

Original Article

Abdominal obesity and paraspinal muscles in computed tomography image: relationships with triple negative breast cancer

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Abstract: Obesity is a risk factor for the development of breast cancer, like many other cancers, and we aimed to evaluate the association between abdominal fat distribution and muscle mass measured on computed tomography (CT) and triple-negative breast cancer subtype in women. We studied 421 patients with breast cancer diagnosed at our hospital who had an abdominal CT scan. Abdominal fat distribution, including visceral, subcutaneous, and total fat amounts in mm², and paraspinal muscle density (psoas, erector spinae multifidus, and total muscle density) were measured using CT scans. Analysis was performed to assess the association between participants' medical information obtained from electronic medical records (EMR), abdominal fat tissue distributions, paraspinal muscle tissue densities, and triple-negative and non-triple-negative breast cancer. Visceral obesity and the ratio of visceral to subcutaneous fat tissue were found to increase the risk of triple-negative breast cancer in women (OR = 1.89 [95% CI = 1.23-2.94]) and (OR = 9.09 [95% CI = 5.55-14.28]), respectively. Regression analysis based on body composition also revealed an association between low fat and low muscle mass and triple-negative breast cancer (OR = 10 [95% CI = 5.55-20]). Our findings demonstrate a clear association between triple-negative breast cancer and abdominal fat distribution and visceral-to-subcutaneous fat ratio, suggesting that abdominal fat distribution is a useful indicator of triple-negative breast cancer risk factors.

Keywords: Triple-negative breast cancer, intra-abdominal fat, adipose tissues, skeletal muscles, computed tomography, body composition

Introduction

Breast cancer is the most common cancer in women in both developed and developing countries. It is known that one in seven women develops breast cancer at some point in their lives [1]. After the ovaries, the main source of estrogen production in women is fat tissue [2]. A relationship has been reported between increased fat tissue and the risk of developing estrogen receptor-positive breast cancer, particularly in postmenopausal women [3, 4]. Among molecular subtypes based on protein expression status, triple-negative breast cancer, which lacks expression of estrogen receptor (ER), progesterone receptor (PR), and human epidermal growth factor receptor 2 (HER2), accounts for up to 15% of breast cancer cases. Triple-negative breast cancers are generally

more aggressive, have a poorer prognosis, and are more likely to metastasize to the liver and lungs than other subtypes [5].

Epidemiological studies indicate that obesity, as measured by body mass index (BMI), is positively associated with an increased risk of triple-negative breast cancer [6]. However, the association between obesity, as measured by BMI, and the risk of triple-negative breast cancer differs between premenopausal and postmenopausal women. In postmenopausal women, most studies have found no association [7, 8] or a decreased risk with increasing BMI and body fat [9]. However, a systematic review and meta-analysis found that premenopausal women with a body mass index ≥ 30 kg/m² had a higher risk of developing triple-negative breast cancer compared with non-obese

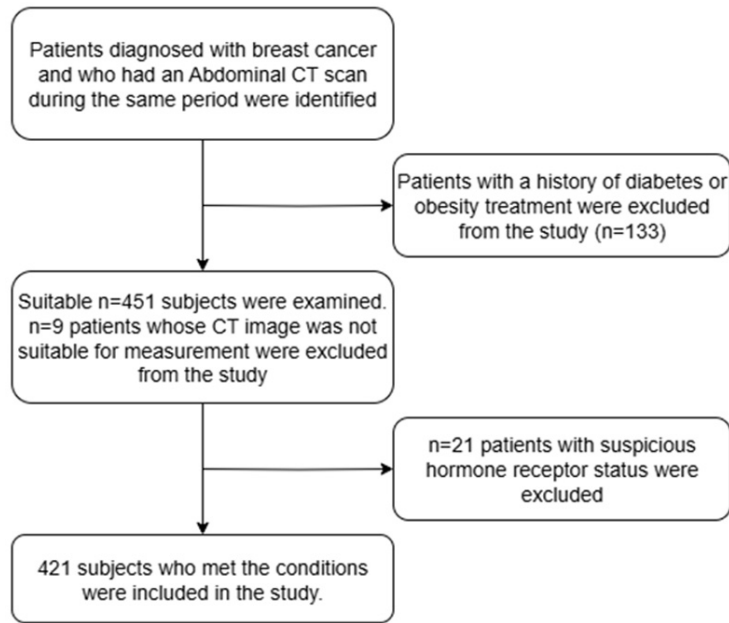


Figure 1. Flowchart of participant inclusion in the study.

women [6]. Furthermore, increased abdominal fat, assessed by waist circumference, hip circumference, and waist-to-hip ratio (WHR), has been shown to increase the risk of the triple-negative breast cancer subtype in premenopausal women [9].

