Correlation anthropometrics in resistant hypertensive patients with diagnosis of moderate and severe obstructive sleep apnea

Correlação antropométrica em pacientes hipertensos resistentes com diagnóstico de apneia obstrutiva do sono moderada e grave

João Carlos Moreno de Azevedo *
Tiago de Oliveira Chaves
Elizabeth Silaid Muxfeldt
Michel Silva Reis

Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brazil

Date of first submission: January 3, 2024
Last received: February 12, 2025
Accepted: February 12, 2025
Associate editor: Ana Paula Cunha Loureiro

***Correspondence:** jmorenodeazevedo@gmail.com

Abstract

Introduction: Obstructive sleep apnea (OSA) is characterized by a chronic and progressive disorder that is associated with cardiovascular diseases. **Objective:** To correlate the apnea-hypopnea index (AHI) with anthropometric parameters in patients of both sexes diagnosed with resistant arterial hypertension. **Methods:** A total of 106 patients (57.5% women, mean age 61 ± 8 years) were evaluated, 41 with moderate OSA and 65 with severe OSA. The diagnosis of OSA was made by nocturnal polysomnography. The somatotype was determined and the waist circumference (WC), neck circumference (NC) and hip circumferences were measured, followed by the waist-to-hip ratio, waist-to-height ratio and neck-to-height ratio (NHR). Height and body mass measurements were also collected to calculate the body mass index (BMI). **Results:** Among the participants, 62% were obese, 64% had abdominal obesity and 25% had increased NC. The anthropometric variables that best correlated with AHI were WC (r = 0.325; p = 0.0006), BMI (r = 0.245; p = 0.0115) and NHR (r = 0.245; p = 0.0115) in both sexes. Among women, the best correlation was with WC (r = 0.281; p = 0.0285). **Conclusion:** Anthropometric and body composition variables (WC, BMI, and NHR) are important for patients with OSA, including BMI in women, optimizing the screening of these patients for polysomnography.

Keywords: Anthropometrics measurements. Obstructive sleep apnea. Resistant hypertension.

Resumo

Introdução: *A apneia obstrutiva do sono (AOS) é caracterizada por um distúrbio crônico e progressivo que está associado a doenças cardiovasculares.* ***Objetivo:*** *Correlacionar o índice de apneia-hipopneia (IAH) com parâmetros antropométricos em pacientes de ambos os sexos diagnosticados com hipertensão arterial resistente.* ***Métodos:*** *Foram avaliados 106 pacientes (57,5% mulheres, média de idade de 61 ± 8 anos), 41 com AOS moderada e 65 com AOS grave. O diagnóstico de AOS foi feito por polissonografia noturna. Determinou-se o somatotipo e medidas as circunferências da cintura (CC), pescoço (CP) e quadril, seguidas das relações cintura-quadril, cintura-estatura e pescoço-estatura (RPE). Também foram coletadas medidas de altura e massa corporal para cálculo do índice de massa corporal (IMC).* ***Resultados:*** *Entre os participantes, 62% eram obesos, 64% apresentavam obesidade abdominal e 25% apresentavam CP aumentada. As variáveis antropométricas que melhor se correlacionaram com o IAH foram CC (r = 0,325; p = 0,0006), IMC (r = 0,245; p = 0,0115) e RPE (r = 0,245; p = 0,0115) em ambos os sexos. Entre as mulheres, a melhor correlação foi com a CC (r = 0,281; p = 0,0285).* ***Conclusão:*** *Variáveis antropométricas e de composição corporal (CC, IMC e RPE) são importantes para pacientes com AOS, incluindo o IMC em mulheres, otimizando a triagem desses pacientes para polissonografia.*

Palavras-chave: *Medidas antropométricas. Apneia obstrutiva do sono. Hipertensão resistente.*

Introduction

Obstructive sleep apnea (OSA) is characterized by a chronic, progressive disorder that is associated with cardiovascular diseases, including hypertension, resistant hypertension (RHT) and chronic heart failure.[1] Individuals with this condition have high mortality and morbidity, sympathetic hyperactivity, chronic inflammation, increased oxidative stress, and endothelial dysfunction.[2-4]

