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Efficacy of anthropometric measures in predicting hypertension among adult Ghanaians: A community-based cross-sectional study

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Abstract

Background: As global rates of hypertension continue to rise, especially in developing countries, there is an urgent need for effective screening tools. Anthropometry offers a practical approach to assessing the risks associated with hypertension due to its simplicity and cost-effectiveness.

Objective: This study aimed to evaluate the efficacy of waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and body mass index (BMI) in predicting hypertension among adults in the Cape Coast metropolis in Ghana.

Methods: This analytical cross-sectional study involved 390 adults from three local communities. Anthropometric data were collected using standardised equipment, and hypertension was defined based on the WHO blood pressure classification. The validity of the anthropometric measures was assessed using positive predictive value (PPV) and negative predictive value (NPV), as well as specificity and sensitivity. IBM SPSS version 26 was used for statistical analyses. Chi-square and linear regression models were used to determine the associations between anthropometric measures and hypertension.

Results: Among 390 participants (mean age: 34.6 ± 13.8 years; 50% female), WC and WHtR were significantly associated with hypertension (WC: β = 0.256, 95% Confidence Intervel [CI]: 0.173 - 0.445, p = 0.011; WHtR: β = 0.310, 95% CI: 0.210 - 0.458, p = 0.024), whereas body mass index (BMI) was not (β = 0.034, p = 0.466). WHtR demonstrated the highest sensitivity (88.4%), while WC had the highest specificity (81.7%) for predicting hypertension.

Conclusion: This study highlights the importance of WC and WHtR as valuable and effective anthropometric measures for predicting hypertension in a clinical setting. Incorporating these measures into routine health assessments could enhance the early detection and management of hypertension, thereby contributing to better public health outcomes. Further research is needed to confirm these findings in diverse populations and longitudinal studies.

Keywords: Anthropometry, hypertension, waist circumference, waist-to-height ratio, public health

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INTRODUCTION

Obesity is increasingly recognised as a significant chronic health condition that greatly contributes to both morbidity and overall mortality rates [1]. This is particularly concerning as the incidence of obesity in some developing nations surpasses that in developed countries, and continues to escalate rapidly [2]. Given the critical health implications of obesity, it is essential to have reliable methods for measuring body composition, which is a focal point of epidemiological, clinical, and population studies

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[3]. Although advanced imaging techniques like dual-energy x-ray absorptiometry, magnetic resonance imaging, and computed tomography offer accurate measurements, anthropometry remains the most widely utilised method due to its portability, non-invasiveness, cost-effectiveness, and suitability for field studies [4,5].

Despite the availability of more precise techniques, these are often unsuitable for general use due to high costs and risk factors and are therefore reserved for specific research contexts [5]. Consequently, simple anthropometric measures serve as practical proxies for assessing obesity in clinical settings and large-scale epidemiological studies [5]. The Body Mass Index (BMI), which correlates weight with height, is the simplest and most prevalent obesity metric [5]. Although a high BMI is directly associated with increased risks of cardiovascular disease (CVD) and hypertension [5], it does not reflect variations in body fat distribution, particularly abdominal fat, which can significantly differ among individuals and within narrow BMI ranges [6]. Research has shown that cardiovascular risk factors such as hypertension, lipid levels, and glucose concentrations have a stronger association with abdominal adiposity, measured through waist circumference (WC) and waist-to-hip ratio (WHR), than with overall adiposity indicated by BMI [7]. Despite this, BMI remains a critical indicator for major health issues like type 2 diabetes and hypertension [2]. As a result, both WC and WHR are extensively used in clinical and research settings to provide a clearer picture of intra-abdominal and total body fat [8]. Further complicating the evaluation of obesity's impact on health are the differential effects of fat distribution. Upper-body obesity is more often associated with adverse cardiovascular and metabolic outcomes than lower-body obesity [9]. The challenge remains in determining the most effective cut-off points for WC and WHR to identify at-risk individuals. Proposals vary, with some suggesting gender-specific cut-offs based on BMI-defined overweight and obesity thresholds, while others recommend universal cut-offs that vary by age [5].

