HİTİT MEDICAL JOURNAL
HİTİT ÜNİVERSİTESİ TIP FAKÜLTESİ DERGİSİ
e-ISSN: 2687-4717 Cilt|Volume: 6 • Sayı|Issue: 3 - Ekim|October 2024

Evaluation of Current Anthropometric Measurements to Detect Abdominal Obesity in Older Adults

Yaşlı Erişkinlerde Abdominal Obeziteyi Tespit Etmek için Güncel Antropometrik Ölçümlerin Değerlendirilmesi

Uğur Kalan[1, 2] | **Ferhat Arık**[3]

[1]Ermenek State Hospital, Department of Internal Medicine, Karaman, Türkiye
[2]Ankara Etlik City Hospital, Department of Hematology, Ankara, Türkiye
[3]Tomarza Yasar Karayel State Hospital, Department of Internal Medicine, Kayseri, Türkiye

Sorumlu Yazar | Correspondence Author
Uğur Kalan
ugurkalan70@hotmail.com
Address for Correspondence: Ankara Etlik City Hospital T6 Tower Hematology Clinic Ankara, Türkiye.

Makale Bilgisi | Article Information
Makale Türü | Article Type: Araştırma Makalesi | Research Article
Doi: https://doi.org/10.52827/hititmedj.1382223
Geliş Tarihi | Received: 27.10.2023
Kabul Tarihi | Accepted: 02.07.2024
Yayım Tarihi | Published: 14.10.2024

Atıf | Cite As
Kalan U, Arık F. Comparison of Anthropometric Measurements to Evaluate Abdominal Obesity in Older Adults. Hitit Medical Journal 2024;6(3):266-273. https://doi.org/10.52827/hititmedj.1382223

Hakem Değerlendirmesi: Alan editörü tarafından atanan en az iki farklı kurumda çalışan bağımsız hakemler tarafından değerlendirilmiştir.
Etik Beyanı: Ermenek Devlet Hastanesi'nde lokal etik komite tarafından etik onay alınmıştır. (23.08.2019-E.195/99795470)
İntihal Kontrolleri: Evet (iThenticate)
Çıkar Çatışması: Yazarlar çalışma ile ilgili çıkar çatışması beyan etmemiştir.
Şikayetler: hmj@hitit.edu.tr
Katkı Beyanı: Fikir/Hipotez: UK Tasarım: UK Veri Toplama/Veri İşleme: UK, FA Veri Analizi: UK, FA Makalenin Hazırlanması: UK, FA.
Hasta Onamı: : Tüm hastalardan yazılı onam alınmıştır.
Finansal Destek: Bu çalışma ile ilgili herhangi bir finansal kaynaktan yararlanılmamıştır.

Peer Review: Evaluated by independent reviewers working in the at least two different institutions appointed by the field editor.
Ethical Statement: The investigation conformed to the Declaration of Helsinki and approved by the local ethics committee (Ermenek Devlet Hastanesi-23.08.2019-E.195/99795470).
Plagiarism Check: Yes (iThenticate)
Conflict of Interest: The authors declared that, there are no conflicts of interest.
Complaints: hmj@hitit.edu.tr
Authorship Contribution: : Idea/Hypothesis: UK Design: UK Data Collection/Data Processing: UK, FA Data Analysis: UK, FA Manuscript Preparation: UK, FA.
Informed Consent: Written informed consent was obtained from all participants.
Financial Disclosure: There are no financial funds for this article.

Comparison of Anthropometric Measurements to Evaluate Abdominal Obesity in Older Adults

ABSTRACT

Objective: Central/Abdominal obesity is an important health problem that is growing all over the world. Abdominal obesity has been recognized as a main risk factor for cardiovascular and metabolic events. There are various measurements ranging from anthropometric indices to imaging methods for the determination of abdominal obesity. However, anthropometric studies involving older adults are scarce in the literature. The purpose of this study is to compare the current anthropometric measures used to evaluate abdominal obesity in older adults.

Material and Method: In total, 104 outpatients aged 65 years or older were enrolled in this cross-sectional study. For any reason, patients with an indication for Dual-energy-X-ray Absorptiometry (DXA) were included. Anthropometric and hemodynamic measurements were taken. DXA was used to measure body composition, especially fat ratio.

