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Anthropometric factors, including A body shape index (ABSI), and the risk of breast cancer among Nigerian women: a case-control study

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Abstract

Breast cancer (BC) incidence is increasing in Nigeria, alongside rising levels of obesity and central adiposity. While body mass index (BMI) is commonly used to assess adiposity, it may inadequately capture fat distribution relevant to BC risk. This study examined the associations between multiple anthropometric measures – including BMI, waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), weight and A Body Shape Index (ABSI) – and BC risk among Nigerian women, and evaluated whether WHR and ABSI provide additional predictive value beyond BMI. A hospital-based case-control study was conducted in five public hospitals in Lagos and Abuja, Nigeria, involving 379 women with histologically confirmed BC and 403 cancer-free controls. Standardised protocols were used to obtain anthropometric measurements. WHR was calculated as WC divided by HC, BMI as weight divided by height squared and ABSI as $WC/(BMI^{2/3} \times height^{1/2})$. Information on socio-demographic, reproductive and lifestyle factors was collected through semi-structured interviews. Multivariable unconditional logistic regression models were used to estimate adjusted odds ratios (ORs) and 95% confidence intervals (CIs), with analyses stratified by menopausal status and trend tests conducted across tertiles. Among premenopausal women, a high WHR was associated with an increased risk of BC (OR 2.26, 95% CI: 1.12–4.58), whereas higher BMI was inversely associated with risk (OR 0.44, 95% CI: 0.20–0.96). ABSI demonstrated a modest positive trend across tertiles among all women (*p*-trend = 0.038). No statistically significant associations were observed between anthropometric measures and BC risk among postmenopausal women. These findings suggest that measures of central adiposity, particularly WHR, may be more relevant than BMI for assessing BC risk among premenopausal Nigerian women. Interventions aimed at reducing visceral fat accumulation may contribute to lowering the burden of early-onset BC in this setting.

Keywords: *breast neoplasms, anthropometry, body mass index, body shape index, case-control studies, Sub-Saharan Africa*

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Introduction

Anthropometric measures such as obesity have been increasing across Africa, including Nigeria, since 1990 [1, 2], and are expected to rise further due to urbanisation, Westernized diets and ongoing nutrition transitions [2–5]. The incidence of breast cancer (BC) in Nigeria has been increasing since 1976, with disproportionately high mortality [6]. Previous studies in Nigeria have examined associations between anthropometric measures, including body mass index (BMI), waist-to-hip ratio (WHR), height, hip circumference (HC) and waist circumference (WC) and BC risk, but findings have been inconsistent [7–11]. Many studies also lacked adjustment for key confounders, such as physical activity (PA).

This study investigated the associations between BC risk and BMI, WHR, WC, HC, weight and, for the first time in Africa, A Body Shape Index (ABSI). ABSI is an emerging marker of adiposity derived from WC, BMI and height, and has been linked to all-cause mortality and cancer risk in U.S. and European populations [12, 13]. Unlike BMI, which does not distinguish lean mass from adiposity or reflect fat distribution [12, 14], ABSI provides a measure of adiposity independent of BMI while accounting for both general and central adiposity [12, 14, 15]. To the best of our knowledge, the role of ABSI with respect to BC risk has not been previously investigated in sub-Saharan Africa.

Material and methods

Using a case–control design, participants were recruited from four public tertiary hospitals – University of Lagos Teaching Hospital, Lagos State University Teaching Hospital, University of Abuja Teaching Hospital, Gwagwalada and National Hospital Abuja – and one secondary health facility, General Hospital Lagos Island (GHLI).

Lagos, located in southern Nigeria, is the largest city in sub-Saharan Africa, with an estimated population exceeding 12.5 million in 2016 [16]. Abuja, in northern Nigeria, is the Federal Capital Territory and one of the fastest-growing cities globally, with a population of over 3.5 million in 2016 [17]. These cities were selected to enhance the external validity of the study due to their marked ethnic and socioeconomic diversity [18].

In Nigeria, over 86% of BC cases are diagnosed in tertiary health facilities, which also serve as referral centres for private hospitals and lower levels of care because of better diagnostic capacity and specialised personnel. A secondary health facility was therefore included to improve the generalisability of the study findings.

Recruitment of participants

Eligible cases were women aged 20–80 years with a histologically confirmed diagnosis of invasive BC who attended oncology clinics in the participating hospitals between October 2016 and May 2017. Women whose diagnostic results were more than 18 months before the interview date were excluded.

Controls were recruited from outpatient ophthalmology clinics in the same hospitals during the same period. The ophthalmology departments provide comprehensive preventive, curative and rehabilitative eye care services and therefore attract patients from diverse socioeconomic backgrounds. Eligible controls were female ophthalmology patients or female relatives (visitors) of patients [19], aged 20–80 years, with no personal history of BC or benign breast disease. Where a patient's close relative was selected as a control, the patient was excluded and vice versa, to minimise similarity in exposure patterns between cases and controls.

All participants were assessed by collaborating physicians as physically and psychologically fit to participate. These physicians were not involved in interviewing to minimise interviewer bias.

The study objectives and procedures were explained to potential participants during clinic hours. Trained interviewers comprising doctors, nurses and graduates of related disciplines – subsequently approached interested individuals in the clinic waiting areas to confirm eligibility and obtain consent. Cases were recruited sequentially according to their listing in the daily oncology clinic attendance register, in line with

Research

departmental regulations that restricted patient contact to clinic hours only. As access to attendance registers was not permitted in ophthalmology clinics, controls were approached based on order of arrival and seating position in the waiting areas.

Data collection procedures

All eligible participants who provided written or oral informed consent were interviewed face-to-face using a semi-structured questionnaire. The questionnaire was developed specifically for this study, drawing on previously validated instruments and adapted to the local context. Information was collected on demographic, socioeconomic, reproductive and lifestyle variables. The questionnaire was pretested among 17 participants at GHLI, and necessary modifications were made before data collection.

Interviewers were selected to ensure proficiency in English, relevant local languages and Nigerian Pidgin English. They received 2–4 hours of training before the study, including recorded mock interviews, covering effective interview techniques and standardised anthropometric measurements. Completed questionnaires were reviewed daily for completeness and accuracy, and where feasible, participants were re-contacted to address missing or inconsistent information.

Measurement of anthropometric variables

For cases, weight and height were measured by trained interviewers using a calibrated weighing scale and a mobile stadiometer. In each center, measurements were assigned to one interviewer to minimise interobserver bias. A minimum of two measurements were obtained for each subject, and where there were variations (> 0.5 kg), a third measurement was taken. The weight was measured with the scale at the zero reading [20, 21]. Participants removed their shoes, outer coats and any other external objects. They were measured with both feet on the platform, with their arms naturally hanging downward, looking forward and remaining still. Readings were taken to the nearest 0.1 kg. For the height measurement, participants removed their shoes and head ties where possible. The body's mid-axillary line was parallel to the stadiometer while the head position was in the Frankfort plane. The headpiece was lowered until it touched the crown of the head, compressing the hair. The measurement was read to the nearest 0.1 cm.

