Title: Upper torso pain and musculoskeletal structure and function in women with and without large breasts: A cross sectional study

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Abstract

Background: Women with large breasts frequently experience upper torso pain secondary to their breast size. Evidence is lacking on the underlying causes of this pain. This study investigated whether upper torso pain and musculoskeletal structure and function differed between women with large breasts and women with small breasts.

Methods: A linear regression, adjusting for body mass, compared the upper torso pain, thoracic flexion torque due to breast mass, thoracic kyphosis, shoulder active range-of-motion, and scapular retraction muscle strength of 27 women with large breasts (bilateral breast volume > 1200 ml, age 45.9 y SD 9.9 y, BMI 29.0 kg/m^2 SD 3.8 kg/m^2) and 26 women with small breasts (bilateral breast volume < 800 ml, age 43.8 y SD10.9 y, BMI 23.3 kg/m^2 SD 2.9 kg/m^2).

Findings: Women with large breasts reported had a higher upper torso pain score (46.6, 95%CI 33.3-58.0 versus 24.1, 95%CI 12.5-37.8), accompanied by a larger flexion torque (5.9 Nm, 95%CI 4.5-5.8 Nm versus 0.9 Nm, 95%CI 0.8-2.4 Nm), greater thoracic kyphosis (34°, 95%CI 31-38° versus 27°, 95% CI 24-31°), decreased shoulder elevation range-of-motion (160°, 95%CI 158-163° versus 169°, 95%CI 166-172°), and decreased scapular retraction endurance-strength (511.4 s, 95%CI 362.2-691.3 s versus 875.8 s, 95%CI 691.5-1028.4 s) compared to the women with small breasts.

Interpretation: Differences in the upper torso posture, range-of-motion, and muscle strength of women with large breasts provides insight into underlying causes of their musculoskeletal pain. This information can be used to develop evidence-based assessment and treatment strategies to relieve and prevent symptom progression.

Key words:

Musculoskeletal pain, women's health, thoracic kyphosis, breast, muscle strength, range-of-motion

1. INTRODUCTION

Large breasts can contribute to serious negative health consequences for women, including neck and back pain, headaches, painful bra-strap grooves in their shoulders, and disabling neural symptoms in their upper limbs[1-5]. These factors can also limit the ability of women with large breasts to participate in physical activity and, in chronic cases, necessitate breast reduction surgery[2,6-8]. In addition to the well-documented negative consequences associated with reduced physical activity, physical inactivity due to symptoms associated with a large breast size, high BMI or musculoskeletal pain can lead to weight gain, as well as further increases in breast size because increases in BMI have been associated with increases in breast volume[9]**.** Alarmingly, the prevalence of this unique women's health problem is likely to escalate because the average bra size has increased over the past two decades from a small bra cup size (34B) to a large bra cup size (34DD)[10]. Despite the potential negative health consequences associated with large breasts, there is a lack of evidence upon which to base appropriate interventions to treat symptoms. No guidelines exist to develop pre-emptive strategies in order to prevent the progression of symptoms to a situation where breast reduction surgery is required. Most previous research in this field has focused only on women who have reached the stage where they require breast reduction surgery. There is a paucity of research investigating the underlying mechanisms of musculoskeletal pain associated with large breasts and a lack of evidence on the intensity, severity and incidence of musculoskeletal symptoms suffered by women with large breasts, who are not yet seeking breast reduction surgery.

One mechanism underlying the musculoskeletal symptoms associated with large breasts is thought to be increased thoracic kyphosis[1,3,4,8]. This increased forward curvature of the upper torso has been the attributed to a flexion torque on the thoracic spine created by excessive breast mass[3,4]. Although the size of this flexion torque is yet to be reported, vertebral column radiographs of women with large breasts (D+ cup bra size) have revealed significantly greater thoracic kyphosis compared to women with small breasts (A cup bra size)[3]. Thoracic kyphosis has also been found to be significantly reduced post-breast reduction surgery[8,11,12], although other researchers found no relationship between thoracic kyphosis and breast size in post-menopausal women (mean age 69 years)[5]. Unfortunately, the researchers in this study did not screen for osteoporosis, which might have masked the effects of breast size on thoracic kyphosis. Two studies that recruited only young women as participants[13, 14] found no relationship between breast size and thoracic pain, suggesting that increased thoracic kyphosis and thoracic pain are likely to be long-term rather than immediate consequences of having large breasts. It should be noted, however, that the cohort numbers in these two studies was relatively small and that the breasts of the participants were not very large when comparing their bra sizes to objectively calculated breast volumes[9].

