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Body Mapping as Risk Factors for Non-Communicable Diseases in Ghana: Evidence from Ghana's 2023 Nationwide STEPS Survey

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Abstract

Noncommunicable diseases (NCDs) are the leading cause of global morbidity and mortality, accounting for over 43 million deaths in 2021, with 18 million occurring in individuals under 70 years. Low- and middle-income countries (LMICs) bear the brunt, with over 80% of premature deaths attributed to NCDs, primarily cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes. Beyond health impacts, NCDs drive significant economic losses, estimated at $7 trillion between 2011 and 2025, while prevention costs are far lower. This secondary analysis of a national survey explores how body mapping measures such as BMI, waist circumference, and waist-to-hip ratio can predict the risk of major NCDs, including hypertension, diabetes, and heart diseases. The Ghana STEPS survey employed a cross-sectional design to assess noncommunicable disease (NCD) risk factors nationwide using the WHO STEPwise approach, incorporating demographic and behavioral data collection (Step 1), physical measurements (Step 2), and biochemical assessments (Step 3). A nationally representative sample of 5,775 participants was selected using multistage stratified sampling, ensuring proportional representation by region, urban/rural residency, age, and gender. Ethical approval was obtained, and informed consent was secured from participants. Anthropometric and biochemical data were collected following standardized protocols, including measurements of height, weight, waist and hip circumferences, blood pressure, fasting glucose, and lipid profiles. Data were analyzed using STATA 17.0, accounting for complex survey design with appropriate weighting. The study found significant sex-based differences in anthropometric measures, with men being taller and lighter while women had higher waist and hip circumferences and BMI. The prevalence of NCDs increased with age, highest in participants aged 60–69 years, and was more common in females than males. Lower educational attainment and marital status (widowed, divorced, or separated) were associated with higher NCD prevalence, while obesity and very high waist circumference were the strongest predictors of NCD risk. ROC analysis of anthropometric measures showed fair predictive ability, with waist circumference, BMI, and waist-to-hip ratio showing similar modest performance in identifying individuals with at least one NCD. Anthropometric measures such as waist circumference, hip circumference, BMI, waist-to-hip ratio, and waist-to-height ratio are strongly associated with the risk of major noncommunicable diseases

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(NCDs) like hypertension, diabetes, dyslipidemia, and cardiovascular events. However, individually, these measures lack sufficient accuracy for effective screening. Integrated screening approaches combining multiple risk factors, along with tailored interventions, should be implemented to improve early detection and management of NCDs, particularly in resource-limited settings.

Keywords: obesity; hypertension; diabetes; screening; anthropometric; BMI; NCD

1. Introduction

Globally, noncommunicable diseases have the highest morbidity and mortality more than any other group of diseases. According to the World Health Organization, in 2021, noncommunicable diseases (NCDs) was responsible for over 43 million deaths globally, of which 18 million were deaths in people less than 70 years [1]. More than 80% of all noncommunicable diseases deaths in persons aged less than 70 years occurs in low-and middle-income countries (LMIC) [2]. Cardiovascular diseases are leading cause, responsible for 19 million deaths, followed by cancers (10 million), chronic respiratory diseases (4 million), and diabetes (over 2 million) [1].

NCDs pushes many people into poverty, as it leads to loss of productivity along with catastrophic health expenditure which leads to insuperable access barriers to healthcare services for some people living with NCDS [3]. LMICs are projected to lose about $7 trillion (2011 – 2025) with annual loss of about $500 billion due to treatment of NCDs. Cost of interventions to prevent or reduce the burden of NCDs are projected as $170 billion for the same period [4]. There is therefore the urgency of improving financial risk protection in health in LMIC settings and ensuring that NCDs are taken into to integrated NCDs interventions to address NCDs related mortality [5].

Addressing NCDs requires among other interventions, screening and identification of high-risk individuals and putting measures to address the modifiable risk factors. Global evidence shows that a combination of four behavioral risk factors—notably tobacco smoking, harmful consumption of alcohol, lack of physical exercise, and unhealthy diets—account for more than a third of NCDs. Genetic or metabolic risk factors like obesity, high cholesterol, high fasting blood glucose, and high blood pressure also have direct impacts on risk vulnerability for NCDs [6]. However, other factors easily identifiable through body mapping and anthropometric measures with the aid of less expensive tools include body mass index (BMI), waist circumference, hip circumference, waist to hip ratio [7]. Waist circumference and waist-to-hip ratio (WHR) are widely used as proxy measures for visceral adipose tissue (VAT) due to their strong association with elevated risks of various health conditions and mortality across most populations [7,8].

Obesity is a well-known risk factor for prediabetes, impaired glucose intolerance and diabetes [9,10]. The impact of obesity is also garnering greater attention among cancer prevention efforts as well particularly with colorectal cancer and female breast cancer [11,12]. Additionally, there is increasing evidence that obesity and chronic lung disease are inter-related [13]. In Ghana, Nuertey et al. demonstrated that, hypertension, arthritis, dyslipidemia, blindness and visual impairment were associated with obesity among the elderly [14,15]. In addition , several other studies in Ghana have shown the rising trend of obesity across the lifespan [16–18] with prominence among children, and young adults [19–22]. Obesity is one side of the double burden of malnutrition, and in 2024, more people were obese than underweight in every WHO region of the world except for South-East Asia Region [23]. The aim of this secondary analysis of the data from the nationwide survey of risk factors for NCDs using the WHO STEPwise approach to NCD surveillance is to determine the association of elements of body mapping such as BMI, waist circumference, hip circumference, waist to hip ratio on the risk of developing any of the major noncommunicable diseases; hypertension, diabetes, dyslipidemia and history of heart attack or stroke and determine the ability of each of the body mapping factors to correctly predict the likelihood of an adult living with any of the major NCDs.

