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Comparative Evaluation of Waist- to-Height Ratio, Body Mass Index, and Waist-to-Hip Ratio in an Adult Primary Care Population: A Cross-sectional Study

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Abstract

Background

Body mass index (BMI) does not describe fat distribution. Waist-to-height ratio (WHtR) and waist-to-hip ratio (WHR) may provide complementary information about central adiposity in primary care.

Objective

To compare the distributions and pairwise correlations of BMI, WHtR, and WHR and to describe the prevalence of dyslipidemia and hypertension in an adult primary care cohort.

Methods

This cross-sectional study enrolled adults from two family medicine clinics affiliated with St. John Hospital and Medical Center in Detroit, Michigan. Standardized anthropometric measurements, blood pressure, and fasting laboratory values were obtained. Analyses used complete cases and included descriptive statistics and Pearson correlations among the three anthropometric indices.

Results

Of 467 enrolled participants, 406 (86.9%) had complete data. The mean (SD) age was 50.1 (16.0) years; 193 (47.5%) were men and 213 (52.5%) were women. Mean (SD) BMI was 30.1 (6.9) kg/m2, WHtR was 0.61 (0.08), and WHR was 0.95 (0.09). Hypertension was present in 160 participants (39.4%) and dyslipidemia in 177 (43.6%). BMI and WHtR were strongly correlated ($r = 0.893$, $p < 0.001$); WHtR and WHR were moderately correlated ($r = 0.346$, $p < 0.001$); and BMI and WHR were weakly correlated ($r = 0.156$, $p < 0.05$). A WHtR threshold of 0.50 classified 57.6% of participants as having increased cardiometabolic risk, compared with 52.7% classified as obese by BMI.

Conclusion

The three anthropometric indices were not interchangeable. WHtR tracked closely with BMI but produced a modestly higher screening yield, whereas WHR captured a less closely correlated dimension of body shape. WHtR may be a practical complement to BMI in primary care; outcome-specific regression or discrimination analyses are required before claiming predictive superiority for dyslipidemia or hypertension.

Key points

What is already known? Central adiposity measures may complement BMI because BMI does not directly describe body-fat distribution.

What this study adds In 406 primary care participants, BMI and WHtR were strongly correlated, while correlations involving WHR were weaker. The WHtR screening threshold classified 57.6% as at increased risk, versus 52.7% classified as obese by BMI.

How this might affect practice Routine waist and height measurements could add a simple central-adiposity screen to BMI, while clinicians should avoid treating different anthropometric indices as interchangeable.

Introduction

Obesity is associated with hypertension, dyslipidemia, type 2 diabetes, cardiovascular disease, and premature mortality [1, 4]. BMI remains the most widely used anthropometric index because it is inexpensive, reproducible, and readily available in clinical records [1, 3]. However, BMI estimates weight relative to height and does not distinguish adipose tissue from lean mass or directly describe regional fat distribution.

Central adiposity has particular clinical relevance because visceral and ectopic fat are linked to insulin resistance, inflammation, adverse lipid profiles, and elevated blood pressure [4, 5]. Waist circumference and ratios that incorporate waist circumference have therefore been proposed as complements to BMI. WHR relates waist circumference to hip circumference, while WHtR scales waist circumference to height.2,5

Systematic reviews and meta-analyses have reported that central-adiposity indices often discriminate cardiometabolic risk factors at least as well as BMI, with WHtR showing practical advantages across populations [6–11]. A simple WHtR threshold of 0.50 also supports a memorable public-health message: keep waist circumference below half of height [6, 9, 11]. Nonetheless, the three indices quantify overlapping but non-identical constructs, and their empirical relationships should be examined within the population in which they are used.

This study compared the distributions and pairwise correlations of BMI, WHtR, and WHR in adults attending two family medicine clinics and described the accompanying burden of study-defined hypertension and dyslipidemia. The primary purpose of the present report was descriptive and correlational because outcome-specific regression coefficients, receiver operating characteristic curves, and paired classification-discordance results were not available in the finalized aggregate study record.

