Anthropometric measures and breast cancer risk among Hispanic women in Puerto Rico

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Abstract

Introduction Increased risk of postmenopausal breast cancer associated with anthropometric measures including Body Mass Index (BMI), adult weight gain, and waist circumference has been observed in North American and European populations, but little evidence is available for Hispanic women. Breast cancer is the leading type of cancer, and leading cause of cancer-related deaths among Hispanic women in Puerto Rico (PR). However, compared with the United States, breast cancer incidence rates are lower but increasing more rapidly.

Purpose To examine associations between anthropometric characteristics and breast cancer risk in Hispanic women in PR.

Methods Data from a population-based case–control study in the San Juan metropolitan region (cases = 315; controls = 348) were used to examine associations between anthropometric measures and breast cancer risk, also considering menopausal status and hormone therapy (HT).

Results Among premenopausal participants, there was a significant trend for lower odds of breast cancer with higher BMI and borderline significant with higher waist to height ratio (WHtR). For postmenopausal participants, a significant trend for lower odds of breast cancer was observed with higher WHtR, and waist to hip ratio (WHR), borderline significant with higher BMI, and higher odds with height. Among postmenopausal participants using HT, a significant trend for lower odds of breast cancer was observed with higher waist circumference, WHIR, WHR, and body shape index.

Conclusion Our study provides evidence of anthropometric differences in relation to breast cancer risk in PR compared to previous studies. Future studies should include analyses of fat and lean mass distribution, and hormone receptor status to further understand anthropometry and breast cancer risk among Hispanic women.

Keywords Body size · Adiposity · Breast cancer · Hispanic women

Introduction

Excess weight gain and body fat accumulation during adulthood have been consistently associated with increased breast cancer risk and mortality in postmenopausal women [1–5]. Among premenopausal women, an inverse but inconsistent association between adiposity and breast cancer risk has been observed [5, 6]. The inconsistency may be explained by possible differences in body fat distribution. For example, a high abdominal adiposity as measured by dual-energy X-ray absorptiometry (DEXA) in premenopausal women has been associated with increased risk of developing breast cancer [7].

Differences in associations between excess fat accumulation, obesity, menopausal status, and breast cancer risk have also been reported for different racial/ethnic groups.
For example, in a population-based case–control study conducted in New Mexico [8], adult weight gain and obesity were risk factors for breast cancer in both Hispanic and non-Hispanic women; but different from non-Hispanic white women, the risk was not influenced by menopausal status in the Hispanic group. In another case–control study [9], adult weight gain and obesity were associated with increased breast cancer risk among non-Hispanic white women but with reduced risk among Hispanic women, suggesting that the link between obesity on breast cancer risk may differ by race/ethnicity. Most studies have used Body Mass Index (BMI) for overweight or obesity classification [10–12], which could be problematic because BMI does not account for differences in the proportion or distribution of body fat or lean body mass, and also because common cut points for overweight-obesity classification might not apply equally in different populations [10–13].

In addition to BMI, other anthropometric measures of body size and proportions have been associated with breast cancer risk in pre- and postmenopausal women, including height, sitting height, skinfold thickness, waist circumference, waist to hip ratio (WHR), and body shape index (ABSI). Adult standing height, likely influenced by nutrition and growth factors during childhood, has been more strongly associated with postmenopausal than premenopausal breast cancer risk [14–16]. However, it is unclear if the association between standing height and breast cancer risk is explained by sitting height or leg length. While it has been reported that both components of standing height provide similar direct associations with postmenopausal breast cancer risk [16], differences have also been reported with leg length directly associated with postmenopausal breast cancer and sitting height indirectly associated with premenopausal breast cancer risk [17]. Skinfold thickness, used to predict body fat, particularly at the triceps and subscapular, have also been associated with breast cancer [18]. Waist circumference, used as an index of body fat accumulation in the abdominal and visceral area, has been associated with elevated insulin resistance, inflammation, and breast cancer risk [19]. Interestingly, a waist circumference at or above 88 cm in women has been found to be an indicator of risk equivalent to 30 kg/m² of BMI [2].

Also, a WHR at or above 0.85, another index of abdominal fat accumulation, is associated with breast cancer risk among both pre- and postmenopausal women [20, 21]. However, it has been suggested that the association between waist circumference, WHR, and breast cancer risk may result from their correlation with BMI [22]. Using ABSI, another anthropometric measure that removes the correlation between BMI, waist circumference and standing height; its association with breast cancer is not consistent [23, 24]. It has been suggested that ABSI combined with BMI would improve the prediction of cancer risk [23]. There is also evidence suggesting that, like BMI, the relationship between height and waist circumference with breast cancer risk varies with different race-ethnic groups [25–28]. To our knowledge, there is limited evidence of the correlation between a large variety of anthropometric measures that are indicators of obesity in breast cancer, and evidence of their association with pre- and postmenopausal breast cancer risk in different race/ethnicity groups is also limited.