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2. Materials and Methods

Study Design

The Ghana STEPS survey utilized a cross-sectional design to assess the prevalence of non-communicable diseases (NCDs) risk factors across the country. The study followed the World Health Organization's (WHO) STEPwise approach, which includes three sequential components: Step 1: Collection of demographic and behavioral data through a structured questionnaire. Step 2: Physical measurements such as height, weight, blood pressure, and waist circumference. Step 3: Biochemical assessments, including fasting blood glucose and lipid profiles.

Sample Size and Sampling Procedure

The sample size of 5,775 participants was calculated based on a precision-based formula, considering a 95% confidence level, a 5% margin of error, and a design effect of 1.5 to account for cluster sampling and stratification . A multistage sampling technique was employed to ensure national representation:

Stage 1: Enumeration areas (EAs) were selected using a probability proportional to size method. Stage 2: Fifteen households were randomly selected from each EA.

Stage 3: One eligible participant was randomly selected from each household using an electronic randomization tool embedded in the eSTEPS application. Stratification was applied to ensure proportional representation by region, urban/rural residency, age, and gender.

Ethical Approval and Participant Consent

Ethical clearance was obtained from the Ghana Health Service Ethics Review Committee before initiating the survey (GHS-ERC 032/08/22). All participants received detailed information about the study's purpose, procedures, and potential risks. Written informed consent was obtained from each participant before enrollment. Confidentiality was maintained through data anonymization and secure storage systems.

Outcome Variables

The outcome variable is defined as having being diagnosed of the at least one of the major noncommunicable diseases; hypertension, diabetes, dyslipidemia, history of heart attack or stroke. To obtain this, any participant who answered "yes" to any of the questions "Have you ever been told by a doctor or other health worker that you have raised blood pressure or hypertension?", "Have you ever been told by a doctor or other health worker that you have raised blood sugar or diabetes?", "Have you ever been told by a doctor or other health worker that you have raised cholesterol?", and "Have you ever had a heart attack or chest pain from heart disease (angina) or a stroke (cerebrovascular accident or incident)?" were coded as having an NCD event and those who did not answer yes to any of these questions were coded as not having an NCD diagnosis. For the measurements, for hypertension, diabetes and total cholesterol, the reference ranges were applied to classify each individual as having any of the above diagnosis or not. For hypertension, the average of all three repeated measurements of systolic and diastolic blood pressures were used to classify a patient as hypertensive.

Anthropometric and Other Measurements

Pregnant women were excluded from all anthropometric measurements. Height was measured to the nearest 0.1 cm using a portable stadiometer, with participants standing upright without shoes, feet together. Weight was measured to the nearest 0.1 kg using a calibrated (Omron body composition monitor) digital weighing scale, with participants wearing light clothing and no shoes. Waist circumference (WC) was measured to the nearest 0.1 cm using a flexible, non-stretchable measuring tape placed midway between the lower margin of the last rib and the top of the iliac crest, with the

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participant in a standing position at the end of a normal expiration. Hip circumference (HC) was measured at the widest part of the hips to the nearest 0.1 cm. The waist-to-hip ratio (WHR) was calculated as the ratio of waist circumference to hip circumference, and the waist-to-height ratio (WHtR) was also computed. Hip circumference was classified as normal, increased, or substantially increased based on established thresholds.

A point-of-care analyzer, CardioChek plus was used to measure the Total Cholesterol, and HDL and the result recorded directly on the Android tablet , and the Onetouch Select Plus for fasting blood glucose.

Data Collection Process

The data collection process occurred in three phases: Phase 1: Questionnaire Administration; Demographic and behavioral data, including age, gender, education, smoking habits, alcohol consumption, physical activity, and dietary habits, were collected using an interviewer-administered questionnaire. Interviews were conducted in local languages, including Twi, Ga, Ewe, and Dagbanli, with interpreters engaged where necessary. Phase 2: Physical Measurements; Physical measurements were conducted using standardized equipment and protocols: Height was measured using a portable stadiometer. Weight was measured using calibrated digital scales. Blood pressure was recorded using automated monitors (Omron), with three readings taken at five-minute intervals. Waist circumference was measured with a non-stretchable measuring tape. Phase 3: Bio-sample Collection; Fasting blood and urine samples were collected to assess glucose levels using One Touch select plus flex, lipid profiles, and other biochemical markers measured with CardioChek Plus. Participants were instructed to fast for 8–12 hours before sample collection. Samples were processed in accordance with WHO biosafety and quality control guidelines.

Data Analysis

Data were analyzed using STATA version 17.0 (StataCorp, College Station, TX, USA). Analysis accounted for the complex survey design, with appropriate weighting applied to generate nationally representative estimates. Prevalence and associations between variables were assessed using descriptive and inferential statistical methods. The weighting process was conducted at three distinct levels: individual-level weighting, population distribution weighting, and adjustment for non-response. The final weight was calculated as the inverse of the product of these three components. For the analysis, data were stratified by age groups and rural-urban classifications. Descriptive statistical methods were utilized to summarize the socio-demographic characteristics of the participants and the prevalence of obesity and categorized using the standard BMI cutoffs. Categorical variables were reported as frequencies and percentages, while continuous variables were summarized as means with their corresponding standard deviations (SD), where appropriate.