Obesity, and more specifically, visceral fat accumulation, is a significant risk factor for the development of malignancy [10]. Furthermore, some studies have reported an association with increased recurrence after cancer treatment [11] and higher mortality [12]. Some studies find no significant association between the amount of visceral fat and the development of colon and pancreatic cancer [1]. Recently, visceral fat has been identified as a key indicator in determining the effectiveness of antiangiogenic agents in patients with colon and kidney cancer. Therefore, visceral fat is considered important in predicting treatment response. Various studies have been conducted on the methodology for measuring abdominal fat using computed tomography [2, 13]. Calculations based on a single slice are sufficient [14]. Some studies have used the umbilicus as a reference point [15, 16], while others have used a bone or intervertebral disc level as a reference point [17, 18]. Recent studies have also suggested the use of computed tomography (CT)-assessed adiposity and skeletal muscle density as measures of body composition [19]. Seg-

mentation performed with semi-automatic programming can accurately measure subcutaneous fat tissue (SFT), visceral fat tissue (VFT), intramuscular adipose tissue (IMAT), and muscle tissue to fat tissue ratios in a single CT section in the abdominal region [20]. While there is one study examining the relationship between body composition assessed by CT in breast cancer patients and triple-negative breast cancer subtypes [21], there are insufficient studies using visceral fat to subcutaneous fat ratios and muscle to fat ratios of specific muscles to examine the relationship between these values and triple-negative breast cancer, as well as other breast cancer subtypes.

In our study, we aimed to evaluate and compare the results in both premenopausal and postmenopausal women using this information.

Materials and methods

Patient population

Women diagnosed with breast cancer between January 2015 and December 2024 were identified retrospectively through a search of the hospital electronic records system. Participants aged 25 to 92 years with a histopathological diagnosis of breast cancer were included. Among these patients, those who had an abdominal CT scan within a 6-month period, including 3 months before and 3 months after their breast cancer diagnosis, were included in the study. In 86% of the patients included in the study, an abdominal CT scan was performed after a breast cancer diagnosis. In patients with multiple CT scans, the initial scan was used to minimize the impact of the disease on BMI. Patients with a history of diabetes, diabetes treatment, or any obesity-related interventions or medical treatments were excluded. Furthermore, patients without an evaluable CT scan at the umbilicus were excluded. Forty-one participants with conflicting or incomplete information regarding hormone receptor status were excluded from the study. A total of 421 breast cancer patients who met these criteria were enrolled (**Figure 1**). The protocol was



Figure 2. Measurements of the paraspinal muscles density. (A) Density measurement of the psoas muscles, (B) erector spinae and multifidus muscles by drawing them manually. Segmentation and measurement were performed automatically with 3D slicer software based on density.

approved by the HNEAH Institutional Ethics Committee (No: HNEAH-KAEK-2021-184).

Body composition measurements

CT images, jointly evaluated by two radiologists with over 40 years of combined experience, were analyzed using 3D Slicer. 3D Slicer 5.6.1 is open-source software for medical image processing and visualization used in medical image analysis and research (<http://www.slicer.org/> accessed on December 12, 2024). On the umbilicus-level CT image, the amounts of subcutaneous fat, visceral fat, and total abdominal fat were recorded separately using the area measurement method. Total fat was first measured using the manual demarcation method, followed by visceral fat, and subcutaneous fat was calculated by subtracting it from

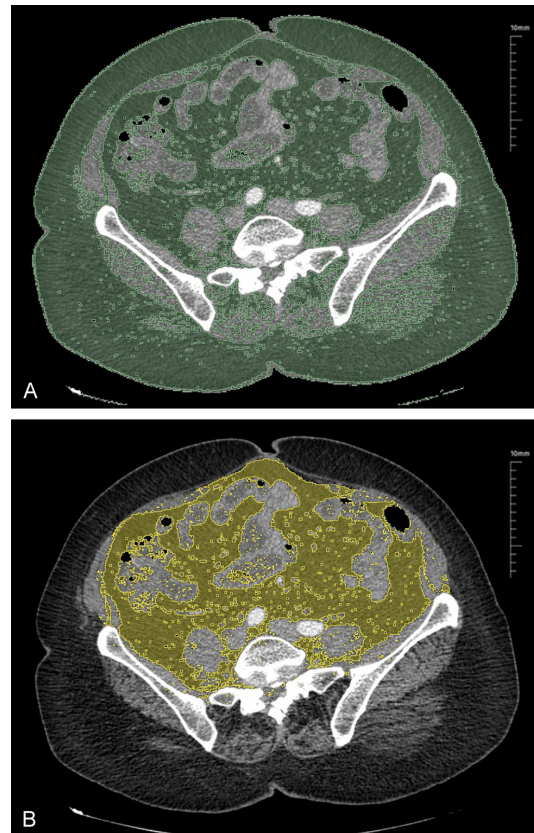


Figure 3. Measurements of abdominal fat from a CT image. (A) Measurement of total abdominal fat tissue amount and (B) visceral fat tissue amount by segmentation. Segmentation and measurement were performed automatically with 3D slicer software based on density.

the total fat. For the paraspinal muscles, the average density of the psoas muscles was measured separately, and the erector spinae and multifidus muscles were measured separately as a group, measured in Hounsfield units (HU). The average of the results was calculated and used as the total muscle density. Visceral and subcutaneous adipose tissue measurements were recorded in mm². Adipose tissue was identified and measured by segmenting the measured area, with a lower limit of -190 HU and an upper limit of -30 HU as thresholds (**Figures 2 and 3**).

