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The association between adiposity indices and the odds of breast cancer based on findings from a case control study

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Adiposity is a major risk factor for the development of cancers, such as breast cancer(BC) in adults. However, the role of central adiposity or general obesity as primary predictors of BC occurrence and progression is not well-established. Therefore, the current study aimed to assess the association between various adiposity indices, including a body shape index(ABSI), abdominal volume index(AVI), body roundness index(BRI), conicity index(CI), body adiposity index(BAI), reciprocal ponderal index(RPI), and waist to height$^{0.5}$ ratio(WHt$^{0.5}$R) as surrogates for predicting the odds of BC in adult women. This case-control study was conducted at Shohada and Imam Hossain hospitals in Tehran and included 134 newly diagnosed BC cases and 267 controls. Anthropometric variables, including weight, height, and waist circumference were measured using standard methods, and various adiposity indices were calculated accordingly. The odds ratios(ORs) with 95% confidence intervals(CIs) for BC were reported across tertiles of adiposity indices using multivariable logistic regression. Participants in the highest tertile of BRI(OR:2.07;95% CI:1.04–4.12), BAI(OR:2.06;95% CI:1.05–4.03), and WHt$^{0.5}$R(OR:1.81;95% CI:1.01–3.55) had significantly higher odds of BC compared to those in the lowest tertile($P < 0.05$). Additionally, each SD increase in RPI was associated with lower odds of BC(OR:0.77;95% CI:0.61–0.98,$P = 0.034$). However, no significant associations were observed for CI, AVI, and ABSI with the odds of BC. Our results suggest that WHtR, BRI, BAI, and WHt$^{0.5}$R may be more effective predictors of BC odds among the evaluated adiposity indices.

Keywords Adiposity indices, Breast cancer, Body mass index, Waist circumference, ROC curve

Abbreviations

ABSI	A body shape index
AVI	Abdominal volume index
BAI	Body adiposity index
BC	Breast cancer
BMI	Body mass index
CI	Conicity index
BRI	Body roundness index

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FCT	Food composition table
FFQ	Food frequency questionnaire
METs	Metabolic equivalent
OR	Odds ratio
HC	Hip circumference
HRT	Hormone replacement therapy
IR	Insulin resistance
ROC	Receiver operating characteristic
RPI	Reciprocal ponderal index
SD	Standard deviation
SES	Socioeconomic status
T2D	Type 2 diabetes
TLGS	Tehran Lipid and Glucose Study
USDA	United States Department of Agriculture
WC	Waist circumference
WHR	Waist-to-hip ratio
WHtR	Waist-to-height ratio
$WHt^{0.5}R$	Waist to $height^{0.5}$ ratio

Breast cancer (BC) is the most common cancer among women worldwide, with approximately 1.7 million new cases annually, accounting for 25% of all female cancers and 12% of all new cancer cases[1]. In Iran, BC is the most prevalent cancer and the fifth leading cause of mortality among women[2]. Over the past five decades, changes in human lifestyle have significantly contributed to the rising incidence and prevalence of BC globally[3]. Adipose tissue is considered an active metabolic organ. Excessive fat accumulation, particularly in visceral adipose tissue, is associated with various endocrine and metabolic disruptions, including insulin resistance (IR), inflammation, elevated estrogen levels, and hormonal imbalances, all of which are linked to a higher risk of BC[4]. Furthermore, a recent systematic review and meta-analysis of matched case-control studies found that obesity, among modifiable risk factors for BC, had the highest odds ratio[5].

In recent years, various measures have been developed to assess body fat distribution, and researchers have sought to establish optimal thresholds for these indices across different health conditions[6,7]. However, due to differences in body composition among ethnic and racial groups, using a single cut-off point for these indicators across various populations has not yielded satisfactory or practical results[8]. To date, several studies have investigated the relationship and prediction of common anthropometric indices, such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) with the risk of BC[9–14].

In addition to the commonly used measurements, newer indicators have recently been developed, incorporating basic anthropometric measures, such as neck circumference with age, gender, and body fat indicators, including blood lipid levels, to enhance cancer risk prediction[15]. Krakauer et al.[15] and Thomas et al.[16] proposed A body shape index (ABSI) and body roundness index (BRI) to estimate body fat distribution, respectively. Data from the UK Biobank demonstrated an association between ABSI and an increased risk of BC[17]. Previous research found a link between BRI score and the risk of colorectal and liver cancers[9,18]. Li et al. reported that WHtR and BRI are more effective predictors of liver cancer risk compared to WC and ABSI[18]. The abdominal volume index (AVI) has also been used as a measurement to estimate the total volume of the abdominal region[19]. The conicity index (CI), evaluated for its ability to predict metabolic issues in young women[20], has shown a significant association with an increased risk of BC[21]. In addition, indices such as the body fat index (BAI) (17), reciprocal ponderal index (RPI), and waist to $height^{0.5}$ ratio ($WHt^{0.5}R$) have been applied in epidemiological studies to predict the risk of chronic diseases[22–24].

