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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

Non-communicable diseases (NCDs) are the leading global cause of death, causing over 43 million deaths in 2021, including 18 million premature deaths, disproportionately affecting low- and middle-income countries. NCDs also incur significant economic losses, estimated at USD 7 trillion from 2011 to 2025, despite low prevention costs. This study evaluated body mapping indicators: body mass index (BMI), waist circumference, and waist-to-hip ratio—for predicting NCD risk, including hypertension, diabetes, and cardiovascular diseases, using data from a nationally representative survey in Ghana. The study sampled 5775 participants via multistage stratified sampling, ensuring proportional representation by region, urban/rural residency, age, and gender. Ethical approval and informed consent were obtained. Anthropometric and biochemical data, including height, weight, waist and hip circumferences, blood pressure, fasting glucose, and lipid profiles, were collected using standardized protocols. Data analysis was conducted with STATA 17.0, accounting for complex survey design. Significant sex-based differences were observed: men were taller and lighter, while women had higher BMI and waist/hip circumferences. NCD prevalence increased with age, peaking at 60–69 years, and was higher in females. Lower education and marital status (widowed, divorced, separated) correlated with higher NCD prevalence. Obesity and high waist circumference strongly predicted NCD risk, but individual anthropometric measures lacked screening accuracy. Integrated screening and tailored interventions are recommended for improved NCD detection and management in resource-limited settings.

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

Academic Editor: Nobuyuki Takahashi

Received: 24 June 2025
Revised: 22 August 2025
Accepted: 3 September 2025
Published: 3 October 2025

Citation: Mwin, P.K.; Nuertey, B.D.; Ansong, J.; Nartey, E.B.; Gyimah, L.; Tabong, P.T.-N.; Abbeyquaye, E.P.; Eshun, P.F.; Ampem Amoako, Y.; Totah, T.; et al. Body Mapping as Risk Factors for Non-Communicable Diseases in Ghana: Evidence from Ghana's 2023 Nationwide Steps Survey. *Obesities* **2025**, *5*, 71. https://doi.org/10.3390/obesities5040071

1. Introduction

Globally, non-communicable diseases have the highest morbidity and mortality of any other group of diseases. According to the World Health Organization, in 2021, non-communicable diseases (NCDs) were responsible for over 43 million deaths globally, of which 18 million were deaths in people less than 70 years old [1]. More than 80% of all non-communicable disease deaths in persons aged less than 70 years occur in low- and middle-income countries (LMIC) [2]. Cardiovascular diseases are the leading cause, responsible for 19 million deaths, followed by cancers (10 million), chronic respiratory diseases (4 million), and diabetes (over 2 million) [1]. Global diabetes prevalence is expected to increase from 537 million in 2021 to 783 million by 2045, with healthcare costs in excess of USD 1054 billion, representing a 46 percent rise [3]. Cardiovascular diseases are the leading cause of death globally and are anticipated to account for over 24 million deaths annually by 2030, with the greatest increases occurring in low- and middle-income countries due to rapid urbanization, aging populations, and lifestyle transitions [4].

NCDs push many people into poverty, as they lead to loss of productivity along with catastrophic health expenditure, which leads to insurmountable access barriers to healthcare services for some people living with NCDS [5]. LMICs are projected to lose about USD 7 trillion (2011–2025), with an annual loss of about USD 500 billion due to the treatment of NCDs. The cost of interventions to prevent or reduce the burden of NCDs is projected as USD 170 billion for the same period [6]. There is therefore an urgency to improve financial risk protection in health in LMIC settings and ensure that NCDs are incorporated into integrated NCD interventions to address NCD-related mortality [7].

Addressing NCDs requires, among other interventions, screening and identifying high-risk individuals, and implementing measures to address 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—accounts 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 a direct impact on the risk vulnerability for NCDs [8]. 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, and waist-to-hip ratio [9]. 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 [9,10].

Obesity is a well-known risk factor for prediabetes, impaired glucose intolerance, and diabetes [11,12]. The impact of obesity is also garnering greater attention among cancer prevention efforts, particularly with colorectal cancer and female breast cancer [13,14]. Additionally, there is increasing evidence that obesity and chronic lung disease are interrelated [15]. In Ghana, Nuertey et al. demonstrated that hypertension, arthritis, dyslipidemia, blindness, and visual impairment were associated with obesity among the elderly [16,17]. In addition, several other studies in Ghana have shown a rising trend of obesity across the lifespan [18–20], with a particular prominence among children and young adults [21–24]. 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 the South-East Asia Region [25].