Increased thoracic kyphosis has been linked to a forward head and shoulder posture, and altered scapulae alignment, which in combination have been associated with reduced shoulder flexion range-of-motion[15-17]. Poor mobility of the upper thoracic spine has also been identified as a predictor of neck and shoulder pain[18]. Therefore, decreased mobility in the upper thoracic spine and shoulder complex secondary to an increased thoracic kyphosis, might also contribute to musculoskeletal pain suffered by women with large breasts. The effect of large breasts on shoulder range-of-motion, however, is yet to be investigated.

Thoracic extensor muscle length and, in turn strength, can also be affected by increased thoracic kyphosis[13,17]. Reduced thoracic extensor muscle strength is one of the factors thought to contribute to age-related hyper-kyphosis[20], and has been found in older, estrogen-deficient women with hyper-kyphosis[17]. Reduced thoracic extensor muscle strength has also been found in breast reduction mammoplasty candidates who displayed increased thoracic kyphosis[2,7] and was found to increase six months post-breast reduction surgery[7].

Women with large breasts might also adapt to the greater load generated by their breasts and increase their thoracic extensor muscle strength. Although back extensor muscle strength and endurance is very important for maintaining normal postural alignment[20], it is not known whether a decrease in the capability of the thoracic extensor muscles to generate extension torque and control anterior shear force leads to an increase in kyphosis angle[21] or whether the increased compression and shear forces imposed on spinal functional units by an increased thoracic kyphosis angle compromises the thoracic extensor muscles force generation capacity[22] and length-tension relationship[23]**.** We speculated that the combination of an increased flexion torque on the thoracic spine (due to the weight of large breasts) and weaker muscles in the posterior region of the thoracic spine might alter both the posture and the tissue loading in the thoracic region of the vertebral column and, in turn, contribute to musculoskeletal pain experienced by women with large breasts. No previous research, however, has objectively measured and compared thoracic muscle strength and endurance in women with and without large breasts.

A greater understanding of differences in the upper torso musculoskeletal structure and function between women with large breasts and women with small breasts would provide evidence for physical therapists to develop effective health care strategies to treat and prevent symptom progression in female patients with large breasts. Therefore, we aimed to identify differences in the upper torso pain and musculoskeletal structure and function of women with large breasts and women with small breasts. We hypothesized that women with large breasts would report significantly more frequent and severe occurrences of musculoskeletal pain in the upper torso, and would display significantly greater thoracic kyphosis and flexion torque, less shoulder and thoracic spine range-of-motion, and less scapular retraction muscle strength and endurance compared to women with small breasts.

2. METHODS

2.1 Participants and ethical issues

Fifty-three women (mean 44.8 y SD 10.3 y) were recruited as participants through local community advertising. Inclusion criteria were aged 18-60 years, not currently seeking breast reduction surgery, and wearing either a large bra cup size (DD or larger) or a small bra cup size (A or B). The upper age was set at 60 years to allow for the accumulated effect of breast hypertrophy on the upper torso[2], while reducing the likelihood of complications associated with age-related diseases[24]. Exclusion criteria were current pregnancy or breast-feeding; previous breast or spinal surgery; any other musculoskeletal condition that affected shoulder, cervical, or thoracic spine range-of-motion or that prevented participants assuming the positions required for data collection; a current diagnosis of osteoporosis or epilepsy (due to flashing lights associated with the scanning system described below); or current menstrual-related breast pain.

Twenty-seven of the women self-reported a large bra cup size and 26 self-reported a small bra cup size. The breast size of each participant was then objectively classified by calculating their breast volume following procedures described in detail elsewhere[25]. In brief, each breast was scanned (Artec Studio 9, Artec Eva, USA; 16 Hz) while the participants lay prone with their breasts freely suspended between two tables. The volume of the three-dimensional scanned breast structure was calculated using Geomagic Studio® software (Three D Systems, South Carolina, USA)[25]. Women with bilateral breast volumes > 1200 ml were allocated to the participant group with large breasts[4, 26, 27], whereas women with bilateral breast volumes < 800 ml were allocated to the participant group with small breasts[28, 29]. The mean breast volumes of the two participant groups were significantly different (mean volume of the group with large breasts was five times that of the group with small breasts; Table 1).