Statistical analysis

First, we examined the relationship between patient, tumor, and body composition characteristics and triple-negative breast cancer subtype using chi-square analysis. Patients were divided into two groups: high visceral fat and

Table 1. Distribution of breast cancer patient characteristics by subtype

	TNBC N = 116 (%)	Non-TNBC N = 305 (%)	Total
Age	60.8 ± 7.8	56.6 ± 6.4	57.8 ± 7.2
BMI	27.8 ± 3.9	26.2 ± 5.1	26.7 ± 4.8
Subcutaneous fat tissue (mm ²)	26920 ± 10681	34294 ± 14524	32263 ± 13957
Visceral fat tissue (mm ²)	18240 ± 6957	15276 ± 5494	16093 ± 6071
Total fat tissue (mm ²)	45160 ± 14939	47513 ± 18266	48356 ± 17507
Psoas density (HU)	39.5 ± 10.1	47.7 ± 10.5	45.5 ± 10.9
ES/MF density (HU)	32.8 ± 9.5	39.6 ± 10.2	38.6 ± 10.6
Total muscle density (HU)	39.2 ± 9.8	44.3 ± 10.3	42.1 ± 10.8

TNBC, Triple-negative breast cancer; BMI, Body mass index; HU, Hounsfield Unit; ES, Erector spinae; MF, Multifidus.

low visceral fat, determined by the average ratio of visceral fat to subcutaneous fat. Similarly, two groups were created for total muscle density [21, 22]. To examine the associations between abdominal fat and muscle adiposity values and triple-negative breast cancer subtype, we first performed univariate logistic regression analysis to calculate odds ratios (ORs) and 95% confidence intervals (CIs). All statistical analyses were performed using IBM SPSS software, Version 26.0 (IBM Corp, Armonk, NY, USA).

Results

Our study participants included 421 breast cancer patients with available hormone receptor status data; 116 (27.6%) of these participants were diagnosed with triple-negative breast cancer. The overall mean age of the participants was 57.8 ± 8.2 years. The prevalence of obesity and overweight was 42.2% and 28.4%, respectively, for triple-negative breast cancer, 32.5% and 22.2% for non-triple-negative breast cancer, and 35.2% and 24% for all breast cancer patients overall. Patients with the triple-negative breast cancer subtype had a higher rate of obesity (body mass index > 30 kg/m²) than those with non-triple-negative breast cancer (42.2% vs. 32.5%; $P = 0.018$; **Table 2**). Patients with triple-negative breast cancer had a higher rate of large tumors (greater than 2 cm, 62.1% vs. 43.0%) compared to patients with non-triple-negative breast cancer ($P < 0.05$) (**Table 1**).

In terms of abdominal fat tissue and distribution, the values in terms of the amount of visceral fat tissue and the ratio of visceral fat tissue to subcutaneous fat tissue were signifi-

cantly higher in participants with triple-negative breast cancer subtype compared to participants without triple-negative breast cancer subtype ($P < 0.05$). In triple negative breast cancer patients, the proportion of individuals with low fat and low muscle group was found to be 45.7%, which was significantly high, while in the non-triple negative breast cancer group, the proportion of individuals with low fat and high muscle group was found to be 43.6%, which was significantly high (**Table 2**).

Table 3 shows the results of regression analyses for the associations between specific body composition components and triple-negative breast cancer subtype. Anthropometric factors were dichotomized as low and high based on the median value, and we performed logistic regression to assess the association between anthropometric measurements and triple-negative breast cancer subtype.

A significant association was found between high visceral fat tissue and triple-negative breast cancer (OR = 1.89 [95% CI = 1.23-2.94]), while a particularly strong association was found between the visceral fat tissue to subcutaneous fat tissue ratio and triple-negative breast cancer subtype (OR = 9.09 [95% CI = 5.55-14.28]).

In muscle density measurements, when the psoas, erector spinae, and multifidus muscles were compared with the total muscle density values, the relationship between low muscle density and triple-negative breast cancer subtype was significant (OR = 3.89 [95% CI = 2.45-6.19]) (**Table 3**).

In the regression analysis performed according to body composition, an association was found

Table 2. Patient and tumor characteristics by breast cancer subtype

Variables	TNBC N = 116 (%)	Non-TNBC N = 305 (%)	Total BC N = 421 (%)	p-value
BMI				
Underweight < 18.5	0	6 (2)	6 (1.4)	0.018*
Normalweight 18.5-24.9	34 (29.3)	132 (43.3)	166 (39.4)	
Overweight 25-29.9	49 (42.2)	99 (32.5)	148 (35.2)	
Obese > 30	33 (28.4)	68 (22.2)	101 (24)	
Tumor Size				
< 2 cm	44 (37.9)	174 (57)	218 (51.8)	0.01*
> 2 cm	72 (62.1)	131 (43)	203 (48.2)	
Subcutaneous Fat Tissue				
Low	69 (59.5)	149 (48.9)	218 (51.8)	0.063
High	47 (40.5)	156 (51.1)	203 (48.2)	
Visceral Fat Tissue				
Low	52 (44.8)	185 (60.7)	237 (56.3)	0.01*
High	64 (55.2)	120 (39.3)	184 (43.7)	
Total Fat Tissue				
Low	72 (62.1)	169 (55.4)	241 (57.2)	0.217
High	44 (37.9)	136 (44.6)	180 (42.8)	
Visceral/Subcutaneous Fat Ratio				
Low	34 (29.3)	240 (78.7)	274 (65.1)	0.01*
High	82 (70.7)	65 (21.3)	147 (34.9)	
Total Muscle Density				
Low	84 (72.4)	123 (40.3)	207 (49.2)	0.01*
High	32 (27.6)	182 (59.7)	214 (50.8)	
ES/MF Density				
Low	82 (70.7)	120 (39.3)	206 (48.9)	0.01*
High	34 (29.3)	185 (60.7)	215 (51.1)	
Psoas Density				
Low	84 (72.4)	109 (35.7)	193 (45.8)	0.01*
High	32 (27.6)	196 (64.3)	228 (54.2)	
Body Composition				
Normal (Low fat, High muscle)	19 (16.4)	133 (43.6)	152 (36.1)	0.01*
High fat, High muscle	13 (11.2)	49 (16.1)	62 (14.7)	
Low fat, Low muscle	53 (45.7)	36 (11.8)	89 (21.1)	
High fat, Low muscle	31 (26.7)	87 (28.5)	118 (28)	

