrument used and the prediction equations used to estimate body fat.

In review of the subject, Heyward and Stolarczyk (2000) reported that between 3% and 9% of the variability in skinfold measurement could be attributed to measurement errors existing between different evaluators. Pollock *et al.* (1986) found a 10% systematic error in the measurement of skinfolds in different locations, in both men and women. The authors reported that the reliability between different evaluators is increased when all of them follow the procedures for standardized tests, practice skinfolds measurements together and mark the location of the folds.

Flegal *et al.* (2009) in a study of population sizes (n = 12901 adults) propose tables in which the distribution of body fat percentage is corresponding to the distribution of BMI, WC and WtHR. Thus, for a given percentile range of one or more of these variables, there are equivalent percentile intervals for body fat percentage. Thus, the authors propose a classification of reviews by intervals rather than fixed percentages values for the assessment and classification of body composition.

Katch and McArdle (1988, *apud* Pollock, Wilmore, 1993) also propose other anthropometric sites in order to estimate %BF in men and women, such as waist circumference at the height of the umbilicus, hip, thigh, arm and forearm circumferences.

Similarly, the United States Air Force uses only the waist circumference at the height of the iliac crest, in order to assess the body composition of its military, classifying them through specific points tables for men and women (UNITED STATES AIR FORCE, 2013).

Likewise, Deurenberg, Weststrate and Seidell (1991), in a study with 1229 individuals between 7 and 83 years old, of both sexes, correlated the BMI, gender and age with %BF, proposed its prediction by regression equations. The authors found a coefficient of determination (R^2) of 0.79 and standard error of estimate having 4.1% compared to %BF, pointing out that the prediction error is comparable with other methods for determination of the body fat percentage through skinfolds and bioelectrical impedance.

Although it seems clear that BMI is an important indicator for health, their relationship with the body fat percentage is different for each ethnic group. Deurenberg, Deurenberg-Yap and Staveren (1998) reported that there are different levels of BMI for the same body fat percentage studied, when considering distinct populations such as Balkan, Chinese, Ethiopians, Indonesians, Polynesians and Thais. The authors also suggested that there should be different cutoff points in the BMI classification for each specific population.

In Brazil there are few studies that attempt to estimate the body fat percentage through BMI and waist circumference. Dumith *et al.* (2009) studied 54 young adults of both sexes, between 17 and 33 years old in southern region of Brazil. Besides the BMI and waist circumference, the authors included the waist-to-height ratio (WtHR) and the waist-hip ratio (WHR) in association with the body fat percentage calculated using 4 skinfolds. The authors presented equations with high coefficient of determination (R^2> 80%) and low standard error of estimate (SEE <0.09), but they suggest that further studies should be conducted in more representative samples.

3 METHODOLOGY

This research had a transverse nature and used the method of deductive reasoning of a quantitative nature. The theoretical framework used was grounded in the preparation of ICA 54-1, with books and texts from journals presenting publications related to the anthropometry study. The results were also discussed in the light of other research conducted with foreign individuals and Brazilians.

For selection of the sample, they used the method proposed by Lopes Júnior (2013). This process was based on the database of the CDA and therefore suitable for studies with COMAER military. Men and women, between 20 and 30 years old (inclusive) were selected, from the Military Organizations that met the following conditions:

a) they made and sent the results of the second PFAT of 2012 for the CDA. From 312 OM of COMAER, 227 OM (72.75%) met this criterion;

b) they used skinfolds for assessing the body fat percentage. From 227 OM of COMAER, 108 OM (47.57%) met this criterion;

c) Physical Education Sections (SEF) of 108 OM were then instructed to answer the questionnaire on the quality of the anthropometric data collection proposed by Lopes Júnior (2013). From these, 73 OM (67.59%) sent their answers;

d) after the analysis, the author identified that 10 (16.69%) out of 73 OM faithfully followed all the procedures of data collection provided by ICA 54-1; and

e) starting from the PFAT data, from the 10 OM mentioned, the results of all military age group of the study were selected, thus making the sample of 1,154 militaries (986 men and 169 women). According to data from the Personnel Management System of Brazilian Air Force (SIGPES), this number represents 3.11% of the 37,037 military members of COMAER, of both genders, for the age group in question, being 85.44% men and 14,46% women.