BMI was coded according to the WHO classification; Underweight: BMI <18.499, Normal weight: BMI 18.5-24.99, Overweight: ≥25.0 BMI ≤ 29.99 and Obesity: BMI ≥30.0. Also for waist circumference, the following cut offs were used: for men, <94.9cm normal, 95-101.9 cm high and ≥102 cm very High. And for females, <80cm for normal, 80 – 87.9 cm for high and ≥ 88cm for very high. Also for hip circumference, males, <93.999=normal, 94/101.999=increased, ≥102 =substantially increased and for the females, ≤79.999=normal, 80 - 87.99=increased, and ≥88/max=Substantially increased. For waist to hip ratio, whr ≥ 0.9 for men and 0.85cm for women was considered as substantially increased. Statistical significance was determined using a p-value threshold of <0.05. To explore factors linked to the outcome variable of having a diagnosis of a non-communicable disease (NCD), univariate logistic regression was conducted to calculate crude odds ratios (ORs) along with 95% confidence intervals (CIs). Variables with a p-value below 0.20 in the univariate analysis were included in a multivariable logistic regression model to control for potential confounding factors and to compute adjusted odds ratios (AORs) with 95% CIs. The final model was optimized using a backward stepwise approach guided by the Akaike Information Criterion (AIC). Variance inflation factor (VIF) analysis was employed to check for multicollinearity among independent variables, with

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a VIF >10 indicating no significant collinearity. The Hosmer-Lemeshow test was used to assess the goodness-of-fit of the multivariable model. All analyses adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to ensure clarity and reproducibility.

3. Results

3.1. Characteristics of Study Participants

Table 1 presents the characteristics of study participants by sex, including age, height, weight, waist circumference, hip circumference, BMI, waist-to-hip ratio, and waist-to-height ratio. The mean age for all participants was 35.14 years, with men having a slightly lower mean age (34.82 years) compared to women (35.47 years). Men were taller (170.3 cm) than women (159.71 cm), and their weight was slightly lower (65.56 kg) compared to women (66.89 kg). Waist circumference was smaller in men (81.9 cm) than in women (88.3 cm), while women had a larger hip circumference (101 cm) compared to men (94.3 cm). The overall BMI was 24.9, with men having a lower BMI (22.7) than women (26.3). The waist-to-hip ratio was similar between men and women, while the waist-to-height ratio was lower in men (0.481) than in women (0.555). These differences in physical characteristics highlight variations between male and female participants.

Table 1. Characteristics of study participants segregated by sex.

Characteristics	All Participants Mean (95% CI)	Men Mean (95% CI)	Women Mean (SD)
Age (years)	35.14 [34.6-35.7]	34.82 [33.9-35.7]	35.47 [34.9-36.1]
Height (cm)	165.2 [163.9-166.5]	170.3[168.2-172.5]	159.71[158.4-161.0]
Weight (Kg)	66.0 [64.5-67.5]	65.56 [63.87-67.24]	66.89 [65.75-68.04]
Waist Circumference (cm)	85.9 [84.9-86.8]	81.9 [80.1-83.7]	88.3 [87.3-89.3]
Hip Circumference	98.9 [98.0-99.8]	94.3 [92.5-96.1]	101 [100.8-102.7]
BMI (kg/m^2)	24.9 [24.7-25.1]	22.7[22.3-23.1]	26.3[26.0-26.6]
Waist to Hip ratio	0.867 [0.865-0.869]	0.866[0.863-0.870]	0.867[0.846-0.870]
Waist to height ratio	0.527 [0.523-0.531]	0.481 [0.474-0.488]	0.555 [0.551-0.560]

3.2. Characteristics of Participants with at Least One Self-Reported NCD Diagnosis

Table 2 presents the distribution of participants with at least one non-communicable disease (NCD) diagnosis according to demographic, socioeconomic, and anthropometric variables. Significant findings are as follows: The prevalence of NCDs increased progressively with age, with the lowest prevalence observed in the youngest group (18–29 years: 14.2%, 95% CI: 11.8–17.0) and the highest in participants aged 60–69 years (52.1%, 95% CI: 46.8–57.4, $p < 0.001$). This trend underscores age as a strong determinant of NCD burden. Sex differences were notable, with females exhibiting a higher prevalence of NCDs (30.8%, 95% CI: 28.6–33.1) compared to males (21.3%, 95% CI: 18.7–24.0, $p < 0.001$).

Educational attainment showed a significant association with NCD prevalence ($p = 0.006$). Participants with no formal education had the highest prevalence (30.6%, 95% CI: 27.8–33.5), whereas those with primary education had the lowest (21.6%, 95% CI: 16.9–27.2). Participants with secondary or tertiary education demonstrated intermediate prevalence rates, suggesting a complex interaction between education level and health outcomes. Marital status was significantly associated with NCD prevalence ($p < 0.001$). Those currently married had the highest prevalence (31.6%, 95% CI: 29.4–33.9). This was followed by participants classified as "others" (36.0%, 95% CI: 32.3–39.9), which include widowed, divorced, or separated individuals. Participants who had never married had the lowest prevalence (14.9%, 95% CI: 12.3–17.8). Occupation also influenced NCD prevalence ($p < 0.001$). Self-employed individuals had a higher prevalence (30.3%, 95% CI: 28.2–32.6), as did government employees (27.2%, 95% CI: 20.4–35.3). Unemployed participants and those in non-government employment demonstrated lower prevalence rates.