Moreover, certain populations, such as Asians, demonstrate higher metabolic and cardiovascular risks at lower BMI thresholds [10]. Hsuan et al. [11] provided evidence that abdominal obesity, rather than overall body mass, significantly contributes to metabolic and cardiovascular risks in this demographic, highlighting the importance of WHR, especially when BMI falls within a normal range. In studies conducted in China, different anthropometric measures were evaluated for their effectiveness in identifying cardiovascular disease (CVD) risk factors [12]. The findings indicated that while BMI and WC were the most effective for men, WC and WHR were more suitable for women [12, 13]. This underscores the necessity of using tailored anthropometric measurements that reflect both general and central obesity to enhance the predictive accuracy of nutrition-related non-communicable diseases (NR-NCDs) such as hypertension.

Given the complexities of determining the most effective anthropometric measure for predicting NR-NCDs, ongoing research comparing WHR and BMI is essential. Such research is crucial to ascertaining which method best predicts the individuals at greatest risk of NR-NCDs, thus aiding in the early detection and management of these diseases. Nutritionists, dietitians, public health practitioners, and other stakeholders must understand which measurement is more relevant for early detection and intervention. Therefore, this study aims to assess the efficacy of WHR, WHtR, WC and BMI as predictors of hypertension among adults in the Cape Coast Metropolis, providing critical data to inform public health strategies and improve health outcomes in the region.

MATERIALS AND METHODS

Study design and location

This community-based analytical cross-sectional study was conducted in the Cape Coast Metropolis, which serves as the regional capital of the Central Region of Ghana. Cape Coast spans an area of 122 square kilometres. Data collection occurred from June 5, 2020, to July 28, 2020, involving 390 randomly selected adult participants aged 18 years and older. These participants were from three communities within the metropolis: Amamoma, Kwaprow, and Abura, comprising 195 females and 195 males.

Study population and sampling procedure

A convenience sampling approach was used, with an added element of randomness. All seats at the screening centres in the three selected communities were numbered, and a subset of seats was randomly tagged. Adults who were present, sat on tagged seats, and consented to participate were included in the study.

Anthropometric measurements and data collection

Anthropometric data were collected using standard equipment. Participants' height and weight were measured with a stadiometer and a weighing scale, respectively, after they had removed their footwear and any heavy clothing. The Omron BF-511 full-body sensor body composition monitor and scale were utilised to assess BMI. Waist and hip circumferences were measured with a non-stretchable tape. Additionally, a structured questionnaire was used to obtain demographic information from the subjects.

Measurement and definition of hypertension

Blood pressure (BP) measurements were taken using a mercury sphygmomanometer (Reishter, Germany) tailored to the arm circumference of the subjects by a skilled nurse. Participants were seated, having rested for 10 minutes, and were instructed to abstain from smoking or consuming caffeine for at least 30 minutes prior to blood pressure measurement, which was in line with standard WHO recommendations. Two consecutive BP readings were taken 10 minutes apart, during which participants remained seated with their left hand at heart level and palms facing upward. The average of these two measurements was recorded as the final BP. Hypertension was defined based on the first Korotkoff sound (systolic blood pressure, SBP) and the disappearance of the last Korotkoff sound (diastolic blood pressure, DBP), with thresholds set at SBP > 140 mmHg or DBP > 90 mmHg. In addition, individuals who self-reported current use of antihypertensive medication were classified as hypertensive, regardless of their measured blood pressure.

Data analysis
The data analysis was conducted using IBM SPSS version 26.0 software (Chicago, Illinois, USA). Categorical variables were presented as percentages, and continuous variables were expressed as means ± standard deviations. The Chi-square test was utilised to analyse the association between anthropometric parameters and hypertension. Additionally, linear regression analysis was employed to evaluate the impact of various anthropometric indicators on blood pressure. Sensitivity, specificity, positive predictive value, negative predictive value, and relative risk were computed for each anthropometric variable using cross-tabulation and standard formulas for diagnostic test evaluation. All tests were considered significant at a p-value of less than 0.05.