Results: The mean age of patients was 74.6-6.9. The ratio of adiposity determined by DXA, which was used as reference/gold standard method, was in the range of 3.8-52.5%. Mean value of adiposity was 31.5-10.9%. When gender and anthropometric indicators were compared, body mass index (BMI), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and body adiposity index (BAI) were significant *($p<0.05$)*; conicity index (CI), a new body shape index (ABSI) and abdominal volume index (AVI) were not significant *($p>0.05$)*. The best three anthropometric indicators that estimating the fat ratio in participants were; BMI *($r=0.718$, $p<0.05$)*, WHtR *($r=0.503$, $p<0.05$)*, and AVI *($r=0.480$, $p<0.05$)*, respectively.

Conclusion: Many advanced diagnostic methods and medical devices, can not be used in primary healthcare clinics. Therefore, practical approaches that are most compatible with advanced research are coming to the fore. In this study, we have shown that BMI is the most appropriate anthropometric measurement to detect abdominal obesity in geriatric patients.

Keywords: Abdominal obesity, adiposity, anthropometry, dual-energy x-ray absorptiometry, obesity, older adults.

ÖZET

Amaç: Santral/Abdominal obezite tüm dünyada büyümekte olan önemli bir sağlık sorunudur. Abdominal obezite, kardiyovasküler ve metabolik olaylar için ana risk faktörü olarak kabul edilmiştir. Abdominal obezitenin belirlenmesi için antropometrik indekslerden görüntüleme yöntemlerine kadar çeşitli ölçümler mevcuttur. Bununla birlikte, literatürde yaşlı erişkinleri içeren antropometrik araştırmalar azdır. Bu çalışmanın amacı ise, yaşlı erişkinlerde abdominal obeziteyi değerlendirmek için güncel antropometrik ölçümleri karşılaştırmaktır.

Gereç ve Yöntem: Toplamda, 65 yaş ve üstü 104 ayaktan poliklinik hastası bu kesitsel çalışmaya dahil edildi. Herhangi bir sebepten ötürü, Dual-Energy X-ray Absorbsiyometri (DXA) endikasyonu olan hastalar çalışmaya alındı. Görüntülemeye ek olarak antropometrik ve hemodinamik ölçümleri alındı. DXA, vücut kompozisyonunu, özellikle yağ oranını ölçmek için kullanıldı.

Bulgular: Yaş ortalaması 74,6 - 6,9 olan toplam 104 hasta çalışmaya alındı. Referans/altın standart yöntem olarak kullanılan DXA ile belirlenen adipozite oranı %3,8-52,5 aralığındaydı. Yağlanmanın ortalama değeri %31,5 -10,9 idi. Cinsiyet ve antropometrik göstergeler karşılaştırıldığında, body mass index (BMI), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) ve body adiposity index (BAI) anlamlıydı *($p<0,05$)*; conisity index (CI), a new body shape index (ABSI) ve abdominal volume index (AVI) anlamlı değildi *($p>0,05$)*. Katılımcılarda yağ oranını tahmin eden en iyi üç antropometrik gösterge ise sırasıyla; BMI *($r=0,718$, $p<0,05$)*, WHtR *($r=0,503$, $p<0,05$)* ve AVİ *($r=0,480$, $p<0,05$)* olarak tespit edildi.

Sonuç: Birçok ileri tetkik yöntemleri ve tıbbi cihazlar, birinci basamak sağlık kliniklerinde kullanılamamaktadır. Bu nedenle, ileri düzeydeki araştırmalarla en uyumlu pratik yaklaşımlar ön plana çıkmaktadır. Bu çalışmada geriatrik hastalarda, BMI'nin abdominal obeziteyi tespit etmede en uygun antropometrik ölçüm olduğunu gösterdik.

Anahtar Sözcükler: Abdominal obezite, adipozite, antropometri, Dual-Energy X-ray Absorbsiyometri, obezite, yaşlılar.

Introduction

The increase in the older adults population is a global reality and is gaining momentum (1). The prevalence of overweight and obesity is increasing in oldeionizingr adults. Accordingly, morphophysiological changes and chronic noncommunicable diseases are increasing in this elderly population (2).