The WC and HC of all participants were measured to the nearest 0.1 cm using a SECA 203 ergonomic tape. The WC was taken at a position slightly above the umbilicus (midpoint between the lower margin of the least palpable rib and the top of the iliac crest). The HC was measured at the widest portion of the buttocks. The WHR was obtained by computing the ratio of the WC and HC. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). ABSI was computed using the formula ABSI $= WC/(BMI^{2/3} height^{1/2})$ [12, 13].

Confounding variables

Variables were considered confounders if they had been consistently identified as such in existing literature. These included family history of BC, ethnicity, income, educational attainment, urbanicity, menopausal status, parity, age at first birth, lifetime duration of breastfeeding, age at menarche, oral contraceptive use, PA and alcohol consumption.

Anthropometric variables entered into the models were weight, height, WC, HC, BMI and WHR. For these variables, inclusion was guided by statistical criteria: variables with likelihood ratio test *p*-values <0.20 or those that changed the effect estimate by more than 10% upon removal from the model were retained as covariates.

Statistical analysis

All anthropometric variables (with the exception of BMI and WHR) were divided into three approximately equal-sized categories (tertiles) based on their distributions among controls. For BMI, the WHO cutoff points for normal weight, overweight and obesity (<24.99, 25.00–29.99 and ≥30.00 kg/m^2) were used. Notably, the values approximately coincided with our cutoff points for BMI when categorised into tertiles. For the WHR, a 0.85 lower cutoff was applied, which is consistent with the WHO recommendation for defining women with a substantially increased risk of metabolic disorders [22]. While the upper categorical values of BMI (≥30 kg/M^2), HC (≥105 cm) and body weight(≥77 kg) were used as indicators of general obesity, the upper values of WHR (≥0.90) and WC (≥91.40 cm) and ABSI (≥0.077) were used as indicators of central obesity – fat accumulation around the abdominal or visceral regions of the body. The ABSI is considered a measure of abdominal and overall distribution of adiposity. Notably, there is currently no consensus on the appropriate cutoffs for defining central (abdominal) obesity or general obesity among the African population [22]. We analysed data for all women and subgroups comprising women of reproductive age (< 50 years), women aged ≥50 years, premenopausal women and postmenopausal women, consistent with previous indigenous and international studies [23–25].

The distributions of these anthropometric variables were compared between the patients and controls. Categorical data were compared using chi-square (χ^2) tests. The associations between the anthropometric variables of interest and BC were modeled using unconditional binary logistic regression. Unconditional binary logistic regression is recommended to be more appropriate for frequency-matched data than for individually matched data, for which conditional logistic regression is considered more appropriate [26, 27]. The analysis was performed with the Statistical Product for Service Solutions version 25. Multicollinearity was assumed to exist if the tolerance value for each continuous variable was >0.1 and the variance inflation factor was <10 [28].

The relationship between BC risk and each anthropometric variable was investigated using three models adjusted for relevant explanatory variables selected based on existing literature. In the first model (the minimally adjusted model), age (as a continuous variable) and study site were included as *a priori* covariates, regardless of statistical significance. This approach was employed to account for the frequency matching by age between cases and controls and to enhance the external validity of the findings.

The relevant potential confounders were adjusted in the second model (core confounder-adjusted model) if they met the criteria for adjustment. These variables selected a priori were education (nonformal/primary, secondary, postsecondary, first degree/higher national diploma-HND and > first degree), income (< ₦18,000[$51.4]; ₦18,000- ₦49,000[$140]; ₦50,000[$142.9] - ₦100,000[$285.7]; > ₦100,000), parity (continuous variable), age at first birth (continuous variable), menopausal status (premenopausal and postmenopausal), total months of breastfeeding (continuous), age at menarche (≤ 13 years, >13 years), oral contraceptive use (Yes, No), family history of BC (Yes, No), alcohol consumption (Yes, No) and total PA (tertiles). Other relevant anthropometric covariates (weight, height, WC, HC, BMI and WHR) were adjusted in the third model (fully adjusted model). A p value <0.05 (two-sided) was considered to indicate statistical significance for trend tests across variable categories. p = values were based on the likelihood ratio test. The significance of the odds ratios (ORs) reported for the categorical variables were based on 95% confidence intervals (CIs). Although missing data were not included in the percentage calculations; however, they were reported separately to allow a transparent assessment of response completeness across variables.

Sensitivity analysis

The original study design was primarily intended to include only patients diagnosed within 1 year before enrollment and controls recruited exclusively from the ophthalmology departments of the participating hospitals. To assess whether relaxing these criteria as contained in the study protocol affected the findings, a sensitivity analysis was conducted. This analysis excluded patients diagnosed between 12 and 18 months before enrollment and controls from the general outpatient department (GOPD) initially included to meet sample size requirements. Results of this sensitivity analysis are presented in Supplementary Table 1.

Results

Recruitment result and distribution of participants characteristics

A total of 379 cases and 403 controls were recruited. Among these, 62 cases (16.4%) were diagnosed between 12 and 18 months before the interview, while 16 controls (4%) were recruited from the GOPD. Differences in the proportions of participants with various characteristics between cases and controls are reported in Supplementary Table 2. The unadjusted result showed a significant difference in the proportion of the anthropometric measures between cases and controls with regard to ABSI and WHR (Table 1). However, women in the upper WHR category had a significantly greater risk of BC than women in the lowest WHR category did (Table 1).

Table 1. Relationship between anthropometric factors and BC risk (unadjusted analysis).

Characteristics	Control *n* (%)	Case *n* (%)	OR (95% CI)	[∞]*p*-value
Weight				0.757
<65.00	120 (32.4)	121 (35.0)	1.00 (ref)	
65.00–76.99	121 (32.7)	111 (32.1)	0.91 (0.63, 1.31)	
77.00+	129 (34.9)	114 (32.9)	0.88 (0.61,1.25)	
Missing[δ]	33 (8.2)	33 (8.7)		
Mean	72.4 ± 15.9	71.30 ± 15.5		
Height				0.834
<1.58	101 (27.4)	100 (29.2)	1.00 (ref)	
1.58–1.63	132 (35.9)	121 (35.4)	0.93 (0.64, 1.34)	
1.64+	135 (36.7)	121 (35.4)	0.91 (0.63, 1.31)	
Missing[δ]	35 (8.7)	37 (9.8)		
Mean	1.61 ± 0.07	1.61 ± 0.07		
WC				0.562
<81.50				
81.50–91.39	118 (32.8)	119 (34.2)	1.00 (ref)	
91.40+	121 (33.6)	104 (29.9)	0.85 (0.59, 1.23)	
Missing[δ]	121 (33.6)	125 (35.9)	1.02 (0.72,1.46)	
Mean	43 (10.2)	31 (8.2)		
	87.1 ± 13.2	86.7 ± 13.4		
HC				0.171
<94.80	119 (33.1)	127 (36.6)	1.00 (ref)	
94.30–104.99	119 (33.1)	125 (36.0)	0.98 (0.69, 1.40)	
105.00+	122 (33.9)	95 (27.4)	0.73 (0.51, 1.05)	
Missing[δ]	10 (10.3)	32 (8.4)		
Mean	100.5 ± 12.3	98.7 ± 12.1		
BMI				0.644
<24.99	118 (32.2)	121 (35.4)	1.00 (ref)	
24.99–29.99	128 (34.9)	116 (33.9)	0.88 (0.62, 1.26)	
30.00+	121 (33.0)	105 (30.7)	0.85 (0.59, 1.22)	
Missing[δ]	30 (8.90)	37 (9.80)		
Mean	27.9 ± 5.7	27.5 ± 5.7		
WHR				0.045
<0.85	128 (35.7)	106 (30.5)	1.00 (ref)	
0.85–0.89	128 (35.7)	111 (32.0)	1.05 (0.73,1.50)	
0.90+	103 (28.7)	130 (37.5)	1.52 (1.06, 2.20)	
Missing[δ]	44 (10.9)	32 (8.4)		
Mean	0.87 ± 0.08	0.88 ± 0.09		
ABSI				0.041
<0.073	111 (31.2)	103 (31.2)	1.00 (ref)	
0.073–0.076	111 (31.2)	77 (23.3)	0.75 (0.51, 1.11)	
0.077+	134 (37.6)	150 (45.5)	1.21 (0.85, 1.72)	
Missing[δ]	47 (11.7)	49 (12.9)		
Mean	0.08 ± 0.01	0.08 ± 0.01		