RESULTS

Gender distribution was even, with each sex constituting 50% (195 individuals) of the sample (Table 1). Age-wise, the sample was predominantly youthful, with the 18 - 29 years age group representing the largest segment at 39.4% (154 individuals). The age group with the least number of participants was 70 - 89 years (10.7%). A significant majority, 57.2% (223 individuals), had attained higher education, underscoring a well-educated demographic. Occupational data revealed a diverse economic background among the participants. Civil servants formed the largest group at 43.1% (n = 168), reflecting strong public sector employment. This was followed by self-employed individuals at 20.3% (n = 79), traders at 19.0% (n = 74), and farmers at 17.7% (n = 69). With regard to marital status, over half of the participants were single, accounting for 54.1% (n = 211).

Anthropometric and clinical characteristics of the respondents
Table 2 summarises the anthropometric and clinical characteristics of the study participants. The average height and weight were 1.65 ± 0.10 m and 64.00 ± 12.50 kg, respectively. Participants had a mean body mass index (BMI) of 23.80 ± 5.00 kg/m², waist circumference of 88.50 ± 15.00 cm, and hip circumference of 95.20 ± 15.00 cm. The average waist-to-hip ratio was 0.95 ± 0.10, while the waist-to-height ratio was 0.56 ± 0.10. Mean systolic and diastolic blood pressure values were 135 ± 25 mmHg and 84 ± 12 mmHg, respectively. Males exhibited slightly higher values in terms of height, WHtR, and WHR ($p < 0.05$).

Prevalence of hypertension
Figure 1 illustrates the prevalence of hypertension among respondents, categorised by gender. Of the respondents, 25.38% were hypertensive. The graph indicates that 73.33% of the females were normotensive and 26.67% were hypertensive. In comparison, the male population showed a slightly higher percentage of normotensive individuals at 75.9%, with 24.1% being hypertensive.

Association between anthropometric measurements and hypertension
Table 3 presents the results of a chi-square analysis examining the relationship between various anthropometric

Table 1. Socio-demographic characteristics

Characteristic	Frequency (n)	Percentage (%)
Sex		
Female	195	50.0
Age group		
18-29 years	154	39.4
30-49 years	126	32.2
50-69 years	69	17.6
70-89 years	42	10.7
Educational Level		
None	48	12.3
Primary	29	7.4
Middle/JHS	34	8.7
Secondary/SHS	56	14.4
Higher	223	57.2
Occupation		
Civil Servant	168	43.1
Farming	69	17.7
Trading	74	19.0
Self-employed	79	20.3
Marital Status		
Married	142	36.4
Divorced	7	1.8
Widowed	30	7.7
Single	211	54.1

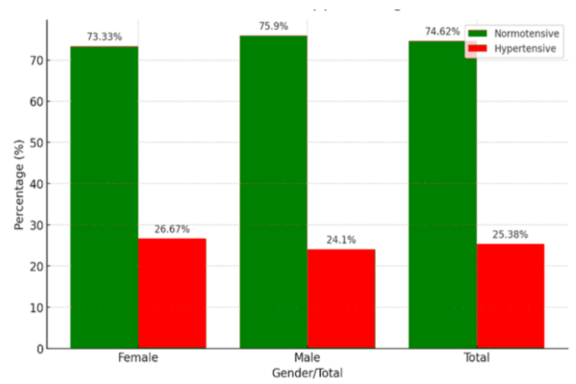

Figure 1. Prevalence of normotension and hypertension by gender

parameters (WC, WHR, WHtR, and BMI) and hypertension. The chi-square test indicates a statistically significant association ($p < 0.05$) between these anthropometric variables and hypertension.

Linear regression analysis of the relationship between anthropometric measurements and hypertension

Table 4 presents the results of a linear regression analysis examining the relationship between various anthropometric measurements and hypertension. The data indicated that only WC and WHtR show significant associations with hypertension ($p = 0.011$ and $p = 0.024$, respectively), while WHR and BMI were not statistically significant ($p = 0.458$ and $p = 0.466$, respectively). Specifically, the WC variable had a standardised coefficient of 0.293. WHtR showed a stronger association, with a standardised coefficient of 0.325. Both variables had statistically significant t-values, indicating a strong influence on the likelihood of hypertension. Conversely, WHR and BMI did not show statistically significant associations with hypertension. This suggests that they are not reliable predictors of hypertension in this analysis.