The existing literature reveals several critical gaps in research examining adiposity indicators and BC risk. First, previous studies have predominantly focused on established indicators such as BMI and WC, while newer adiposity markers remain relatively understudied. Second, the limited existing research yields inconclusive results, and importantly, optimal diagnostic thresholds for these indicators have not been well-established within the Iranian population. Therefore, this study aims to comprehensively address these research gaps by assessing the relationship between adipocyte indices and the odds of BC, comparatively evaluating their predictive capabilities, and determining precise, population-specific cut-off points for each indicator in the Iranian population.

Results

Study population characteristics by case and control groups

The mean ± standard deviation (SD) age and BMI of the study population were 47.9 ± 10.3 years and 29.4 ± 5.51 kg/m^2, respectively. Table 1 presents the general characteristics of the study participants. Compared to the control group, BC patients were significantly older and had higher age at first pregnancy, WHtR, prevalence of menopausal status, and family history of cancer. They also reported lower usage of anti-inflammatory drugs, lower vitamin D supplement intake, and reduced energy intake. However, no significant differences were observed between the two groups in terms of mean physical activity, smoking prevalence, history of pregnancy or breastfeeding, socioeconomic status, and educational level. Regarding adiposity indices, the case group had higher BRI and $WHt^{0.5}R$ and lower RPI compared to the control group ($P < 0.05$). No significant differences were found between cases and controls for other adiposity indices, including ABSI, AVI, CI, and BAI.

	Control ($n=267$)	Case ($n=134$)	*P*-value
Demographic data			
Age (year)	47.1 ± 10.0	49.5 ± 10.7	0.035
First pregnancy age (year)	18.2 ± 7.4	19.6 ± 8.6	0.040
Waist circumference (cm)†	96.4 ± 13.2	99.5 ± 14.5	0.093
Body mass index (Kg.m^2)	29.0 ± 5.4	30.1 ± 5.7	0.071
WHR†	0.89 ± 0.10	0.90 ± 0.07	0.661
WHtR†	0.60 ± 0.08	0.63 ± 0.09	0.034
Physical activity (MET/min/week)	32.7 ± 5.2	32.9 ± 5.4	0.701
Smoking (yes, %)	3.4	3.0	0.842
Menopausal status (yes, %)	42.7	53.7	0.037
Cancer family history (yes, %)	20.6	30.6	0.028
Anti-inflammatory drug (yes, %)	17.2	7.5	0.007
Vitamin D supplement intake (yes, %)	24.3	14.9	0.029
Breastfeeding history (yes, %)	86.1	85.8	0.930
Pregnancy history (yes, %)	89.8	89.5	0.845
Education level (Bachelor and higher, %)	14.6	19.4	0.178
Socio economic status (%)			0.531
Low (%)	37.1	38.1	
Middle (%)	43.8	37.3	
High (%)	18.7	21.6	
Energy intake (Kcal/d)	2753 ± 798	2562 ± 612	0.015
Adiposity indices			
A body shape index	0.08 ± 0.008	0.08 ± 0.005	0.775
Abdominal volume index	19.1 ± 5.3	20.3 ± 5.8	0.104
Body roundness index	5.7 ± 2.1	6.4 ± 2.4	0.031
Conicity index	1.3 ± 0.1	1.3 ± 0.1	0.514
Body adiposity index	36.1 ± 7.5	37.6 ± 7.9	0.130
Reciprocal ponderal index	38.3 ± 2.5	37.7 ± 2.4	0.027
Waist to height$^{0.5}$ ratio	7.64 ± 1.1	7.9 ± 1.2	0.041

Table 1. Study population characteristics among the breast cancer patients and healthy participants. *Data are expressed as mean ± SD and percentage (%) for continuous and categorical variables, respectively. †Data was measured in 78 cases and 262 controls.