TNBC, Triple-negative breast cancer; BMI, Body mass index; ES, Erector spinae; MF, Multifidus. *p < 0.05.

between low fat, low muscle group individuals and triple negative breast cancer group (OR = 10 [95% CI = 5.55-20]) (**Table 4**).

Discussion

In this study, we evaluated the relationship between the amount and distribution of abdominal fat measured by CT, the density of the paraspinal muscles, and the triple-negative breast cancer subtype. Obesity is now recognized as a

significant risk factor for many types of cancer [11]. Abdominal fat tissue, especially visceral fat tissue, contains metabolically active adipocytes [1]. Adipose tissue is known as the body's largest endocrine organ because it secretes numerous cytokines and hormones. An increase in adipose tissue leads to increased synthesis of leptin, also known as the hunger hormone. Chronic inflammation in increased adipose tissue results in increased levels of IL-6 and TNF. Levels of these cytokines, along with

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Table 3. Odds ratio (95% CI) of the association between body composition components and TNBC subtype

Variables (range)	TNBC N = 116 (%)	Non-TNBC N = 305 (%)	Multivariate Odds ratio (95% CI)	p-value
Subcutaneous Fat Tissue				
Low (12633-32263)	69 (59.5)	149 (48.9)	1.54 (0.99-2.37)	0.063
High (32264-87179)	47 (40.5)	156 (51.1)	ref	
Visceral Fat Tissue				
Low (3376-16093)	52 (44.8)	185 (60.7)	ref	0.01*
High (16094-36378)	64 (55.2)	120 (39.3)	1.89 (1.23-2.94)	
Total Fat Tissue				
Low (20957-48356)	72 (62.1)	169 (55.4)	1.32 (0.85-2.04)	0.217
High (48357-106171)	44 (37.9)	136 (44.6)	ref	
Visceral/Subcutaneous Fat Ratio				
Low (0.17-0.55)	34 (29.3)	240 (78.7)	ref	0.01*
High (0.56-1.95)	82 (70.7)	65 (21.3)	9.09 (5.55-14.28)	
Total Muscle Density				
Low (16-42)	84 (72.4)	123 (40.3)	3.89 (2.45-6.19)	0.01*
High (43-71)	32 (27.6)	182 (59.7)	ref	
ES/MF Density				
Low (15-38)	82 (70.7)	120 (39.3)	3.86 (2.41-6.21)	0.01*
High (39-68)	34 (29.3)	185 (60.7)	ref	
Psoas Density				
Low (17-45)	84 (72.4)	109 (35.7)	4.72 (2.95-7.55)	0.01*
High (46-75)	32 (27.6)	196 (64.3)	ref	

TNBC, Triple-negative breast cancer; ES, Erector spinae; MF, Multifidus; ref, reference. *p < 0.05.

Table 4. Association between breast cancer subtype and body composition phenotype

Variables	TNBC N = 116 (%)	Non-TNBC N = 305 (%)	Multivariate Odds ratio (95% CI)	p-value
Body Composition				
Normal (Low fat, High muscle)	19 (16.4)	133 (43.6)	ref	
High fat, High muscle	13 (11.2)	49 (16.1)	0.54 (0.25-1.17)	0.12
Low fat, Low muscle	53 (45.7)	36 (11.8)	10 (5.55-20)	0.01*
High fat, Low muscle	31 (26.7)	87 (28.5)	2.5 (1.33-4.76)	0.21

TNBC, Triple-negative breast cancer; ref, reference. *p < 0.05.

leptin, have been reported to increase in many types of cancer. Therefore, obesity is thought to be a factor in cancer development, progression, and metastasis [23]. The relationship between inflammation and cancer was first described over a century ago by Virchow, who observed an increase in leukocytes in neoplastic tissue [24]. The amount of visceral fat and the ratio of visceral fat to subcutaneous fat were found to be associated with an increased likelihood of triple-negative breast cancer. Interestingly, and unlike other studies, the likelihood of the triple-negative breast cancer sub-

type was found to be higher in those with low fat and low muscle mass compared to those with normal body composition (low fat/high muscle mass).

Previous studies using obesity as determined by body mass index (BMI) have yielded conflicting results. These studies generally emphasize the association between obesity and breast cancer in the postmenopausal period [12, 25]. A large-scale study by Vatten et al. reported that obesity in the premenopausal period is protective [26]. Carmichael et al. reported that

obesity was not significantly associated with mortality or survival in breast cancer patients [27]. Similarly, Katoh et al. reported that obesity had no effect on recurrence or survival in 301 postmenopausal breast cancer cases [28]. However, some studies have reported that breast cancer patients, especially those with a BMI over 40, have a three-fold increased risk of death compared to non-obese patients [29, 30]. The poor prognosis is thought to be due to increased estrogenic stimulation in obese patients with estrogen receptor positivity. However, when obesity is assessed using BMI, the amount of visceral fat, which is thought to be associated with chronic inflammation, cannot be assessed [31].