Excessive fat concentration in the abdominal region, especially the increase of visceral adipose tissue, is independently associated with higher incidence of metabolic alterations, particularly cardiovascular diseases, diabetes, stroke, which are the main causes of morbidity and mortality (3, 4). For these reasons, body composition and fat distribution assessments have become more important in clinical practice and epidemiological studies. These high fat concentrates in the abdomen have been associated with metabolic and cardiovascular changes (5). Despite the important role of abdominal obesity, practical measurements of abdominal fat are not readily available. For obesity-related chronic diseases, it is important to target the efforts to reduce adiposity in the risk group.

Various methods have been developed to evaluate adiposity, ranging from waist circumference (WC) to computed tomography (CT). Currently, we can evaluate abdominal fat sections in detail with CT and magnetic resonance imaging (MRI) for the evaluation of body composition (6, 7). However, application of CT/MRI for body composition assessment in routine clinical practice is limited and impractical because of cost, scanner access, and exposure to significant ionising radiation. Another imaging method, Dual energy X-ray absorptiometry (DXA) is a technique that provides a reliable estimate of whole body composition and regional distribution of fat and lean mass (8). Unlike CT/MRI, this technique is quick, accurate, widely available, relatively inexpensive, and exposes subjects to minimal amounts of ionizing radiation (9). Furthermore, such technologically complex imaging methods are very difficult to implement routinely.

Expect these imaging methods, various anthropometric indices are used to measure central obesity. Body mass index (BMI) is by far the most commonly applied approach that is used to categorise obesity in individual subjects. Despite its widespread use; it is also routinely applied to estimate body fat in both epidemiological studies and clinical applications. But, BMI does not offer a true indication of body composition and is affected by age, gender, and ethnic differences (10, 11). Therefore, many anthropometric indicators have been developed.

Several indices have been proposed to measure central obesity, including waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR). More recent indices; body adiposity index (BAI), abdominal volume index (AVI), conisity index (CI), and a new body shape index (ABSI), which can be calculated from simple data such as weight, height, WC, and hip circumference (HC) are also in place (12-15).

Therefore, the present study aims to determine which anthropometric indicators are more compatible by using DXA as the “gold standard” for the detection of adiposity and central obesity in the older adults.

Material and Methods

A total of 104 outpatients, who applied an Internal Medicine Clinic between May 2020 – April 2021, were included in this cross-sectional study. The criteria for inclusion were age 65 years or over, who applied to clinic for any reason, and the ability to understand and answer questions. The investigation conformed to the Declaration of Helsinki and approved by the local ethics committee (Ermenek Devlet Hastanesi-23.08.2019-E.195/99795470), and verbal and written informed consent was obtained from all participants. Exclusion criteria included refusal to participate in the study, patients under 65 years of age, those receiving parenteral/enteral nutritional support, bedridden patients whose height and weight could not be measured, and those with serious diseases that could cause deterioration in general condition. A designed questionnaire was administered to consented study participant. Trained healthcare providers measured blood pressure and anthropometric data, including weight (kg), height (m), WC (cm), and HC (cm). Moreover, excessive clothing, accessories, and shoes were removed to ensure accurate measurements. Weight was measured with on a digital electronic scale (Genius 220 PLUS, Korea) with a capacity of 250 kg and a sensitivity of 100g. Height was measured while participants stood against a wall with their heels and buttocks in contact with the wall. WC was recorded while standing at the time of normal expiration. The measurement was obtained at the midpoint between the inferior angle of the ribs and the suprailiac crest. HC was measured at the maximal circumference over the buttocks. Both WC and HC were done with a non-stretchable and accurately calibrated scale with 0.5-cm precision and the mean value of the three trials was used as the criterion value. The other indicators used to evaluate obesity and adiposity were calculated using the following formulas:

$$WHR = waist\ (cm)/hip\ (cm)$$

$$WHtR = waist\ (cm)/height\ (cm)$$

$$BMI = \frac{weight\ (kg)}{height\ (m)^2}$$

$$CI = \frac{waist\ (m)}{\left[0.109\ x\ \sqrt{weight\ (kg)/height\ (m)}\right]}$$