Adiposity indices and their associations with BC odds

The odds ratios (ORs) and 95% confidence intervals (CIs) for BC across tertiles of adiposity indices are presented in Table 2. In the crude model, a significant positive association was observed between BRI and BC (OR: 2.08; 95% CI: 1.10–3.90, P for trend = 0.019). In the final model, after adjusting for confounding factors, including age at first pregnancy, menopausal status, family history of cancer, anti-inflammatory drug use, vitamin D supplementation, and energy intake, participants with the highest BRI had higher odds of BC compared to those with the lowest BRI (OR: 2.07; 95% CI: 1.04–4.12, P for trend = 0.031). In the crude model, each SD increase in BRI was associated with a 32% higher odds of BC (OR: 1.32, 95% CI: 1.03–1.68, $p=0.024$). This association persisted in the fully adjusted model, with each SD increase in BRI showing a 31% higher odds of BC (OR: 1.31, 95% CI: 1.00–1.71, $p=0.047$). As shown in Table 2, a significant positive association was found between BAI and BC odds in both the crude model (OR: 2.13, 95% CI: 1.12–4.03, $p=0.019$) and the final model (OR: 2.06, 95% CI: 1.05–4.03, $p=0.030$). While no significant association was found between WHt$^{0.5}$R and BC odds in the crude model, the fully adjusted model indicated higher odds of BC for participants in the highest tertile of WHt$^{0.5}$R compared to the lowest tertile (OR: 1.81, 95% CI: 1.01–3.55, $p=0.045$). Each SD increase in WHt$^{0.5}$R was also positively associated with higher odds of BC (OR: 1.29, 95% CI: 1.00–1.67, $p=0.043$). Per SD increment, RPI was inversely associated with BC odds in the crude model (OR: 0.79; 95% CI: 0.64–0.98; $P=0.033$) and the fully adjusted model (OR: 0.77; 95% CI: 0.61–0.98; $P=0.034$). However, no significant association was found between ABSI, AVI, or CI and odds of BC in either crude or adjusted models.

ROC analysis for adiposity indices in predicting the odds of BC

The findings of the receiver operating characteristic (ROC) curve analysis evaluating the sensitivity and specificity of adiposity indices in predicting BC status are presented in Table 3. The area under the curve (AUC) with 95% CI was as follows: WHtR (AUC: 0.58, 95% CI: 0.52–0.63, $P=0.034$), BRI (AUC: 0.58, 95% CI: 0.52–0.63, $P=0.034$), BAI (AUC: 0.57, 95% CI: 0.51–0.62, $P=0.040$), and WHt$^{0.5}$R (AUC: 0.57, 95% CI: 0.51–0.62, $P=0.05$). The predictive capacity of these four indices in estimating the odds of BC is moderate, yet remains statistically significant. The optimal cut-off values for these indices were WHtR: 0.64, BRI: 6.43, BAI: 33.5, and WHt$^{0.5}$R: 8.1.