Few studies have evaluated anthropometric characteristics and their association with breast cancer risk among Hispanic women outside the United States (USA) mainland living in their country of origin. In Puerto Rico (PR), cancer is the leading cause of death, and breast cancer is the leading type of cancer and leading cause of cancer deaths among women [29]. Although the incidence rate of breast cancer is lower in PR than in the USA, it is increasing more rapidly [30]. According to the 2020 Behavioral Risk Factor Surveillance System (BRFSS: https://www.cdc.gov/brfss/brfssprevalence/index.html), the prevalence of obesity among women in PR (34.1%) is within the highest reported among women in the USA. Therefore, understanding the correlation between various anthropometric measures and their association with breast cancer risk among Hispanic women in PR is highly relevant. In this study we used data from a population-based case–control study of breast cancer in PR to compare and examine associations between a variety of anthropometric measures and breast cancer risk.

Materials and methods

Women between 30 and 79 years of age residents of the San Juan metropolitan area participated in a population-based case–control study (ATABEY Study). Its design, and implementation have been described elsewhere [31]. The study was approved by the University of Puerto Rico Medical Sciences Campus Institutional Review Board and by the IRB of all participating institutions.

Cases (n = 315) with incident, primary, pathologically confirmed breast cancer diagnosed within 1 year of the study interview, and with no history of previous cancer other than non-melanoma skin cancer, were ascertained and recruited from hospitals with oncology departments, and private oncologist’s offices where breast cancer patients were diagnosed or treated. The list of hospitals and clinics, and the completeness of case ascertainment evaluation was obtained from the Puerto Rico Central Cancer Registry. Controls (n = 348) with no history of cancer, other than non-melanoma skin cancer, were selected and frequency-matched to cases by broad geographical residential area using the Puerto Rico Health Interview Survey model for control ascertainment [31].
Three consecutive anthropometric measures, including current body weight, were made by one of two trained nurses in the Puerto Rico Clinical and Translational Research Consortium at the University of Puerto Rico, Medical Science Campus. Measurements were taken in the morning with participants in fasting state and nurses blinded to case–control status. Standing and sitting height were measured in cm with a SECA stadiometer (model 217; SECA North America, California, USA). Standing height was measured without shoes and socks and with light clothing, back and buttocks touching the scale and eyes directed to a perpendicular point in front. Sitting height was measured similar to standing height but with participants sitting in a stool of known height. Sitting height to height ratio was later calculated. Body weight was measured to the nearest 0.1 kg using a TANITA balance (model BF-522 W; TANITA Corporation, Illinois, USA). Participants were asked to remove shoes and socks, clean their feet with an alcohol swab, and stand on the balance with feet touching the metal surface when the scale displayed a zero. BMI was determined from standing height and weight measures (weight in kg/height in m²).

Waist circumference was measured in the horizontal plane midway between the lowest rib and the iliac crest after a normal exhalation. Hip circumference was measured in the horizontal plane at the widest part of the buttocks close to the inguinal area. Both circumferences were measured to the nearest 0.1 cm with a Gulick-II anthropometric tape (Performance Health, Chicago, ILL). WHR (waist circumference divided by hip circumference) and waist to height ratio (WHtR, waist circumference divided by height) were later calculated.

Height, weight, and waist circumference were used to determine ABSI [32], a measure linked to cancer risk and mortality [33, 34]. Participants also self-reported their body weight at one year prior to the study and at every decade starting at 20 years of age. Lifetime weight gain was determined from current measured weight minus self-reported weight at 20 years of age. Participants were encouraged to recall lifetime events that would help identify weight at each decade, and age at menarche and menopause. Women were defined as postmenopausal if their menses had ceased naturally for at least one year. Also considered postmenopausal were women who had a bilateral oophorectomy, on hormone therapy who were over age 50, had a hysterectomy and were older than 50, and women older than 50 whose menses had ceased for at least one year due to radiation or other medical treatment.

Measures of skinfold thickness in mm, an estimate of subcutaneous adipose tissue and body fat, were obtained at the triceps (vertical fold midpoint between the acromion and olecranon processes), suprailiac (diagonal fold just above the iliac crest and aligned with mid-axillary line), and thigh (vertical fold midpoint between the upper top of the patella and the inguinal crease) using a Lange caliper (Beta Technology, Houston, TX). The sum of these skinfolds was used to estimate body density and percent fat using available equations specifically for Hispanic groups [35].

\[
\text{Body Density} = 1.0994921 - (0.0009929 \times \text{sum of triceps, thigh, and suprailiac skinfolds}) - (0.001392 \times \text{age in years})
\]

Body Fat Percentage = \(\frac{4.87}{\text{body density}} - 4.41\)