$$BAI = \frac{hip\ (cm)}{height\ (m)^{1.5}} - 18$$

$$AVI = \frac{\left[2\ x\ (waist\ (cm)^2) + 0.7\ x\ [(waist\ (cm) - hip\ (cm))^2]\right]}{1000}$$

$$ABSI = \frac{waist\ (m)}{BMI^{2/3} x\ height\ (m)^{1/2}}$$

Systolic and diastolic blood pressures were measured on the nondominant arm, using a properly fitted cuff with participants in sitting position, with back supported and legs uncrossed.

A venous blood sample was collected from participants following 12-hours of fasting to evaluate serum concentrations of glucose, total cholesterol, triglycerides, Low Density Lipoprotein (LDL), and High Density Lipoprotein (HDL).

Histogram, QQ graphs, and Shapiro-Wilk test were used to analyze the data distribution. Levene test was used for homogeneity of variance. Pearson chi-square analysis and Fisher exact tests are conducted for evaluating qualitative data. The correlations coefficients and their significance were calculated using Pearson test. The correlations were also tested separately for the eight work status groups (WC, WHR, WHtR, BAI, AVI, CI, ABSI, BMI). $p<0.05$ was considered significant.

Results

The overall characteristics of the 104 patients, of whom the mean age 74.6±6.9 years, are shown in Table I. The majority of the participants were women (63.5% vs 36.5%). The ratio of adiposity determined by DXA, was in the range of 3.8-52.5% and the mean value of adiposity was 31.5±10.9%. Also, there was a significant difference between gender and fat percentage (women vs men; 34.1±9.1 vs 26.9±8.7, $p<0.05$).

Table I Anthropometric, clinical and biochemical characteristics of the participants according to gender

Variables	Total (n=104)	Women (n=66)	Men (n=38)	*p value*
Age (years)	74.6±6.9	73.8±5.7	76.1±5.1	*0.105*
Weight (kg)	63.5±11.5	62.5±10.4	65.2±10.6	*0.277*
Height (cm)	154.2±8.99	149.6±6.8	162.1±6.4	*<0.001*
Waist (cm)	94.6±10.9	94.8±9.4	94.3±9.4	*0.832*
Hip (cm)	103.5±11.5	105.9±9.3	99.2±8.5	*0.004*
Fat (%)	31.5±10.9	34.1±9.1	26.9±8.7	*<0.001*
BMI	26.7±4.9	27.8±5.2	24.8±3.8	*0.003*
CI	1.36±0.11	1.35±0.12	1.36±0.10	*0.609*
WHR	0.91±0.08	0.89±0.07	0.95±0.08	*<0.001*
WHtR	0.61±0.07	0.63±0.06	0.58±0.05	*<0.001*
BAI	35.8 (30.6-41.3)	39.1 (35.4-43.7)	30.0 (26.3-32.3)	*<0.001*
AVI	17.7 (15.0-20.1)	17.6 (14.9-20.8)	17.7 (15.4-19.7)	*0.960*
ABSI	0.86±0.86	0.85±0.08	0.87±0.07	*0.184*
SBP (mm/Hg)	134.06±17.1	136.5±16.7	129.8±17.3	*0.055*
DBP (mm/Hg)	76.3±1.01	77.3±9.78	74.6±11.11	*0.209*
Glucose (mg/dL)	105 (96-119)	106 (96-119)	104 (96-104)	*0.700*
Cholesterol (mg/dL)	189±51.7	199.3±53.2	171.1±44.2	*0.007*
Triglycerides (mg/dL)	132.2 (78-156)	123.5 (86.7-192.5)	98 (74.5-117.7)	*0.008*
HDL (mg/dL)	47.7±12.7	50.5±12.9	42.9±10.8	*0.003*
LDL (mg/dL)	114.2±37.1	118.6±38.4	106.5±33.9	*0.110*

ABSI: A Body Shape Index, AVI: abdominalvolume index, BAI: body adiposity index, BMI: Body mass index, CI: Conicity index, DBP: diastolic blood pressure, HDL: High Density Lipoprotein, LDL: Low Density Lipoprotein, SBP: Systolic blood pressure, WHR: waist-to-hip ratio, WHtR: waist-to-height ratio. The data is expressed mean±standard deviation or median at first and third quarter.