The two participant groups were matched for age, height, and physical activity level

(Table 1), which was assessed using the International Physical Activity Questionnaire (levels 1-3; 1 = low (inactive), 2 = moderate (active), and 3 = high (active)[30]. It was not possible to match the participant groups for body mass or body mass index. A sample size of 26 achieved a power of 80% ($P < 0.05$, 6° mean difference in kyphosis angle, pooled standard deviation of 8°), based on data reported in previous research that compared the kyphosis angle of women who wore A cup bras and D cup bras[3]. The University Human Research Ethics Committee (HE13/053) approved all recruiting and testing procedures and all participants gave written informed consent. The one researcher (KC) collected all data for this cross-sectional study, which took place in the Biomechanics Research Laboratory at the University of Wollongong.

TABLE 1. Characteristics of the participant group with large breasts and with small breasts. Values expressed as a mean (SD). Asterisks represent significance (***P*<0.001).

Variable	Large breasts (n = 27)	Small breasts (n = 26)	Mean Difference (95% CI)	*P*-value
Age (years)	45.9 (9.9)	43.8 (10.9)	1.97 (-3.8-7.7)	0.494
Height (m)	1.65 (0.05)	1.63 (0.08)	0.15 (-0.21-0.52)	0.412
Body mass (kg)	*78.7 (11.8)	61.9 (9.9)	16.7 (10.7-22.8)	**<0.001**
Body mass index (kg/m^2)	*29.0 (3.8)	23.3 (2.9)	5.74 (3.87-7.61)	**<0.001**
Physical activity level (1-3)	2.6 (0.75)	2.8 (0.44)	0.21 (-0.55-0.13)	0.212
Bilateral breast volume (ml)	*2373 (863)	453 (150)	1921 (1576-2266)	**<0.001**

2.2 Upper torso musculoskeletal pain

A total upper torso pain score was determined from the severity and frequency of the participant's reported musculoskeletal pain in seven regions of the upper torso (neck, shoulders, arms, upper back, lower back, breasts, and head), which were graded on a colourcoded body chart. Severity was graded using a visual analogue scale (VAS; 0 = no pain; 10 = worst possible pain) and frequency was scaled from 1-3 (1 = rarely, ≤ 1 time per month; 2 = occasionally, ≤ 3 times per month; 3 = frequently, ≥ 1-3 times per week) [31]. The the total upper torso pain score (maximum = 210) was the sum of the severity and frequency scores multiplied within each region (maximum = 30 each region).

2.3 Thoracic kyphosis

Thoracic kyphosis angle was measured with a Flexicurve ruler (Faber-Castell, Germany)[32], which was molded to the posterior surface of each participant's vertebral column, with its ends aligned with C7 and the L5-S1 interspace. The Kyphosis Angle, previously correlated to the thoracic kyphosis Cobb angle[32], was measured on a grid paper trace of the curve. Intra-rater reliability for this measurement was high (ICC = 0.94; 11 women unassociated with the study measured on three non-consecutive occasions).

2.4 Thoracic flexion torque

The flexion torque created by the participants' breasts on their thoracic spine was calculated by multiplying each participant's mean bilateral breast weight (volume x breast density 0.94 kg/m^3 x acceleration due to gravity)[4] by the moment arm. The moment arm, derived from a scan taken of each participant while they were standing upright (Geomagic® software, 3D Systems, South Carolina, USA), was measured as the distance between the apex of the thoracic kyphosis and the estimated centre of gravity of the breast (determined automatically by the Geomagic® software based on the breast volume distribution).

2.5 Shoulder range-of-motion

Each participant's **active** range-of-motion was measured using two clinical tests that require thoracic extension to achieve full range: (i) shoulder flexion range-of-motion (degrees) and (ii) Apley's Scratch Test (centimeters)[33]. The participant's lumbar spine was stabilized during both tests to isolate thoracic spine extension.