Mean anthropometric measures were compared between cases and controls using the student t-test for continuous and \(\chi^2\) tests for categorical variables. Women with missing values were excluded from the specific anthropometric variable only. For covariates, missing values for age at menarche and age at menopause were replaced with the median by menopausal and case–control status. Spearman correlation coefficients were obtained between all anthropometric variables. Tertiles of each anthropometric variable were created for pre- and postmenopausal women based on the distribution of controls to three groups. Odds ratios and 95% confidence intervals were computed with unconditional logistic regressions. Odds ratios were adjusted for continuous variables (age, age at menarche, parity, and age at menopause) and for categorical variables (education, previous benign breast disease, and family history of breast cancer) representing potential confounders. All analyses were examined stratified by menopausal status. Because use of postmenopausal hormone therapy (HT) has been linked to breast cancer risk [36], we also analyzed the risk of postmenopausal breast cancer in our cases and controls stratified by HT. Differences in strata were examined with a multiplicative test of interaction. All statistical tests conducted with the IBM SPSS Statistics for Windows, Version 27.0. (Armonk, NY: IBM Corp), were two-sided and considered statistically significant at an alpha less than 0.05, and borderline significant at an alpha equal to 0.05.

**Results**

Characteristics of participants by case–control status and by menopausal status are shown in Table 1. Compared with controls, cases were somewhat older, but age was not significantly different between cases and controls in the analyses stratified by menopausal status. Regardless of menopausal status, cases had more years of education, fewer births, and more previous benign breast disease than controls. Age at menarche and use of HT were not different between postmenopausal cases and controls. Estrogen receptor (ER), progesterone receptor (PR) and human epidermal growth factor
receptor (HER2) status was known for 76.2%, 74.3%, and 59.4% of cases, respectively. Of these, 78.3% were ER+, 67.9% were PR+, and 20.3% were HER2+[31]. Among the cases, 90.8% reported having received surgical treatment for their breast cancer, 31.4% received radiation, and 32.4% chemotherapy (data not shown).

When anthropometric characteristics were compared between cases and controls (Table 2), no significant differences were observed for body weight, lifetime weight gain, height, WHR, estimated body fat and lean body mass. However, compared to controls, cases had lower BMI, waist circumference, and WHtR. We compared current body weight with that reported at one year previous. There were no significant differences between current and reported weight in both cases and controls (weight: cases = 71.7 ± 14.8 vs. 71.3 ± 14.5 kg, and controls = 74.3 ± 18.0 vs. 73.2 ± 18.0 kg, respectively, data not shown). In the analyses of anthropometric characteristics by menopausal status (Table 2), there were no significant differences between premenopausal cases and controls. For the postmenopausal group, cases were taller, and had lower waist circumference, WHtR, and WHR than controls. Sitting height and ABSI were similar between cases and controls with a mean of 0.80 (SD 0.005) m, and 0.075 (SD 0.006) m11/6 kg−2/3, respectively.

Significant correlations observed between anthropometric variables for premenopausal and postmenopausal women are shown in Table 3. Most anthropometric variables in pre- and postmenopausal cases and controls were significantly correlated (p < 0.05). The strongest correlations (≥ 0.75) between anthropometric variables not sharing one or more measures are in bold. In premenopausal cases the strongest correlation was for BMI and lifetime weight gain. In postmenopausal cases, the strongest correlation was for BMI and waist circumference. In premenopausal controls, the strongest correlations were for BMI and waist circumference, BMI and lifetime weight gain, and waist circumference and lifetime weight gain. For postmenopausal controls, none of the correlations reached our definition for strong correlation.

Anthropometric variables with significant trend for odds of breast cancer by menopausal status in cases and controls are shown in Table 4. There was a significant trend toward lower odds of premenopausal breast cancer for those in the highest compared to the lowest tertile of BMI (p for trend = 0.03) and borderline significant trend with higher WHtR (p for trend = 0.05). For postmenopausal participants, a significant trend for lower odds of breast cancer were observed for those in the highest tertile of WHtR (p for trend = 0.01), and WHR (p for trend = 0.04); and borderline significant for lower odds with higher waist circumference (p for trend = 0.05). Also significant was the trend for higher odds for postmenopausal women in the highest tertile of height (p for trend = 0.04). The trend was not significant for the odds of premenopausal or postmenopausal breast cancer with lifetime weight gain, sitting height, sitting height to