Obesity is also a common profile in patients with OSA, leading to metabolic disorders such as insulin resistance and/or diabetes mellitus, hepatic steatosis and dyslipidemia,[5] as well as physiological disorders such as RHT, defined as the lack of blood pressure control when using three classes of antihypertensive drugs, preferably a thiazide diuretic, a renin-angiotensin aldosterone system inhibitor, and a calcium channel blocker, or using four drugs with controlled blood pressure.[6] Some simple, easily accessible, and practical anthropometric parameters should be part of the routine evaluation of patients with OSA. Body mass index (BMI) and neck circumference (NC) are the most used.[7] However, there are other simple tools, already widely used in the assessment of cardiometa-bolic risk and that could possibly help the assess-ment of patients with OSA, especially waist circumference (WC),[8,9] waist/height ratio (WHtR),[10] waist/hip ratio (WHR),[11] and neck/height ratio (NHR).[12]

Thus, the aim of the present study is to correlate the apnea-hypopnea index (AHI) with various anthropometric parameters in adult patients of both sexes who have a diagnosis of RHT and moderate and severe OSA.

Methods

This is a cross-sectional and observational study. The patients included are part of a large cohort of resistant hypertensive patients being followed up at a specialized clinic at a university hospital. The inclusion criteria followed the following parameters: i) presenting a clinical diagnosis of RHT; ii) presenting a clinical diagnosis of moderate and severe OSA defined by the AHI > 15/h; iii) being 18 years of age. On the other hand, the exclusion criteria adopted were: i) individuals with decompensated chronic pulmonary and cardiovascular diseases; and ii) patients who did not accept to participate in the study. The study was approved by the Human Research Ethics Committee of the Hospital Universitário Clementino Fraga Filho - Universidade Federal do Rio de Janeiro (protocol: 3.659.973; CAAE: 18385219.7.0000.5257), where all participants read and signed the informed consent form before being included in the research and obtained the information.

Resistant hypertension

All participants had a previous diagnosis of RHT defined by the use of at least three antihypertensive drugs of different pharmacological classes, preferably including a thiazide diuretic without office blood pressure control. Office blood pressure, heart rate, and antihypertensive drugs in use were registered.

Polysomnography

For the diagnosis of OSA, patients underwent overnight polysomnography at the Sleep Laboratory of the university hospital. The Fast-Poli26i 26-channel digital polygraph with accessories was used to perform the procedure. In addition, the International Classification for Sleep Disorders[13] was used to classify the severity of the disease. OSA was classified as moderate AHI (between 15 and 29/h) and severe AHI (≥ 30/h).[13]

Anthropometric measurements, calculations of body composition, and somatotype

All anthropometric measurements were determined according to the recommendations of the International Society for Advancement in Kinanthropometry (ISAK);[14] the measurements and the respective calculations for the determination of body density (sum of seven skin folds: triceps, mid-axillary, subscapular, pectoral, abdominal, suprailiac and thigh) of Polock,[15,16] of the percentage of fat (used in the formula of Siri: (4.95/(sum of Pollock's 7 folds)-4.5)*100),[17] bone diameters (sum of diameters of biestyloid + wrist biepicondyle + knee biepicondyle), and somatotype by the formula (triceps + subscapularis + supra-iliac)*170.18/height, being classified as: endomorphic (11 to 14), mesomorphic (1 to 10), and ectomorph (0.5 to 9).[18,19] Skin fold thickness was determined using an adipometer (Cescorf Scientific Top Tec 2), and bone diameter measurements were taken using a caliper (Cescorf 60 cm) and expressed in millimeters.