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Body mass index (BMI) revealed a strong association with NCD prevalence. Obesity was associated with the highest prevalence (44.6%, 95% CI: 40.2–49.0), followed by overweight individuals (32.0%, 95% CI: 28.5–35.6). Participants with normal BMI had significantly lower prevalence (20.5%, 95% CI: 18.3–22.9), and underweight individuals had the lowest prevalence (19.9%, 95% CI: 15.3–25.3). Anthropometric measurements further highlighted the association between body composition and NCDs. Participants with very high waist circumference had a prevalence of 44.5% (95% CI: 40.8–48.2), compared to 27.7% (95% CI: 24.2–31.6) for those with high waist circumference and 20.2% (95% CI: 18.1–22.5) for those with normal waist circumference. Similarly, participants with substantially increased hip circumference had the highest prevalence (32.0%, 95% CI: 29.8–34.2), while those with normal hip circumference had the lowest prevalence (18.5%, 95% CI: 15.3–22.0, $p < 0.001$).

In contrast, ethnicity and religion did not show statistically significant differences in NCD prevalence. Across ethnic groups, prevalence ranged from 24.7% (95% CI: 20.7–29.3) among Mole Dagbani participants to 33.3% (95% CI: 27.3–40.0) among Ga/Dangme participants ($p = 0.238$). Similarly, across religious groups, prevalence varied minimally, ranging from 20.4% (95% CI: 13.5–29.5) among participants of other religions to 29.2% (95% CI: 22.6–36.8) among those practicing traditional religions ($p = 0.412$).

Table 2. Proportion of participants with at least one self-reported NCD diagnosis.

Variable	Self-reported at least			Measured with at least one NCD		
	Weighted N(%)	NCD (%) [95%CI]	p-value	Weighted N(%)	NCD (%) [95%CI]	p-value
Age			<0.001			<0.001
18 to 29 years	2292 (44.0)	14.2 [11.8,17.0]		1420 (26.2)	27.6 [24.6,30.9]	
30 to 44 years	1641 (31.5)	28.6 [26.1,31.4]		2110 (38.9)	47.3 [43.9,50.7]	
45 to o59 years	930 (17.9)	40.8 [37.2,44.6]		1331 (24.5)	64.4 [60.6,68.0]	
60 to 69 years	345 (6.6)	52.1 [46.8,57.4]		570 (10.5)	72.3 [40.6,45.4]	
Sex			<0.001			<0.001
Male	2624 (50.4)	21.3 [187,24.0]		2019 (37.2)	37.5 [34.5,40.6]	
Female	2583 (49.6)	30.8 [28.6,33.1]		3412 (62.8)	48.6 [45.8,51.5]	
Level of education			0.006			0.005
No formal education	1381 (26.5)	30.6 [27.8,33.5]		1866 (34.4)	48.7 [44.3,53.1]	
Primary	611 (11.7)	21.6 [16.9,27.2]		660 (12.2)	50.0 [35.34,46.88]	
SHS	1597 (30.7)	25.7 [23.0, 28.7]		1608 (29.6)	42.9 [39.46,46.37]	
Tertiary	1618 (31.1)	24.0 [21.0,27.4]		1297 (23.9)	39.1 [35.07,43.3]	
Ethnicity			0.238			0.0178
Akan	2050 (39.4)	25.5 [23.2,28.0]		2197 (40.5)	44.9 [41.9,48.0]	
Ga/Dangme	300 (5.8)	33.3 [27.3,40.0]		283 (5.2)	53.8 [43.7,63.5]	
Ewe	689 (13.2)	27.3 [22.9,32.1]		693 (12.8)	44.3 [38.9,49.8]	
Mole Dagbani	1040 (20.0)	24.7 [20.7,29.3]		1000 (18.4)	37.9 [32.8,43.3]	
Others	1127 (21.7)	25.5 [22.2,29.1]		1259 (23.2)	40.7 [35.8,45.7]	
Religion			0.412			0.0511
Chistian	3608 (69.3)	26 [24.6,28.5]		3916 (72.1)	44.9 [42.3,47.5]	
Muslim	1312 (25.2)	24.7 [21.1,28.7]		1915 (22.0)	38.9 [33.5,44.7]	
Traditional	183 (3.5)	29.2 [22.6,36.8]		197 (3.6)	34.0 [25.8,43.3]	
Others	104 (2.0)	20.4 [13.5,29.5]		123 (2.3)	46.7 [34.1,59.7]	
Marital Status			<0.001			<0.001
Never married	1954 (37.5)	14.9 [12.3,17.8]		1252 (23.1)	28.4 [25.0,32.0]	
Currently married	2445 (47.0)	31.6 [29.4,33.9]		2964 (54.6)	49.9 [46.9,52.8]	
Others	808 (15.5)	36.0 [32.3,39.9]		1215 (22.4)	58.5 [54.4,62.5]	
Occupation			<0.001			<0.001
Unemployed	441 (8.5)	25.9 [19.5,33.5]		421 (7.8)	43.3 [35.5,51.5]	
Government employee	232 (4.5)	27.2 [20.4,35.3]		254 (4.7)	51.2 [43.0,59.4]	
Non-government employee	516 (9.9)	21.3 [17.1,26.3]		397 (7.3)	42.0 [35.1,49.2]	
Self-employed	2974 (57.1)	30.3 [28.2,32.6]		3682 (67.8)	48.5 [46.0,51.0]	
Others	1044 (20.1)	15.8 [12.6,19.6]		677 (12.5)	26.2 [21.5,31.6]	
BMI						<0.001
Underweight	495 (9.5)	19.9 [15.3,25.3]		440 (8.8)	33.7 [27.0,41.1]	
Normal	2943 (56.5)	20.5 [18.3,22.9]		2698 (51.3)	36.0 [33.3,38.8]	
Overweight	1082 (20.8)	32.0 [28.5,35.6]		1246 (23.7)	51.5 [47.1,55.8]	
Obese	688 (13.2)	44.6 [40.2,49.0]		872 (16.6)	66.0 [60.74,70.86]	