Methods

Study design and setting

This cross-sectional observational study was conducted from 1 October 2004 through 31 March 2005 at two family medicine clinics affiliated with St. John Hospital and Medical Center in Detroit, Michigan.

Participants

Adults aged 20 years or older who attended routine primary care or preventive visits were recruited consecutively. Participants were required to provide written informed consent and to complete anthropometric measurements, blood-pressure assessment, and fasting laboratory testing. Pregnancy, ascites or another condition affecting waist measurement, inability to stand for height or weight measurement, dialysis-dependent kidney failure, incomplete study data, and inability to provide consent were exclusion criteria.

Data collection and measurements

Trained study personnel administered a standardized study-specific questionnaire developed by the investigators to collect relevant demographic and clinical information (See supplementary file 1). The questionnaire was designed for standard data collection covering; demographic characteristics, medical history, medication use, smoking, alcohol use, family cardiovascular history, and prior diagnoses of hypertension, diabetes, and dyslipidemia. Height was measured without shoes using the same wall-mounted stadiometer and weight with a calibrated scale. Waist circumference was measured at the midpoint between the lower palpable rib and the iliac crest after normal expiration; hip circumference was measured at the point of maximal gluteal protrusion [2]. Measurements were recorded to the nearest 0.1 cm or 0.1 kg.

BMI was calculated as weight in kilograms divided by height in metres squared. WHO categories were used for descriptive classification [1]. WHR was calculated as waist circumference divided by hip circumference; central obesity thresholds were > 0.90 for men and > 0.85 for women [2]. WHtR was calculated as waist circumference divided by height, with 0.50 used as the screening threshold for increased cardiometabolic risk [6, 9, 11].

Resting blood pressure was measured after at least 5 minutes seated, using an appropriately sized cuff at heart level. Two measurements were obtained and averaged. Fasting blood samples were analyzed for total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides, and plasma glucose.

Outcomes

Hypertension and dyslipidemia status were taken from the finalized study variables, which integrated measured values and relevant medication treatment. For the present report, hypertension was defined as systolic blood pressure at least 130 mm Hg, diastolic blood pressure at least 80 mm Hg, or current antihypertensive treatment [12]. Because recruitment preceded publication of the 2017 ACC/AHA guideline, this threshold represents retrospective harmonization to the definition documented in the finalized study record; results using the historical 140/90 mm Hg threshold were not available in the

supplied aggregate record. Dyslipidemia was defined by one or more of the following: total cholesterol at least 200 mg/dL, LDL-C above the applicable treatment threshold for the recorded cardiovascular risk category, HDL-C below 40 mg/dL in men or 50 mg/dL in women, triglycerides at least 150 mg/dL, or lipid-lowering treatment [13].

Statistical analysis

The analysis used participants with complete anthropometric, clinical, and laboratory data. Continuous variables are reported as mean (SD) and median; categorical variables as number and percentage. Pearson correlation coefficients quantified pairwise linear associations among BMI, WHtR, and WHR. Statistical significance was defined as a two-sided p value below 0.05. The aggregate record did not contain outcome-specific regression estimates or ROC statistics; therefore, no adjusted or discrimination claims are made in this report. Analyses were performed in IBM SPSS Statistics (IBM Corp, Armonk, New York).

Ethics and reporting

The study was approved by the Ascension Health System/St. John Health Institutional Ethics Committee (Federalwide Assurance FWA00000192) before participant enrollment. All participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki [14]. This report follows the STROBE recommendations for cross-sectional studies [15].

Patient and public involvement

Patients and the public were not involved in the design, conduct, analysis, or reporting of this study.

Results

Participants and baseline characteristics

A total of 467 participants were enrolled. Sixty-one were excluded because one or more required anthropometric, clinical, or laboratory values were incomplete, leaving 406 participants (86.9%) in the complete-case analysis. The analytic cohort included 193 men (47.5%) and 213 women (52.5%). Most participants were White (336 [82.8%]), 59 (14.5%) were African American, and 11 (2.7%) were recorded in other racial or ethnic groups (Table 1).