WC (to measure the waist, the midpoint between the anterior superior iliac crest and the last rib was used), hip (the point used to measure the hip is the largest perimeter of the gluteal region at the height of the bilateral greater trochanter),[20,21] and NC (in the standing position at the level of the cricothyroid cartilage)[22] were detemined in centimeters by a metallic measuring tape (Cescorf). Increased WC was defined as WC > 102 cm in men and > 88 cm in women, while increased NC was defined as NC > 43 cm in men and > 41 cm in women. The WHR was calculated by dividing the values found for the waist and hip, the WHtR was the waist divided by height and the NHR was obtained by dividing the NC by height. Finally, measurements of height and body mass were determined, respectively, by a stadiometer (Cardiomed, 0.1 mm) and electronic scale (SHOENLE, 100 g) in order to calculate BMI = kg/m^2. Obesity is defined when the BMI is > 30 kg/m^2.

Statistical analysis

Data were submitted to the normality test (Kolmogorov-Smirnov) and homogeneity test (Levene). Categorical variables were described as percentages, while continuous variables were described as mean and standard deviation because they had a symmetrical distribution. The student test (normal continuous variables) and the chi-square were used for categorical variables. Next, multiple linear regression analysis was used to assess the correlation and explained variance (r^2 an r^2 adjusted) in AHI with BMI, NC, WC, fat percentage, WHR, WHtR, NHR as independent variables. Finally, the multiple linear regression analysis was applied in man and woman participants group. A p-value of < 0.05 was adopted for all inferential analyses. All analyses were conducted using IBM SPSS Statistics version 19.0 (SPSS Inc., Chicago, IL).

Results and discussion

A total of 106 individuals diagnosed with RHT and moderate and severe OSA were eligible. There was no statistically significant difference between the groups in terms of demographic and anthropometric characteristics, blood pressure levels and anti-hypertensive drugs regimen in use (Table 1). Figure 1 presents the multiple regression model showing the AHI predictor variables. NC, WHtR and WHR could explain between 10 and 12% of AHI behavior. Tables 2 and 3 shows the multiple regression model between anthropometric data from the AHI between men and women. Only the variable BMI markedly influenced the AHI among women.

The results found suggest the importance of evaluating simple and practical variables in patients with OSA, due to the ease of execution, practical application and the panorama that these anthropometric variables could help in a possible risk stratification in environments that do not have an assessment considered gold standard.[16] It is worth noting that variables such as BMI and WC are widely used to stratify cardiometabolic risk,[14,22] and can therefore be extrapolated to the assessment of individuals with OSA. The main finding of the present study revealed significant correlations between AHI and NC, WHR and WHR.

Table 1 - Demographic, anthropometrics, and apnea-hypopnea classification of participants

Variables	Total (n = 106)	Moderate OSA (n = 41)	Severe OSA (n = 65)
Age (years)	61.00 ± 8.00	60.00 ± 7.00	61.00 ± 8.00
Female sex*	61 (57.50)	26 (42.60)	35 (57.40)
Body weight (kg)	85.70 ± 17.90	80.50 ± 14.90	89.10 ± 18.90
Height (m)	1.60 ± 0.10	1.60 ± 0.10	1.61 ± 0.10
Body mass index (kg/m^2)	33.20 ± 5.70	31.50 ± 4.70	34.30 ± 6.10
Obesity*	76 (71.70)	26 (63.40)	50 (76.90)
Neck circumference (cm)	39.60 ± 3.80	38.90 ± 3.10	40.10 ± 4.10
Neck circumference ↑.*[1]	26 (24.50)	7 (17.10)	19 (29.20)
Waist circumference (cm)	97.20 ± 13.50	95.00 ± 9.00	98.60 ± 15.60
Waist circumference ↑.*[2]	68 (64.10)	25 (61.00)	43 (66.20)
Waist-to-hip ratio	0.90 ± 0.10	0.90 ± 0.10	0.90 ± 0.20
Waist-to-height ratio	0.60 ± 0.10	0.60 ± 0.10	0.60 ± 0.10
Neck-to-height ratio	0.25 ± 0.02	0.24 ± 0.02	0.25 ± 0.02
Percentage of fat	31.60 ± 5.20	31.40 ± 5.20	31.80 ± 5.30
Apnea-hypopnea index (h)	42.00 ± 21.00	22.00 ± 4.00	54.00 ± 18.00**
Somatotype profile			
Endo – Mesomorphic*	64 (60.40)	26 (40.60)	38 (59.40)
Meso – Endomorphic*	42 (39.60)	15 (35.70)	27 (64.30)
Physiological variables			
Heart rate (beat per minute)	90.00 ± 16.90	86.60 ± 18.30	92.20 ± 15.70
Systolic blood pressure (mmHg)	147.80 ± 28.80	149.70 ± 26.80	146.70 ± 30.20
Diastolic blood pressure (mmHg)	88.70 ± 16.30	89.80 ± 13.70	88.00 ± 17.80
Medications*			
ECAi (%)	54 (59.00)	25 (64.00)	29 (55.00)
AT1 blocker (%)	38 (41.00)	14 (36.00)	24 (45.00)
Beta blocker (%)	73 (79.00)	32 (82.00)	41 (77.00)
Calcium channel blocker (%)	74 (80.00)	34 (87.00)	42 (77.00)
Spironolactone (%)	42 (46.00)	17 (44.00)	25 (47.00)