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Waist Circumference						<0.001
Normal	3383 (65.0)	20.2 [18.1,22.5]		2964 (56.4)	35.1 [32.4,37.8]	
High	837 (16.1)	27.7 [24.2,31.6]		890 (16.9)	51.1 [46.2,56.0]	
Very High	987 (19.0)	44.5 [40.8,48.2]		1402 (26.7)	64.9 [60.8,68.8]	
Hip Circumference			<0.001			<0.001
Normal	1693 (32.5)	18.5 [15.3,22.0]		1269 (24.1)	32.3 [28.5,36.4]	
Increased	920 (17.7)	23.2 [19.8,27.1]		862 (16.4)	39.1 [34.6,43.9]	
Substantially increased	2593 (49.8)	32.0 [29.8,34.2]		3125 (59.5)	52.0 [49.0,55.0]	
Waist to Hip ration						<0.001
Normal	2839 (54.0)	15.2 [13.9,16.7]		2839 (54.0)	35.0 [32.2,37.8]	
Increased	2417 (46.0)	20.6 [19.1,22.3]		2417 (46.0)	57.5 [54.3,60.7]	

3.3. Body Mapping Related Factors Associated with at Least One Self-Reported NCD Diagnosis

Table 3 presents the risk factors associated with non-communicable diseases (NCDs), with crude odds ratios (CORs) and adjusted odds ratios (AORs) reported alongside confidence intervals (CIs) and p-values. Age was strongly associated with NCD risk, with the odds increasing progressively in older age groups. Compared to participants aged 18–29 years, those aged 30–44 years had an AOR of 1.85 (95% CI: 1.43–2.41, $p < 0.001$), while participants aged 45–59 years and 60–69 years had higher risks, with AORs of 3.18 (95% CI: 2.37–4.26, $p < 0.001$) and 5.38 (95% CI: 3.90–7.42, $p < 0.001$), respectively. Females had higher odds of having NCDs compared to males in crude analysis (COR: 1.65, 95% CI: 1.36–2.01, $p < 0.001$); however, the association was not statistically significant after adjustment (AOR: 1.22, 95% CI: 0.91–1.63, $p = 0.186$).

Educational attainment showed mixed associations. While primary education was protective in crude analysis (COR: 0.63, 95% CI: 0.45–0.87, $p = 0.006$), the association was not significant after adjustment (AOR: 0.87, 95% CI: 0.60–1.26, $p = 0.473$). Tertiary education was associated with increased NCD risk after adjustment (AOR: 1.36, 95% CI: 1.01–1.82, $p = 0.042$). Ethnicity showed limited associations, with Mole Dagbani participants having a significantly higher NCD risk compared to Akan participants after adjustment (AOR: 1.42, 95% CI: 1.02–1.97, $p = 0.036$). Marital status was a significant factor, as participants classified as "others" (widowed, divorced, or separated) had an elevated NCD risk compared to those who were never married (AOR: 1.40, 95% CI: 1.04–1.89, $p = 0.028$), while the association for currently married participants was not significant after adjustment (AOR: 1.26, 95% CI: 0.94–1.68, $p = 0.118$).

Obesity was a strong risk factor, with obese participants having an AOR of 1.77 (95% CI: 1.15–2.74, $p = 0.010$) compared to underweight individuals. Overweight participants showed elevated crude odds (COR: 1.90, 95% CI: 1.32–2.74, $p = 0.001$), but the association was not significant after adjustment (AOR: 1.29, 95% CI: 0.86–1.94, $p = 0.219$). Participants with very high waist circumference had significantly increased odds of NCDs compared to those with normal waist circumference (AOR: 1.47, 95% CI: 1.06–2.02, $p = 0.019$). Substantially increased hip circumference was associated with higher NCD risk in crude analysis (COR: 2.08, 95% CI: 1.62–2.66, $p < 0.001$); however, this association was not significant after adjustment (AOR: 1.04, 95% CI: 0.74–1.47, $p = 0.813$).

Occupational status did not show statistically significant associations with NCD risk after adjustment for otther socio-demographic variables. Self-employment and government employment, among other categories, were not significantly related to NCD risk ($p > 0.05$). Religious affiliation also showed no significant associations with NCD risk in both crude and adjusted models. These findings highlight the critical role of age, obesity, and body composition as primary risk factors for NCDs, while other variables like education and marital status demonstrate nuanced relationships. Table 4 displays risk factors associated with having at least one of the measured NCDs: raised blood pressure, raised fasting blood sugar, raised total cholesterol and a history of myocardial infarction or Cerebrovascular accident.

Table 3. Risk factors associated with self-reported NCDs.