As a result of this process, and considering that the data of the present study were collected by applicators of PFAT duly qualified and trained by the CDA, it appears that all procedures were followed described in detail in ICA 54-1 in its Attachment A, fields 7, 8 and 9, respectively, referred to weight, height and waist circumference (WC), and Attachment C (full) for triceps, suprailiac, pectoral, abdominal and thigh skinfolds (BRAZIL, 2011).

Weight was measured by mechanical or digital scales with a resolution of 100g and stature through stadiometers or measuring tapes glued to the wall with a resolution of 0.5 cm. Waist circumference (WC) was collected with a flexible tape measure with a resolution of 1 mm. The WC measurement was carried out at its narrowest point between the edge of the 10th rib and the upper edge of the iliac crest, perpendicular to the longitudinal axis of the torso.

BMI (kg/m^2) was calculated by dividing weight (in kg) by the square of height (meters). WtHR was obtained by dividing the WC by the height (both in cm) and WPBMI (kg/m) was the result of the product between the WC (meters) and BMI (kg/m^2).

The body fat percentage, as prescribed by the ICA 54-1, was calculated from the Siri equation (1961). Thus, the value of body density was calculated by dividing the sum of 3 skinfolds, and the pectoral, abdominal and thigh for men (JACKSON; POLLOCK, 1978) and the triceps, supra-iliac and thigh, for women (JACKSON; POLLOCK; WARD, 1980).

Once selected, the data were evaluated by independent study variables (WC, BMI, WtHR and WPBMI) and the dependent variable (%BF) was isolated. Then, several spreadsheets were created in Microsoft Excel, where statistical calculations were made. For descriptive analysis, we calculated the averages, standard deviations (SD), minimum and maximum values, which have undergone the test of Student t test in order to check whether there was a significant difference between the genders.

The association of the outcomes between %BF and each independent variable alone was tested by means of linear regression, obtaining the Pearson correlation coefficient (r), the coefficient of the variable (beta) and its standard error, the value of p, the coefficient of determination R^2, and the standard error of estimate (SEE).

In order to associate more than one independent variable in the same equation (multiple regression) for prediction of %BF, auxiliary regressions tests (simple) were applied before and between WC, BMI, WtHR and WPBMI (test of multicollinearity). The purpose was to check if there is dependency or independency among them, since, in some cases, a mathematical function is different and, therefore, there may be a strong association between them. For example: WPBMI is the product of WC with BMI. Thus, it is suspected that the WPBMI and BMI would show a strong dependence on each other, which may affect multiple regressions and, for this reason, should be avoided. Both, were excluded from the prediction models %BF, combinations of independent variables with present an $R^2 > 80\%$ in the auxiliary regressions.

Finally, models for prediction of %BF were created through multiple regressions that considered gender, age and at least one of the independent variables. In other multiple regressions, we also considered gender and age, and two or more independent variables were aggregated, provided that the conditions of multicollinearity test were met.

The software used to process the statistical calculations was Microsoft Excel 2007, using the 'Data Analysis - Regression' tool, and other statistical functions available. Appropriate correlations were considered that had Pearson coefficient $r \geq 0.90$ and coefficient of determination $R^2 \geq 0.80$. A index $p \leq 0.05$ of significance was accepted.

Although this study presents a process for selecting data and methodological design that seeks to mitigate the effects of measurement errors on the results, it still has limitations. The selection process adopted does not guarantee that the data have sufficient validity and reliability, mainly because it has not been possible to investigate precisely the intra and inter-evaluators existing among all applicators of PFAT of OM selected.

The CDA, presents quantitative data that can attest to the accuracy and expertise in the application of PFAT, therefore require conducting validation studies, in the same was as presented by Lhoman *et al.* (1984).