| Characteristic                        | All cases (n = 315) | All controls (n = 348) | Pre-menopausal Cases (n = 84) | Controls (n = 134) | Post-menopausal Cases (n = 231) | Controls (n = 214) |
|---------------------------------------|---------------------|------------------------|-------------------------------|-------------------|--------------------------------|-------------------|
| Age (years)                           | 58.7 (11.0)         | 54.0 (13.4)*           | 45.4 (5.3)                    | 40.2 (6.4)        | 63.5 (8.2)                     | 62.7 (8.5)        |
| Education (n, %)                      |                     | *                      | *                             | *                 | *                              | *                 |
| < 12 years schooling                  | 48, 15.2            | 84, 24.1               | 10, 11.9                      | 30, 22.4          | 38, 16.5                       | 54, 25.2          |
| 12 years                              | 54, 17.1            | 69, 19.8               | 7, 8.3                        | 25, 18.7          | 47, 20.3                       | 44, 20.6          |
| Technical/vocational/associate        | 84, 26.7            | 96, 27.6               | 24, 28.6                      | 39, 29.1          | 60, 26.0                       | 57, 26.6          |
| Bachelor                              | 82, 26.0            | 77, 22.1               | 26, 31.0                      | 28, 20.9          | 56, 24.2                       | 49, 22.9          |
| Graduate                              | 47, 14.9            | 22, 6.3                | 17, 20.2                      | 12, 9.0           | 30, 13.0                       | 10, 4.7           |
| Age at menarche (years)               | 12.2 (1.6)          | 12.5 (1.8)             | 12.0 (1.6)                    | 12.5 (1.9)        | 12.3 (1.7)                     | 12.5 (1.8)        |
| Number of births                      | 2.1 (1.5)           | 2.5 (1.7)*             | 1.7 (1.3)                     | 2.3 (1.5)*        | 2.3 (1.6)                      | 2.6 (1.7)*        |
| Age at menopause (years)              | –                   | –                      | –                             | –                 | 47.4 (6.9)                     | 46.8 (6.4)        |
| Family history of breast cancer (n, %yes) | 66, 21.0            | 30, 8.6*               | 11 (13.1)                     | 7, 5.2*           | 55, 23.8                       | 23, 10.7*         |
| Previous benign breast disease (n, %yes) | 147, 46.7            | 89, 25.6*              | 37, 44.0                      | 25, 18.7*         | 110, 47.6                      | 64, 29.9*         |
| Hormone therapy (n, % ever)           | –                   | –                      | –                             | –                 | 86, 38.2 (n = 225)             | 61, 29.6 (n = 206) |

Values for continuous variables are mean (SD); for categorical variables, values are n (percentage). Family history of breast cancer in first-degree relatives. Two-sided comparisons of means between cases and controls were computed by T-test for continuous and \( \chi^2 \) test for categorical variables; \( *p < 0.05 \).
**Table 2** Anthropometric characteristics of study participants by case–control status, and by menopausal status

| Characteristic          | All cases (n = 315) | All controls (n = 348) | Premenopausal Cases (n = 84) | Premenopausal Controls (n = 134) | Postmenopausal Cases (n = 231) | Postmenopausal Controls (n = 214) |
|------------------------|---------------------|------------------------|-----------------------------|---------------------------------|-------------------------------|----------------------------------|
| Weight (kg)            | 71.7 (14.8)         | 74.1 (17.9)            | 74.1 (16.9)                 | 77.7 (20.8)                     | 70.9 (13.9)                   | 71.8 (15.5)                     |
| Lifetime weight gain (kg) | 19.3 (12.9)       | 19.4 (14.6)            | 20.0 (14.6)                 | 19.7 (16.3)                     | 19.0 (12.3)                   | 19.3 (13.5)                     |
| Height (m)             | 1.55 (0.07)         | 1.54 (0.08)            | 1.57 (0.07)                 | 1.57 (0.08)                     | 1.54 (0.07)                   | 1.53 (0.07)                     |
| Body Mass Index (kg/m²) | 30.0 (6.0)         | 31.2 (7.4)             | 30.2 (6.6)                  | 31.7 (8.7)                      | 29.9 (5.7)                    | 30.8 (6.5)                      |
| Sum of skinfolds (mm)  | 80.9 (17.3)         | 83.4 (22.3)            | 84.6 (16.9)                 | 86.4 (21.8)                     | 79.4 (17.3)                   | 81.5 (22.5)                     |
| Body fat (%)           | 40.8 (8.2)          | 41.8 (10.7)            | 41.7 (8.2) (n = 83)         | 42.3 (10.6)                     | 40.5 (8.1)                    | 41.5 (10.7)                     |
| Lean body mass (kg)    | 41.7 (8.0)          | 42.0 (8.6)             | 42.2 (7.2) (n = 83)         | 43.2 (8.6)                      | 41.6 (8.3)                    | 41.3 (8.6)                      |
| ABSI (m⁻¹/kg⁻²/³)      | 0.075 (0.006)       | 0.075 (0.006)          | 0.073 (0.006)               | 0.073 (0.005)                   | 0.076 (0.006)                 | 0.077 (0.007)                   |
| Sitting height (m)     | 0.52 (0.03)         | 0.52 (0.03)            | 0.52 (0.03)                 | 0.52 (0.04)                     | 0.52 (0.02)                   | 0.52 (0.03)                     |