Table 2: Anthropometric and clinical characteristics of the respondents

Variables	General (n = 390)	Male (n = 195)	Female (n = 195)	t-statistic	p-value
Height (m)	1.65 ± 0.10	1.70 ± 0.12	1.60 ± 0.08	9.682	0.007
Weight (kg)	64.00 ± 12.50	68.00 ± 14.00	60.00 ± 11.00	6.274	0.249
BMI (kg/m²)	23.80 ± 5.00	24.00 ± 5.50	23.60 ± 4.50	0.786	0.432
Waist Circumference (cm)	88.50 ± 15.00	89.00 ± 16.00	88.00 ± 14.00	0.656	0.512
Hip Circumference (cm)	95.20 ± 15.00	94.00 ± 16.00	96.40 ± 14.00	1.576	0.116
Waist-Hip Ratio	0.95 ± 0.10	0.96 ± 0.11	0.94 ± 0.09	4.965	0.044
Waist-Height Ratio	0.56 ± 0.10	0.57 ± 0.11	0.55 ± 0.09	6.965	0.039
SBP (mmHg)	135 ± 25	137 ± 26	133 ± 24	1.578	0.116
DBP (mmHg)	84 ± 12	85 ± 13	83 ± 11	1.640	0.102

The table presents detailed comparisons of height, weight, Body Mass Index (BMI), waist and hip circumferences, waist-hip ratio, waist-height ratio, and blood pressure values (both systolic and diastolic) between males and females.
n = number, m = meters, kg = kilogram, cm = centimeter, and mmHg = millimeters of mercury

Table 3: Association between anthropometric measurements and hypertension

Variables	Categories	Normal (n1 = 291)	Hypertensive (n2 = 99)	χ^2	P-value
Waist Circumference (cm)	Normal	233	58	15.34	0.021
	Abnormal	58	41		
Hip Circumference (cm)	Normal	240	60	12.76	0.052
	Abnormal	51	39		
Waist-Hip Ratio	Normal	247	64	18.89	0.009
	Abnormal	44	35		
Waist-Height Ratio	Normal	251	69	13.55	0.033
	Abnormal	40	30		

*Chi-Square (χ^2) Analysis of Anthropometric Measurements and Hypertension

Table 4: Linear regression analysis of the relationship between anthropometric measurements and hypertension

model	Unstandardized		Standardized Coefficients			
	B	S.E.	B	t	95% CI	P-value
Constant	0.612	0.113	—	4.59	0.295 – 0.743	0.031
WC	0.299	0.069	0.256	4.48	0.173 – 0.445	0.011
WHR	-0.054	0.040	-0.045	-0.57	-0.152 – 0.084	0.458
WHtR	0.388	0.063	0.310	5.33	0.210 – 0.458	0.024
BMI	0.039	0.062	0.034	0.56	0.157 – 0.087	0.466

*The table provides a regression analysis summary with coefficients for different anthropometric measures (WC, WHR, WHtR, BMI) and a constant. Each model parameter includes an unstandardized coefficient (B), standard error (S.E.), standardised coefficient (Beta), t-statistic, 95% confidence interval (CI), and p-value. WC = waist circumference, WHR = waist-hip-ratio, WHtR = waist-to-height ratio, BMI = body mass index

Table 5: Specificity, sensitivity, predictive values, and relative risk

Parameters	SEN	SPE	PPV	NPV	OR
BMI	34.2	76.95	49.4	65.55	1.596
WHR	62.7	57	46.55	71.25	1.862
WC	57.95	81.7	68.4	75.05	3.23
WHtR	88.35	46.55	49.4	87.4	6.175

The table presents diagnostic accuracy parameters for four anthropometric measures: BMI, WHtR, WC, and WHR. Each measure is evaluated by its Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, and Odds Ratio. WC = waist circumference, WHR = waist-hip-ratio, WHtR = waist-to-height ratio, BMI = body mass index, SEN = sensitivity, SPE = specificity, PPV = positive predictive value, NPV = negative predictive value and OR = odds ratio.