Adiposity indices	OR of breast cancer (95% CI)				Per one SD	*P*-value
	T1	T2	T3	*P* trend		
ABSI						
Median score, SD	0.075	0.080	0.086	–		–
Case/total	28/114	24/113	26/113	–		–
Crude model	1.00 (Ref)	0.83 (0.44–1.54)	0.90 (0.49–1.67)	0.790	0.96 (0.74–1.25)	0.801
Model 1*	1.00 (Ref)	0.74 (0.39–1.40)	0.74 (0.39–1.41)	0.297	0.88 (0.66–1.16)	0.379
Model 2†	1.00 (Ref)	0.70 (0.36–1.35)	0.70 (0.36–1.38)	0.352	0.88 (0.66–1.18)	0.415
AVI						
Median score, SD	14.7	18.8	24.0	–		–
Case/total	22/114	24/112	32/112	–		–
Crude model	1.00 (Ref)	1.15 (0.60–2.20)	1.69 (0.91–3.15)	0.087	1.23 (0.97–1.58)	0.087
Model 1*	1.00 (Ref)	1.01 (0.52–1.96)	1.45 (0.76–2.76)	0.268	1.15 (0.89–1.49)	0.266
Model 2†	1.00 (Ref)	1.00 (0.50–1.97)	1.65 (0.84–3.24)	0.123	1.22 (0.93–1.59)	0.142
BRI						
Median score, SD	3.91	5.68	7.78	–		–
Case/total	20/114	24/115	34/111	–		–
Crude model	1.00 (Ref)	1.22 (0.63–2.37)	2.08 (1.10–3.90)	0.019	1.32 (1.03–1.68)	0.024
Model 1*	1.00 (Ref)	1.15 (0.59–2.26)	1.80 (0.93–3.48)	0.087	1.23 (0.95–1.58)	0.111
Model 2†	1.00 (Ref)	1.14 (0.57–2.27)	2.07 (1.04–4.12)	0.031	1.31 (1.00–1.71)	0.047
CI						
Median score, SD	1.20	1.29	1.40	–		–
Case/total	23/114	28/113	27/113	–		–
Crude model	1.00 (Ref)	1.29 (0.69–2.41)	1.24 (0.66–2.33)	0.524	1.07 (0.84–1.37)	0.567
Model 1*	1.00 (Ref)	1.13 (0.59–2.15)	1.00 (0.51–1.96)	0.831	0.97 (0.75–1.27)	0.872
Model 2†	1.00 (Ref)	1.09 (0.56–2.11)	1.01 (0.50–2.03)	0.987	0.99 (0.76–1.30)	0.996
BAI						
Median score, SD	30.1	35.8	43.5	–		–
Case/total	19/1112	26/114	34/113	–		–
Crude model	1.00 (Ref)	1.46 (0.75–2.83)	2.13 (1.12– 4.03)	0.019	1.23 (0.95–1.59)	0.114
Model 1*	1.00 (Ref)	1.42 (0.73–2.76)	1.95 (1.02–3.74)	0.044	1.17 (0.90–1.52)	0.226
Model 2†	1.00 (Ref)	1.36 (0.68–2.69)	2.06 (1.05–4.03)	0.030	1.22 (0.93–1.60)	0.148
RPI						
Median score, SD	35.7	38.2	40.3	–		–
Case/total	50/133	41/134	43/132	–		–
Crude model	1.00 (Ref)	0.74 (0.45–1.24)	0.80 (0.48–1.34)	0.386	0.79 (0.64–0.98)	0.033
Model 1*	1.00 (Ref)	0.76 (0.45–1.27)	0.87 (0.52–1.46)	0.622	0.82 (0.66–1.02)	0.085
Model 2†	1.00 (Ref)	0.65 (0.37–1.11)	0.81 (0.47–1.40)	0.405	0.77 (0.61–0.98)	0.034
$WHt^{0.5}R$						
Median score, SD	6.70	7.66	8.71	–		–
Case/total	22/114	22/113	34/113	–		–
Crude model	1.00 (Ref)	0.91 (0.46–1.78)	1.57 (0.82–2.98)	0.176	1.20 (0.92–1.56)	0.166
Model 1*	1.00 (Ref)	1.02 (0.53–1.97)	1.82 (0.98–3.37)	0.047	1.28 (0.97–1.69)	0.082
Model 2†	1.00 (Ref)	0.88 (0.44–1.77)	1.81 (1.01–3.55)	0.045	1.29 (1.00–1.67)	0.043

Table 2. The OR (95% CI) of breast cancer across tertiles and per increment of one standard deviation of adiposity indices among the study population. ABSI: A body shape index, AVI: abdominal volume index, BAI: body adiposity index, CI: conicity index, BRI: body roundness index, RPI: reciprocal ponderal index, WHT^5R: waist to $height^{0.5}$ ratio. *Model 1: adjusted for age, first pregnancy age. †Model 2: adjusted for model 1 and menopausal status, family history of cancer, anti-inflammatory drug use, Vitamin D supplementation, smoking, physical activity, and energy intake.

Sensitivity and specificity values ranged from 0.43 to 0.75 and 0.39 to 0.75, respectively. Corresponding Youden Indices for WHtR, BRI, BAI, and $WHt^{0.5}R$ were 0.16, 0.16, 0.15, and 0.15 respectively.

Discussion

In this study, we evaluated various adiposity indices in predicting the odds of BC using a case-control design involving 401 participants. The most notable finding was the positive association of BRI, BAI, and $WHt^{0.5}R$