2.6 Scapular retractor strength

After extensive pilot testing, scapular retraction exercises were used to test the strength and endurance of the posterior muscles of the thoracic region (thoracic erector spinae, middle trapezius, and rhomboids major and minor). This was deemed important because the scapular retractor muscles **also function as thoracic extensors** and assist the thoracic erector spinae **in resisting** the flexion torque generated by breast weight[34, 35]. Thoracic extension tests, such as the Biering-Sorensen Test, were not used because they were considered too uncomfortable or difficult for women with large breasts to perform. Isometric scapular retraction and thoracic extension strength were measured while the participants stood in a lunge position, with each foot on a scale, and holding onto a metal bar connected to a dynamometer[34] (Figure 1). Extensive familiarization and continual feedback during testing ensured the strength assessment was localized to scapular retraction and thoracic extension, without any other body movement or weight shift on the scales.

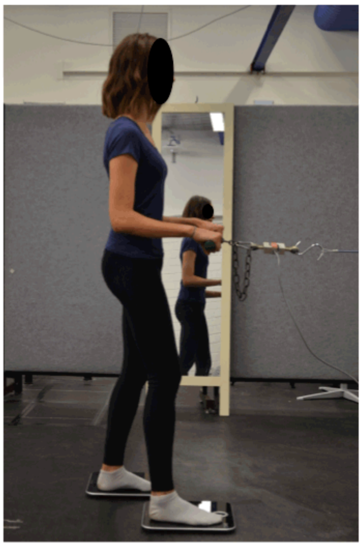

Figure 1: Maximal isometric voluntary contraction strength and endurance strength test position. Participants pulled against the dynamometer by retracting their scapulae and extending their thoracic spine without moving any other part of their body or shifting their

weight on the scales.

Maximal isometric voluntary contraction (MVC) strength was measured as the peak force (N) of three trials recorded using a load cell (Orientec, A&D, Japan; 1 kN capacity). The protocol increased the force (converted to kilograms) from rest to maximum over 5 seconds, with 60 to 90 seconds rest between trials[36] and required a minimum of two of the three peak forces to be within 5% of each other[36]. Endurance strength (measured in the same position) had the load set at 60% of each participant's MVC isometric force, for the maximal duration they could maintain the target load within 20% variation, guided by visual feedback on a computer screen[36]. Extensive pilot testing found a load of 60% MVC was required to induce fatigue within a reasonable time frame. The chief investigator constantly monitored each participant, both visually and with light intermittent palpation, to ensure each participant isolated her scapular retractor and thoracic extensor muscles during each trial. The test was terminated when the target force was less than 40% MVC for 3 seconds[36]. The one researcher (KC) collected all strength and endurance data (test-retest reliability was high; ICC MVC = 0.90, endurance = 0.99 respectively; testing six women unassociated with the study on two non-consecutive occasions).

2.7 Statistical analysis

Means and standard deviations for the outcome variables characterizing total upper torso pain, thoracic kyphosis, thoracic flexion torque, active shoulder range-of-motion, and scapular retractor muscle strength and endurance were calculated for the two participant groups (women with large breasts and women with small breasts). A linear regression, adjusting for body mass, compared the outcome variables between the two groups because they could not be matched for body mass. As the main categorical independent variable (breast size) was observed, not manipulated, the independence assumption between the covariate (BMI) and the independent variable (breast size) was not deemed to be relevant. It is noted, however, that the mean differences in the variables were at any given value of the covariate (BMI). All statistical calculations were performed using Prism 6 software (GraphPad Software, USA), with an alpha level of 0.05.

3. RESULTS

3.1 Upper torso musculoskeletal pain

The mean total upper torso musculoskeletal pain scores calculated for both participant groups are listed in Table 2 and the mean pain scores within each body region are illustrated in Figure 2. In agreement with our hypothesis, the total upper torso pain score of the participants with large breasts was significantly higher compared to the women with small breasts (Table 2). Regional pain scores and their standard deviations were also higher for the participants with large breasts (Figure 2), with the highest regional pain scores reported in the thoracic region.

TABLE 2. Upper torso pain, structure and function of the participant group with large breasts and with small breasts. Values expressed as a mean (95% CI). Asterisks represent significance (*P<0.01).