Optimal measurement of fat tissue requires both the amount and distribution of fat tissue. Various anthropometric measurements (hip circumference, waist circumference, or abdominal sagittal diameter) are not reliable for assessing visceral fat [31]. They cannot distinguish between visceral fat and subcutaneous fat. Only radiological imaging methods can truly measure visceral and subcutaneous fat separately. Sonography, an easily accessible and rapid method for measuring visceral fat in daily clinical practice, can be used [31]. However, because sonography yields operator-dependent results, obtaining repeatable measurements is difficult. Therefore, the reliability of sonographic measurements is low [14]. Establishing a standard for measurement is particularly challenging in obese patients. Computed tomography is the most commonly used imaging method for measuring abdominal fat because it is easily accessible, rapid, and reliable. However, CT scans are risky due to ionizing radiation. MRI, which carries no radiation risks, can also be used [32]. However, MRI has several disadvantages compared to CT scanning. It is more expensive and less accessible than CT. Furthermore, specific sequences are required to ensure homogeneity of the fat segmentation area, and optimal assessment may not be achieved with routine sequences. Therefore, retrospective assessment of visceral fat on MRI is not appropriate.

Numerous studies have been conducted on measuring abdominal fat with CT, optimizing the method used, and demonstrating the relationship between visceral fat and metabolic syndrome or visceral fat and cardiovascular

disease risk [13-16]. In these studies, the cross-sectional level at which fat is measured has been debated, with the umbilicus level being the most frequently used level. Previous studies have used various upper and lower HU values to define adipose tissue on CT scans. The upper limits ranged from -10 to -50 HU, while the lower limits ranged from -150 to -250 HU [15]. The values used in our study (-30 and -200 HU) are within the accepted ranges for defining adipose tissue.

In our study, subcutaneous adipose tissue, visceral adipose tissue, and total abdominal adipose tissue were quantified separately, because visceral adipose tissue is known to be metabolically more active than subcutaneous adipose tissue due to its high lipolytic activity and release of large amounts of free fatty acids [33]. However, most studies examining the relationship between body size and triple-negative breast cancer subtypes have used measurements of body mass index and waist circumference, which do not distinguish between adipose tissue and skeletal muscle components. CT is a highly accurate method for measuring fat distribution and skeletal muscle mass because of its ability to provide segmentable cross-sectional images [34]. This study found a significant association between high visceral fat and the ratio of visceral to subcutaneous fat with the triple-negative breast cancer subtype. A similar previous study on the relationship between adiposity assessed by CT and triple-negative breast cancer reported that high and low subcutaneous fat and visceral fat were associated with the triple-negative breast cancer subtype [21]. Several studies have reported that increased visceral fat assessed by CT is associated with a higher probability of developing ER-negative, PR-negative, and HER2-negative breast cancers compared to ER, PR, and HER2-positive breast cancers. A case-control study found an increased risk of developing triple-negative breast cancer in women with a higher waist-to-hip ratio [35]. A case-analysis study reported that women with triple-negative breast cancer were more likely to be obese than those with other breast cancer subtypes [36].

The mechanisms directly linking subcutaneous and visceral fat to triple-negative breast cancer subtypes are unclear. However, some studies have attempted to explain possible

links between obesity and triple-negative breast cancer subtypes. First, as mentioned above, obesity-mediated inflammatory cytokines, such as leptin, have been suggested to be involved in activation pathways that stimulate invasion and metastasis [37]. Circulating levels of insulin and leptin are elevated in obesity [38]. Insulin stimulates leptin overexpression, which creates an autocrine loop to stimulate breast cancer cell growth [37]. Furthermore, activation of insulin's mammalian target of rapamycin (mTOR) has been implicated as a predictor of poor prognosis in women with triple-negative breast cancer [39]. Moreover, mTOR promotes the switch from mitochondrial to aerobic respiration, the Warburg effect [40]. The Warburg effect increases glucose uptake, which, through mitochondrial dysfunction, provides anabolic precursors for the rapid growth of triple-negative breast cancers [38].

In our study, a significant association was found between the amount of visceral fat, the ratio of visceral fat to subcutaneous fat, and the triple-negative breast cancer subtype. Two large case-control studies [6, 41] reported that increased waist-to-hip ratio was associated with an increased risk of triple-negative breast cancer in premenopausal women. Another study found no association between obesity and the triple-negative breast cancer subtype in postmenopausal women [21]. Postmenopausal women generally exhibit less aggressive phenotypes and estrogen-dependent lesions, likely a consequence of steroid hormone production from fat cells [42]. Premenopausal women, on the other hand, generally exhibit more aggressive phenotypes (large size, high tumor grade, and high proliferation rate) and hormone-independent lesions [42]. Because our study primarily focused on investigating the relationship between triple-negative breast cancer subtypes and obesity, the evaluation was conducted without distinguishing between premenopausal and postmenopausal women. This assessment can be considered one of the most significant limitations of our study.