[δ]Missing values were not considered in the computation of percentages associated with the samples of variable groups

Table 2. Adjusted associations between anthropometric variables and BC risk among women of all ages (multiple regression).

Main effects	Model 1 (minimally adjusted) [a]OR (95% CI)	Model 2 (core confounder adjusted) OR (95% CI)	Model 3 (fully adjusted) OR (95% CI)
Weight			
<65	1.00 (ref)	1.00 (ref)[a2]	1.00 (ref)[b]
65–76.99	0.91 (0.63, 1.31)	0.81 (0.49, 1.36)	0.78 (0.46,1.34)
77+	0.89 (0.62, 1.28)	0.80 (0.47, 1.37)	0.74 (0.41,1.32)
p for trend	0.799	0.655	0.546
Height			
<1.58	1.00 (ref)	1.00 (ref)[c]	1.00(ref)[d]
1.58–1.63	0.93 (0.64, 1.35)	0.88 (0.57,1.43)	0.88 (0.55, 1.43)
1.64+	0.91 (0.62, 1.34)	1.20 (0.73, 1.97)	1.20 (0.73, 1.98)
p for trend	0.881	0.429	0.415
WC			
<81.50	1.00 (ref)	1.00 (ref)[e]	1.00 (ref)[f]
81.50–91.39	0.86 (0.59, 1.24)	0.91 (0.57,1.46)	0.94 (0.45, 1.58)
91.40+	1.04 (0.72, 1.50)	1.12 (0.68,1.83)	1.75 (0.88, 3.46)
p for trend	0.557	0.698	0.111
HC			
<94.8	1.00 (ref)	1.22 (ref)[e2]	1.00(ref)[g]
94.8–104.99	1.00 (0.70, 1.43)	1.13 (0.80,1.85)	1.22 (0.76, 1.96)
105+	0.74 (0.51, 1.07)	0.69 (0.44, 1.08)	0.51 (0.27, 0.95)
p for trend	0.192	0.040	0.005
BMI			
<24.99	1.00 (ref)	1.00 (ref)[c]	1.00 (ref)[h]
25.00–29.99	0.87 (0.61, 1.25)	1.17 (0.69, 1.98)	1.13 (0.66, 1.93)
≥30.00	0.80 (0.55, 1.17)	0.94 (0.54, 1.64)	0.86 (0.48, 1.54)
p for trend	0.501	0.679	0.588
WHR			
<0.85	1.00 (ref)	1.00 (ref)[e]	1.00 (ref)[i]
0.85–0.89	1.18 (0.81, 1.73)	1.11 (0.68,1.81)	1.20 (0.72, 2.00)
0.90+	1.43 (1.00, 2.05)	1.45 (0.91, 2.30)	1.50 (0.92, 2.45)
p for trend	0.146	0.268	0.270
ABSI			
<0.073	1.00 (ref)	1.00 (ref)[j]	1.00 (ref)[k]
0.073–0.076	0.75 (0.50, 1.11)	0.62 (0.37, 1.03)	0.60 (0.36,1.01)
0.077+	1.21 (0.85, 1.72)	1.75 (0.73, 1.90)	1.16 (0.71, 1.88)
p for trend	0.041	0.035	0.038
Per 5-unit increase	1.03 (0.93,1.14)	1.05 (0.92,1.19)	1.04 (0.91,1.18)

[a] adjusted for age and study sites. [a2]Additionally, adjusted for, income, menopausal status, oral contraceptive use, age at first birth, alcohol use, total PA and family history of BC. [b]Additionally, adjusted for height. [c]adjusted for income, urbanicity, education, menopausal status, age at first birth, total PA & family history of BC. [d]Additionally, adjusted for BMI [e]Additionally, adjusted for income, menopausal status, parity, alcohol consumption, total months of breastfeeding, family history of BC & total PA. [f]Additionally, adjusted for HC. [e2]Additionally adjusted for ethnicity, income, menopausal status, parity, total months of breastfeeding, total PA & family history of BC. [f]Additionally, adjusted for HC. [g]Additionally, adjusted for WC. [h]Additionally, adjusted for WHR [i] Additionally, adjusted BMI. [j]Additionally, adjusted for income, family history of BC, menopausal status, parity, alcohol consumption and total PA. [k] Additionally, adjusted for BMI

Research

Overall associations (all women)

According to Table 2, after adjusting for potential confounders, differences in weight and WC were not significantly associated with BC risk. There was no statistically significant difference in BC risk between taller women (≥1.64 m) and shorter women (<1.58 m). Women in the upper tertile of HC had a significantly reduced risk compared with those in the lower tertile (OR 0.51, 95% CI: 0.27–0.95; *p* for trend = 0.005). High BMI (≥30 kg/m²) was not associated with increased risk in the overall population. High WHR showed a nonsignificant increased risk after full adjustment (OR 1.50, 95% CI: 0.92–2.45). Trends across ABSI categories were significant in minimally adjusted models ($p = 0.041$) and remained significant when BMI was included ($p = 0.038$).

Premenopausal women

Among premenopausal women (Table 3), high BMI (≥30 kg/m²) was associated with a significantly reduced BC risk compared with BMI <25 kg/m² (OR 0.44, 95% CI: 0.20–0.96). Women with high WHR (>0.9) had a significantly increased risk compared with low WHR (<0.85) (OR 2.36, 95% CI: 1.12–4.58). HC in the upper tertile was associated with reduced risk compared to observations in the lowest tertile (OR 0.39, 95% CI: 0.16–0.97; *p* for trend = 0.009). These patterns were consistent among younger women (<50 years: OR 0.32, 95% CI: 0.13–0.77) (Supplementary Table 3).