Table 1
Demographic characteristics of the analytic cohort (N = 406)

Characteristic	n (%)
Sex	
Men	193 (47.5)
Women	213 (52.5)
Race/ethnicity	
White	336 (82.8)
African American	59 (14.5)
Other	11 (2.7)

The mean (SD) age was 50.1 (16.0) years and mean BMI was 30.1 (6.9) kg/m2. Mean waist circumference was 38.0 (6.6) inches and mean hip circumference was 43.2 (6.0) inches. Mean systolic and diastolic blood pressure were 124.6 (20.6) mm Hg and 78.7 (9.8) mm Hg, respectively (Table 2).

Table 2
Baseline anthropometric and clinical characteristics (N = 406)

Variable	Mean (SD)	Median
Age, years	50.1 (16.0)	50
Weight, lb	184.8 (46.5)	181
BMI, kg/m²	30.1 (6.9)	30.0
Waist circumference, in	38.0 (6.6)	38
Hip circumference, in	43.2 (6.0)	42
Systolic blood pressure, mm Hg	124.6 (20.6)	120
Diastolic blood pressure, mm Hg	78.7 (9.8)	80

BMI, body mass index; SD, standard deviation.

Anthropometric indices and laboratory profile

Mean (SD) WHtR was 0.61 (0.08) and mean WHR was 0.95 (0.09) (Table 3). The WHtR threshold of 0.50 classified 234 participants (57.6%) as having increased cardiometabolic risk. In comparison, the BMI obesity threshold classified 214 (52.7%) as obese. These percentages represent different screening constructs and were not treated as paired measures of diagnostic accuracy.

Table 3
Distribution of anthropometric indices (N = 406)

Statistic	BMI	WHtR	WHR
Mean	30.1	0.61	0.95
Median	30.0	0.61	0.95
Mode	28.5	0.70	0.98
SD	6.9	0.08	0.09

BMI, body mass index; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; SD, standard deviation.

Mean total cholesterol was 205.5 (40.9) mg/dL, LDL-C 120.9 (34.7) mg/dL, HDL-C 45.7 (15.5) mg/dL, triglycerides 173.2 (89.0) mg/dL, and fasting plasma glucose 101.9 (45.5) mg/dL (Table 4).

Table 4
Fasting laboratory measurements (N = 406)

Variable	Mean (SD), mg/dL	Median, mg/dL
Total cholesterol	205.5 (40.9)	203
LDL-C	120.9 (34.7)	120
HDL-C	45.7 (15.5)	44
Triglycerides	173.2 (89.0)	159
Fasting plasma glucose	101.9 (45.5)	94

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation.

Hypertension and dyslipidemia

Study-defined hypertension was present in 160 participants (39.4%), and dyslipidemia was present in 177 (43.6%) (Table 5).

Table 5
Prevalence of study-defined hypertension and dyslipidemia (N = 406)

Condition	Present, n (%)	Absent, n (%)
Hypertension	160 (39.4)	246 (60.6)
Dyslipidemia	177 (43.6)	229 (56.4)
Correlations among anthropometric indices		

BMI and WHtR showed a strong positive correlation (r = 0.893, p < 0.001). WHtR and WHR were moderately correlated (r = 0.346, p < 0.001), while BMI and WHR were weakly correlated (r = 0.156, p < 0.05) (Table 6). Thus, approximately 79.7% of the observed variance in one of BMI and WHtR was linearly shared with the other (r2 = 0.797), compared with 12.0% for WHtR and WHR and 2.4% for BMI and WHR. These are inter-index associations and do not measure prediction of hypertension or dyslipidemia.

Table 6
Pearson correlations among anthropometric indices (N = 406)

Index	BMI	WHR	WHtR
BMI	1.000	0.156*	0.893†
WHR	0.156*	1.000	0.346†
WHtR	0.893†	0.346†	1.000

*p < 0.05; †p < 0.001. BMI, body mass index; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

Discussion

Principal findings

This adult primary care cohort had a high burden of generalized and central adiposity, with study-defined hypertension in 39.4% and dyslipidemia in 43.6%. BMI and WHtR were strongly correlated, but WHR was only weakly correlated with BMI and moderately correlated with WHtR. The WHtR threshold of 0.50 produced a screening-positive proportion 4.9 percentage points higher than the proportion meeting the BMI obesity threshold.