In our study, which is different and interesting from other studies, there was a significant relationship between those with low fat, high muscle body composition and non-triple negative breast cancer, while there was a significant relationship between those with low fat, low

muscle body composition and the triple negative breast cancer subtype. Despite the lack of studies investigating the relationship between skeletal muscle areas and triple-negative breast cancer subtype, previous studies [43, 44] have examined the relationship between skeletal muscle areas and survival. Most studies have reported an association between low muscle mass and an increased risk of death. Another study indicated that skeletal muscle fat may be an important factor in the prognosis of triple-negative breast cancer [21]. Muscle catabolic processes that cause sarcopenia are associated with multiple systemic etiological processes, including altered energy balance, mitochondrial dysfunction, oxidative stress, and immune system alterations [45]. These changes contribute to chronic low-grade inflammation, which can particularly affect skeletal muscle. Markers of chronic low-grade inflammation that are also increased during sarcopenia and normal aging include CRP, IL-1 β , IL-6, and TNF [46, 47]. The increased inflammatory response and changes in metabolism during cancer and cancer treatment lead to loss of muscle mass [48, 49]. The relationship between aging, cancer, cancer treatment, and sarcopenia can be explained in this way. However, it is also argued that increased inflammation in sarcopenia may lead to cancer development [45]. The significant association between the low muscle, low fat phenotype and TNBC in our study is striking. It is clear that additional studies are needed to determine whether muscle loss is a cause or a consequence.

Limitations of this study include the fact that CT scanning involves ionizing radiation, and since it is clear that it would not be possible to perform a CT examination solely for the purpose of obesity assessment in a patient who does not already have a CT scan, it is not possible to present generalizable results for breast cancer patients. For similar reasons, because not all breast cancer patients have an abdominal CT scan, our study represents a limited and small group within the overall breast cancer patient population. Although primarily for staging purposes, our study conducted a retrospective analysis using available CT scans. Therefore, the time intervals between CT scans performed at the time of diagnosis are not standardized. These timing differences can be considered a significant limitation. Only patients

with available abdominal CT scans were included in our study. The availability of an abdominal CT scan may have represented a subgroup with more advanced disease or other comorbidities. The potential impact of this selection bias is a significant limitation of the study. One of the most significant limitations of our study is the failure to separate patients based on menopausal status. Previous studies have emphasized the association between obesity, generally determined by body mass index (BMI), and postmenopausal breast cancer [12, 25]. However, these studies generally focused on hormone receptor-positive breast cancers. Although the relationship between TNBC and obesity was investigated in our study, not evaluating menopausal status is an important limitation. Considering menopausal status in future studies will provide valuable information.

In conclusion, we showed that obesity, specifically the amount of visceral fat and the ratio of visceral fat to subcutaneous fat measured from a CT image passing through the umbilicus, was associated with TNBC subtype in breast cancer patients. Additionally, a significant association was found between those with a low fat, high muscle body composition and non-triple negative breast cancer, while a significant association was found between those with a low fat, low muscle body composition and the triple negative breast cancer subtype. These findings highlight the need for prospective studies assessing body composition and TNBC risk, using larger sample sizes and non-breast cancer controls. Because obesity and muscle mass are modifiable risk factors in cancer patients, a better understanding of the relationships between obesity, abdominal fat distribution, and muscle mass and breast cancer can help develop new preventive strategies. This can lead to the development of new preventive and prognostic management strategies for TNBC.

Disclosure of conflict of interest

None.

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References

- [1] Schlienger JL, Luca F, Vinzio S and Pradignac A. Obesity and cancer. *Rev Med Interne* 2009; 30: 776-782.
- [2] Guiu B, Petit JM, Bonnetain F, Ladoire S, Guiu S, Cercueil JP, Krausé D, Hillon P, Borg C, Chauffert B and Ghiringhelli F. Visceral fat area is an independent predictive biomarker of outcome after first-line bevacizumab-based treatment in metastatic colorectal cancer. *Gut* 2010; 59: 341-347.
- [3] Xia X, Chen W, Li J, Chen X, Rui R, Liu C, Sun Y, Liu L, Gong J and Yuan P. Body mass index and risk of breast cancer: a nonlinear dose-response meta-analysis of prospective studies. *Sci Rep* 2014; 4: 74-80.
- [4] Munsell MF, Sprague BL, Berry DA, Chisholm G and Trentham Dietz A. Body mass index and breast cancer risk according to postmenopausal estrogen-progestin use and hormone receptor status. *Epidemiol Rev* 2014; 36: 114-136.
- [5] Sharma P, López-Tarruella S, García-Saenz JA, Khan QJ, Gómez HL, Prat A, Moreno F, Jerez-Gilarranz Y, Barnadas A, Picornell AC, Monte-Millán MD, González-Rivera M, Massarrah T, Pelaez-Lorenzo B, Palomero MI, González Del Val R, Cortés J, Fuentes-Rivera H, Morales DB, Márquez-Rodas I, Perou CM, Lehn C, Wang YY, Klemp JR, Mammen JV, Wagner JL, Amin AL, O'Dea AP, Heldstab J, Jensen RA, Kimler BF, Godwin AK and Martín M. Pathological response and survival in triple-negative breast cancer following neoadjuvant carboplatin plus docetaxel. *Clin Cancer Res* 2018; 24: 5820-5829.
- [6] Pierobon M and Frankenfeld CL. Obesity as a risk factor for triple-negative breast cancers: a systematic review and meta-analysis. *Breast Cancer Res Treat* 2013; 137: 307-314.
- [7] Ahn J, Schatzkin A, Lacey JV Jr, Albanes D, Ballard-Barbash R, Adams KF, Kipnis V, Mouw T, Hollenbeck AR and Leitzmann MF. Adiposity, adult weight change, and postmenopausal breast cancer risk. *Arch Intern Med* 2007; 167: 2091-2102.
- [8] Suzuki R, Rylander-Rudqvist T, Ye W, Saji S and Wolk A. Body weight and postmenopausal breast cancer risk defined by estrogen and progesterone receptor status among swedish women: a prospective cohort study. *Int J Cancer* 2006; 119: 1683-1689.
- [9] Bandera EV, Chandran U, Hong CC, Troester MA, Bethea TN, Adams-Campbell LL, Haiman CA, Park SY, Olshan AF, Ambrosone CB, Palmer JR and Rosenberg L. Obesity, body fat distribution, and risk of breast cancer subtypes in african american women participating in the