Despite strong evidence linking obesity and related anthropometric measures with the risk of non-communicable diseases, there remains limited data on how different body mapping indicators compare in their predictive performance within African populations, including Ghana. While some studies have examined associations between obesity and individual NCD outcomes, few have assessed the predictive value of multiple anthropometric indices—such as BMI, waist circumference, waist-to-hip ratio, and waist-to-height ratio—simultaneously in a nationally representative adult sample. Furthermore, the threshold at which these measures effectively identify individuals at risk of multiple NCDs remains unclear, particularly in low-resource settings where cost-effective screening tools are critically needed.

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 non-communicable 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.

2. Materials and Methods

2.1. Study Design

The Ghana STEPS survey utilized a cross-sectional design to assess the prevalence of non-communicable disease (NCD) 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.

2.2. Sample Size and Sampling Procedure

To determine the sample size necessary to obtain the desired population estimate for key risk factors, the WHO recommends using the formula:

$$n = \mathrm{z}^2 \mathrm{D} p(1-p)/\mathrm{e}^2,$$

where:

n = Sample size;

D = Design effect;

p = Estimated proportion or prevalence within the target population at the time of the first survey;

z = Level of confidence in the sample mean or prevalence as an estimate of the population mean or prevalence;

e = Margin of error.

In this study, p represents the nationwide prevalence of any NCD-related risk factors. As this was the first nationally representative survey to provide prevalence data on key risk factors for NCDs in Ghana, WHO recommends assuming that 50% of participants will have at least one risk factor (such as tobacco use, alcohol use, unhealthy diet, or physical inactivity) for the purposes of sample size estimation. In cases where p is unknown, it is often assumed to be 50%.

To calculate the minimum sample size (n), the following assumptions were made:

z = 1.96 (corresponding to a 95% confidence level);

D = 1.5 (design effect);

p = 0.5 (or 50%);

e = 0.05 (or 5% margin of error).

Using these parameters, the minimum sample size obtained is 576. This sample size is then adjusted for the number of strata, which in this case is 8 (comprising four age groups:

18–29, 30–44, 45–59, 60–69, and two sex categories: male and female). Additionally, the sample size is adjusted for an expected response rate of 80% (0.8).

The final adjusted sample size for the survey was 5775, based on the distribution to EAs. Since one participant is selected per household, this number is equivalent to the number of households to be selected. With a fixed number of 15 households per EA, a total of 385 EAs was required to achieve the desired sample size.

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.

2.3. 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.

2.4. Outcome Variables

The outcome variable is defined as having been diagnosed with at least one of the major non-communicable diseases: hypertension, diabetes, dyslipidemia, or a 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 of hypertension, diabetes, and total cholesterol, reference ranges were applied to classify each individual as having any of the above diagnoses or not. For hypertension, the average of all three repeated measurements of systolic and diastolic blood pressures was used to classify a patient as hypertensive.

2.5. Anthropometric and Other Measurements

Pregnant women were excluded from all anthropometric measurements. From the data, 167 (4.9%) of women reported being pregnant and were excluded from anthropometric measurement as well as from this analysis. 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, Model HBF-701, Karada Scan) 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 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. For blood pressure measurement, an Omron automatic blood pressure monitor, Model: M6 AC (HEM-7322.E), was used.

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

2.6. Data Collection Process

The data collection process consisted of 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 h before sample collection. Samples were processed in accordance with WHO biosafety and quality control guidelines. Biochemical parameters were determined from capillary blood.