Postmenopausal women

Among postmenopausal women (Table 4), high BMI was not significantly associated with BC risk (OR 1.25, 95% CI: 0.58–2.69). A similar observation was made among older women (Supplementary Table 4). Height was significantly associated with risk only when categorised in quartiles (Q4 versus Q1: OR 2.31, 95% CI: 1.01–5.32; Supplementary Table 5). WHR did not show a statistically significant association (OR 1.27, 95% CI: 0.65–2.51), and trends in ABSI were not significant in this subgroup. HC was not significantly associated with BC among postmenopausal or older women (Supplementary Table 4).

Sensitivity analysis

Excluding patients diagnosed between 12 and 18 months and controls from the GOPD did not materially change the results, indicating that the findings are robust (Supplementary Table 1)

Discussion

Key findings

We observed that high BMI and HC were associated with a reduced risk of BC, particularly among premenopausal and younger women. In contrast, high WHR was associated with increased risk in these subgroups. Increased adult height was associated with a higher risk among postmenopausal and older women. Although the upper tertile of ABSI was not significantly associated with BC in all women, a significant effect across ABSI categories was observed. High body weight and WC were not significantly associated with risk, regardless of age or menopausal status.

Comparison with previous studies

An increased risk of BC with higher WHR has been reported in previous indigenous studies [8]. We extended these findings by showing that this association persisted after adjustment for multiple confounders, including total PA and BMI, particularly among premenopausal and younger women. The lack of association among postmenopausal women may reflect sample size limitations. Findings from other regions have been inconsistent [24, 29–33], with some prospective studies based on self-reported body size showing nonsignificant associations [30–32].

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Table 3. Adjusted associations between anthropometric variables and BC risk among premenopausal women (multiple regression).

Variables	Cases *n* (%)	Control n (%)	Model 1 (Minimally adjusted) [a]OR (95% CI)	Model 2 (core model) OR (95% CI)	Model 3 (Fully adjusted) OR (95% CI)
Weight					
<65	77 (37.0)	73 (32.6)	1.00(ref)	1.00 (ref)[b]	1.00 (ref)[c]
65–76.99	73 (35.1)	64 (28.6)	1.11 (0.66, 1.87)	0.91 (0.47, 1.77)	1.04 (0.52,2.08)
77+	58 (27.9)	87 (38.8)	0.61 (0.35, 1.05)	0.48 (0.24, 0.95)	0.55 (0.26, 1.17)
Per 5 units increase					
			0.94 (0.88, 1.01)	0.97 (0.97, 1.00)	0.94 (0.85,1.04)
Height					
<1.58	57 (27.8)	39 (17.4)	1.00 (ref)	1.00 (ref)[d]	100 (ref)[e]
1.58–1.63	72 (35.1)	94 (42.0)	0.61(0.34, 1.10)	0.61 (0.32,1.19)	0.65 (0.33, 1.27)
1.64+	76 (37.1)	91 (40.6)	0.55 (0.31, 0.97)	0.64 (0.34, 1.21)	0.71 (0.37, 1.39)
Per 10 units increase			0.81(0.62,1.08)	0.90 (0.66, 1.22)	0.96 (0.69, 1.30)
WC					
<81.50					
81.50–91.39	66 (44.3)	77 (37.9)	1.00 (ref)	1.00 (ref)[f]	1.00 (ref)[g]
91.40+	44 (29.5)	62 (30.5)	0.85 (0.51, 1.42)	0.74 (0.43,1.28)	0.74 (0.39, 1.39)
Per 5 units increase	39 (25.2)	64 (31.5)	0.78 (0.46, 1.34)	0.74 (0.41,1.34)	1.49 (0.62, 3.57)
			0.94 (0.86, 1.02)	0.95(0.86, 1.04)	1.02 (0.90,1.15)
HC					
<94.8	70 (31.8)	82 (39.6)	1.00 (ref)	1.00 (ref)[h]	1.00 (ref) [i]
94.8–104.99	68 (30.9)	76 (36.7)	0.99 (0.62, 1.58)	1.35 (0.77, 2.33)	1.35 (0.73, 2.52)
105+	82 (37.3)	49 (23.7)	0.52 (0.30, 0.92)	0.59 (0.32, 1.08)	0.39 (0.16,0.97)
p for trend			0.016	0.026	0.009
Per unit increase			0.98 (0.96, 1.00)	0.98 (0.96, 1.01)	0.98 (0.95, 1.01)
BMI					
< 24.99	71 (34.3)	90 (41.1)	1.00 (ref)	1.00 (ref)[j]	1.00 (ref)[k]
25.00–29.99	63 (30.4)	78 (35.6)	0.91 (0.55, 1.51)	1.02 (0.54, 1.94)	0.87 (0.44, 1.72)
≥30.00	73 (35.3)	51 (23.3)	0.60 (0.34, 1.06)	0.49 (0.23, 1.01)	0.44 (0.20, 0.96)
Per 5 units increase			0.85 (0.71, 1.03)	0.82(0.64, 1.06)	0.79 (0.60, 1.03)
WHR					
<0.85	54 (36.5)	79 (39.1)	1.00 (ref)	1.00 (ref)[l]	1.00 (ref)[c]
0.85–0.89	43 (29.1)	60 (29.7)	1.03 (0.62, 1.72)	1.31 (0.67, 2.56)	1.55 (0.78, 3.11)
0.90+	51 (34.5)	63 (31.2)	1.47 (0.84, 2.55)	1.93 (0.95, 3.91)	2.26 (1.12, 4.58)
ABSI					
<0.073	57 (40.4)	73 (36.5)	1.00(ref)[a]	1.00 (ref)[m]	1.00 (ref)[c]
0.073–0.076	39 (27.7)	68 (34.0)	0.76 (0.45, 1.30)	0.80 (0.42, 1.48)	0.75 (0.39, 1.43)
0.077+	45 (31.9)	59 (29.5)	1.09 (0.64, 1.87)	1.22 (0.63, 2.36)	1.18 (0.60, 2.32)
p for trend			0.417	0.418	0.433
Per 5 units increase			1.00 (0.87, 1.14)	1.03 (0.86, 1.23)	1.02 (0.83,1.22)

[a]Adjusted for study site, individual ages, [b] Additionally adjusted for ethnicity, education, family history of BC, Parity, total months of breastfeeding, alcohol consumption, total PA. [c]Additionally, adjusted for height. [d]Additionally, adjusted for ethnicity, education, urbanicity, parity, age at menarche and total PA. [e]Additionally, adjusted for body weight. [f]Additionally, adjusted for ethnicity, education, Parity, total PA. [g]Additionally, adjusted for HC[h]Additionally, adjusted for ethnicity, education, total months of breastfeeding, Parity, total PA, [i]Additionally, adjusted for WC. [j]Additionally, adjusted ethnicity, education, Parity, alcohol consumption and total PA. [k]Additionally, adjusted for WHR (quartile). [l]Additionally, adjusted for education, urbanicity, Parity, alcohol consumption and total PA. [m]Additionally, adjusted for, education, parity, alcohol consumption and total PA

Table 4. Adjusted associations between anthropometric variables and BC risk among postmenopausal women (multiple regression).