- AMBER consortium. *Breast Cancer Res Treat* 2015; 150: 655-666.
- [10] Bergstrom A, Hsieh CC, Lindblad P, Lu CM, Cook NR and Wolk A. Obesity and renal cell cancer - a quantitative review. *Br J Cancer* 2001; 85: 984-990.
- [11] Ohki T, Tateishi R, Shiina S, Goto E, Sato T, Nakagawa H, Masuzaki R, Goto T, Hamamura K, Kanai F, Yoshida H, Kawabe T and Omata M. Visceral fat accumulation is an independent risk factor for hepatocellular carcinoma recurrence after curative treatment in patients with suspected NASH. *Gut* 2009; 58: 839-844.
- [12] Renehan AG, Tyson M, Egger M, Heller RF and Zwahlen M. Body mass index and incidence of cancer: a systematic review and meta-analysis of prospective observational studies. *Lancet* 2008; 371: 569-578.
- [13] Borkan GA, Gerzof SG, Robbins AH, Hults DE, Silbert CK and Silbert JE. Assessment of abdominal fat content by computed tomography. *Am J Clin Nutr* 1982; 36: 172-177.
- [14] Shen W, Punyanitya M, Wang Z, Gallagher D, St-Onge MP, Albu J, Heymsfield SB and Heshka S. Visceral adipose tissue: relations between single-slice areas and total volume. *Am J Clin Nutr* 2004; 80: 271-278.
- [15] Kobayashi J, Tadokoro N, Watanabe M and Shinomiya M. A novel method of measuring intra-abdominal fat volume using helical computed tomography. *Int J Obes Relat Metab Disord* 2002; 26: 398-402.
- [16] Taira K, Hikita M, Kobayashi J, Bujo H, Takahashi K, Murano S, Morisaki N and Saito Y. Delayed post-prandial lipid metabolism in subjects with intra-abdominal visceral fat accumulation. *Eur J Clin Invest* 1999; 29: 301-308.
- [17] Kuk JL, Church TS, Blair SN and Ross R. Does measurement site for visceral and abdominal subcutaneous adipose tissue alter associations with the metabolic syndrome? *Diabetes Care* 2006; 29: 679-684.
- [18] Lee S, Janssen I and Ross R. Interindividual variation in abdominal subcutaneous and visceral adipose tissue: influence of measurement site. *J Appl Physiol* (1985) 2004; 97: 948-954.
- [19] Faron A, Sprinkart AM, Kuetting DLR, Feisst A, Isaak A, Endler C, Chang J, Nowak S, Block W, Thomas D, Attenberger U and Luetkens JA. Body composition analysis using CT and MRI: intra-individual intermodal comparison of muscle mass and myosteatosis. *Sci Rep* 2020; 10: 11765.
- [20] Mühlberg A, Museyko O, Laredo JD and Engelke K. A reproducible semi-automatic method to quantify the muscle-lipid distribution in clinical 3D CT images of the thigh. *PLoS One* 2017; 12: e0175174.
- [21] Aduse-Poku L, Bian J, Gopireddy DR, Hernandez M, Lall C, Falzarano SM, Masood S, Jo A and Cheng TD. Associations of computed tomography image-assessed adiposity and skeletal muscles with triple-negative breast cancer. *Cancers (Basel)* 2022; 14: 1846.
- [22] Caan BJ, Meyerhardt JA, Kroenke CH, Alexeeff S, Xiao J, Weltzien E, Feliciano EC, Castillo AL, Quesenberry CP, Kwan ML and Prado CM. Explaining the obesity paradox: the association between body composition and colorectal cancer survival (C-SCANS Study). *Cancer Epidemiol Biomarkers Prev* 2017; 26: 1008-1015.
- [23] Raucci R, Rusolo F, Sharma A, Colonna G, Castello G and Costantini S. Functional and structural features of adipokine family. *Cytokine* 2013; 61: 1-14.
- [24] Rogers CJ, Prabhu KS and Vijay-Kumar M. The microbiome and obesity-an established risk for certain types of cancer. *Cancer J* 2014; 20: 176-180.
- [25] Li CI, Stanford JL and Daling JR. Anthropometric variables in relation to risk of breast cancer in middle-aged women. *Int J Epidemiol* 2000; 29: 208-213.
- [26] Vatten LJ and Kvinnsland S. Prospective study of height, body mass index and risk of breast cancer. *Acta Oncol* 1992; 31: 195-200.
- [27] Carmichael AR, Bendall S, Lockerbie L, Prescott RJ and Bates T. Does obesity compromise survival in women with breast cancer? *Breast* 2004; 13: 93-96.
- [28] Katoh A, Watzlaf VJ and D'Amico F. An examination of obesity and breast cancer survival in post-menopausal women. *Br J Cancer* 1994; 70: 928-933.
- [29] Petrelli JM, Calle EE, Rodriguez C and Thun MJ. Body mass index, height, and postmenopausal breast cancer mortality in a prospective cohort of US women. *Cancer Causes Control* 2002; 13: 325-332.
- [30] Ménard S, Casalini P, Agresti R, Pilotti S and Balsari A. Proliferation of breast carcinoma during menstrual phases. *Lancet* 1998; 352: 148-149.
- [31] Hirooka M, Kumagi T, Kurose K, Nakanishi S, Michitaka K, Matsuura B, Horiike N and Onji M. A technique for the measurement of visceral fat by ultrasonography: comparison of measurements by ultrasonography and computed tomography. *Intern Med* 2005; 44: 794-799.
- [32] Carlier RY, De Truchis P, Ronze S, Mompoin D, Vallee C and Melchior JC. MRI of intra-abdominal fat and HIV-associated lipodystrophy: a case review. *J Radiol* 2007; 88: 947-956.
- [33] Heymsfield SB and Shen W. Obesity: BAI as a new measure of adiposity-throw away your scale? *Nat Rev Endocrinol* 2011; 7: 321-322.