Another issue relates to the lack of cross-validation form the %BF estimates. The prediction equations of body fat percentage using the anthropometric variables must be confirmed by calculating the standard error of the estimate based on another process of indirect assessment of body composition such as hydrostatic weighing, plethysmography or dual energy X-ray radiological absorptiometry. Because they involve high cost and sophisticated logistics, they could not be performed.

4 RESULTS

Among the 1,154 military assessed, 986 were men and 168 were women. The description of the sample in terms of average, standard deviation, minimum and maximum values, stratified by gender, are presented in Table 1.

Table 1: Description of the sample according to the characteristics studied.

Gender	Variable	Average	Standard deviation	Minimum	Maximum
Men (n=986)	Age (years old)	23,07	2,94	20,00	30,00
	Height (cm)	175,38	6,37	157,00	197,00
	Weight (kg)	75,74	10,73	49,20	116,30
	BMI (kg/m^2)	24,59	2,99	16,63	35,42
	WC (cm)	79,25	8,20	57,00	109,00
	RCE	45,21	4,67	32,61	62,35
	WPBMI (kg/m)	19,67	4,17	10,61	37,41
	%BF (3 folds equation of Jackson and Pollock, 1978)	14,38	5,62	2,46	29,52
Women (n=168)	Age (years old)	26,49	2,59	20,00	30,00
	Height (cm)	163,37	6,00	151,00	183,00
	Weight (kg)	60,94	8,69	45,00	94,00
	BMI (kg/m^2)	22,81	2,81	17,78	34,95
	WC (cm)	70,37	7,55	52,00	98,00
	RCE	43,11	4,66	31,52	59,04
	WPBMI (kg/m)	16,20	3,63	9,93	30,34
	%BF (3 folds equation of Jackson, Pollock and Ward, 1980)	24,49	5,85	12,73	50,77

Caption: BMI - body mass index; WC - waist circumference; WtHR - waist-to-height ratio; WPBMI - Waist product - BMI; and % BF - body fat percentage. Student t test was significant to $p < 0.001$ for men and women for all variables.
Reference: The author.

Table 2: Correlation of body fat percentage measured by skinfold with four anthropometric indicators.

Gender	Variable	Correlation(r)	Coefficient of the variable	EP of the coefficient (%)	Value p	R^2 (%)	SEE (%)
Men (n=986)	BMI (kg/m²)	0,659	1,239	0,045	0,000	43,5	4,225
	WC (cm)	0,668	0,458	0,016	0,000	44,7	4,18
	WtHR	0,657	0,79	0,02	0,000	43,1	4,237
	WPBMI (kg/m)	0,709	0,954	0,03	0,000	50,2	3,964
Women (n=168)	BMI (kg/m²)	0,624	1,299	0,126	0,000	38,9	4,584
	WC (cm)	0,532	0,412	0,051	0,000	28,3	4,966
	WtHR	0,531	0,667	0,083	0,000	28,2	0,968
	WPBMI (kg/m)	0,620	0,999	0,098	0,000	38,4	4,602

Caption: BMI - body mass index; WC - waist circumference; WtHR - waist-to-height ratio; WPBMI - Waist product-BMI; EP - standard error; p Value - index of statistical significance; R^2 - coefficient of determination; and SEE - standard error of the estimate.
Reference: The author.

By applying the Student t test, it was found that there was no statistical difference ($p < 0.001$) compared between men and women for the age, height, weight, BMI, WC, WtHR, the WPBMI and %BF averages.

These results can be explained, at least in part, by the difference of the number (n) between both genders. However, the data selection process proved to be suitable to the extent that the proportion of military members of both genders existing in the COMAER was respected.

Table 2 shows the correlation of the body fat percentage estimated by skinfold with other anthropometric indicators analyzed.

It is observed that in the case of men, the variable that was associated with a greater body fat percentage was WPBMI with $r = 0.709$. For each unit increase in WPBMI, the body fat percentage had an average increase of almost 1 percentage point (0.954%). For women, both BMI as WPBMI showed very similar results with both presenting $r > 0.620$ and coefficient of determination $R^2 > 38\%$.