Adiposity indices	AUC (95% CI)	*p*	Cut-off	Sensitivity	Specificity	Youden Index
BMI*	0.54 (0.49–0.59)	0.111	31.6	0.34	0.75	0.09
Waist circumference †	0.56 (0.50–0.61)	0.112	101	0.44	0.68	0.13
WHR†	0.53 (0.48–0.59)	0.293	0.87	0.60	0.50	0.11
WHtR†	0.58 (0.52–0.63)	0.034	0.64	0.43	0.72	0.16
ABSI†	0.50 (0.45–0.56)	0.884	0.076	0.80	0.27	0.08
AVI†	0.55 (0.50–0.61)	0.133	20.7	0.45	0.68	0.12
BRI†	0.58 (0.52–0.63)	0.034	6.43	0.43	0.75	0.16
CI†	0.53 (0.48–0.59)	0.324	1.26	0.70	0.39	0.10
BAI†	0.57 (0.51–0.62)	0.040	33.5	0.75	0.39	0.15
RPI*	0.55 (0.50–0.60)	0.054	38.2	0.58	0.53	0.12
$WHt^{0.5}\mathbf{R}$†	0.57 (0.51–0.62)	0.050	8.1	0.43	0.72	0.15

Table 3. AUCs, optimal cut-off, sensitivity, specificity, and Youden index for the adiposity indices in ROC analysis for predicting the odds of breast cancer. BMI: body mass index, ABSI: A body shape index, AVI: abdominal volume index, BAI: body fat index, CI: conicity index, BRI: body roundness index, RPI: reciprocal ponderal index, WHT^5. R: waist to $height^{0.5}$ ratio, WHR: waist to hip ratio, WHtR: waist-to-height ratio. *Analyses were conducted on 134 cases and 267 controls. †Analyses were conducted on 78 cases and 262 controls.

with the odds of BC. Conversely, RPI showed an inverse association with BC odds. Our results also provide cut-off values for these adiposity indicators as potential BC predictors. No significant associations were observed between CI, AVI, ABSI and the odds of BC.

An excess of abnormal adipose tissue, particularly visceral fat, can disrupt the body's homeostasis by releasing inflammatory and lipid-related factors. This disruption may lead to pathological conditions, including oxidative stress, IR, and alterations in cell proliferation[25–27], which underscores the importance of evaluating adiposity indicators in BC. Certain studies have indicated a link between obesity and reduced survival rates in cancer[28,29], while others have found that obesity, compared to a low or healthy BMI (kg/m^2), is associated with decreased mortality following a cancer diagnosis[30,31]. Previous investigations into the obesity paradox have predominantly relied on BMI as a measure of body composition. However, BMI is an inadequate indicator of body composition because it does not differentiate between fat mass and fat-free mass. Therefore, evaluating adiposity indices rather than BMI may provide a more accurate assessment of cancer odds[32]. Given that dysfunction in abdominal adipocytes contributes to chronic inflammation and metabolic disorders associated with obesity, the impact of adiposity on BC risk deserves further attention[33].

One of the findings of the present study is that WHtR is associated with an increased odds of BC. WHtR, which reflects central adiposity and visceral fat accumulation, may contribute to increased cancer risk through inflammatory mechanisms and metabolic dysregulation[34]. Although WHtR appears to be associated with abdominal obesity and a greater risk of cardiovascular diseases[35], its relationship with the risk of BC has not been extensively investigated. Consistent with our findings, previous research has shown that WHtR is associated with an increased risk of NAFLD and liver cancer[18,36]. However, a population-based case-control study reported an inverse correlation between larger body size (as measured by BMI, WC, and WHtR) and premenopausal BC among Hispanic, African-American, and non-Hispanic white women, specifically for estrogen receptor– and progesterone receptor–positive BC[37]. These conflicting findings emphasize the importance of considering tumor hormone receptor status when examining the relationship between adiposity and BC risk.

Our findings suggest that both BRI and BAI are associated with elevated odds of BC. Research by Solak et al. indicated that BRI is as an independent factor influencing the HOMA index, with BRI serving as a reliable predictor for overweight and obesity, whereas ABSI lacks adequate predictive capability[38]. Similarly, Gao et al., reported that BRI level was associated with an increased risk of colorectal cancer, even after adjusting for potential confounders[9]. Another study found that BRI is linked to overall and cardiovascular mortality rates in a retrospective cohort study involving both men and women in the US. These findings suggest that BRI may provide valuable perspectives on the dysfunction of visceral adipose tissue in relation to cardiovascular and overall mortality[39]. The results of another study also support the idea that BRI could serve as a noninvasive screening tool for assessing mortality risk[40]. In contrast, as a systematic review and meta-analysis showed that while WC and WHtR are effective in screening for metabolic syndrome, no significant associations were found for BRI. However, BRI was found to be outperform BMI, WHR, BAI, and ABSI[41]. A similar finding was reported by Gupta and colleagues, who showed that the sensitivity of BAI surpassed that of BMI and WC[42]. On the other hand, López et al. introduced BAI as an appropriate tool for measuring adiposity[43]. Contrary to our findings, Schulze et al. demonstrated that WC in men and hip circumference (HC) in women serve as more accurate indicators of the percentage of body fat compared to BAI and BMI. Furthermore, BAI was found to be a weaker predictor of type 2 diabetes (T2D) than BMI, with WC emerging as the most significant predictor[44]. In addition, Rivera et al. highlighted a specific positive link between adiposity and high-grade prostate cancer, though they only reported the relevance of BMI, WC, and body fat[45]. In a study of Korean women, existing classifications of obesity based on BMI proved to be more effective than those based on BAI in assessing and predicting the risk of obesity and metabolic complications[46]. Moreover, a cross-sectional study of Spanish adult workers observed that