Variables	Cases *n* (%)	Control *n* (%)	Model 1 [a]OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Weight					
<65	43 (31.2)	45 (30.8)	1.00 (ref)	1.00 (ref)[b]	1.00 (ref)[c]
65–76.99	39 (28.3)	59 (40.4)	0.70 (0.39, 1.25)	0.61 (0.31,1.21)	0.56 (0.28,1.13)
77+	56 (40.6)	42 (28.8)	1.06 (0.59, 1.89)	0.97 (0.48, 1.94)	0.77 (0.36, 1.62)
p for trend			0.299	0.278	0.254
Per unit increase			1.00 (0.98,1.01)	1.00 (0.98,1.02)	1.00 (0.96, 1.08)
Height					
<1.58	43 (31.4)	62 (43.1)	1.00 (ref)	1.00 (ref)[d]	1.00 (ref)[e]
1.58–1.63	60 (43.8)	54 (37.5)	1.23 (0.71, 2.12)	0.95 (0.50, 1.80)	0.99 (0.51, 1.91)
1.64+	34 (24.8)	28 (19.4)	1.52 (0.80, 2.86)	1.86 (0.89, 3.85)	2.04 (0.94, 4.42)
Per 10 units increase			1.11(0.78, 1.58)	1.24 (0.83, 1.87)	1.27 (0.84, 1.94)
WC					
<81.50					
81.50–91.39	37 (26.1)	37 (25.5)	1.00 (ref)	1.00 (ref)[f]	1.00 (ref)[g]
91.40+	44 (31.0)	53 (36.6)	0.84 (0.45, 1.56)	0.80 (0.39,1.64)	0.92 (0.42, 2.02)
Per 5 units increase	61 (43.0)	55 (37.9)	1.11 (0.61, 2.00)	1.14 (0.57, 2.29)	1.51 (0.62, 3.67)
			0.99 (0.91,1.09)	1.02 (0.92,1.12)	1.05 (0.90,1.23)
HC					
<94.8	42 (30.0)	39 (27.9)	1.00 (ref)	1.00 (ref)[f]	1.00 (ref) [h]
94.8–104.99	40 (28.6)	50 (35.7)	0.89 (0.50, 1.59)	1.17 (0.60, 2.29)	1.13 (0.53, 2.44)
105+	58 (41.4)	51 (36.4)	0.84 (0.47, 1.49)	0.86 (0.43, 1.71)	0.65 (0.27, 1.59)
Per unit increase					
			0.99 (0.97, 1.00)	1.00 (0.97, 1.02)	0.98 (0.95, 1.02)
BMI					
<24.99	39 (28.5)	43 (29.9)	1.00 (ref)	1.00 (ref)[i]	1.00 (ref)[j]
25.00–29.99	41 (29.9)	50 (34.7)	0.84 (0.46, 1.52)	1.01 (0.52, 1.96)	1.01 (0.52, 1.97)
≥30.00	57 (41.6)	51 (35.4)	1.12 (0.57, 1.80)	1.00 (0.52, 1.93)	1.01 (0.52, 1.94)
p for trend			0.760	1.000	0.999
Per 5 units increase			0.92 (0.75, 1.13)	0.93 (0.73, 1.17)	0.93 (0.73, 1.17)
WHR					
<0.85	39 (27.5)	43 (29.7)	1.00 (ref)	1.00 (ref)[k]	1.00 (ref)[l]
0.85–0.89	37 (26.1)	41 (28.3)	1.01 (0.54, 1.88)	1.00 (0.49, 2.02)	1.09 (0.53, 2.27)
0.90+	66 (46.5)	61 (42.1)	1.21 (0.69, 2.11)	1.34 (0.71, 2.51)	1.27 (0.65, 2.51)
p for trend			0.587	0.559	0.775
ABSI					
<0.073	33 (24.6)	32 (22.2)	1.00 (ref)	1.00 (ref)[m]	1.00 (ref)[n]
0.073–0.076	27 (20.1)	41 (28.5)	0.63 (0.32, 1.26)	0.45 (0.20, 1.01)	0.45 (0.20, 1.01)
0.077+	74 (55.2)	71 (49.3)	1.04 (0.58, 1.88)	0.95 (0.49, 1.83)	0.93 (0.48, 1.81)
p for trend			0.234	0.079	0.086
Per 5-unit increase			1.02 (0.87, 1.20)	1.04 (0.87, 1.25)	1.04 (0.86, 1.24)

[a]Adjusted for study site, individual ages. [b]Additionally, adjusted for ethnicity, income, age at first birth, oral contraceptive use, total PA. [c]Additionally, adjusted for height. [d]Additionally, adjusted for income, urbanicity, age at first birth, oral contraceptive use, total PA. [e]Additionally, adjusted for body weight. [f]Additionally, adjusted for income, age at first birth, parity, oral contraceptive use, total PA. [g]Additionally, adjusted for HC. [h]Additionally, adjusted for waste circumference. [i]Additionally, adjusted for income, urbanicity, parity, total months of breastfeeding, total PA. [j]Additionally adjusted, for height [k] Additionally adjusted for income, AAFB, oral contraceptive use, total PA, [l]Additionally, adjusted for BMI. [m]Additionally, adjusted for income, Parity, age at first birth, oral contraceptive use, total PA, [n]Additionally, adjusted for BMI

African studies on BMI and BC risk have been contradictory. Some studies based on self-reported body size reported increased risk with obesity [34, 35], whereas studies using objective measurements reported reduced risk, consistent with our findings [7, 9]. While one prior study reported a nonsignificant reduced risk among postmenopausal women, our analysis suggested that BMI effects were largely explained by adjusted covariates [7]. International studies, including IARC reports, indicate that obesity reduces BC risk in premenopausal women but increases it in postmenopausal [36–39]. The nonsignificant increase among older women in our study may reflect the limited sample size.

Our observations on height, body weight and WC were similar to prior studies in Nigeria and internationally, though not statistically significant for all women [7, 8, 32, 40]. Adult height is a recognised risk factor for BC [41], and we observed this association among postmenopausal and older women, highlighting the need for replication in larger samples. Women in the high ABSI category showed a potential increase in BC risk, with a significant association observed only in the trend analysis. Similar associations have been reported in the UK and USA [12, 42].

Implications for the role of central obesity compared to that of general obesity

ABSI behaves similarly to WHR, reflecting central (abdominal) fat accumulation rather than general adiposity. Since BMI does not distinguish lean mass from fat or bone [14, 43], observations suggesting protective effects of obesity based on BMI, especially in premenopausal women, should be interpreted cautiously. Nevertheless, the study is the first African investigation of ABSI and BC, warranting further research. The study findings suggest that anthropometric factors influence BC risk differently by age, menopausal status and fat distribution. General obesity (BMI) may not accurately predict the risk of BC associated with obesity in our population, whereas central obesity (WHR, ABSI) may increase vulnerability, particularly among women of reproductive age [44]. Laboratory studies support central obesity as a stronger predictor than general obesity among premenopausal Black women [45]. This is particularly relevant in sub-Saharan Africa, given its predominantly young population.