Values for continuous variables are mean (SD). Those marked with same letters are significantly different (p < 0.05). Lifetime weight gain = current weight − reported weight at 20 years old; Sum of skinfolds = triceps + suprailiac + thigh (mm); % body fat = (4.87/Body Density) − 4.41; [Body density: = 1.0994921 − (0.0009929 × sum of triceps, thigh and suprailiac skinfolds) − (0.0001392 × age)]; Lean body mass = weight in kg − weight x %body fat; ABSI (a body shape index): = waist in meter/(BMI²/³) (height¹/₂). In italics the number of participants for each measurement.

height ratio, ABSI, sum of skinfolds or percent body fat and lean body mass estimated from skinfold thicknesses.

Trends for odds of postmenopausal breast cancer with anthropometric measures in strata of HT are presented in Table 5. A significant trend for lower odds of postmenopausal breast cancer were observed for participants using HT who were in the highest tertile for waist circumference (p for trend = 0.01), WHtR (p for trend = 0.01), WHR (p for trend = 0.03), and ABSI (p for trend = 0.02). For participants not using HT, a significant trend for higher odds of postmenopausal breast cancer was observed among those in the highest tertile of height (p for trend = 0.04). The trend was not significant for the odds of postmenopausal breast cancer regardless of HT status with lifetime weight change, BMI, sum of skinfolds, percent body fat, sitting height, and lean body mass.

**Discussion**

To our knowledge, this case–control study is the first population-based study reporting breast cancer risk in relation to anthropometric characteristics among women in PR. We found that high BMI was associated with a significant trend for lower odds of breast cancer in premenopausal participants. Among postmenopausal women, high WHtR and WHR were associated with lower breast cancer odds, specifically among those who had ever used HT. For this group, high waist circumference and high ABSI were also associated with a significant trend for lower odds of breast cancer. For postmenopausal women never using HT, there was a trend for a positive association of height with odds of breast cancer.

Compared to other Hispanic women in the continental USA [37], women in our study were, on average, similar in BMI but slightly lower in body weight, height, and waist circumference. Compared to controls, cases had lower BMI, waist circumference, and WHtR. However, 45% of our cases
Table 3  Statistically significant correlations (*p < 0.05) between anthropometric variables by case–control and menopausal status

| Anthropometric variable | LWG (kg) | BMI (kg/m²) | Waist-C (cm) | WHtR | WHR | LWG (kg) | BMI (kg/m²) | Waist-C (cm) | WHtR | WHR |
|-------------------------|----------|-------------|--------------|------|-----|----------|-------------|--------------|------|-----|
| Lifetime WG (kg)        |          |             |              |      |     |          |             |              |      |     |
| Premenopausal cases     |          |             |              |      |     |          |             |              |      |     |
| BMI (kg/m²)             | 0.80*    |             |              |      |     |          |             |              |      |     |
| Waist-C (cm)            | 0.70*    | 0.78*       |              |      |     |          | 0.68*       | 0.80*        |      |     |
| WHtR                    | 0.67*    | 0.84*       | 0.94*        |      |     | 0.61*    | 0.84*       | 0.94*        |      |     |
| WHR                     | 0.30*    | 0.28*       | 0.68*        | 0.66*|      | 0.23*    | 0.30*       | 0.59*        | 0.61*|     |
| Sum of skinfolds (mm)   | 0.57*    | 0.63*       | 0.50*        | 0.49*| 0.10 | 0.30*    | 0.35*       | 0.27*        | 0.28*| 0.04|
| Body fat (%)            | 0.57*    | 0.64*       | 0.50*        | 0.49*| 0.10 | 0.30*    | 0.36*       | 0.27*        | 0.29*| 0.05|
| Lean body mass (kg)     | 0.53*    | 0.59*       | 0.60*        | 0.50*| 0.25*| 0.60*    | 0.61*       | 0.60*        | 0.48*| 0.22*|
| ABSI (m^{11/6} kg^{-2/3}) | −0.04  | −0.11       | 0.46*        | 0.37*| 0.77*| −0.06    | −0.08       | 0.46*        | 0.41*| 0.67*|
| Sitting height (m)      | 0.23*    | 0.09        | 0.23*        | 0.01 | 0.06 | 0.06     | −0.15*      | −0.03        | −0.25*| −0.20*|
| Postmenopausal cases    |          |             |              |      |     |          |             |              |      |     |
| BMI (kg/m²)             |          |             |              |      |     | 0.74*    |             |              |      |     |
| Waist-C (cm)            |          |             |              |      |     | 0.64*    | 0.72*       |              |      |     |
| WHtR                    |          |             |              |      |     | 0.56*    | 0.78*       | 0.93*        |      |     |
| WHR                     |          |             |              |      |     | 0.05     | 0.11        | 0.55*        | 0.56*|     |
| Sum of skinfolds (mm)   | 0.73*    | 0.75*       | 0.69*        | 0.66*| 0.28*| 0.53*    | 0.50*       | 0.35*        | 0.31*| −0.11|
| Body fat (%)            | 0.74*    | 0.75*       | 0.70*        | 0.67*| 0.29*| 0.53*    | 0.50*       | 0.36*        | 0.32*| −0.11|
| Lean body mass (kg)     | 0.30*    | 0.54*       | 0.54*        | 0.41*| 0.11 | 0.37*    | 0.49*       | 0.55*        | 0.47*| 0.25*|
| ABSI (m^{11/6} kg^{-2/3}) | −0.02  | −0.16       | 0.16         | 0.19*| 0.64*| −0.19*   | −0.08       | 0.11         | −0.10| −0.10|
| Sitting height (m)      | 0.07     | 0.02        | −0.01        | −0.18*| −0.26*| 0.19*    | −0.08       | 0.11         | −0.10| −0.10|