When gender and anthropometric indicators were compared, BMI, WHR, WHtR, and BAI were significant (*p<0.05*), while CI, ABSI, and AVI were not significant (*p>0.05*). There was no statistical difference between men and women for the variables: systolic blood pressure (SBP), diastolic blood pressure (DBP), glucose, and LDL (Table I).

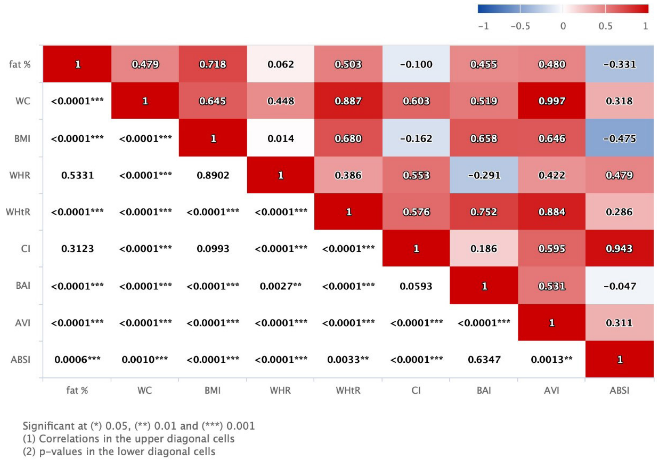

Figure I Correlation of anthropometric indicators in predicting the abdominal fat ratio in all participants

The performance of anthropometric indicators in predicting the abdominal fat ratio in older adults is presented in Figure I. The best three anthropometric indicators that estimating the fat ratio in the total sample were; BMI (*r=0.718, p<0.05*), WHtR (*r=0.503, p<0.05*), and AVI (*r=0.480, p<0.05*), respectively (Figure I).

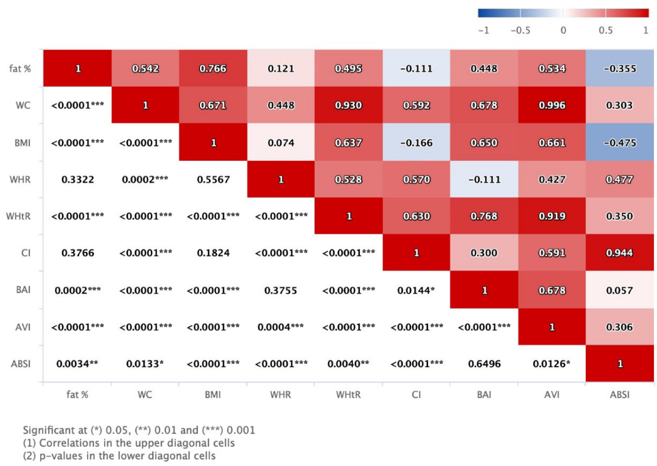

Figure II Correlation of anthropometric indicators in predicting the abdominal fat ratio in female participants

If we evaluate according to gender, the anthropometric indicators that performed well in predicting the fat ratio were; BMI (*r=0.766, p <0.05*), WC (*r=0.542, p<0.05*), and AVI (*r=0.534, p<0.05*) for women (Figure II-III). The most consistent anthropometric measurements for men were BMI (*r=0.548, p<0.05*), AVI (*r=0.422, p<0.05*), and WC (*r=0.420, p<0.05*) (Figure II-III). When the correlation of anthropometric indicators, which is statistically significant with the percentage of fat, is carefully analyzed, it is realized that the indicators that perform best in all three groups (total, women, and men) are almost the same. Furthermore, adiposity was negatively correlated with ABSI in all groups (*r=-0.331* in total, *r=-0.355* in women, and *r=-0.216* in men).