Variables	COR	95%CI	p-value	AOR	95%CI	p-value
Age						
18 to 29 years	Ref			Ref		

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30 to 44 years	2.43	1.91, 3.09	<0.001	1.85	1.43, 2.41	<0.001
45 to o59 years	4.17	3.16, 5.50	<0.001	3.18	2.37, 4.26	<0.001
60 to 69 years	6.58	4.87, 8.89	<0.001	5.38	3.90, 7.42	<0.001
Sex						
Male	Ref			Ref		
Female	1.65	1.36, 2.01	<0.001	1.22	0.91, 1.63	0.186
Level of education						
No formal education	Ref			Ref		
Primary	0.63	0.45, 0.87	0.006	0.87	0.60, 1.26	0.473
SHS	0.79	0.64, 0.96	0.019	1.05	0.81, 1.35	0.719
Tertiary	0.72	0.58, 0.89	0.003	1.36	1.01, 1.82	0.042
Ethnicity						
Akan	Ref			Ref		
Ga/Dangme	1.46	1.07, 2.00	0.019	1.36	1.00, 1.84	0.052
Ewe	1.09	0.84, 1.43	0.505	1.24	0.96, 1.62	0.103
Mole Dagbani	0.96	0.74, 1.25	0.757	1.42	1.02, 1.97	0.036
Others	1.00	0.80, 1.24	0.980	1.22	0.96, 1.54	0.098
Religion						
Chistian	Ref					
Muslim	0.91	0.73, 1.14	0.401			
Traditional	1.14	0.79, 1.65	0.470			
Others	0.71	0.43, 1.17	0.174			
Marital Status						
Never married	Ref			Ref		
Currently married	2.65	2.08, 3.37	<0.001	1.26	0.94, 1.68	0.118
Others	3.23	2.47, 4.22	<0.001	1.40	1.04, 1.89	0.028
Occupation						
Unemployed	Ref			Ref		
Government employee	1.07	0.65, 1.78	0.786	0.73	0.42, 1.26	0.259
Non-government employee	0.78	0.50, 1.21	0.260	0.83	0.50, 1.39	0.478
Self-employed	1.25	0.85, 1.84	0.261	0.87	0.56, 2.35	0.547
Others	0.54	0.34, 0.85	0.009	0.72	0.42, 1.22	0.219
BMI						
Underweight	Ref			Ref		
Normal	1.04	0.76, 1.43	0.792	1.04	0.74, 1.46	0.816
Overweight	1.90	1.32, 2.74	0.001	1.29	0.86, 1.94	0.219
Obese	3.25	2.27, 4.65	<0.001	1.77	1.15, 2.74	0.010
Waist Circumference						
Normal	Ref			Ref		
High	1.52	1.19, 1.93	0.001	1.11	0.83, 1.49	0.469
Very High	3.16	2.56, 3.92	<0.001	1.47	1.06, 2.02	0.019
Hip Circumference						
Normal	Ref			Ref		
Increased	1.34	0.99, 1.81	0.060	1.08	0.79, 1.46	0.639
Substantially increased	2.08	1.62, 2.66	<0.001	1.04	0.74, 1.47	0.813

Reference=Ref; COR=Crude Odds Ratio; AOR=Adjusted Odds Ratio.

Table 4. Risk factors associated with having at least one of the measured NCDs: raised blood pressure, raised fasting blood sugar, raised total cholesterol and a history of myocardial infarction or Cerebrovascular accident.

Variables	**COR**	**95%CI**	**p-value**	**AOR**	**95%CI**	**p-value**
Age						
18 to 29 years	Ref			Ref		
30 to 44 years	2.35	1.98, 2.79	<0.001	1.79	1.38, 2.32	<0.001
45 to o59 years	4.73	3.78, 5.92	<0.001	3.00	2.24, 4.04	<0.001
60 to 69 years	6.85	5.22, 8.99	<0.001	5.09	3.73, 6.94	<0.001
Sex						
Male	Ref			Ref		
Female	1.58	1.36, 1.82	<0.001	1.20	0.90, 1.59	0.218
Level of education						
No formal education	Ref			Ref		
Primary	0.73	0.56, 0.95	0.022	0.92	0.65, 1.29	0.624
SHS	0.73	0.64, 0.97	0.026	1.06	0.82, 1.36	0.645
Tertiary	0.67	0.53, 0.86	0.001	1.34	1.01, 1.77	0.041
Ethnicity						
Akan	Ref			Ref		

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Ga/Dangme	1.42	0.94, 2.15	0.093	1.33	0.98, 1.81	0.068
Ewe	1.42	0.76, 1.26	0.505	1.17	0.92, 1.50	0.182
Mole Dagbani	0.75	0.58, 0.96	0.024	1.46	1.04, 2.04	0.026
Others	0.84	0.67, 1.06	0.143	1.23	0.98, 1.55	0.079
Religion						
Chistian	Ref					
Muslim	0.78	0.61, 1.01	0.061			
Traditional	0.63	0.42, 0.996	0.031			
Others	1.07	0.63, 1.84	0.788			
Marital Status						
Never married	Ref			Ref		
Currently married	2.51	2.08, 3.02	<0.001	1.29	0.96, 1.74	0.068
Others	3.55	2.85, 4.42	<0.001	1.43	1.05, 1.94	0.022
Occupation						
Unemployed	Ref			Ref		
Government employee	1.37	0.84, 2.23	0.202	0.78	0.48, 1.31	0.361
Non-government employee	0.95	0.63, 1.42	0.784	0.85	0.50, 1.44	0.546
Self-employed	1.23	0.88, 1.73	0.229	0.89	0.57, 1.37	0.589
Others	0.46	0.29, 0.73	0.001	0.73	0.42, 1.25	0.260
BMI						
Underweight	Ref			Ref		
Normal	1.01	0.80, 1.53	0.541	1.01	0.72, 1.41	0.952
Overweight	2.09	1.46, 2.98	<0.001	1.27	0.85, 1.91	0.240
Obese	3.82	2.56, 5.62	<0.001	1.67	1.01, 2.54	0.019
Waist Circumference						
Normal	Ref			Ref		
High	1.93	1.57, 2.38	<0.001	1.11	0.83, 1.50	0.478
Very High	3.42	2.77, 4.21	<0.001	1.40	1.02, 1.993	0.036
Hip Circumference						
Normal	Ref			Ref		
Increased	1.34	1.014, 1.79	0.040	1.04	0.78, 1.40	0.783
Substantially increased	2.27	1.86, 2.76	<0.001	1.08	0.77, 1.52	0.647
Waist to hip ratio						
Normal	Ref					
Increased	2.52	2.13, 2.97	<0.001	1.08	0.89, 1.31	0.433

Reference=Ref; COR=Crude Odds Ratio; AOR=Adjusted Odds Ratio.