Note: OSA = obstructive sleep apnea; ECAi = angiotensin converting enzyme inhibitors; AT1 blocker: Angiotensin II AT1 receptor blocker. Data presented as mean ± standard deviation, except for *n (%) = number of patients (percentage). [1]Increased neck circumference: men > 43 cm and women > 41 cm; [2]Increased waist circumference: men > 102 cm and women > 88 cm; **p < 0.05.

Table 2 - Multiple regression model between anthropometric variables and apnea-hypopnea index according to gender

Men (n = 45)	r^2	F	p	ß	lower	upper
Body mass index	0.03	1.29	0.262	0.23	-1.34	3.37
Neck circumference (cm)	0.06	1.43	0.266	-0.34	-8.81	3.37
Waist circumference (cm)	0.08	1.03	0.301	1.32	-0.06	4.10
Fat percentage	0.09	0.10	0.446	-0.13	-2.58	1.45
Waist/hip ratio	0.12	1.43	0.401	1.08	24.50	265.61
Waist/height ratio	0.18	2.66	0.241	-1.15	-686.58	-21.35
Neck/height ratio	0.22	1.92	0.197	0.59	-293.70	1567.90

Note: p < 0.05.

Table 3 - Multiple regression model between anthropometric variables and apnea-hypopnea index according to gender

Women (n = 60)	r2	F	p	ß	lower	upper
Body mass index	0.08	5.04	0.028	0.13	-1.00	1.83
Neck circumference (cm)	0.10	3.09	0.053	-1.23	-16.57	0.54
Waist circumference (cm)	0.10	2.00	0.121	1.96	-0.17	4.67
Fat percentage (%)	0.11	1.67	0.169	0.01	-1.42	1.56
Waist/hip ratio	0.11	1.34	0.125	0.81	-63.48	532.48
Waist/height ratio	0.11	1.11	0.368	-1.78	-862.92	45.99
Neck/height ratio	0.18	1.68	0.132	1.43	2693.50	0.28

Note: $p < 0.05$.