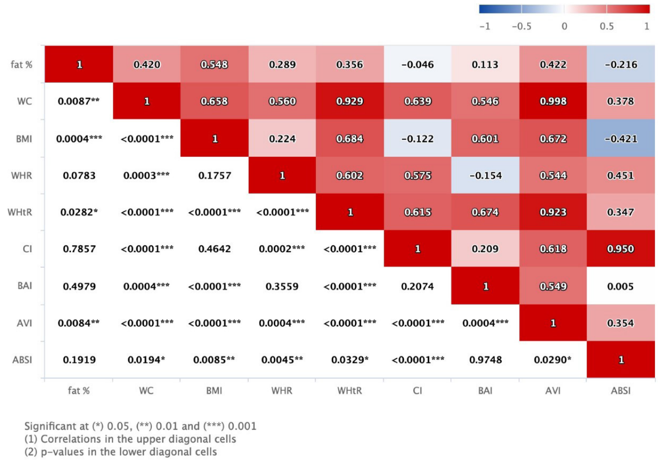

Figure III Correlation of anthropometric indicators in predicting the abdominal fat ratio in male participants

Discussion

Abdominal obesity is a major risk factor for chronic diseases such as cardiovascular disease, stroke and diabetes (16). Various anthropometric indicators have been developed to detect abdominal obesity quickly and effectively. This study evaluated multiple anthropometric indicators to detect abdominal obesity in older adults, using DXA as the reference method.

BMI, despite its widespread use in clinical practice, does not assess body fat distribution and is influenced by factors such as age, gender, and ethnicity. Our study found a strong association between abdominal obesity and BMI in elderly individuals. The lack of athletic individuals in our study population likely contributed to the success of BMI in predicting abdominal obesity. Studies conducted by Geliebter et al. and YA Sung et al. also demonstrated BMI's superiority in estimating body fat compared to other anthropometric measurements . However, the limited number of studies focusing on older adults and our study's sample size restrict generalization. Previous research indicates that while BMI is a convenient and widely used measure, it fails to differentiate between muscle and fat mass. In older adults, where muscle mass tends to decrease with age, BMI may not accurately reflect adiposity. This limitation is particularly significant in populations with a high prevalence of sarcopenia. Therefore, while BMI provides a useful general indication of obesity, it should be used in conjunction with other measures for a more comprehensive assessment.

Geliebter et al. investigated the best method to determine abdominal fat ratio in 19 severely obese female patients and found BMI to be the most appropriate anthropometric measurement, similar to our findings (17). Another study showed a significant correlation between BMI and body fat in postmenopausal older women A cross-sectional study by YA Sung et al. with 2950 female patients demonstrated that BMI-based classification was superior to other anthropometric measurements (18, 19). While our study is consistent with literature data, the lack of sufficient studies in older adults and our study's sample size do not allow for generalization in this regard.

WHtR was also found to be strongly associated with adiposity in all participants (*$r=0.503$, $p<0.05$*). WHtR adjusts for height and provides a single cut-off point, regardless of gender and ethnicity, making it an effective measure. Roriz et al. reported high accuracy of WHtR in obesity discrimination, supporting our findings (5).

Lee et al.in their meta-analysis showed that WHtR was more successful than BMI, WC, and WHR in determining cardiovascular risk (20). WHtR's ability to adjust for height and provide a single cut-off point regardless of gender and ethnicity makes it a versatile tool. Ashwell and Hsieh highlighted the simplicity and effectiveness of WHtR, suggesting it could simplify the public health message on obesity (21).

AVI, a newer anthropometric tool, ranked third after BMI and WHtR in detecting abdominal obesity (*$r=0.480$, $p<0.05$*). It has shown strong obesity assessment capability in both male and female patients. Studies from Iran and China corroborate our results, highlighting AVI's utility in obesity assessment (22, 23).

AVI was developed to assess glucose metabolism impairment and measure general body volume, providing a comprehensive assessment of body fat distribution. Guerrero-Romero and Rodríguez-Morán found that AVI was strongly related to impaired glucose tolerance and type 2 diabetes mellitus, further supporting its use in clinical settings (13). WC is a well-known marker of visceral adiposity and is associated with a higher risk of metabolic abnormalities and cardiovascular diseases compared to BMI (24). Our study found WC to be strongly correlated with adiposity in all participants ($r=0.479$, $p<0.05$), particularly in female patients (*$r=0.542$, $p<0.05$*) and to a lesser extent in male patients ($r=0.420$, $p<0.05$). The correlation between WC and AVI may be due to their shared reliance on waist and hip circumference in their formulas.