adiposity measurements incorporating WC, specifically WHtR and WC, may serve as more effective indicators than BAI and BMI for assessing metabolic and cardiovascular risk[47]. Although there are conflicting findings in this area, BAI may function as a supplementary marker for screening populations; however, its validity must be established in various populations.

Among adiposity indices, our study revealed significant findings for $WHt^{0.5}R$ and RPI, where limited prior evidence exists. Our results demonstrated a positive association between $WHt^{0.5}R$ and BC odds, suggesting its potential as a meaningful adiposity indicator for cancer risk. Lu et al. previously supported this perspective, showing that WHtR, WC, and $WHt^{0.5}R$ are more beneficial predictors than BMI for cardiometabolic multimorbidity in middle-aged and elderly populations[26]. Moreover, WC-related obesity metrics showed a more pronounced effect compared to general obesity indicators, with WHtR exhibiting a notably stronger influence on estimated glomerular filtration rates than $WHt^{0.5}R$ and WHR[22]. Our study found an inverse association between RPI and BC odds. A study conducted in Pakistan, investigating the accuracy of anthropometric indices for predicting metabolic syndrome (MetS), reported that all indices, except RPI, were significantly higher in individuals with MetS compared to those without[48]. In contrast, research in Indian children and adolescents associated higher RPI values with increased fatness and elevated health risks[49]. This discrepancy likely reflects the complexity of RPI as a metabolic indicator, underscoring the importance of context-specific assessments of adiposity indices in different metabolic conditions and populations. Additional research provides complementary insights into RPI's physiological significance. Brahim et al. found that in healthy, active male students, RPI was the most effective indicator of maximal oxygen uptake (VO2max) performance[50]. These findings highlight RPI's complexity as an anthropometric marker, revealing its potential to provide insights beyond conventional body composition assessments and suggesting its utility as a dynamic indicator of metabolic health across diverse populations. However, the limited existing evidence necessitates further research to clarify RPI's role in assessing disease risks and metabolic characteristics.

We did not find a significant association between other adiposity indices, including CI, AVI, and ABSI and increased odds of BC. While Zhang et al., identified CI as an independent risk factor for all-cause mortality in the elderly population[51], Fontela et al. reported insufficient evidence regarding the association between CI and coronary artery disease[52]. AVI has demonstrated utility as a reliable anthropometric index for estimating total abdominal volume, showing significant correlations with impaired glucose tolerance, T2D, depression, and anxiety[19,53]. ABSI has shown positive correlations with various cancer types, suggesting that body shape factors may influence cancer progression[54]. However, a study of prostate cancer patients revealed no significant associations between adiposity indicators such as waist circumference and ABSI with cancer clinical manifestation[55]. These divergent findings underscore the complexity of adiposity indices and highlight the need for further research across diverse populations to elucidate their potential role in cancer risk assessment.

Our study provides cut-off points for predicting the odds of BC and highlights the broader potential of these adiposity indices in cancer screening. The variability in cancer prevalence and adipose tissue distribution across sexes[56], suggests that developing sex-specific thresholds could significantly enhance the precision of these predictive models. Future research should focus on validating these cut-off points across different population groups and cancer types, potentially expanding the utility of these adiposity indices as screening tools. Such stratified approaches could improve early detection strategies, particularly for cancers where body composition plays a significant role in risk assessment.