2.7. 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 used to summarize the socio-demographic characteristics of the participants and to categorize the prevalence of obesity, using 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 < 18.4; normal weight: BMI 18.5–24.9; overweight: BMI ≥ 25.0 and ≤ 29.9; and obesity: BMI ≥ 30.0 [26]. Also for waist circumference, the following cutoffs were used: For men: <94.9 cm—normal, 95–101.9 cm—high, and $\geq$102 cm—very high. For females: <80 cm—normal, 80–87.9 cm—high, and $\geq$ 88 cm—high. Hip circumference: For males: <93.9 = normal, 94/101.9 = increased, and $\geq$102 = substantially increased. For females: $\leq$79.9 = normal, 80–87.9 = increased, and $\geq$88/max = substantially increased [27]. For the hip ratio, whr $\geq$ 0.9 for men and 0.85 cm 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 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 35.1 years, with men having a slightly lower mean age (34.8 years) compared to women (35.5 years). Men were taller (170.3 cm) than women (159.7 cm), and their weight was slightly lower (65.6 kg) compared to women (66.9 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 (0.48) than in women (0.55). These differences in physical characteristics highlight variations between male and female participants.

Table 1. Characteristics of study participants segregated by sex.

Characteristics	All Participants	Men	Women
	Mean (95% CI)	**Mean (95% CI)**	**Mean (SD)**
Age (years)	35.1 [34.6–35.7]	34.8 [33.9–35.7]	35.4 [34.9–36.1]
Height (cm)	165.2 [163.9–166.5]	170.3 [168.2–172.5]	159.7 [158.4–161.0]
Weight (Kg)	66.0 [64.5–67.5]	65.6 [63.9–67.2]	66.9 [65.8–68.0]
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]	101.0 [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	0.9 [0.9–0.9]	0.9 [0.9–0.9]	0.9 [0.9–0.9]
Waist-to-Height Ratio	0.5 [0.5–0.5]	0.5 [0.5–0.5]	0.6 [0.61–0.6]

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, categorized by 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, $p < 0.001$).

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, $p < 0.001$).

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

Variable	Self-Reported at Least One NCD			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 59 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]	
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 ratio						<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]	

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 ($p = 0.412$).

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

Supplementary Table S1 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, $p = 0.186$).

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 other 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 3 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 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 59 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

Table 3. *Cont.*

Variables	COR	95% CI	*p*-Value	AOR	95% CI	*p*-Value
Ethnicity						
Akan	Ref			Ref		
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. AOR: Adjusted odds ratios (AOR) were estimated using multivariable logistic regression models controlling for potential confounders, including age, sex, level of education, ethnicity, religion, marital status, and occupation.

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 cutoff 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 cutoff 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 cutoff 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 cutoff 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. Supplementary Table S2 and Figure 1 display the results from the ROC analysis.