- [34] Shen W, Punyanitya M, Wang Z, Gallagher D, St-Onge MP, Albu J, Heymsfield SB and Heshka S. Total body skeletal muscle and adipose tissue volumes: estimation from a single abdominal cross-sectional image. *J Appl Physiol* (1985) 2004; 97: 2333-2338.
- [35] Millikan RC, Newman B, Tse CK, Moorman PG, Conway K, Dressler LG, Smith LV, Labbok MH, Geradts J, Bensen JT, Jackson S, Nyante S, Livasy C, Carey L, Earp HS and Perou CM. Epidemiology of basal-like breast cancer. *Breast Cancer Res Treat* 2008; 109: 123-139.
- [36] Trivers KF, Lund MJ, Porter PL, Liff JM, Flagg EW, Coates RJ and Eley JW. The epidemiology of triple-negative breast cancer, including race. *Cancer Causes Control* 2009; 20: 1071-1082.
- [37] Rose DP and Vona-Davis L. The cellular and molecular mechanisms by which insulin influences breast cancer risk and progression. *Endocr Relat Cancer* 2012; 19: 225-241.
- [38] Dietze EC, Chavez TA and Seewaldt VL. Obesity and triple-negative breast cancer: disparities, controversies, and biology. *Am J Pathol* 2018; 188: 280-290.
- [39] Massihnia D, Galvano A, Fanale D, Perez A, Castiglia M, Incorvaia L, Listì A, Rizzo S, Cicero G, Bazan V, Castorina S and Russo A. Triple negative breast cancer: shedding light onto the role of Pi3k/Akt/Mtor pathway. *Oncotarget* 2016; 7: 60712-60722.
- [40] Robey RB and Hay N. Is akt the “warburg kinase”?-akt-energy metabolism interactions and oncogenesis. *Semin Cancer Biol* 2009; 19: 25-31.
- [41] Phipps AI, Malone KE, Porter PL, Daling JR and Li CI. Body size and risk of luminal, HER2-overexpressing, and triple-negative breast cancer in postmenopausal women. *Cancer Epidemiol Biomarkers Prev* 2008; 17: 2078-2086.
- [42] Rose DP and Vona-Davis L. Interaction between menopausal status and obesity in affecting breast cancer risk. *Maturitas* 2010; 66: 33-38.
- [43] Del Fabbro E, Parsons H, Warneke CL, Pulivarthi K, Litton JK, Dev R, Palla SL, Brewster A and Bruera E. The relationship between body composition and response to neoadjuvant chemotherapy in women with operable breast cancer. *Oncologist* 2012; 17: 1240-1245.
- [44] Villaseñor A, Ballard-Barbash R, Baumgartner K, Baumgartner R, Bernstein L, McTiernan A and Neuhouser ML. Prevalence and prognostic effect of sarcopenia in breast cancer survivors: the heal study. *J Cancer Surviv* 2012; 6: 398-406.
- [45] Ligibel JA, Schmitz KH and Berger NA. Sarcopenia in aging, obesity, and cancer. *Transl Cancer Res* 2020; 9: 5760-5771.
- [46] Beyer I, Mets T and Bautmans I. Chronic low-grade inflammation and age-related sarcopenia. *Curr Opin Clin Nutr Metab Care* 2012; 15: 12-22.
- [47] Franceschi C, Capri M, Monti D, Giunta S, Olivieri F, Sevini F, Panourgia MP, Invidia L, Celani L, Scurti M, Cevenini E, Castellani GC and Salvioli S. Inflammaging and anti-inflammaging: a systemic perspective on aging and longevity emerged from studies in humans. *Mech Ageing Dev* 2007; 128: 92-105.
- [48] von Haehling S, Morley JE and Anker SD. An overview of sarcopenia: facts and numbers on prevalence and clinical impact. *J Cachexia Sarcopenia Muscle* 2010; 1: 129-133.
- [49] Yanai H. Nutrition for sarcopenia. *J Clin Med Res* 2015; 7: 926-931.