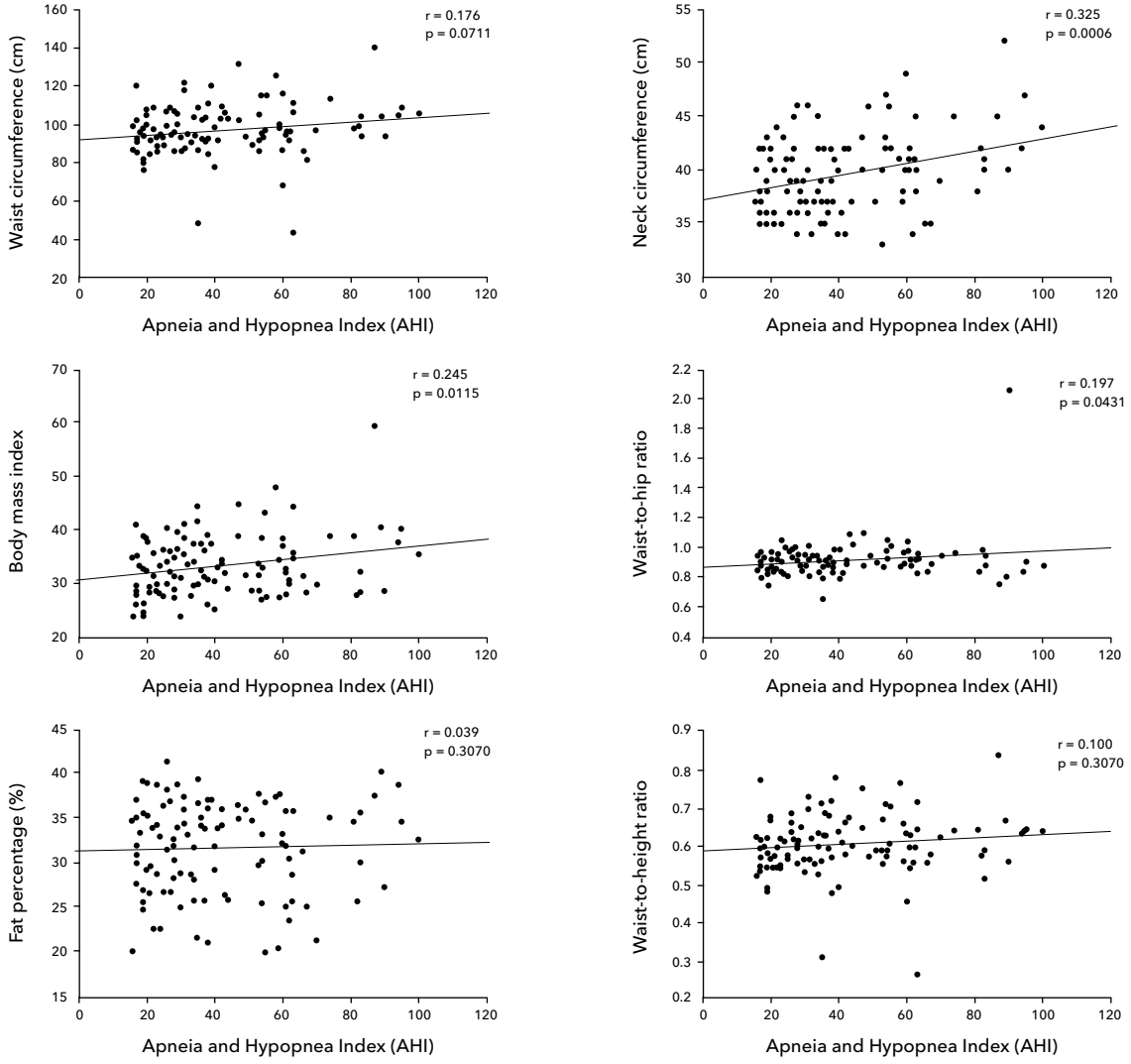

Figure 1 - Multiple regression model between anthropometric variables and apnea-hypopnea index in general population.

According to Nokes et al.,[23] who evaluated a cohort of 1,227 women with BMI > 30 kg/m^2, the AHI was shown to have a significant association with BMI, corroborating our results, where BMI showed a positive and significant correlation with AHI only among women.

In a previous study, Polesel et al.[22] evaluated the importance of anthropometric variables in patients with OSA. The variables measured and correlated with OSA showed different behaviors for the sexes. In men, WHtR and NC were better and correlated with individuals with mild and moderate OSA. Whereas for severe OSA, BMI appeared to be more important and had a greater correlation. In turn, women showed a more important correlation with WC. In the present study, men and women were not evaluated separately, to the detriment of the small number of males. Thus, the correlations of anthropometric variables and body composition presented in the study with the AHI were analyzed globally.