Potential biological plausibility

The role of general obesity in postmenopausal BC is likely mediated by estrogen, produced primarily by adipose tissue after menopause [30, 46, 47]. Abdominal obesity may influence risk through insulin, IGF and leptin pathways, especially in premenopausal women [48]. Height likely reflects cumulative genetic and early-life nutritional exposures, supporting a life-course approach to BC prevention [41].

Strengths and limitations

Strengths of this study include objective anthropometric measurements, rigorous confounder adjustment and inclusion of participants from both southern and northern Nigeria, enhancing generalisability [7, 8]. Comparisons with national data on wealth, parity and age at first birth further support representativeness [49]. Limitations include a small sample size among older/postmenopausal women, lack of dietary data and potential reverse causation due to measurements after BC diagnosis [50]. Moreover, we did not carry out any independent investigation to confirm the BC diagnosis status of controls. Hence, we may not rule out the presence of occult or BC.

Conclusion

This study found that body fat distribution, particularly WHR, was more strongly associated with BC risk than BMI, with ABSI showing complementary value. Central adiposity was especially relevant in premenopausal women, suggesting that interventions targeting visceral fat may help reduce early-onset BC risk in Nigerian populations.

Conflicts of interest

The authors declare no conflicts of interest.

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Supplementary Tables

Supplementary Table 1. Relationship between anthropometric factors and BC risk (Sensitivity analysis).

Variable groupings	[π]OR(95% CI)	[Σ]OR(95% CI)
BMI		
<24.99	1.00 (ref)	1.00 (ref)
25.00–29.99	1.13 (0.65, 1.94)	1.22 (0.71, 2.11)
≥30.00	0.85 (0. 47, 1.53)	0.83 (0.46,1.51)
p for trend	0.58	0.372
WHR		
<0.85	1.00 (ref)	1.00 (ref)
0.85–0.89	1.15 (0.68, 1.94)	1.14 (0.68, 1.91)
0.90+	1.53 (0.93, 2.252)	1.44 (0.87, 2.37)
p for trend	0.234	0.35
ABSI		
<0.073	1.00 (ref)	1.00 (ref)
0.073–0.076	0.66 (0.39, 1.12)	0.62 (0.37, 1.04)
0.077+	1.26 (0.77, 2.08)	1.13 (0.70, 1.85)
	0.043	0.053
Height		
<1.58	1.00 (ref)	1.00 (ref)
1.58–1.63	0.88 (0.54, 1.44)	0.94 (0. 58, 1.52)
1.64+	1.18 (0.67, 2.06)	1.24 (0.71, 2.15)
p for trend	0.503	0.51
Weight		
<65	1.00 (ref)	1.00 (ref)
65–76.99	0.88 (0.54,1.44)	0.92 (0.56,1.50)
77+	0.90 (0.53,1.52)	0.89 (0.53, 1.51)
p for trend	0.863	0.907
WC		
<81.50	1.00 (ref)	1.00 (ref)
81.50–91.39	0.95 (0.55,1.62)	0.91 (0.53,1.54)
≥91.40	1.86 (0.92, 3.77)	1.73 (0.85, 3.53)
p for trend	0.086	0.123
HC		
<94.8	1.00 (ref)	1.00 (ref)
94.8–104.99	1.20 (0.74, 1.95)	1.22 (0.75, 1.96)
≥105	0.53 (0.26, 1.01)	0.48 (0.26, 0.91)
p for trend	0.013	0.002

[π] Fully adjusted model restricted to cases diagnosed within 1 year
[Σ] fully adjusted model restricted to ophthalmology clinic controls

Supplementary Table 2. Participants' characteristics.

Characteristics	Control	Case	∞p-
	n (%)	*n* (%)	
Age			0.583
<50.00 years	247(61.3)	225 (59.4)	
≥50.00 years	156 (38.7)	154 (40.6)	
Mean ± SD	46.8 ± 10.8	47.1 ± 10.7	0.556[β]
Ethnicity			0.098
Yoruba	192 (47.9)	155 (41)	
Igbo	100 (24.9)	128 (33.9)	
Hausa/Fulani	14 (3.5)	13 (3.4)	
Niger Deltans	51 (12.7)	42 (11.1)	
Other Northern Tribes	44 (11)	40 (10.6)	
Missing values[µ]	2(0.5)	1(0.3)	
Marital status			0.545
Never married	33 (8.3)	36 (9.5)	
Widowed	32 (8.0)	26 (6.9)	
Divorced/separated	9 (2.3)	14 (3.7)	
Married	325 (81.5)	301 (79.8)	
Missing values[µ]	4(1)	2(0.5)	
Religion			0.145
Christianity	315 (78.8)	310 (82.9)	
Islam	85 (21.3)	64 (17.1)	
Missing values[µ]	4(1)	2(0.5)	
Family history of BC (FHBC)			0.002
No	381 (95.3)	339 (89.4)	
Yes	19 (4.8)	40 (10.6)	
Missing values[µ]	3(0.7)	0(0)	
Parity			0.09
Median (IQR)	3.0 (2)	3.0(2)	
Missing	3(0.9)	5(1.5)	
Total months of breast feeding			0.48
Median (IQR)	36(36)	36.5(41)	
Missing	2(0.3)	1(0.6)	

Continued

Research

Supplementary Table 2. Participants' characteristics. *Continued*

Age at first birth			0.577β
Mean ± SD	25.5 ± 4.8	25.3± 5.1	
Missing valuesµ	58(14.4)	49(12.9)	
Menopausal status			0.02
Premenopausal	229 (56.8)	161 (42.5)	
Unknown/artificial*	20 (5.0)	64 (16.9)	
Post- menopausal (natural menopause)	154 (38.2)	154 (40.6)	
Education			<0.001
Non formal/Primary	37 (9.3)	63 (16.6)	
Junior/Senior secondary	96 (24)	109 (28.8)	
Post-secondary	73 (18.3)	71 (18.7)	
1st degree/HND	134 (33.5)	110 (29)	
>1st degree	60 (15)	26 (6.9)	
Missing valuesµ	3(0.7)	0(0)	
Respondents' income			<0.001
< ₦18,000	71 (18.9)	100 (28.7)	
₦18,000–₦49, 000	106 (28.3)	128 (36.7)	
₦50,000–₦100,000	123 (32.8)	77 (22.1)	
> ₦100,000	75 (20.0)	44 (12.6)	
Missing valuesµ	28 (6.9)	30(7.9)	
History of regular alcohol consumption			0.003
No	235 (78.1)	225 (67.4)	
Yes	66 (21.9)	109 (32.6)	
Missing values	102(25.3)	45(11.9)	
PA (MET-hr/wk)			0.082
<128.20	134 (36.9)	112 (29.5)	
128.20–184.29	118 (32.5)	131(34.5)	
≥184.30	111 (30.6)	137 (36.1)	
Missing valuesµ	23 (5.7)	16 (4.2)	

δM-W = Mann-Whitney *U* test (*p* value) SD = standard deviation ∞differences between cases and controls based on LRT (likelihood ratio test). *Excluded (participants with contradictory answers /Participants whose menstrual flow ceased as a result of other reasons apart from the natural process). β Based on *t*-test of independent samples. * Missing values includes 'not applicable'. µMissing values were not considered in the computation of percentages associated with the samples of variable groups

Supplementary Table 3. Relationship between BC and anthropometric variables among women younger than 50 years (multiple regression).