It should be noted, from Table 2, that all variables (BMI, WC, WtHR and WPBMI) showed a positive correlation with the %BF above 0.65 for males and up to 0.53 for women.

The coefficient of determination (R^2) reflects the degree to which one or more independent variables Y determine the dependent variable X. Its value can be interpreted as a percentage, indicating the percentage in X variance that is explained by Y variance.

The highest coefficient of determination (R^2) presented in Table 2 for men was 50.2% and related to WPBMI. This means that this indicator alone is able to explain only 50.2% of the variation in distribution of %BF of the sample. As a result, the other 49.8% of the variation in %BF is not explained by the WPBMI, and it is not possible to identify what are the other factors are that could mediate the correlation. For women, BMI explains only 38.9% of the variation in the %BF of the sample. For this reason, it is understood that the highest values of R^2 were only moderate, as there is a considerable amount of variation unexplained.

The standard error of the estimate is less than 5% for all correlations. Despite being within the standards of other studies, as pointed out by Deurenberg, Weststrate and Seidell (1991), their meanings corroborate the idea that the association is not strong enough to be adopted without restrictions.

Table 3 presents the results of the auxiliary regression for multicollinearity test.

Table 3: Test of multicollinearity among the independent variables.

Gender	Indicators	BMI with WC	BMI with WtHR	BMI with WPBMI	WC with WtHR	WC with WPBMI	WtHR with WPBMI
Men	Pearson (r)	0,727	0,729	0,937	0,939	0,915	0,887
	R^2	0,528	0,532	0,879	0,881	0,837	0,787
	p-Value	0,000	0,000	0,000	0,000	0,000	0,000
Women	Pearson (r)	0,742	0,740	0,944	0,943	0,916	0,884
	R^2	0,550	0,548	0,891	0,890	0,838	0,782
	p-Value	0,000	0,000	0,000	0,000	0,000	0,000

Caption: BMI - body mass index; WC - waist circumference; WtHR - waist-to-height ratio; WPBMI - Waist product-BMI; Pearson (r) - Pearson coefficient of determination; p-Value - index of statistical significance and R^2 - coefficient of determination.
Reference: The author.

As pointed out by the results in Table 3, the coefficient of determination was high ($R^2 \geq 0.80$) in both genders for BMI with WPBMI, WC with WtHR and WC with WPBMI. Therefore, as detailed in the methodology, the associations of these variables together were excluded from the multiple regression prediction of %BF.

Table 4 presents the regression equations, considering gender and age, taking as a basis each of the four variables in isolation, and also BMI with WC, BMI with WtHR and WtHR with WPBMI because they had met the criteria of the collinearity test.

It is observed that the largest R^2 adjusted was approximately 64% and SEE < 4.0% for both regressions in which the WPBMI was one of the indicators. These results indicate that the predictions should be considered carefully as they present moderate coefficients of determination.

Table 4 also shows that in all equations in which BMI was one of the variables, there was some restriction on their use. In theory, %BF is expected to increase with any increase in BMI, since both are directly proportional, as shown by the data presented in Table 2. However, in two of the equations presented, %BF decreases with the increasing of BMI. This paradox is evidenced by the fact that the coefficient that multiplies the BMI has a negative value (see highlights in bold in Table 4). On the other hand the equation having BMI and WC as indicators, presents p-Value = 0.476 (also in bold), therefore not achieving the statistical significance criterion determined. As a result, the last three equations in Table 4 were removed from subsequent analysis.

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5 ANALYSIS OF RESULTS

This research is one of the few Brazilian studies that associates anthropometric variables with the body fat percentage in a large and representative sample size of a particular population.

The data from this study contradict in part some of the studies previously cited. Flegal *et al.* (2009) present stronger correlations with Pearson correlation (r) greater than 0.78 for men and 0.80 for women, for the association of body fat percentage with BMI, WC and WtHR. In this research, as shown in Table 2, the highest values of the Pearson correlation coefficient (r) are on the order of 0.709 for men (when combined with WPBMI) and 0.624 for women (when associated with the BMI).