LWG lifetime weight gain, BMI Body Mass Index, Waist-C waist circumference, WHtR waist to height ratio, WHR waist to hip ratio. Sum of skinfolds: triceps, suprailiac, and thigh, ABSI a body shape index

In bold values ≥ 0.75 excluding variables calculated with one or more similar measures
and 53% of our controls were in the obese category based on BMI, and 25% of cases and 33% of controls had waist circumference higher than 95 cm and WHtR higher than 0.62: both indicative of excess visceral fat accumulation [38–40]. Also, 30% of cases and 33% of controls had lifetime weight gain higher than 23 kg, and body fat above 40% was observed in 25% of cases and 33% of controls. Most anthropometric measures correlated strongly and directly with each other. For example, those with high BMI also tended to have high waist circumference and high WHtR, which combination suggest a potentially higher risk of obesity-related diseases.

The significant trend for lower odds of breast cancer associated with higher WHtR, and borderline significant with higher BMI in premenopausal participants, is consistent with others [5, 9, 41]. However, Chen et al. [42], in their meta-analysis of 31 cohort studies, observed no association between BMI and premenopausal breast cancer, and Gravena et al. [43] also reported no association of BMI and premenopausal breast cancer in Brazil. Among Hispanic women, Slattery et al. [9] and John et al. [44] observed findings similar to ours, particularly when stratified by hormone receptor status [44]. However, as suggested by John et al. [44], the observed inverse association between premenopausal breast cancer and BMI and WHtR should be interpreted in light of the many documented health benefits associated with the control of body size and adiposity [10].

For postmenopausal participants, the observed significant trend for lower odds of breast cancer associated with higher WHtR and WHR, and borderline significant with higher waist circumference, is not consistent with previous reports that have shown positive association with waist circumference [44, 45] and WHR [45], and positive association with WHtR for ER + PR + breast cancer [44]. Our results also differ from Gravena et al. [43] who reported a higher risk of breast cancer with higher BMI among postmenopausal women in Brazil, and support the report of no association between BMI and breast cancer risk among Mexican American women in the USA [9]. It is possible that differences in HT use among postmenopausal women influence the association between anthropometric measures and breast cancer risk. In one study, a positive association between BMI, WHR, and adult weight gain and postmenopausal breast cancer was reported only among those not using HT compared to HT users [46]. However, we observed no significant trend for breast cancer risk associated with BMI regardless of HT use, but a significant trend for lower odds of postmenopausal breast cancer with higher waist circumference, WHR, and WHtR among ever using HT. Although it is possible that potential racial/ethnic differences suggested in the metabolic profile and etiology related to breast cancer [47] might help explain our findings, this area of research needs to be further developed.