Variable	Large breasts (n = 27)	Small breasts (n = 26)	P-value
Thoracic kyphosis angle (°)	*35 (32-38)	27 (24-31)	**0.01**
Flexion Torque (Nm)	*5.9 (4.5-5.8)	0.9 (0.8-2.4)	**<0.001**
Total upper torso pain (score/210)	*46.6 (33.3-58.0)	24.1 (12.5-37.8)	**0.04**
Shoulder range of motion (°)	*160 (158-163)	169 (166-172)	**<0.001**
Apley’s scratch test (cm)	1.6 (-2.0-3.2)	-3.2 (-4.7-0.6)	0.21
MVC strength (kg)	15.4 (13.4-16.6)	15.4 (14.2-17.4)	0.53
Endurance-strength (seconds)	*511.4 (362.2-691.3)	875.8 (691.5-1028.4)	**0.01**

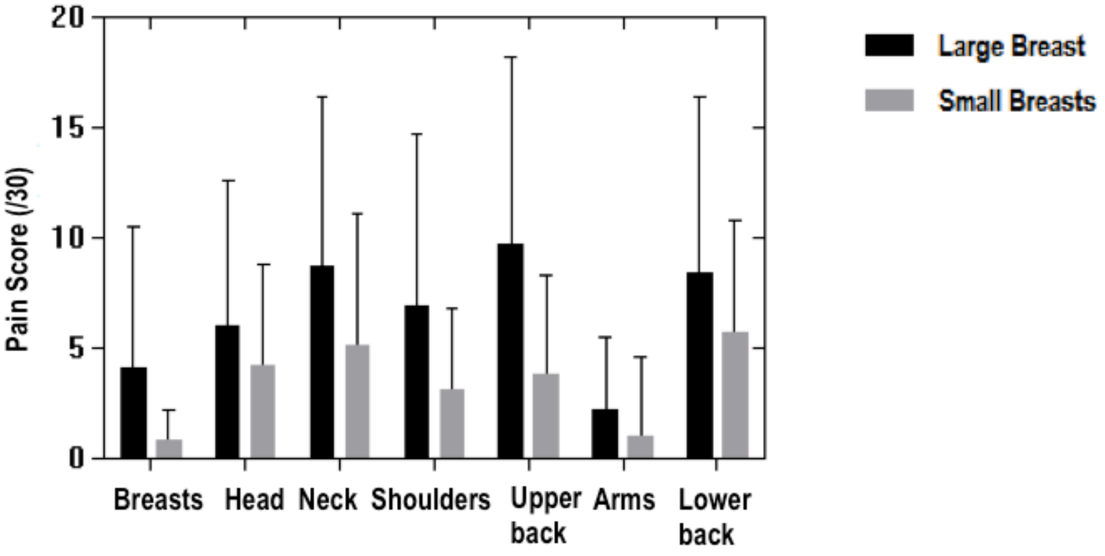

Figure 2: Mean (+standard deviation) regional pain scores (maximal possible score = 30). The higher the score, the greater the reported pain.

3.2 Thoracic kyphosis, flexion torque, range-of-motion, strength and endurance

The mean thoracic kyphosis, flexion torque, range-of-motion, strength and endurance data calculated for both participant groups are listed in Table 2. The mean thoracic kyphosis angle and flexion torque were significantly greater for the participants with large breasts compared to the participants with small breasts. Participants with large breasts also had significantly less **active** shoulder flexion range-of-motion compared to their counterparts with small breasts, although the Apley's scratch test scores were not significantly different (Table 2). Scapular retractor muscle endurance was significantly reduced in the participants with large breasts but no significant between-group difference was found in maximal isometric voluntary contraction strength of the scapular retractor muscles (Table 2).

4. DISCUSSION

To our knowledge, this is the first published study to systematically investigate the musculoskeletal pain, posture, range-of-motion, and muscle strength and endurance of the upper torso in women with large breasts who were not currently seeking breast reduction surgery. The significantly higher upper torso pain scores reported by participants with large breasts, which were greatest in the thoracic region, were accompanied by a significantly greater thoracic kyphosis angle, reduced **active** shoulder flexion range-of-motion, and reduced scapular retractor muscle endurance compared to participants with small breasts. These differences in the upper torso posture, range-of-motion and muscle endurance provide evidence of factors that are likely to contribute to the musculoskeletal pain suffered by women with large breasts and could, in turn, guide the clinical management of these women as discussed below.

We propose that an underlying mechanism for the upper torso pain reported by women with large breasts is long-term altered loading in the thoracic region caused by a combination of greater thoracic kyphosis and a higher flexion torque generated by a large breast weight, restricted active shoulder/thoracic spine range-of-motion, and reduced thoracic extensor muscle endurance strength. This suggests that the women with large breasts in this study had not adapted to the greater thoracic flexion torque generated by their large breast mass by increasing their thoracic extensor endurance strength.