The strengths of our study include face-to-face interviews with participants, which significantly reduced reporting bias. Furthermore, we experienced a notably low rate of patient refusals to participate in the study. Another strength was the estimation of various adiposity indicators and their potential association with BC odds. Moreover, defining cut-off points for indicators significantly correlated with BC was a novel aspect of our work. However, the limitations of the present study also deserve to be mentioned. First, as with other population-based cancer research, a considerable number of patients had passed away before our initial data collection. Second, although the current study's sample size provided adequate power to detect potential associations between most adiposity indices, including ABSI, AVI, BRI, BAI, and WHt0.5R and odds of BC, the statistical power was insufficient to demonstrate associations between two other adiposity indices, including CI and RPI and odds of BC. Therefore, larger-scale studies are warranted to better characterize the possible role of these dietary factors in predicting risk of BC. Third, our study has case-control design that inherently limits causal inference, as adiposity indices were measured post-BC diagnosis. This introduces reverse causality bias; BC-related metabolic changes or medications (e.g., hormone therapy) may change body composition, thereby distorting the reported associations. To address these limitations, replication in larger, prospective cohorts with diverse populations is warranted. Additionally, as this is an observational study, our findings do not inherently imply causation and confounding factors that we could not account for may still be present. The interviewers collecting data were not blinded to the case and control statuses, which might have introduced measurement errors. Nevertheless, it is important to note that the interviews were conducted by nutrition experts and trained interviewers with several years of experience in nutritional research. Their expertise ensured the accuracy of the data collected and helped minimize measurement errors in reporting participant information.

In conclusion, our results suggest that adiposity indices, particularly BRI, BAI, and $WHt^{0.5}R$ may play a significant role in influencing the odds of BC. From a preventive perspective, reducing these fat indices could potentially be effective in mitigating the occurrence and progression of BC.

Materials and methods

Study population

This case-control study assessed the predictive power of various adiposity indices for the odds of BC among Iranian women. Participants were recruited from Imam Hossain and Shohada hospitals in Tehran from September 2015 to February 2016. The study included 136 newly diagnosed BC patients aged ≥ 30 years, with

diagnoses confirmed histologically within the previous six months, and 272 women admitted to the same hospitals during the study period for non-neoplastic conditions. The age range of participants was 30–73 years in the case group and 14–81 years in the control group.

For the case group, we excluded participants who followed a special diet, had a history of hormone replacement therapy (HRT), or were pregnant or lactating. Similarly, we applied exclusion criteria to the control group, excluding those who followed special dietary habits, were pregnant or lactating, had a history of HRT or benign breast disease, or had physician-diagnosed cancer at any site. The study's participation rate was 92%. Seven participants (five from the control group and two from the case group), were excluded from the analysis due to reported energy intakes being outside the range of ±3 SD from the mean energy intake of the study population. Ultimately, 401 participants were included in the final analysis (134 cases and 267 controls). This study adhered to the principles of the Declaration of Helsinki, and all participants provided written informed consent prior to enrollment.

Socio-demographic, anthropometric, and physical activity

Information on socio-demographic variables, including age, first pregnancy age, smoking status, marital status, menopausal status, occupation, family cancer history, breastfeeding history, educational level, medication and supplement use, socioeconomic status (SES), and other lifestyle-related factors, was collected by trained interviewers. SES was calculated based on family size (≤4 or >4 members), education level (academic or non-academic), and housing status (ownership or leasehold). Participants received a score of 1 if their family size was ≤4, had a college education, or owned a house, and a score of 0 otherwise. The total SES score ranged from 0 (minimum) to 3 (maximum), with scores categorized as high (3), moderate (2), or low (1 or 0)[57].

Participants' body weight was measured to the nearest 100 g using digital scales, while they wore minimal clothing and no shoes. Height was measured to the nearest 0.5 cm in a standing position without shoes using a tape meter. WC was measured at the narrowest point after a natural exhalation, and HC was measured at the widest point of the hips, both to the nearest 0.5 cm using a tape measure. BMI was calculated as weight (kg) divided by the square of the height (m^2. Physical activity levels were assessed using a valid and reliable questionnaire[58] and expressed in metabolic equivalent hours per week (METs h/wk)[59].

Dietary assessment

Dietary information was collected using a validated, reliable, semi-quantitative 168-item food frequency questionnaire (FFQ) designed for the Tehran Lipid and Glucose Study (TLGS)[60]. Trained dietitians asked participants to report the frequency of consumption for each food item over the previous year, on a daily, weekly, or monthly basis. These frequencies were then converted into daily gram intake using standard household measures[61]. The energy, macronutrient, and micronutrient intake were calculated using the United States Department of Agriculture (USDA) food composition table (FCT) for most items and the Iranian FCT for local foods not listed in the USDA database[62]. Food frequencies were subsequently converted to daily intake scales.