ABSI, designed to minimize correlation with weight, height, and BMI, showed a negative correlation with adiposity in all groups. This distinct characteristic suggests that ABSI may offer unique insights into central obesity and its cardiometabolic risks . Despite its significant correlation with the female group and all participants, ABSI did not show a significant relationship in the male group.

ABSI was proposed by Krakauer and Krakauer as a novel index that better captures the contribution of WC to central obesity and its clinical outcomes (25). Bertoli et al. found ABSI to be associated with cardiometabolic risk factors in a large cohort of Caucasian adults, further supporting its potential utility (15).

Given the practical limitations in primary healthcare settings, DXA, though reliable and accurate, is not always feasible due to cost and complexity. Our study demonstrated that simple, economical, and convenient anthropometric measurements like BMI, WHtR, and AVI can effectively assess obesity in older adults. These measurements are easy to implement in primary healthcare, offering a pragmatic alternative when advanced imaging methods are unavailable. The increasing prevalence of obesity among older adults necessitates effective and accessible methods for assessment and intervention. Practical approaches like BMI, WHtR, and AVI can aid in early detection and management of obesity-related complications, ultimately reducing the burden on healthcare systems. The results of this study provide an understanding of the efficacy of BMI, WHtR, and AVI as indicators of abdominal obesity in an elderly population, particularly within the operational limitations of primary healthcare settings. Our comparative analysis, juxtaposed with the DXA gold standard, not only corroborates BMI's significant correlation with abdominal adiposity but also highlights the diagnostic relevance of WHtR and AVI. This underlines their utility in geriatric obesity assessment, offering a pragmatic alternative in scenarios where DXA is not feasible.

Further research, particularly longitudinal studies, is needed to explore the long-term reliability of these measurements and their correlation with clinical outcomes in elderly patients. With the increasing prevalence of obesity in older populations and its associated health risks, these findings have significant implications for public health strategies. Practical approaches that are simple and cost-effective can help manage obesity-related complications and reduce the burden on the healthcare system.

Longitudinal studies would be invaluable in understanding the dynamic changes in body composition and fat distribution over time in older adults. Such investigations would help refine obesity management protocols and improve patient care in geriatric populations.

Conclusion

This study systematically evaluated the efficacy of various anthropometric measurements in detecting abdominal obesity in older adults using DXA as the gold standard. The findings revealed that BMI, WHtR, and AVI are reliable indicators, with BMI showing the highest correlation with DXA measurements. This suggests that BMI is a practical tool for assessing abdominal obesity in primary healthcare settings due to its simplicity and strong correlation. The study underscores the importance of easily implementable methods in managing health risks in older populations. Further research is needed to validate these findings and enhance obesity management protocols in geriatric populations.