The association between obesity and NC with OSA is already well established, so much so that these anthropometric measurements are used in screening for high risk of OSA in various questionnaires such as the Berlin and the STOP-BANG. In our sample, 62.3% were obese and 24.5% were overweight. With 64.1% of abdominal obesity and 24.5% with increased NC, these conditions could increase associations with cardiometabolic diseases. However, significant results were found among three of the six proposed variables – BMI, WHR and NC, ratifying the importance of evaluating individuals with OSA not only with polysomnography, considered the gold standard.[15] Supposedly, the reason why the correlations showed weak associations in relation to the patients' AHI was the heterogeneity of the body profile of the patients involved in the present study. That is, for even those individuals with obesity conditions and anthropometric parameters above what would be recommended as a cutoff point for both sexes,[13] the anthropometric variables presented a similar profile, regardless of the disease classification, which was composed of moderate or severe OSA.

In a previous study, WC was considered a better predictor of comorbidities than BMI,[24,25] as in other studies that also evaluated WC in individuals with OSA or respiratory disorders.[26,27] It is worth mentioning that WC in both men and women, when they present circumferences above the recommended parameters, is suggestive of central fat accumulation and, consequently, the risks for cardiometabolic diseases are increased.[28] In this sense, greater visceral fat is related to a low-grade inflammatory condition and is associated with the risk of development and diagnosis for individuals with OSA.[29]

Anthropometric variables are essential for determining the body profile in healthy individuals,[30] as well as in patients with different clinical profiles.[31-34] In this way, different anatomical points, such as WC, WHR, WHtR, NC, and body composition parameters such as fat percentage and BMI, should be part of the routine assessment of patients with cardiometabolic disorders[35] and this should also be applied to individuals with OSA.

It is also worth mentioning the positive aspects and limitations of the present study. Regarding the positive aspects, it is important to emphasize polysomnography, a method considered the gold standard for the clinical determination of the diagnosis for patients with OSA. In addition, the anthropometric variables measured and evaluated in the study met the ISAK recommendations.[14] On the other hand, limitations such as the non-inclusion of individuals with mild OSA or without OSA clinical and morphological characteristics different from the patients presented and the non-assessment of body composition by electrical bioimpedance or dual-energy x-ray absorptiometry are noteworthy. In addition, our study evaluated only resistant hypertensive patients, not allowing these data to be extrapolated to hypertensive patients in general.

Conclusion

The data presented allowed us to verify that anthropometric and body composition variables (WC, BMI and NHR) are relevant for patients with moderate and severe OSA, highlighting BMI in women, which can refine the screening of these patients, better targeting performing polysomnography.

Authors' contributions

All authors were responsible for the conception and design of the study, data curation, formal analysis and research, methodology, writing, review, administration and supervision of the project, and approval of the final version.

References

1. Jehan S, Zizi F, Pandi-Perumal SR, McFarlane SI, Jean-Louis G, Myers AK. Obstructive sleep apnea, hypertension, resistant hypertension and cardiovascular disease. Sleep Med Disord. 2020;4(3):67-76.

2. Drager LF, McEvoy RD, Barbe F, Lorenzi-Filho G, Redline S. Sleep apnea and cardiovascular disease: lessons from recent trials and need for team science. Circulation. 2017;136(19):1840-50. https://doi.org/10.1161/circulationaha.117.029400

3. Venkataraman S, Vungarala S, Covassin N, Somers VK. Sleep apnea, hypertension and the sympathetic nervous system in the adult population. J Clin Med. 2020;9(2):591. https://doi.org/10.3390/jcm9020591

4. Baguet JP, Barone-Rochette G, Tamisier R, Levy P, Pépin JL. Mechanisms of cardiac dysfunction in obstructive sleep apnea. Nat Rev Cardiol. 2012;9(12):679-88. https://doi.org/10.1038/nrcardio.2012.141