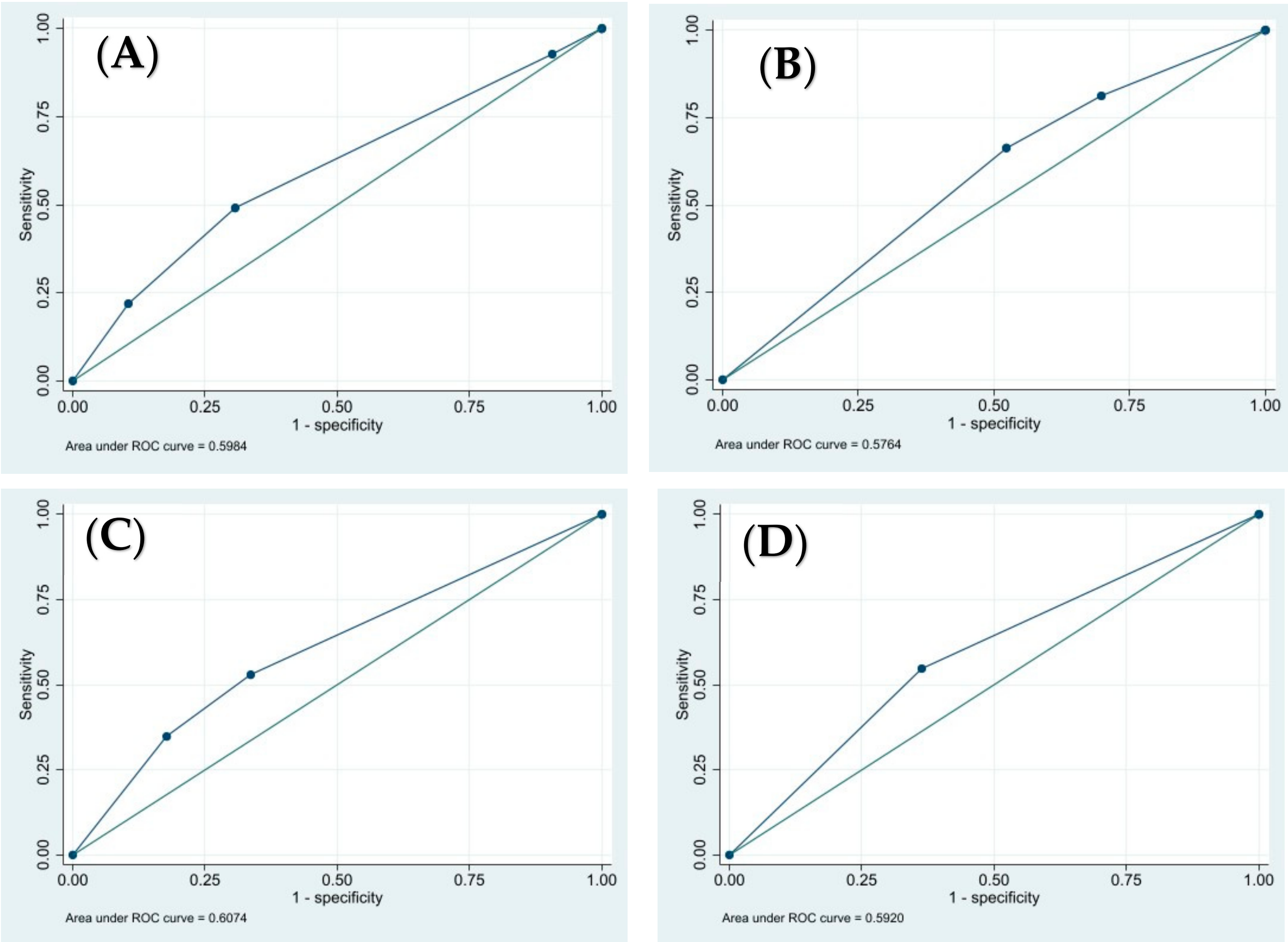

Figure 1. Receiver operator characteristic curve showing area under the curve for (**A**) body mass index, (**B**) hip circumference, (**C**) waist circumference, and (**D**) waist-to-hip ratio.

4. Discussion

Anthropometric measures, including BMI, waist circumference, and hip circumference, are well-known factors that are associated with the risk of developing non-communicable diseases. Hewage et al. (2023) found 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 of NCDs, including diabetes mellitus, cardiovascular disease, and infertility [10]. Other studies in other African countries have produced similar findings [9,28,29]. Additionally, the WHO expert consultation on Waist Circumference and Waist-Hip Ratio in 2008 [30] 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 the results of any waist circumference and waist-to-hip ratio thresholds established through the recommended process could be applied independently or in conjunction with 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 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 [31]. Cardiovascular diseases have been found to have a high association with elevated waist circumference [32–34], with most studies describing the height ratio as a more accurate tool for predicting hypertension than waist-to-hip circumference and BMI [35,36].

This study explored which of these body mapping factors produces 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. used ROC analysis to find that the waist-to-height ratio and, to some degree, Waist circumference are the best predictors of type 2 diabetes, followed by BMI, and then waist-to-hip ratio, which is the weakest predictor in the tested adults [37].

Notably, none of the anthropometric indicators demonstrated strong test performance (AUC $\geq$ 0.75) in predicting the presence of at least one major NCD, including hypertension, diabetes, dyslipidemia, or a history of myocardial infarction or cerebrovascular accident. While waist circumference had the highest AUC among the body measurements, it still fell below the threshold for high predictive accuracy. These results are consistent with those of Jia et al. [37], who found that waist-to-height ratio and waist circumference outperformed BMI and waist-to-hip ratio in predicting type 2 diabetes, but still with modest performance overall.

This study's methodological contribution lies in applying ROC analysis to a composite NCD outcome using a nationally representative dataset. While previous research has often examined anthropometric predictors in relation to individual conditions (e.g., diabetes or hypertension), our approach reflects a more pragmatic scenario in which individuals often have overlapping or co-occurring NCDs. This composite approach provides a more realistic assessment of body mapping indicators as public health screening tools.