It has previously been speculated that women with large breasts have a higher thoracic flexion torque due to their breast mass[1,4], although the size of this torque has not been reported in the literature. Our results confirm this speculation. The magnitude and range of thoracic kyphosis angles found for both participant groups in the present study were consistent with previous research that measured thoracic kyphosis angle using X-rays[3,8]. Furthermore, our range-of-motion and strength results were consistent with musculoskeletal changes associated with large breasts [2,7] and increased thoracic kyphosis[2,19]. Therefore, the tests described in this study are likely to be useful clinical tools to include in the physical assessment of female patients with large breasts. Clinical reasoning is required to determine whether these clinical tests are positive and whether they are related to each individual patient's' symptoms**.** The results may also guide evidence-based treatment strategies to improve clinical management of this increasing sector of the population.

An increased level of breast support could counteract the higher flexion torque found in the participants with large breasts in the current study. Previous research has found the bra-breast forces generated in women with large breasts are lower in high-support bras compared to low-support bras[4]. As correct bra fit is required for a bra to function to its design[5,28] bra fit assessment and education should also be included when treating female patients with large breasts who present with upper torso musculoskeletal pain. As body mass index was also higher in the participant group with large breasts, strategies to reduce body mass, which in turn would decrease breast mass, should also be an integral part of treatment of these women.

Manual therapy and exercises aimed at decreasing thoracic kyphosis, increasing shoulder flexion range and increasing scapular retractor endurance-strength are also likely to be effective treatment strategies for women with large breasts who present with upper torso musculoskeletal pain. Decreasing thoracic kyphosis might also improve the posture of the lumbar and cervical spine and associated symptoms[8]. As endurance rather than maximal strength was compromised in the participants with large breasts, strength exercises for this patient cohort should be endurance based, involving low load/high repetitions[37].

The significantly greater thoracic kyphosis angle in the participant group with large breasts was in contrast to previous research that found no difference in kyphosis angle in young women (mean age 21 years)[13, 14] or post-menopausal women (mean age 69 years)[5]. We attributed this between-study difference to the mean age of the participants in the current study (45 years), who were less likely to be osteoporotic (compared to the post-menopausal women) and more likely to experience the long-term effects of a large breast mass compared to the young women. The increase in thoracic kyphosis secondary to the flexion torque caused by large breasts is a long-term consequence that could be prevented by strategies aimed at decreasing the flexion torque of large breasts (better breast support and weight loss) and increasing strength of the posterior muscles of the thoracic spine to resist the flexion torque. However, further research on a larger participant cohort and using a longitudinal study design is required to verify this notion.

Although increased breast mass is likely to be a strong contributor to the increased upper torso pain reported by the participants with large breasts, it was not the only contributing factor. That is, some participants with small breasts also reported experiencing musculoskeletal pain, and the pain scores of the participants with large breasts varied greatly, evident by the large standard deviations (Figure 2). We postulate that this variability may be related to the ability of the participants to maintain good posture as they aged by balancing the flexion torque generated on their thoracic spine by their breasts. Further research is recommended to investigate the factors that contribute to the upper torso pain experienced by women across the spectrum of breast sizes and ages.

4.1 *Study Limitations*

Due to the cross-sectional design of this study, we are unable to ascertain whether a large breast mass caused the observed differences in upper torso musculoskeletal structure and function that were found between the participants with large and small breasts. Neither do we know if increasing breast size is associated with worsening signs and symptoms within any one individual and at what point increases in breast mass become problematic. As it was not possible to match the two participant groups for BMI, the greater musculoskeletal pain, greater thoracic kyphosis and decreased range and muscle strength might be associated with body mass or BMI, rather than breast size alone. Further longitudinal research is therefore recommended to assess the effectiveness and timing of treatment aimed at modifying upper torso musculoskeletal signs and symptoms and BMI in women with large breasts.

5. CONCLUSIONS

Women with large breasts reported greater upper torso pain, which was accompanied by a greater kyphosis and flexion torque in the thoracic spine, decreased shoulder flexion range-of-motion, and reduced scapular retractor muscle endurance compared to women with small breasts. These between-group differences in upper torso musculoskeletal structure and function provide evidence of factors likely to be contributing to the musculoskeletal pain suffered by women with large breasts. These findings could form the basis for treatment strategies to alleviate these symptoms in female patients with large breasts to prevent their progression.

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