5. Bray GA, Heisel WE, Afshin A, Jensen MD, Dietz WH, Long M, et al. The science of obesity management: an endocrine society scientific statement. Endocr Rev. 2018;39(2):79-132. https://doi.org/10.1210/er.2017-00253

6. Carey RM, Calhoun DA, Bakris GL, Brook RD, Daugherty SL, Dennison-Himmelfarb CR, et al. Resistant hypertension: detection, evaluation, and management. A scientific statement from the American Heart Association. Hypertension 2018;72(5):e53-90. https://doi.org/10.1161/hyp.0000000000000084

7. Martin MS, Roche F, Thomas T, Collet P, Barthélémy JC, Sforza E. Association of body fat composition and obstructive sleep apnea in the elderly: A longitudinal study. Obesity (Silver Spring). 2015;23(7):1511-6. https://doi.org/10.1002/oby.21121

8. Chaves TO, Reis MS. Abdominal circumference or waist circumference? Int J Cardiovasc Sci. 2019;32(3):290-2. https://doi.org/10.5935/2359-4802.20180080

9. Ross R, Neeland IJ, Yamashita S, Shai I, Seidell J, Magni P, et al. Waist circumference as a vital sign in clinical practice: a Consensus Statement from the IAS and ICCR Working Group on Visceral Obesity. Nat Rev Endocrinol. 2020;16(3):177-89. https://doi.org/10.1038/s41574-019-0310-7

10. Mbanya VN, Kengne AP, Mbanya JC, Akhtar H. Body mass index, waist circumference, waist-hip-ratio and waist-height-ratio: which is the better discriminator of prevalent screen-detected diabetes in Cameroonian population? Diabetes Res Clin Pract. 2015;108(1):23-30. https://doi.org/10.1016/j.diabres.2015.01.032

11. Li R, Shi L, Jia J, Li Y, Yang Q, Ruan Y, et al. Differentiating the associations of waist circumference and body mass index with cardiovascular disease risk in a Chinese population. Asia Pac J Public Health. 2015;27(2):NP457-67.

12. Zhao Y, Yan X, Liang C, Wang L, Zhang H, Yu H. Incorporating neck circumference or neck-to-height ratio into the GOAL questionnaire to better detect and describe obstructive sleep apnea with application to clinical decisions. Front Neurosci. 2022;16:1014948. https://doi.org/10.3389/fnins.2022.1014948

13. Sateia MJ. International Classification of Sleep Disorders - Third edition: highlights and modifications. Chest. 2014;146 (5):1387-94. https://doi.org/10.1378/chest.14-0970

14. Stewart AD, Marfell-Jones M, Olds T, Ridder JH. International standards for anthropometric assessment. Lower Hutt, New Zealand: International Society for the Advancement of Kinanthropometry; 2011.

15. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr. 1978;40(3):497-504. https://doi.org/10.1079/bjn19780152

16. Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. Med Sci Sports Exerc. 1980;12(3):175-81.

17. Siri WE. The gross composition of the body. Adv Biol Med Phys. 1956;4:239-80. https://doi.org/10.1016/b978-1-4832-3110-5.50011-x

18. Silva PRP, Trindade RS, De Rose EH. Body composition, somatotype and proporcionality of elite bodybuilders in Brazil. Rev Bras Med Esporte. 2003;9(6):408-12. https://doi.org/10.1590/S1517-86922003000600005

19. Carter JEL. The Heath-Carter somatotype method. 2nd ed. San Diego: San Diego State University; 1975.

20. Peixoto MRG, Benício MHDA, Latorre MRDO, Jardim PCBV. Waist circumference and body mass index as predictors of hypertension. Arq Bras Cardiol. 2006;87:416-23. https://doi.org/10.1590/S0066-782X2006001700011

21. Oliveira A, Cocate PG, Hermsdorff HH, Bressan J, Silva MF, Rodrigues JA, et al. Waist circumference measures: cutoff analyses to detect obesity and cardiometabolic risk factors in a Southeast Brazilian middle-aged men population-a cross-sectional study. Lipids Health Dis. 2014;13:141. https://doi.org/10.1186/1476-511x-13-141