Variables	Cases	Control	Model 1 (Minimally adjusted)	Model 2 (core model)	Model 3 (Fully adjusted)
	n (%)	*n* (%)	[a]OR (95% CI)	OR (95% CI)	OR (95% CI)
Weight				1.00 (ref)[b]	
<65	78 (37.5)	73 (32.6)	1.00 (ref)	0.83 (0.44,1.58)	1.00 (ref)[c]
65–76.99	72 (34.6)	64 (28.6)	1.08 (0.67, 1.70)	0.46 (0.23, 0.91)	0.88 (0.45, 1.72)
77 +	58 (27.9)	87 (38.8)	0.65 (0.40, 1.03)	0.068	0.49 (0.24, 1.00)
p for trend			0.079	0.90 (0.82, 0.99)	0.116
Per 5 units increase			0.94 (0.89, 1.01)		0.91 (0.82,1.01)
Height					
<1.58	57 (27.8)	39 (17.4)	1.00 (ref)	1.00 (ref)[d]	1.00 (ref)[e]
1.58–1.63	72 (35.1)	94 (42.0)	0.54 (0.32, 0.92)	0.56 (0.29,1.07)	0.58 (0.29, 1.13)
1.64+	76 (37.1)	91 (40.6)	0.57 (0.35, 0.94)	0.69 (0.37, 1.28)	0.77 (0.40, 1.49)
Per 10 units increase			0.83 (0.64,1.06)	0.91 (0.68, 1.23)	0.96 (0.71, 1.31)
WC					
<81.40	84 (40.4)	81 (37.0)	1.00 (ref)	1.00 (ref)[f]	1.00 (ref)[g]
81.40–91.99	70 (33.7)	71 (32.4)	0.96 (0.61, 1.51)	0.85 (0.51,1.44)	0.90 (0.49, 1.66)
92.00+	54 (26.0)	67 (30.6)	0.81 (0.49, 1.32)	0.70 (0.39,1.25)	1.56 (0.66, 3.72)
p for trend			0.679	0.473	0.361
Per 5 units increase			0.99 (0.98, 1.01)	0.89 (0.80, 1.00)	1.00 (0.84,1.19)
HC					
<94.8	70 (31.8)	82 (39.6)	1.00 (ref)	1.00 (ref)[h]	1.00 (ref)[i]
94.8–104.99	68 (30.9)	76 (36.7)	1.07 (0.67, 1.68)	1.22 (0.72, 2.06)	1.22 (0.66, 2.23)
105+	82 (37.3)	49 (23.7)	0.52 (0.31, 0.86)	0.46 (0.25, 0.85)	0.32 (0.13,0.77)
p for trend			0.018	0.005	0.002
Per unit increase			0.98 (0.96, 1.00)	0.98 (0.96, 1.00)	0.97 (0.94, 1.00)
			p = 0.028	*p* = 0.018	*p* = 0.027
BMI					
<24.99	71 (34.3)	90 (41.1)	1.00 (ref)	1.00 (ref)[j]	1.00 (ref)[k]
25.00–29.99	63 (30.4)	78 (35.6)	0.89 (0.57, 1.40)	0.91 (0.54, 1.52)	1.00 (0.52, 1.91)
≥30.00	73 (35.3)	51 (23.3)	0.65 (0.40, 1.06)	0.54 (0.30, 0.98)	0.39 (0.18, 0.83)
p for trend			0.211	0.024	0.018
Per 5 units increase			0.85 (0.72, 1.01)	0.75 (0.58, 0.96)	0.72 (0.55, 0.95)
p				0.022	0.015

Continued

Supplementary Table 3. Relationship between BC and anthropometric variables among women younger than 50 years (multiple regression). *Continued*

WHR					
<0.85	70 (33.8)	90 (41.1)	1.00 (ref)	1.00 (ref)[b]	1.00 (ref)[l]
0.85–0.89	58 (28.0)	65 (29.7)	1.19 (0.74, 1.92)	1.36 (0.72,2.58)	1.47 (0.75, 2.87)
0.90+	79 (38.2)	64 (29.2)	1.59 (1.00, 2.54)	2.01 (1.08, 3.74)	2.87 (1.17, 4.46)
p for trend			0.141	0.085	0.049
ABSI					
<0.073	74 (37.4)	79 (36.6)	1.00 (ref)[a]	1.00 (ref)[m]	1.00 (ref)[g]
0.073–0.077	48 (24.2)	75 (34.7)	0.68 (0.42, 1.10)	0.58 (0.31, 1.07)	0.54 (0.29, 1.02)
0.078+	76 (38.4)	62 (28.7)	1.36 (0.85, 2.16)	1.22 (0.65, 2.32)	1.12 (0.58, 2.16)
p for trend			0.024	0.074	0.072
Per 5 units increase			1.05 (0.92, 1.20)	1.06 (0.88, 1.27)	1.03 (0.81, 1.24)

[a]Adjusted for study site, individual ages, [b] Additionally adjusted for ethnicity, education, menopausal status, Parity, age at first birth, , alcohol consumption, total PA. [c]Additionally adjusted for height. [d]Additionally adjusted for ethnicity, education, urbanicity, menopausal status, TBF, AAM, total PA. [e]Additionally adjusted for body weght. [f]Additionally adjusted for education, urbanicity, menopausal status, total months of breastfeeding, Parity, total PA, family history of BC. [g]Additionally adjusted for HC.[h]Additionally adjusted for ethnicity, education, menopausal status, total months of breastfeeding, Parity, total PA, [i]Additionally adjusted for WC [j]Additionally adjusted for ethnicity, education, menopausal status, parity, alcohol consumption, total PA. [k]Additionally adjusted for WHR. [l]Additionally adjusted for BMI. [m]Additionally adjusted for education, urbanicity, FHBC,menopausal status, parity, alcohol consumption total PA

Supplementary Table 4. Relationship between BC and anthropometric variables among women age 50 years and above (multiple regression).