| Characteristics* | Cases | Controls | Adjusted OR** (CI) | p for trend** |
|------------------|-------|----------|--------------------|--------------|
| **Body Mass Index (BMI = kg/m²)** |       |          |                    |              |
| Premenopausal    |       |          |                    |              |
| < 25             | 21    | 31       | 1.00               | 0.03         |
| 25–29.9          | 28    | 37       | 1.01 (0.41–2.49)   |              |
| ≥ 30             | 35    | 65       | 0.45 (0.19–1.07)   |              |
| Postmenopausal   |       |          |                    |              |
| < 25             | 45    | 36       | 1.00               | 0.14         |
| 25–29.9          | 81    | 60       | 1.08 (0.60–1.94)   |              |
| ≥ 30             | 101   | 118      | 0.67 (0.39–1.16)   |              |
| **Waist circumference (cm)** |       |          |                    |              |
| Premenopausal    |       |          |                    |              |
| < 83.8           | 32    | 43       | 1.00               | 0.07         |
| 83.8–95.3        | 29    | 46       | 0.75 (0.34–1.68)   |              |
| > 95.3           | 23    | 43       | 0.48 (0.20–1.14)   |              |
| Postmenopausal   |       |          |                    |              |
| < 86.4           | 94    | 70       | 1.00               | 0.05         |
| 86.4–97.2        | 75    | 70       | 0.84 (0.52–1.35)   |              |
| > 97.2           | 53    | 68       | 0.61 (0.37–1.02)   |              |
| **Waist to height ratio (WHtR)** |       |          |                    |              |
| Premenopausal    |       |          |                    |              |
| < 0.53           | 30    | 44       | 1.00               | 0.05         |
| 0.53–0.62        | 35    | 44       | 0.81 (0.36–1.82)   |              |
| > 0.62           | 19    | 44       | 0.36 (0.15–0.89)   |              |
| Postmenopausal   |       |          |                    |              |
| < 0.57           | 100   | 69       | 1.00               | 0.01         |
| 0.57–0.64        | 65    | 71       | 0.68 (0.42–1.11)   |              |
| > 0.64           | 57    | 68       | 0.59 (0.36–0.97)   |              |
| **Waist to hip ratio (WHR)** |       |          |                    |              |
| Premenopausal    |       |          |                    |              |
| < 0.80           | 27    | 44       | 1.00               | 0.50         |
| 0.80–0.87        | 31    | 44       | 1.11 (0.50–2.46)   |              |
| > 0.87           | 26    | 44       | 0.76 (0.34–1.74)   |              |
| Postmenopausal   |       |          |                    |              |
| < 0.84           | 86    | 69       | 1.00               | 0.04         |
| 0.84–0.90        | 80    | 70       | 1.03 (0.64–1.68)   |              |
| > 0.90           | 56    | 69       | 0.71 (0.43–1.19)   |              |
| **Height (m)**   |       |          |                    |              |
| Premenopausal    |       |          |                    |              |
| < 1.55           | 36    | 53       | 1.00               | 0.81         |
| 1.55–1.60        | 26    | 44       | 1.17 (0.55–2.45)   |              |
| > 1.60           | 22    | 36       | 0.95 (0.43–2.12)   |              |
| Postmenopausal   |       |          |                    |              |
| < 1.50           | 64    | 73       | 1.00               | 0.04         |
| 1.50–1.56        | 83    | 76       | 1.18 (0.72–1.92)   |              |
| > 1.56           | 80    | 65       | 1.42 (0.85–2.37)   |              |

* Tertiles among controls by menopausal status were used as cutoffs to define the categories for all anthropometric variables, except BMI.

** Odds ratios and 95% confidence intervals adjusted for continuous variables such as age, age at menarche, parity, and age at menopause for postmenopausal women; and for categorical variables such as education, previous benign breast disease, and family history of breast cancer. In bold p for trend that are statistically significant (p < 0.05).
Consistent with previous studies [5, 14–17, 48], we found a significant trend of higher odds of breast cancer associated with height, but only among postmenopausal participants who were not HT users. While Mellennmkjar et al. [15] observed both components of height (leg length and sitting height) equally influencing breast cancer risk, Fagherazzi et al. [17] found leg length in postmenopausal women and sitting height in premenopausal women as the most influential risk factors associated with standing height. We did not find a significant trend for pre- or postmenopausal odds of breast cancer associated with sitting height ($p$ for trend $= 0.21$ and 0.06, respectively, data not shown). Although height and sitting height have been related to growth hormone exposure and childhood nutrition and environmental factors [15, 16], the specific biological mechanisms explaining adult height or sitting height attainment on pre- and postmenopausal breast cancer risk are yet to be clarified. Identifying a common regulatory pathway for cellular growth that potentially affects adult height, sitting height, or leg length attainment and cancer development [17] needs to be addressed in future research.

A biological mechanism has been proposed linking excess body weight, especially abdominal adiposity, to metabolic and hormonal disturbances associated with breast cancer risk, such as insulin resistance, inflammation, and exposure to estrogen production via aromatization of androgens [7, 49, 50]. However, we found that higher BMI and higher WHtR, an indirect measure of abdominal adiposity, were associated with a significant trend for lower odds of pre- and postmenopausal breast cancer, respectively. Also different from previous publications [5, 18, 44, 51], we observed that lifetime weight gain and body fat were not associated with a significant trend of breast cancer risk. Keum et al. [49] reported that only among women not using HT, an increased risk of postmenopausal breast cancer was observed for each 5 kg increase in adult weight gain up to 35 kg. Our results differed in that lifetime weight gain and body fat were not associated with a significant trend for postmenopausal breast cancer odds irrespective of HT use. We acknowledge important sources of error in the estimate of lifetime weight gain based on self-report and body fat and lean body mass estimated from skinfold thicknesses using equations with unknown validity in specific study populations like ours. There is also a lack of information regarding body distribution of fat tissue. Therefore, conclusions from our results regarding the association between lifetime weight gain, body