Moreover, although the association between higher body measurements and NCDs is well-established [9,10,28–30], this study challenges the assumption that such measurements alone can be reliably used for clinical screening or diagnosis. In resource-constrained settings where anthropometric screening tools are often used in isolation, this insight is particularly relevant. Our findings suggest that while these measures can indicate elevated risk, they are not sufficient stand-alone predictors, and should be complemented with biochemical or clinical assessments where feasible.

The observed strong association between older age and NCD prevalence, particularly among those aged 60–69 years, aligns with broader epidemiological patterns [31–34]. However, even within these higher-risk age groups, the predictive power of anthropometric indicators remained limited, further underscoring the complexity of NCD risk stratification.

Several studies have proposed alternative indicators, such as the weight-to-height ratio, for improved predictive accuracy, particularly in the context of hypertension [35,36]. Nonetheless, our results suggest that even among these alternative metrics, predictive performance remains modest when applied to a multi-condition outcome. This finding adds a critical nuance to the literature: while anthropometric indicators are useful for population-level surveillance, they may have limited utility in clinical prediction at the individual level.

Comparable evidence from sub-Saharan African settings reinforces the limitations of relying solely on anthropometric measures to predict NCD risk. In Tanzania, a community-based study in Dar es Salaam demonstrated that individuals with an elevated waist circumference had a 34% higher likelihood of hypertension, underscoring the measure's utility as a pragmatic and cost-effective screening tool [38]. Similarly, a four-year cohort study in Malawi found that waist circumference, particularly when combined with fasting plasma glucose, significantly improved the prediction of progression from impaired fasting glucose to type 2 diabetes, yielding an area under the receiver operating characteristic curve (AUC) of 0.79 [39]. These findings affirm that while waist circumference enhances prediction modestly at the population level, it does not achieve high discriminative accuracy for individual-level screening. 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.

We provide these recommendations for practice and research. Anthropometric measures should not be used alone for NCD screening due to their limited predictive accuracy. Additionally, future research should develop and test combined risk prediction models that incorporate anthropometric, biochemical, and behavioral data. Conducting longitudinal studies may improve our understanding of how changes in body composition relate to NCD development over time.

5. Conclusions

While BMI, waist circumference, hip circumference, and waist-to-hip ratio remain valuable indicators for identifying NCD risk, their predictive performance for detecting the actual presence of NCDs in individuals is modest. These findings warrant caution in overreliance on anthropometric screening tools in both clinical and public health contexts. Integrating anthropometric assessments with biochemical and behavioral measures may enhance early detection strategies for NCDs in Ghana and similar settings. Future research should explore the combined predictive power of these indicators across specific NCDs and examine cost-effective, multi-indicator screening models tailored to resource-limited health systems.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/obesities5040071/s1, Supplementary Table S1: Risk factors associated with self-reported NCDs. Supplementary Table S2: 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.

Author Contributions: Conceptualization, B.D.N., J.A. and P.T.-N.T.; Data curation, B.D.N., J.A., Y.A.A., F.J.L., S.S.O.A. and A.H.; Formal analysis, B.D.N.; Investigation, P.F.E., Y.A.A. and T.T.; Methodology, B.D.N., J.A., E.B.N. and P.T.-N.T.; Project administration, P.K.M. and S.S.O.A.; Supervision, J.A., Y.A.A. and A.H.; Validation, P.K.M., L.G. and E.P.A.; Writing—original draft, B.D.N., J.A., E.B.N. and P.T.-N.T.; Writing–review and editing, B.D.N., E.P.A., P.F.E. and Y.A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Norwegian Government and UK Foreign, Commonwealth and Development Office (FCDO) through the World Health Organization, and "The APC was funded by authors".

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Review Committee of the Ghana Health Service (GHS-ERC 032/08/22). Ethics approval date is 1 November 2022.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Acknowledgments: We would like to thank Gladys Obuobie, Cynthia Hagan, Samuel Hagan, Baffour Awuah, Emmanuel Boateng, Rosemary Kisseh, Eric Oppong, Patrick Kuma Aboagye, the Regional Directors of Health Service, Data Collectors, and the Ghana Health Service NCD Program Staff for their various level of support to this work.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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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