3.4. Receiver Operator Curve Analysis of Body Mapping Indicators as a Predictor of Having at Least One Measured NCD; Hypertension, Diabetes, Dyslipidemia or Self-Reported Myocardial Infarction or Stroke

The Receiver Operator Curve (ROC) analysis assessed body mapping indicators as predictors of having at least one non-communicable disease (NCD), including hypertension, diabetes, dyslipidemia, myocardial infarction, or stroke. Waist circumference had an ROC area of 0.607 (95% CI: 0.593–0.621), indicating fair predictive performance. Using a cut-off of "high," it demonstrated a sensitivity of 52.9%, specificity of 66.4%, and correctly classified 59.1% of participants. Hip circumference showed an ROC area of 0.576 (95% CI: 0.562–0.591) with a cut-off of "increased," achieving 81.3% sensitivity, 30.2% specificity, and 57.5% correct classification. Waist-to-hip ratio had an ROC area of 0.592 (95% CI: 0.578–0.606) with a cut-off of "increased," sensitivity of 54.7%, specificity of 63.7%, and correctly classified 58.9% of participants. Body mass index (BMI) showed an ROC area of 0.598 (95% CI: 0.584–0.613) with a cut-off of "overweight," sensitivity of 49.0%, specificity of 69.3%, and 58.5% correct classification. Overall, all indicators demonstrated modest predictive ability, with no single measure strongly outperforming the others. Table 5 and Figure 1 displays the results from the ROC analysis.

Table 5. Receiver Operator Curve analysis of Body mapping indicators as a predictor of having at least one measured NCD; hypertension, diabetes, dyslipidemia or self-reported myocardial infarction or Stroke.

Screening tool	ROC Area [95% CI]	Cut off	Sensitivity %	Specificity %	Correctly classify %
Waist circumference	0.607 [0.593, 0.621]	High	52.9	66.4	59.1
Hip Circumference	0.576 [0.562, 0.591]	Increased	81.3	30.2	57.5

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Waist to Hip Ratio	0.592 [0.578, 0.606]	increased	54.7	63.7	58.9
Body mass index	0.598 [0.584, 0.613]	Overweight	49.0	69.3	58.5