Variables	Cases	Control	Model 1	Model 2	Model 3
	***n* (%)**	***n* (%)**	**[a]OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Weight			1.00 (ref)		
<65	43 (31.2)	47 (32.2)	0.73 (0.41, 1.33)	1.00 (ref)[b]	1.00 (ref)[c]
65–76.99	39 (28.3)	57 (39.0)	1.41 (0.78, 2.54)	0.69 (0.34,1.36)	0.64 (0.32,1.27) 1.14 (0.54, 2.40) 0.222
77 +	56 (40.6)	42 (28.8)	0.083	1.39 (0.69, 2.83)	1.00 (0.91, 1.10)
p for trend			1.02 (0.95,1.10)	0.123	
Per unit increase				1.01 (0.99,1.03)	
Height					
<1.58	43 (31.4)	62 (43.1)	1.00 (ref)	1.00 (ref)[d]	1.00 (ref)[e]
1.58–1.63	60 (43.8)	54 (37.5)	1.59 (0.91, 2.77)	1.09 (0.57, 2.08)	1.10 (0.57, 2.10)
1.64+	34 (24.8)	28 (19.4)	1.77 (0.92, 3.38)	1.91 (0.90, 4.03)	1.91 (0.90, 4.05)
p for trend			0.145	0.195	0.195
Per 10 units increase			1.16 (0.96, 1.43)	1.17 (0.93, 1.46)	1.17 (0.93, 1.46)

Continued

Supplementary Table 4. Relationship between BC and anthropometric variables among women age 50 years and above (multiple regression).

WC					
<81.50	35 (25.0)	37 (26.2)	1.00 (ref)	1.00 (ref)[f]	1.00 (ref)[g]
81.50–91.39	34 (24.3)	50 (35.5)	0.72 (0.39, 1.40)	0.61 (0.28,1.29)	0.58 (0.25,1.33)
91.40+	71 (50.7)	54 (38.3)	1.37 (0.76,2.47)	1.26 (0.62, 2.57)	1.33 (0.53, 3.35)
p for trend			0.082	0.099	0.08
Per 5 units increase			1.03 (0.94,1.12)	1.05 (0.94,1.17)	1.04 (0.91,1.18)
HC	42 (30.0)	39 (27.9)			
<94.8	40 (28.6)	50 (35.7)	1.00 (ref)	1.00 (ref)[f]	1.00 (ref)[h]
94.8–104.99	58 (41.4)	51 (36.4)	0.76 (0.41, 1.39)	1.02 (0.49, 2.12)	1.26 (0.57, 2.80)
105+			1.04 (0.58, 1.86)	1.24 (0.60, 2.60)	0.88 (0.34, 2.27)
p for trend			0.508	0.794	0.628
Per unit increase			1.00 (0.98, 1.02)	1.00 (0.96, 1.03)	1.00 (0.96, 1.03)
BMI					
<24.99	39 (28.5)	43 (29.9)	1.00 (ref)	1.00 (ref)[i]	1.00(ref)[j]
25.00–29.99	41 (29.9)	50 (34.7)	0.87 (0.47, 1.60)	1.11 (0.54, 2.32)	1.11 (0.52, 2.37)
≥30.00	57 (41.6)	51 (35.4)	1.18 (0.65, 2.12)	1.28 (0.63, 2.63)	1.25 (0.58, 2.69)
p for trend			0.573	0.786	0.85
Per 5 units increase			0.99 (0.81, 1.21)	1.04 (0.81, 1.32)	1.05 (0.81, 1.37)
WHR					
<0.85	33 (23.6)	38 (27.1)	1.00 (ref)	1.00 (ref)[k]	1.00 (ref)[l]
0.85–0.89	42 (30.0)	40 (28.6)	1.19 (0.63, 2.26)	0.91 (0.43,1.90)	0.94 (0.44, 2.03)
0.90+	65 (46.4)	62 (44.3)	1.25 (0.70, 2.25)	1.11 (0.57, 2.19)	1.01 (0.49, 2.11)
p for trend			0.751	0.831	0.975
ABSI					
<0.073	29 (22.0)	32 (22.9)	1.00 (ref)	1.00 (ref)[m]	1.00 (ref)[l]
0.073–0.076	29 (22.0)	36 (25.7)	0.89 (0.44,1.79)	0.56 (0.24,1.33)	0.55 (0.23,1.31)
0.077+	74 (56.1)	72 (51.4)	1.15 (0.63, 2.09)	0.93 (0.46, 1.88)	0.95 (0.47,1.93)
Per 5-unit increase			0.674	0.334	0.295
			1.02 (0.87, 1.19)	1.00 (0.83,1.20)	1.01 (0.83, 1.21)

[a]Adjusted for study site, individual ages. [b]Additionally adjusted for income, urbanicity, age at first birth, oral contraceptive use, total PA. [c]Additional adjusted for height. [d]Additionally adjusted for income, urbanicity,age at first birth, oral contraceptive use, total PA. [e]Additionally adjusted for height. [f]Additionally adjusted for income, menopausal status, AAFB, parity, oral contraceptive use, total PA. [g]Additionally adjusted for HC. [h]Additionally adjusted for waste circumference. [i]Additionally adjusted for income, urbanicity, menopausal status, age at first birth, oral contraceptive use & total PA. [j]Additionally adjusted for WHR [k]Additionally adjusted for income, menopausal status, age at first birth, Oral contraceptive use, total PA, [l]Additionally adjusted for BMI. [m]Additionally adjusted for income, FHBC, menopausal status, Parity, age at first birth, oral contraceptive use, total PA

Supplementary Table 5. Relationship between height and BC risk among women ≥50 years and postmenopausal women (based on quartile categorisation).

	Cases	Control	Model 1	Model 2	Model 3
	n (%)	*n* (%)	[a]OR (95% CI)	[b]OR (95% CI)	[c]OR (95% CI)
≥50 years					
Height					
<1.57	35 (25.5)	55 (38.2)	1.00 (ref)	1.00 (ref)[f]	1.00 (ref)[C]
1.57–1.60	34 (24.8)	39 (27.1)	1.36 (0.72, 2.56)	1.35 (0.64 ,2.85)	1.36 (0.64, 2.87)
1.61–1.64	39 (28.5)	29 (20.1)	2.13 (1.09, 4.15)	1.43 (0.66 ,3.10)	1.43 (0.65, 3.10)
1.65+	29 (21.2)	21 (14.6)	2.21 (1.08, 4.52)	2.65 (1.16, 6.08)	2.68 (1.17, 6.16)
p for trend			0.068	0.139	0.134
Postmenopausal women					
Height					
<1.57	39 (28.1)	53 (36.3)	1.00 (ref)	1.00 (ref)	1.00 (ref)[d]
1.57–1.60	33 (23.7)	37 (25.3)	1.22 (0.65, 2.29)	1.32 (0.62 ,2.83)	1.36 (0.63, 2.92)
1.61–1.64	36 (25.9)	30 (20.5)	1.64 (0.85, 3.14)	1.26 (0.58 ,2.73)	1.33 (0.60, 2.95)
1.65+	31 (22.3)	26 (17.8)	1.65 (0.83, 3.27)	2.12 (0.97, 4.69)	2.31 (1.01, 5.32)
p for trend			0.382	0.305	0.258

[a]Adjusted for age and study sites. [b]Additionally adjusted for age at first birth, oral contraceptive use, income, urbanicity, PA. [c]Additionally adjusted for BMI. [d] Adjusted for Body weight

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