When considering gender and age, Dumith *et al.* (2009) found $R^2 > 80\%$ for BMI, WC and WtHR. Likewise, Deurenberg, Weststrate and Seidell (1991) found $R^2 = 79\%$ for regression of %BF using the BMI, age and gender. This study, however, reached the lowest coefficients of determination on the order of 59.6% for WC and 64% for WPBMI and WtHR and WPBMI in their respective associations with %BF (Table 4).

From this comes the understanding that the correlation between anthropometric variables with the body fat percentage, as well as the use of regression equations for the population of the military members of COMAER of both genders, should be interpreted with caution. The highest coefficient of determination found indicates that the variation of values of WtHR, WPBMI, age and gender only explain about 64.3% of the variation in %BF, still leaving a total 35.7% that the model does not explain.

Table 4: Prediction equations for % BF from BMI, WC, WtHR and WPBMI considering gender and age.

Indicators	Equation&	R^2 adjusted	SEE	p-Value
WC	%BF = -38.948 + 13.088 * gender + 0.254 * age + 0.434 * WC	59,6 %	4,24%	0,000
WtHR	%BF = -36.321 + 10.702 * gender + 0.282 * age + 0.741 * WtHR	58,9 %	4,28%	0,000
WPBMI	%BF = -22.183 + 12.436 * gender + 0.256 * age + 0.927 * WPBMI	64,2 %	3,99%	0,000
WtHR and WPBMI	%BF = -24.758 + 12.296 * gender + 0.253 * age + 0.110 * WtHR + 0.816 * WPBMI	64,3%	3,99%	0,044
BMI	%BF = -5.548 + 13.869 * gender + 0.909 * age -**0.296** * **BMI**	56,9 %	4,38%	0,000
BMI and WC	%BF = -41.719 + 12.975 * gender + 0.196 * age + 0.470*CC + 0.036 * BMI	59,6%	4,24%	**0,476**
BMI and WtHR	%BF = -27.389 + 11.880 * gender + 0.484 * age -**0.134** * **BMI** + 0.526 * WtHR	59,4 %	4,25%	0,000

Caption: & Gender Male = 1, Female = 2; age in complete years.
Reference: The author.

The reasons for the difference between this and other studies may be based on sample characteristics and other methodological aspects. Dumith *et al.* (2009) were limited to research 24 university men and 30 university women of the southern region of Brazil, but they adopted stringent procedures for collecting anthropometric data, since all of them were evaluated in the laboratory. They also used Guedes protocol with 4 skinfolds in order to estimate %BF. On the other hand, Deurenberg, Weststrate and Seidell (1991) studied 521 men and 708 women, age between 7 and 83 years old, so inclusive from children through senior citizen, and estimated the body fat percentage through densitometry. Another issue to be considered is the fact that the male and female samples of this study have shown heterogeneity proven by the significant differences ($p < 0.000$) presented in Table 1. This may have affected the coefficients of determination (R^2) of the regression equations shown in Table 4, as the variables do not behave in the same manner in both genders.

An alternative to the value of %BF as an assessment variable for body composition is the location and the distribution of body fat, usually measured by waist circumference. According to the American College of Sports Medicine (2003), the pattern of body fat distribution is recognized as an important predictor of the risk of obesity for health. Individuals with higher waist circumference have a higher risk of hypertension, Type 2 diabetes, hyperlipidemia, coronary artery disease and premature death.

This research found a paradox about the BMI as a decisive indicator of %BF, causing us to reflect on its true value as a body composition assessment index. About it, Wei *et al.* {(1997), in a prospective study} highlighted that WC is a better indicator than BMI in determining obesity related to Non-Insulin Dependent Diabetes Mellitus (NIDDM). Janssen, Katzmarzyk and Ross (2004) indicate that it is the WC and not the BMI that explains the health risks related to obesity. These findings suggest that the distribution of fat, especially localized in the abdominal region, is more important to the health than the total amount of fat.