The strong BMI-WHtR correlation is expected because both ratios incorporate height and increase with body size or abdominal girth. The weaker correlations involving WHR indicate that hip circumference materially changes its relationship with the other indices. Accordingly, the three measures should not be treated as interchangeable, even when they are used within the same clinical encounter.

Comparison with previous evidence

The present descriptive findings are compatible with a broader literature supporting central-adiposity assessment alongside BMI. Meta-analyses have found waist-based measures to be better discriminators of several cardiometabolic risk factors than BMI, with WHtR often showing the strongest or most consistent performance [7–10]. Consensus guidance also supports routine waist measurement because it can provide information beyond BMI [5].

However, external evidence cannot substitute for missing within-study performance statistics. Pairwise correlations among anthropometric indices, screening-positive proportions, and condition prevalence do not establish that one index better predicts hypertension or dyslipidemia. Comparative predictive claims

require outcome-specific regression estimates, confidence intervals, calibration, and preferably ROC curves or another prespecified discrimination analysis. The present report therefore uses cautious language and positions WHtR as a complementary screening measure rather than a proven superior predictor in this cohort.

Clinical implications

BMI remains useful for standardized obesity classification, but it does not directly characterize fat distribution. Measuring waist circumference and height requires little additional time or equipment and permits calculation of WHtR. In this cohort, WHtR identified a slightly larger screening-positive proportion than the BMI obesity threshold. In practice, the two measures may be most useful together: BMI describes weight relative to height, while WHtR adds a simple indication of central adiposity [5, 9, 11].

WHR may offer different information, but it requires two circumference measurements and is influenced by both waist and hip size. The modest correlations between WHR and the other indices in this study reinforce the need to select and interpret anthropometric measures according to their intended clinical purpose.

Strengths and limitations

Strengths include standardized anthropometric measurements, fasting laboratory testing, evaluation of three indices in the same primary care cohort, and a sample large enough to estimate descriptive quantities with reasonable precision. The clinical setting also reflects measurements that can be obtained during routine care.

Several limitations warrant emphasis. The cross-sectional design precludes temporal or causal inference. Participants came from two clinics in one metropolitan area and were predominantly White, which limits generalizability. Complete-case analysis excluded 61 enrolled participants (13.1%) and may have introduced selection bias. The participant-level dataset was archived on a compact disc and is no longer accessible; the available aggregate record did not permit independent reanalysis, paired classification-discordance analysis, adjusted regression, calibration assessment, or ROC comparison. The retrospective application of a contemporary hypertension threshold to data collected in 2004–2005 may also limit comparability with studies using historical definitions. Finally, BMI, WHtR, and WHR are proxies for body composition and were not validated against imaging-based visceral-fat measurements.

Conclusion

BMI, WHtR, and WHR were related but non-interchangeable measures in this adult primary care cohort. WHtR was strongly correlated with BMI and classified a modestly larger proportion above its screening threshold, whereas WHR showed weaker correlations with both measures. These findings support considering WHtR as a practical complement to BMI when central adiposity is clinically relevant. Claims

that WHtR is a superior predictor of hypertension or dyslipidemia in this cohort should await presentation or reanalysis of outcome-specific regression and discrimination results.

Declarations

Ethics approval and consent to participate: The study was approved by the Ascension Health System/St. John Health Detroit Institutional Ethics Committee (Federal wide Assurance FWA00000192) before participant enrollment. All participants provided written informed consent.

Consent for publication: Not applicable.

Competing interests: The authors declare no competing interests.

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Data availability: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions: AE serves as corresponding author and guarantor. AE, contributed to the conception and design of the study, AE and PP acquisition or interpretation of data, AE, BS and KB critical revision of the manuscript, approval of the final version, and accountability for the work.

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