| Characteristics* | Cases Yes HT (n = 147) | Controls Adjusted OR** (CI) | $p$ for trend** | Cases No HT (n = 284) | Controls Adjusted OR** (CI) | $p$ for trend** |
|------------------|------------------------|-----------------------------|-----------------|------------------------|-----------------------------|-----------------|
| Waist circumference (cm) | | | | | | |
| < 86.4 | 39 | 16 | 1.00 | | | 0.01 |
| 86.4–97.2 | 30 | 22 | 0.65 (0.27–1.54) | | | 44 | 45 | 1.06 (0.58–1.96) |
| > 97.2 | 14 | 21 | 0.32 (0.12–0.84) | | | 38 | 43 | 0.90 (0.48–1.72) |
| Waist to height ratio (WHtR) | | | | | | |
| < 0.57 | 46 | 14 | 1.00 | | | 50 | 54 | 1.00 |
| 0.57–0.64 | 21 | 26 | 0.25 (0.10–0.62) | | | 43 | 44 | 1.15 (0.62–2.12) |
| > 0.64 | 16 | 19 | 0.27 (0.10–0.70) | | | 40 | 43 | 0.98 (0.52–1.86) |
| Waist to hip ratio (WHR) | | | | | | |
| < 0.84 | 39 | 16 | 1.00 | | | 43 | 53 | 1.00 |
| 0.84–0.90 | 29 | 17 | 0.68 (0.28–1.67) | | | 50 | 49 | 1.41 (0.77–2.60) |
| > 0.90 | 15 | 26 | 0.25 (0.10–0.65) | | | 40 | 39 | 1.35 (0.71–2.59) |
| A Body Shape Index (ABSI) (m\(^{1/6}\) kg\(^{-2/3}\)) | | | | | | |
| < 0.074 | 33 | 14 | 1.00 | | | 41 | 55 | 1.00 |
| 0.074–0.079 | 27 | 18 | 0.52 (0.20–1.36) | | | 52 | 51 | 1.25 (0.68–2.30) |
| > 0.079 | 23 | 27 | 0.32 (0.12–0.82) | | | 40 | 35 | 1.61 (0.84–3.08) |
| Height (m) | | | | | | |
| < 1.50 | 27 | 18 | 1.00 | | | 36 | 52 | 1.00 |
| 1.50–1.56 | 31 | 23 | 0.99 (0.41–2.37) | | | 48 | 52 | 1.17 (0.63–2.18) |
| > 1.56 | 28 | 20 | 0.92 (0.38–2.25) | | | 51 | 41 | 1.79 (0.92–3.50) |

*Tertiles among controls by menopausal status were used as cutoffs to define the categories for all anthropometric variables, except BMI

**Odds ratios and 95% confidence intervals adjusted for continuous variables such as age, age at menarche, parity, and age at menopause: and for categorical variables such as education, previous benign breast disease, and family history of breast cancer. In bold $p$ for trend that are statistically significant (< 0.05)
Hispanic women. Metric measures in the assessment of breast cancer risk among women is critical, particularly those measures related to metabolic disturbances. Understanding potential differences between current measured weight at the time of the interview and self-reported weight one year prior to the study, and these were highly correlated in both cases and controls \((r = 0.97 \text{ and } 0.95, \text{ respectively})\). Because recall bias and nondifferential misclassification with reported body weight could be a concern, we did analyses using both current weight and self-reported weight one year prior to the study; results were similar (data not shown).

In conclusion, in this population-based case–control study of Hispanic women in PR, we found a significant trend for lower odds of premenopausal breast cancer associated with higher BMI, and borderline significant with higher WHtR. Among postmenopausal women, there was a significant trend for lower odds of breast cancer in association with higher WHtR and WHR, a borderline significant trend with higher waist circumference, and a significant trend for higher odds of breast cancer with higher height. We also observed differences in the trends for postmenopausal breast cancer when we stratified by HT use. Understanding potential differences in anthropometric measurements as risk factors for Hispanic women is critical, particularly those measures related to metabolic disturbances. Future analyses should include measures of body fat and lean mass distribution, and hormone receptor status to further understand the predictive value of anthropometric measures in the assessment of breast cancer risk among Hispanic women.

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### Author contributions
All authors contributed to the study conception and design, including material preparation, data collection and analyses. The first draft of the manuscript was written by FAR-M and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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### Data availability
The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

### Code availability
Not applicable.

### Declarations

#### Conflict of interest
The authors have no conflict of interest to declare that are relevant to the content of this article.

#### Ethical approval
The study was approved by the Institutional Review Board of the University of Puerto Rico Medical Sciences Campus.

#### Consent to participate
Informed consent was obtained from all individual participants in the study.

#### Consent for publication
Participants signed informed consent regarding publication of study data without direct or indirect identifiers.

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