22. Polesel DN, Nozoe KT, Tufik SB, Bezerra AG, Fernandes MTB, Bittencourt L, et al. Gender differences in the applica-tion of anthropometric measures for evaluation of obstructive sleep apnea. Sleep Sci. 2019;12(1):2-9. https://doi.org/10.5935/1984-0063.20190048

23. Nokes B, Orr JE, White S, Luu S, Chen Z, Alex R, et al. Effect of obesity on sleep apnea pathogenesis differs in women versus men: multiple mediation analyses in the retrospective SNOOzzzE cohort. J Appl Physiol (1985). 2024;136(6):1516-25. https://doi.org/10.1152/japplphysiol.00925.2023

24. Hopkins WG. Measures of reliability in sports medicine and science. Sports Med. 2000;30(1):1-15. https://doi.org/10.2165/00007256-200030010-00001

25. Mirzaei M, Khajeh M. Comparison of anthropometric indices (body mass index, waist circumference, waist to hip ratio and waist to height ratio) in predicting risk of type II diabetes in the population of Yazd, Iran. Diabetes Metab Syndr. 2018;12(5):677-82. https://doi.org/10.1016/j.dsx.2018.04.026

26. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. Am J Clin Nutr. 2004;79(3):379-84. https://doi.org/10.1093/ajcn/79.3.379

27. Polesel DN, Hirotsu C, Nozoe KT, Boin AC, Bittencourt L, Tufik S, et al. Waist circumference and postmenopause stages as the main associated factors for sleep apnea in women: a cross-sectional population-based study. Menopause. 2015;22(8):835-44. https://doi.org/10.1097/gme.0000000000000406

28. Davidson TM, Patel MR. Waist circumference and sleep disordered breathing. Laryngoscope. 2008;118(2):339-47. https://doi.org/10.1097/mlg.0b013e3181587d7c

29. Examination Committee of Criteria for 'Obesity Disease' in Japan; Japan Society for the Study of Obesity. New criteria for 'obesity disease' in Japan. Circ J. 2002;66(11):987-92. https://doi.org/10.1253/circj.66.987

30. Luchnikova E, Shchekotov V. Visceral fat level determined using the bioelectrical impedance as a method to assess obstructive sleep apnea risk. J Hypertens. 2015;33(Suppl 1):e90. https://doi.org/10.1097/01.hjh.0000467592.88982.f4

31. Santos DA, Dawson JA, Matias CN, Rocha PM, Minderico CS, Allison DB, et al. Reference values for body composition and anthropometric measurements in athletes. PloS One. 2014;9(5):e97846. https://doi.org/10.1371/journal.pone.0097846

32. Gažarová M, Galšneiderová M, Mečiarová L. Obesity diagnosis and mortality risk based on a body shape index (ABSI) and other indices and anthropometric parameters in university students. Rocz Panstw Zakl Hig. 2019;70(3):267-75. https://doi.org/10.32394/rpzh.2019.0077

33. Khader Y, Batieha A, Jaddou H, El-Khateeb M, Ajlouni K. The performance of anthropometric measures to predict diabetes mellitus and hypertension among adults in Jordan. BMC Public Health. 2019;19(1):1416. https://doi.org/10.1186/s12889-019-7801-2

34. Remya KJ, Mathangi K, Mathangi DC, Sriteja Y, Srihari R, Govindaraju S, et al. Predictive value of craniofacial and anthropometric measures in obstructive sleep apnea (OSA). Cranio. 2017;35(3):162-7. https://doi.org/10.1080/08869634.2016.1206701

35. Lajeunesse-Trempe F, Dufour R, du Souich P, Paquette M, Kaduka LU, Christensen DL. Anthropometric measures and their association with risk factors for cardio-metabolic diseases in Kenyan adults. Ann Hum Biol. 2018;45(6-8):486-95. https://doi.org/10.1080/03014460.2018.1562568