Adiposity indices calculation

A Body Shape Index (ABSI)[15]:

This index used WC, BMI, and height to predict the mortality risk. The ABSI formula was calculated as follows:

$$\mathrm{ABSI} = \mathrm{WC\,(m)}/[\mathrm{BMI}^{2/3}\,(\mathrm{kg/m^2}) \times \mathrm{Height}^{1/2}(\mathrm{m})]$$

Abdominal volume index (AVI)[63]:

This index is a reliable anthropometric tool for the estimation of overall abdominal volume. AVI formula was calculated as follows:

$$\mathrm{AVI} = [2\,\mathrm{cm\,(waist)}^2 + 0.7\,\mathrm{cm\,(WHR)}^2]/1000$$

Body roundness index (BRI)[64]:

BRI is applied as a visual tool for health status evaluations. The BRI formula was calculated as follows:

$$\mathrm{BRI} = 364.2 - (365.5 \times [1 - \pi^{-2} \times \mathrm{WC}^2\,(\mathrm{m}) \times \mathrm{Height}^{-2}\,(\mathrm{m})]^{1/2})$$

Conicity index (CI)[65]:

This index used WC, weight, and height to indicate the healthy status. CI formula was calculated as follows:

$$\mathrm{CI} = 0.109^{-1} \times \mathrm{WC\,(m)}\,[\mathrm{Weight\,(kg)/Height\,(m)}]^{-1/2}.$$

Body adiposity index (BAI)[66]:

The BAI can be used to reflect body fat percentage for adults. BAI formula is provided as follows:

$$\mathrm{BAI} = [\mathrm{hip\,(m)}/(\mathrm{Ht})^{1.5}\,(\mathrm{m})] - 18.$$

Reciprocal ponderal index (RPI)[50]:

This adiposity index was calculated as the relationship between standing height divided by the cube root of body weight.

Waist-to-height0.5 ratio (WHt^5R)[67]:

This index was calculated as waist (cm) divided by height$^{0.5}$ (cm$^{0.5}$). The WHt$^{0.5}$R formula is provided as follows:

$$\mathrm{WHt}^{0.5}\mathrm{R} = \mathrm{Waist}/\mathrm{Height}^{0.5}.$$

Statistical analysis

We used Statistical Package for Social Sciences, version 21 (SPSS Inc., Chicago, IL, USA) for statistical analysis, and a P-value < 0.05 was considered statistically significant. The normality of variables was evaluated using Kolmogorov–Smirnov test and histogram. Demographic characteristics, lifestyle factors, anthropometric indices, and energy intake of cases and controls were reported as frequency (percentages) for qualitative variables and as mean ± SD or median (25–75 IQR) for quantitative variables, as appropriate. We used the independent-sample t-test and chi-square test to assess differences between the case and control groups for continuous and categorical variables, respectively. Participants were divided into tertiles based on adiposity indices, including ABSI, AVI, BRI, CI, BAI, RPI, and WHt$^{0.5}$R. Multivariable logistic regression was used to calculate the odds ratio (OR) with a 95% confidence interval (CI) of BC odds in each tertile of the adiposity indices. The analysis included three models: the crude model; model 1 (adjusted for age and first pregnancy age); and model 2 (adjusted for model 1 variables plus menopausal status, family history of cancer, anti-inflammatory drug use, vitamin D supplementation, smoking, physical activity, and energy intake). To evaluate the sensitivity and specificity of anthropometric and adiposity indices, we used ROC analysis. We also reported the Youden index, a commonly used measure of overall diagnostic effectiveness that combines sensitivity and specificity. Using ROC analysis, we determined the cutoff points for all the above-mentioned adiposity indices to predict the odds of BC, and the AUC was calculated for each index.

Data availability

The data used and/ or analyzed in the present study are available from the corresponding author on reasonable request.

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Author contributions
HF, FT, and ZH contributed to the conception, hypothesis, and design of the study. FT, HF, HA, MKJ, NS, EM, MB, and SJ, contributed to the research, statistical analyses, and manuscript preparation. BR and PM supervised the study. All authors contributed to the manuscript review and critical intellectual content. All authors approved the final version of the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
Informed written consent was obtained from participants. All procedures performed in studies involving human participants adhered to the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study protocol was approved by the research council of the Shahid Beheshti University of Medical Sciences, Tehran, Iran (ethical approval code: IR.SBMU.RETECH.REC.1399.1281).

Additional information
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