References

1. Goldani H, Adami FS, Antunes MT, et al. Applicatility Of The Visceral Adiposity Index (Vai) In The Prediction Of The Components Of The Metabolic Syndrome In Elderly. Nutricion hospitalaria 2015 Oct 1;32(4):1609-15.
2. Maggi S, Noale M, Zambon A, et. al. Validity of the ATP III diagnostic criteria for the metabolic syndrome in an elderly Italian Caucasian population: the Italian Longitudinal Study on Aging. Atherosclerosis 2008;197(2):877-882.
3. Golay A, Chen N, Chen YD, Hollenbeck C, Reaven GM. Effect of central obesity on regulation of carbohydrate metabolism in obese patients with varying degrees of glucose tolerance. The Journal of clinical endocrinology and metabolism 1990;71(5):1299-1304.
4. Landin K, Krotkiewski M, Smith U. Importance of obesity for the metabolic abnormalities associated with an abdominal fat distribution. Metabolism: clinical and experimental 1989 Jun;38(6):572-576.
5. Roriz AKC, Passos LCS, de Oliveira CC, et. al. Evaluation of the accuracy of anthropometric clinical indicators of visceral fat in adults and elderly. PLoS One 2014;9(7):e103499-e.
6. Abate N, Burns D Fau, Peshock RM, et al. Grundy SM, Grundy SM. Estimation of adipose tissue mass by magnetic resonance imaging: validation against dissection in human cadavers. J. Lipid Res 1994 Aug;35(8):1490-1496.
7. Rossner S, Bo Wj Fau, Hiltbrandt E, et al. Adipose tissue determinations in cadavers--a comparison between cross-sectional planimetry and computed tomography. Int J Obes 1990 Oct;14(10):893-902.
8. Glickman SG, Marn Cs Fau, Supiano MA, et. al. Validity and reliability of dual-energy X-ray absorptiometry for the assessment of abdominal adiposity. Journal of Applied Physiology 2004 Aug;97(2):509-514
9. Haarbo J, Gotfredsen A Fau, Hassager C, et. al. Validation of body composition by dual energy X-ray absorptiometry (DEXA). Clin Physiol 1991 Jul;11(4):331-341.
10. Nevill AM, Stewart AD, Olds T, Holder R. Relationship between adiposity and body size reveals limitations of BMI. American journal of physical anthropology 2006;129(1):151-156.
11. Rahman M, Berenson AB. Accuracy of Current Body Mass Index Obesity Classification for White, Black, and Hispanic Reproductive-Age Women. Obstetrics & Gynecology 2010;115(5).
12. Bergman RN, Stefanovski D Fau, Buchanan TA et al. A better index of body adiposity. Obesity (Silver Spring) 2011 May;19(5):1083-1089.

13. Guerrero-Romero F, Rodríguez-Morán M. Abdominal volume index. An anthropometry-based index for estimation of obesity is strongly related to impaired glucose tolerance and type 2 diabetes mellitus. Arch Med Res 2003;34(5):428-432.
14. Valdez R, Seidell JC, Ahn YI, Weiss KM. A new index of abdominal adiposity as an indicator of risk for cardiovascular disease. A cross-population study. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity 1993;17(2):77-82.
15. Bertoli S, Leone A, Krakauer NY, et al. Association of Body Shape Index (ABSI) with cardio-metabolic risk factors: A cross-sectional study of 6081 Caucasian adults. PLoS One 2017;12(9):e0185013-e.
16. Almeida RT, Almeida Mm Fau, Araújo TM, Araújo TM. Abdominal obesity and cardiovascular risk: performance of anthropometric indexes in women. Arq Bras Cardiology 2009 May;92(5):345-50, 362-7, 375-380.
17. Geliebter A, Atalayer D, Flancbaum L, Gibson CD. Comparison of body adiposity index (BAI) and BMI with estimations of % body fat in clinically severe obese women. Obesity (Silver Spring, Md) 2013;21(3):493-498.
18. Bennasar-VM, Lopez GAA, Tauler P, et al. Body adiposity index and cardiovascular health risk factors in Caucasians: a comparison with the body mass index and others. PLoS One 2013;8(5):e63999.
19. Sung YA, Oh JY, Lee H. Comparison of the body adiposity index to body mass index in Korean women. Yonsei Med J 2014;55(4):1028-1035.
20. Lee S, Kuk Jl Fau, Hannon TS, et al. Race and gender differences in the relationships between anthropometrics and abdominal fat in youth. Obesity (Silver Spring) 2008 May;16(5):1066-71.
21. Ashwell M, Hsieh SD. Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. Int J Food Sci Nutr 2005;56(5):303-307.
22. Motamed N, Sohrabi M, Poustchi H, et al. The six obesity indices, which one is more compatible with metabolic syndrome? A population based study. Diabetes Metab Syndr 2017;11(3):173-177.
23. Wang H, Liu A, Zhao T, et al. Comparison of anthropometric indices for predicting the risk of metabolic syndrome and its components in Chinese adults: a prospective, longitudinal study. BMJ Open 2017;7(9):e016062.
24. Sargeant LA, Bennett Fi Fau, Forrester TE, et al. Predicting incident diabetes in Jamaica: the role of anthropometry. Obes Res 2002 Aug;10(8):792-798.
25. Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PLoS One 2012;7(7):e39504.