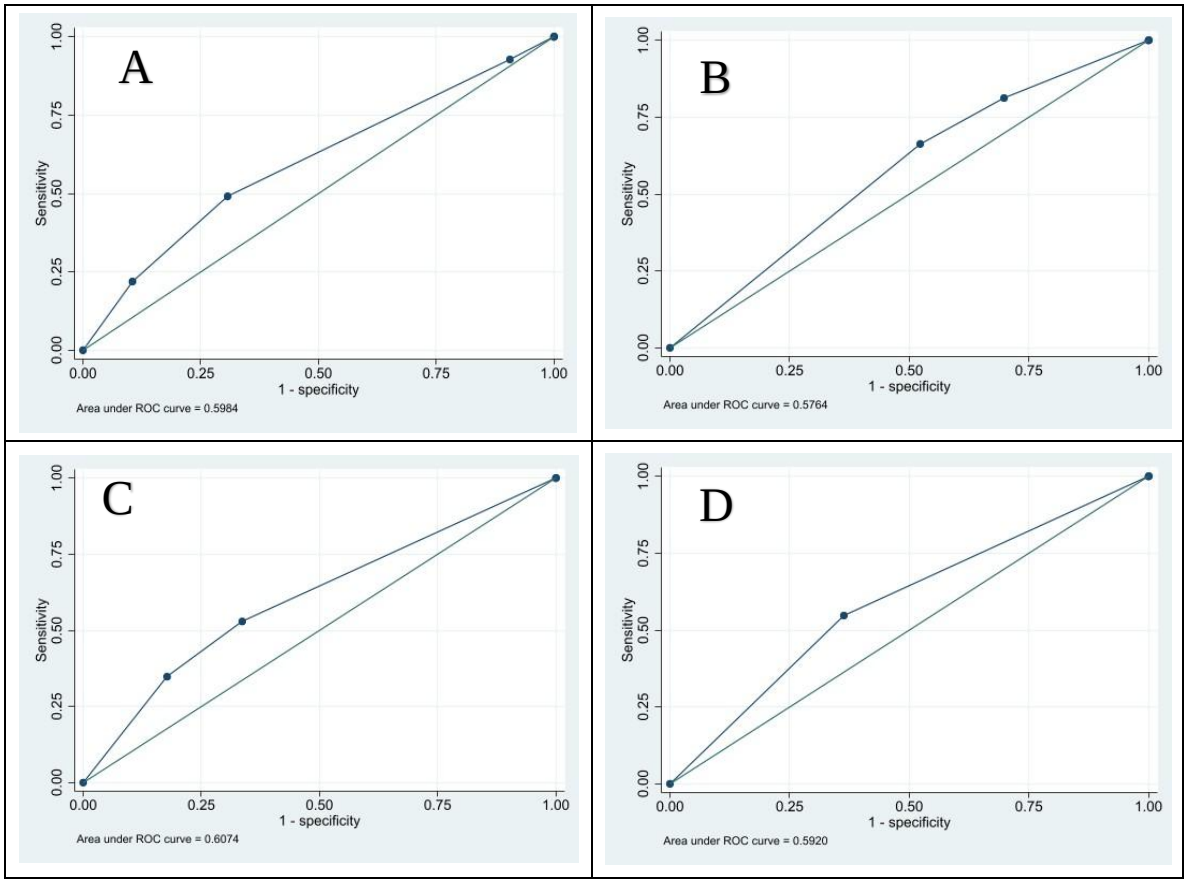

Figure 1. Receiver operator characteristic curve showing area under curve for A. Body Mass Index, B. Hip circumference, C. Waist circumference and D. Waist to hip ratio.

4. Discussion

The study examined body mapping related factors as Risk Factors for Non-Communicable Diseases in Ghana using the data evidence from Ghana's 2023 Nationwide STEPS Survey. The analysis revealed statistically significant association of body mapping factors such as BMI, waist circumference, hip circumference and waist to hip ratio with the likelihood of having at least one diagnosis of a noncommunicable disease. However, none of these factors demonstrate strong test performance in a receiver operator characteristics analysis to successfully predict a person living with at least one of the major NCDS; hypertension, Diabetes, Dyslipidemia and a history of Myocardial infarction or cerebrovascular accident.

Anthropometric measures, including BMI, waist circumference, and hip circumference, are well known factors that are associated with the risk of developing noncommunicable diseases. Hewage et al. in 2023 found out that, BMI, WC, WHR, and HC are intercorrelated anthropometric measurements that can be used either alone or in combination to define obesity and detect the risk for NCDs, including diabetes mellitus, cardiovascular disease, and infertility [24]. Other studies in other African countries produced similar findings [25–27]. Also the WHO expert consultation on Waist circumference and waist-hip ratio in 2008 [28], concluded that previously used anthropometric indicators and measures, such as BMI, waist circumference, and waist-to-hip ratio, are effective in predicting chronic disease risk. The experts further recommended that result of any waist circumference and waist-to-hip ratio thresholds established through the recommended process could be applied independently or alongside BMI. Notwithstanding these recommendations, in this study, BMI emerged as a particularly significant risk factor for having at least one of the major NCDs, with

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obese participants experiencing the highest prevalence rates when compared to the other body measurements. These findings emphasize the critical role of body composition in NCD risk and highlight the need for interventions targeting obesity as a modifiable factor. Older age groups demonstrated significantly increased odds of NCDs, with participants aged 60–69 years showing over fivefold higher odds compared to those aged 18–29 years.

Several studies revealed a range of health risks associated with elevated waist circumference, including hypertension, diabetes mellitus, high cholesterol, joint and lower back pain, hyperuricemia, and Obstructive Sleep Apnea Syndrome [29]. Cardiovascular diseases particularly have been found to have a high association with elevated waist circumference [30–32]with most studies describing weight to height ratio as a more accurate tool for predicting hypertension than waist to hip circumference and BMI [33,34].

This study explored which of this body mapping factors that produce a better screening test performance for predicting the likelihood of a person having at least one of the major NCDs included in the WHO STEPS survey. Receiver Operator Curve (ROC) analysis showed that body mapping indicators provided modest predictive value for NCDs. Waist circumference demonstrated the highest area under the curve (AUC), but no single measure exhibited strong predictive performance. Jia et al. using ROC analysis also found out that Waist to height ratio, and to some degree Waist circumference, are the best predictors of type 2 diabetes, followed by BMI then waist to hip ratio which is the weakest predictor in the tested adults [35].

These findings suggests that, it is not absolutely correct to look at a person and based on the perceived size or measurement of BMI, waist circumference, hip circumference, waist to hip ratio to accurately make a determination on the likelihood of the individual to be living with a major NCDs such as diabetes or Hypertension or raised total cholesterol or have a history of a non-fatal heart attack or stroke.

This study had some limitations. It did not compare the test performance of each of the body mapping characteristics studied in this study with the individual NCDs studied in the study. Future studies should consider this type of analysis..

5. Conclusions

Waist circumference, hip circumference, BMI, waist to hip ratio, waist to height ratio have a strong association with the likelihood of living with at least one of this NCDs; hypertension, Diabetes, dyslipidemia, and a history of a non-fatal myocardial infarction or stroke. However, none of these factors independently has a good test performance in screening for individuals living with any of these noncommunicable diseases.

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Abbreviations

The following abbreviations are used in this manuscript:

NCD	Non-Communicable Disease
LMIC	Low- and Middle-Income Countries
BMI	Body Mass Index
WC	Waist Circumference
HC	Hip Circumference
WHR	Waist-to-Hip Ratio
WHtR	Waist-to-Height Ratio
VAT	Visceral Adipose Tissue
STEPS	STEPwise Approach to Surveillance (WHO methodology)
WHO	World Health Organization
GHS-ERC	Ghana Health Service Ethics Review Committee
ROC	Receiver Operator Characteristic
AUC	Area Under the Curve
COR	Crude Odds Ratio
AOR	Adjusted Odds Ratio
HDL	High-Density Lipoprotein
eSTEPS	Electronic STEPS application used for data collection

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