Specificity, sensitivity, predictive values, and relative risk

Table 5 revealed diverse diagnostic efficiencies of anthropometric measures for hypertension. Body Mass Index (BMI) exhibited relatively low sensitivity (34.2%) but higher specificity (76.95%), suggesting it better identified individuals without hypertension. Its moderate predictive values, with a Positive Predictive Value (PPV) of 49.4% and a Negative Predictive Value (NPV) of 65.55%, implied a modest risk increase, indicated by an odds ratio of 1.596. WHR displayed moderate sensitivity (62.7%) and lower specificity (57%), leading to an odds ratio of 1.862, suggesting a higher relative risk. WC showed better specificity (81.7%), high PPV (68.4%), and NPV (75.05%), marking it as a strong predictor. Waist-to-height ratio topped in sensitivity (88.35%) but had the lowest specificity (46.55%), with the highest odds ratio (6.175), thus presenting as the most significant risk indicator.

DISCUSSION

Hypertension remains a major risk factor for cardiovascular disease and a significant cause of death among adults in Ghana and worldwide, commonly referred to as a silent killer because it frequently goes unnoticed in its early stages or presents without a known cause. When a specific cause, like renal arterial stenosis, is determined, it is termed secondary hypertension. The effects of hypertension, both on individuals and the wider population, are profound; numerous individuals silently succumb to this condition due to late or absent diagnosis and treatment, highlighting the critical need for careful monitoring and prompt intervention [14]. The primary purpose of this study was to evaluate the effectiveness of various anthropometric indices, specifically BMI, WC, WHR, and WHtR, in predicting the risk of hypertension among adults in the Cape Coast Metropolis. By identifying which of these measures most accurately correlates with elevated blood pressure, the study aimed to provide evidence for the integration of practical and cost-effective tools into routine clinical assessments. This objective aligns with the broader public health goal of enhancing early detection and timely intervention for hypertension, especially in resource-limited settings where advanced diagnostic tools may not be readily available.

A study identified WHtR as an effective predictor of hypertension, noting its ability to account for the distribution of abdominal fat, which is closely linked to cardiovascular risk and an important indicator of central obesity[15]. Screening tests confirm WHtR as the superior predictor of hypertension risk [16]. The ability of WHtR to predict cardiovascular risk and hypertension has been highlighted in several studies [5]. A study among Brazilians discovered that WC and BMI are not as good indicators of hypertension as WHtR [17]. This can be attributed to several key factors. Unlike BMI, which reflects general body mass without considering fat distribution, and WC, which does not account for individual height differences, WHtR adjusts WC relative to height. This adjustment allows WHtR to more accurately reflect central (abdominal) adiposity (a stronger predictor of cardiovascular and metabolic risks). Abdominal fat, especially visceral fat, is closely linked to insulin resistance, inflammation, and increased arterial pressure, all of which contribute to hypertension. Therefore, WHtR serves as a better risk indicator by capturing the impact of fat distribution in relation to the body frame, making it more sensitive to cardiovascular risk than BMI or WC alone. This is particularly true when evaluating the distribution of abdominal fat, which is strongly associated with cardiovascular diseases [5,18].

The use of WHtR over other anthropometric measurements is further supported by the Korean ARIRANG study, which showed a substantial correlation between elevated WHtR and an increased risk of hypertension [19]. The importance of WHtR as a simple yet effective method for identifying people at risk of hypertension and related cardiovascular disorders has been severally investigated [5]. Conversely, BMI is significantly less effective in predicting hypertension compared to WC and WHtR. Body mass index, which measures global obesity, does not distinguish between fat and muscle and does not specifically measure central adiposity. The findings from this study, supported by similar hospital and population-based studies, demonstrate that indices of central obesity (WC and WHtR) are more predictive of hypertension risk than BMI. This supports theories of obesity-related hypertension and underscores the value of these anthropometric measurements as screening tools, particularly in a primary care setting [15]. Studies have indicated that WC and WHtR are more predictive of hypertension than BMI [5]. Research has demonstrated that central obesity markers, such as WC and WHtR, are superior to BMI in predicting the risk of hypertension. In contrast to BMI, WHtR exhibited a higher Area Under the Receiver Operating Characteristic (AU-ROC) curve, which suggests that it has a greater predictive potential for hypertension risk, according to the ARIRANG study [19]. Waist-to-height ratio is a superior test for hypertension prediction because it takes into account the distribution of abdominal fat, which is an important indication of cardiovascular risk [19]. Visceral fat is more strongly associated with hypertension and other cardiovascular disorders. Measurements of central obesity, such as WC and WHtR, are substantially correlated with visceral fat [5,13,19].