Flegal *et al.* (2009) focused in determining ranges of WC, BMI and WtHR that are related to intervals of total fat percentage, corroborating the idea that the point value of the percentage of fat may not be the variable of greatest clinical significance in the body composition assessment. This trend reinforces the fact that the United States Air Force (USAF) use waist circumference, measured at the iliac crest (therefore in a site where pressure is higher than that stipulated in this study), as a criterion for assessing body composition of its military of both genders (UNITED STATES, 2013).

About the site DC, Katch and McArdle (1988, *apud* Pollock, Wilmore, 1993) also propose another site beyond the abdominal adopted by ICA 54-1 (2011). In addition, the authors also suggest other measurement circles such as the hip, thigh, arm and forearm in the regression of %BF.

The results of this study, combined with the findings of the above authors suggest that other perimeters and anthropometric indicators can also be associated with body composition assessment.

Thus, although this research has not found strong correlations between anthropometric variables and %BF, the proposed objectives were met, because it was found that there is a positive association between them.

In addition, this research presents a new association between WC and BMI, translated by WPBMI. As far as it could be reviewed, there are frequent associations between weight, height and waist circumference, translated by BMI and WtHR. However, this seems to be one of the first studies to present the Waist Product with BMI (WPBMI) as a potential indicator to be considered in future body composition assessments.

The proposition of the WPBMI as another indicator analysis is based on the fact that both the WC and BMI show a positive correlation with the amount and the distribution of total body fat, associating both meanings to a single variable. By being directly (and not inversely) proportional, the product of both indicators seems to be more appropriate than the ratio between them. Despite the correlations being only moderate, the WPBMI, even adopting the lower abdominal circumference, was the best index associated with body fat percentage in the studied sample.

6 CONCLUSION

The COMAER, through the PFAT, applies the measurement of skinfolds for body composition assessment. However, it was found that the low quality of these measures might compromise the outcome of the estimation of body fat percentage.

Anthropometric measures have received increasing attention from researchers, first for being associated with risks related to health, and second, because they are simpler measurements to be performed in large populations.

This research aimed to investigate to what extent the variables related to weight, height and waist circumference of the military members of COMAER, between 20 and 30 years old, who were valued by PFAT in 2012, correlate with the body fat percentage.

To do so, this research selected data from physical tests of OM that followed the PFAT application procedures, as prescribed in ICA 54-1.

This procedure allowed us to ascertain data on 986 men and 196 women. It used Microsoft Excel 2007 to perform the Student t Test comparison between male and female data. Simple and multiple regressions were also used in order to verify the degree of dependence between WC, BMI, WtHR and WPBMI (multicollinearity test), as well as to estimate %BF, considering gender and age.

The study has some limitations, especially the inability to investigate the intra -and inter-evaluators errors in data collection, as well as convergent validity in predicting fat percentage by other more accurate methods.

Nevertheless, the final opinion is that the study's objectives were achieved, since it was possible to verify the existence of positive associations between anthropometric variables and

%BF in the military members of COMAER. The correlation coefficients (r) were approximately 0.65 to 0.70 for men and 0.53 to 0.62 for women. The highest coefficients of determination R^2 were 50.2% for men and 38.4% for women.

When analyzing the regression of %BF considering gender and age, the best models were those with WPBMI as the variable. Even so, this indicator was able to explain only about 64.0% of the variation in %BF, leaving the other 38% of variation in %BF unexplained by the model. Therefore, the use of the regression must be considered carefully.

As a contribution, this study identified the WPBMI as a potential indicator of body composition assessment. Their results showed positive associations with both the quantity and with the distribution of body fat. It is suggested that further studies investigate the correlation of WPBMI with laboratory indicators determinants of cardiovascular diseases, diabetes mellitus and other disorders associated with obesity, in order to confirm its validity as a useful clinical tool in the body composition assessment.

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