The robust predictive capability of WC and WHtR over BMI in determining hypertension underscores the need for healthcare providers, especially those in primary care settings, to incorporate these measurements into routine assessments, as this may enhance the early identification of individuals at higher cardiovascular risk due to central obesity [5, 19]. Additionally, the application of these anthropometric indices aligns with current healthcare strategies aimed at combating cardiovascular diseases through preventive measures. By prioritising the assessment of WHtR and WC, medical practitioners can better target interventions and educate patients on the specific risks associated with abdominal obesity, thus fostering a more informed and health-conscious community [11].

This strategic shift in focus from global to central obesity indicators could also pave the way for more tailored public health initiatives. As the evidence mounts in favour of WHtR and WC as critical markers for hypertension and related cardiovascular risks, health policies might evolve to include these measurements in standard health check-ups and public health screenings. This could potentially lead to earlier intervention and management strategies, which are crucial in mitigating the long-term effects of hypertension and reducing the overall burden of cardiovascular diseases [11]. Moreover, by integrating WHtR and WC into public health programs, educational campaigns can more effectively communicate the specific dangers of central obesity to the broader population. Such targeted education could empower individuals to make informed lifestyle choices that focus on reducing abdominal fat, such as specific dietary adjustments and appropriate physical activities, thus improving overall health outcomes.

Limitations of the study

The study was conducted in the Cape Coast Metropolis and may not be representative of other regions or populations. This geographical limitation could affect the generalizability of the findings to other settings or ethnic groups, as the sample is confined to a specific locale and demographic. Additionally, the cross-sectional nature of the study limits the ability to establish causality between anthropometric measurements and hypertension. Longitudinal studies would be more effective in determining causal relationships and the dynamics of changes in anthropometric measures and their impact on hypertension over time.

Strengths of the study

Firstly, the study utilises a robust and detailed methodology for collecting and analysing anthropometric data. The use of standard equipment for measuring height, weight, waist and hip circumferences, and blood pressure ensures accuracy and reproducibility of results. Furthermore, employing statistical tools like chi-square tests and linear regression analysis to evaluate the relationships between anthropometric measurements and hypertension enhances the scientific rigour of the findings. Secondly, the study adheres to strong ethical standards, with approval from the Institutional Review Board and informed consent obtained from all participants. This commitment to ethical research practices not only enhances the integrity of the study but also respects the rights and well-being of the participants. The community-based approach, involving local populations in Cape Coast, fosters community engagement and may improve participant compliance and the relevance of the findings to the local context.

Conclusion

In conclusion, the findings from this study reinforce the critical role of precise anthropometric assessments in clinical and public health frameworks. By focusing on central obesity measures like WHR, WHtR and WC, healthcare providers can achieve a more accurate and early diagnosis of hypertension, ultimately leading to better preventive care and management of cardiovascular health. This approach enhances individual patient care and contributes to the broader goal of reducing the prevalence and impact of hypertension within communities.

DECLARATIONS

Ethical consideration

Ethical approval for this study was obtained from the Institutional Review Board of the University of Cape Coast (UCCIRB/CHAS/2020/07). Informed consent was secured from each participant before their inclusion in the study. All anthropometric measurements adhered to established standard protocols, ensuring the ethical integrity of the research.

Consent to publish

All authors agreed on the content of the final paper.

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None

Competing Interest

The authors declare no conflict of interest

Author contribution

KA and ARA conceptualised and designed the research; KA and ARA implemented the research; SOA, ARA, and IA-M conducted the analysis; KA, SOA, AD, MDA, IA-M and ZH wrote the draft manuscript; all authors reviewed the draft manuscript and approved the final version.

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Availability of data

Data is available upon request to the corresponding author

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