ORIGINAL ARTICLE

How do respiratory state and measurement method affect bra size calculations?

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Objectives: To investigate the effects of respiratory state and measurement method on bra size calculation.
Methods: The bra sizes of 16 large-breasted women were measured during two respiratory states, end voluntary inspiration and relaxed voluntary expiration, and using two sizing methods, which were compared against subject-reported bra sizes.
Results: Both respiratory state and measurement method significantly affected bra size estimations, whereby measuring chest circumference during inspiration increased both band and decreased cup size. However, whereas bra size calculated using the standard method differed significantly from subject-reported bra size, cup size calculated using the breast hemi-circumference method did not differ significantly from subject-reported cup size.
Conclusions: As respiratory state significantly affects bra sizes, it should be standardised during bra size measurements. A more valid and reliable bra sizing method should be developed, possibly using the breast hemi-circumference method for cup size estimations and raw under-bust chest circumference values for band size.

Bra size usually incorporates two components, the band size, expressed as a number (eg 32 and 34), and a cup size, expressed as a letter (eg A and B). Band size is calculated by measuring an individual's under-bust chest circumference (UBCC) at the infra-mammary fold. An arbitrary number, described in the Methods section, is then added to the UBCC value to derive band size. Cup size is calculated by measuring the over-bust chest circumference (OBCC) at the level of the fullest part of the breast. The difference between the OBCC and the band size dictates cup size. Cup size is therefore dependent on band size, although the volume of the same cup size (eg C cup) varies between different band sizes (ie a 10C cup has a different volume from a 12C cup). Further, band size is not a standard length (eg the length of a 10C band in one bra style may differ from another 10C band).[1–5]

It has been suggested that 70–100% of women are wearing the wrong size bra, with this fitting discrepancy greatest in large-breasted women.[6 7] Inconsistency exists in bra fit research regarding what constitutes ''correct'' bra size. For example, some studies[6 8] consider correct bra size to be based on a manufacturer's sizing instructions, which are not consistent among manufacturers; others[7] have considered the size each subject reported as being most comfortable as the ''correct fit'', although the ability of women to accurately assess their bra size has also been questioned.[3 4 6–8]

Consequences of an ill-fitting bra

A correct-fitting bra is imperative to good health, as ill-fitting bras have been reported to contribute to numerous upper quadrant pains in women who seek treatment by sports medicine practitioners. These include upper limb neural symptoms and deep bra furrows caused by excessive strap pressure; non-cyclical mastalgia, neck and back pain;[6 9–12] and exercise-induced breast discomfort.[13–15] These symptoms can be so severe as to force large-breasted women to seek reduction mammaplasty[3 6 7 9–12 16] or inhibit these women from participating in physical activity.[13–15] It has been suggested that correct-fitting bras can alleviate some of these symptoms, allowing women to exercise in greater comfort and possibly reduce the need for breast reduction surgery.[3 6 9 10 16] Marketing studies suggest that comfort is not a primary selection criterion for many women when they purchase bras.[6 7 17 18] Instead, factors such as cost, appearance and restriction of breast movement have been cited as important selection criteria.[6 7 13 14 17–19] That is, women are willing to give up physical comfort for physical beauty.[18]

Measuring bra cup size

Acknowledging the importance of a correct-fitting bra, which is impeded by a lack of standardisation in bra sizing,[1–3 6 7] Pechter[7] developed an alternative method of bra cup size measurement. This method involved measuring the breast hemi-circumference from the medial to lateral inframammary fold, across the nipple, while the large-breasted subjects were supine, braless and with their shoulders slightly abducted. A 7-inch measurement was classified as an A cup, 8-inches a B cup, with similar increments for larger cup sizes. (NB measurements used to calculate bra size are usually reported in inches rather than metric units, whereby 1 inch is equivalent to 2.5 cm.) After assessing 100 women, Pechter[7] reported a 77% match to the subject-reported bra cup size compared with a 23% match using the standard bra sizing method. Furthermore, Pechter[7] identified a 2-inch difference in breast hemi-circumference values when large-breasted subjects were measured supine compared with standing. The greatest discrepancies comparing the two methods were evident for larger, ptotic (drooping) breasts.

However, it should be noted that cup volume is not homogeneous among different bra band sizes. For example, the 8-inch breast hemi-circumference value is classified as a B cup only for a 34-inch band size, whereas the same 8 inches is classified as a C cup in a 32-inch band or as A in a 36-inch band size.[1–3] Smith *et al*[4] compared subject-reported bra sizes with total breast volume and found a wide range of breast volumes for one reported cup size, whereas total breast volume for a 34D ranged from 594 to 962 cm^3. These results

Abbreviations: OBCC, over-bust chest circumference; UBCC, under-bust chest circumference

suggest that at least some of the women must have self-selected the wrong-sized bra or that the volume of the cup size was not constant among bras supposed to be the same size.

Problems with bra sizing

A search of 26 websites describing bra-sizing methods, accessed during 2005, showed high variability in the breast position recommended when measuring bra size. Greenbaum *et al*[6] cited that large variations in bra size estimations were caused by using these different recommended postures, especially with large-breasted women in whom the flesh of the breast may ''spill over the subject's hands'', or with breast ptosis, where the circumference would change considerably with different breast positions (fig 1). No recommendations were found with respect to respiratory state during bra size measurement. It is speculated that chest circumference measurements and, in turn, bra band and cup measurements would be influenced by inspiration and expiration. Therefore, we speculate that respiratory state should be standardised during bra size measurement.

Considering the substantial variation in the standard method to measure and calculate bra size, the variation in breast shape, posture and respiratory state during bra size measurement, with inconsistencies between bra companies in cup volume for different band sizes as well as band lengths, it is not surprising that as many as 70% of women have been reported to wear the wrong size bra. To assist women achieve correct fit, it is imperative that a consistent bra size measurement and calculation method and any factors that affect bra size calculation, such as respiratory state, be identified. Therefore, the purpose of this study was to investigate the effects of respiratory state and measurement method on bra size calculation.

METHODS

Subjects

Sixteen large-breasted (⩾C cup), pre-menopausal women (mean (standard deviation (SD) age 31.9 (7.5) years; range 19–40 years) were selected as subjects. The mean (SD) bra band size was 14 (2.3), range 10–18, and mean cup size was D (range C–J), according to Australian sizing standards. Table 1 gives the conversion to international sizes. Exclusion criteria included previous breast surgery, current pregnancy or current breast-feeding. The University of Wollongong Human Research Ethics Committee approved all recruiting and testing procedures and all subjects gave written informed consent to participate in the study.

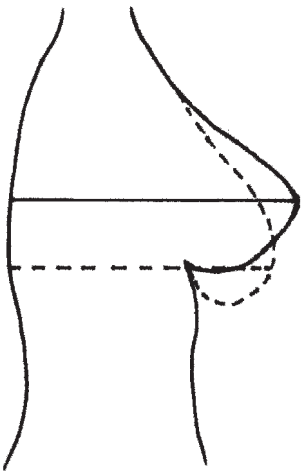

Figure 1 Over-bust chest circumference (OBCC) measured with a subject wearing a bra (bold line) and with their breasts hanging without support (dotted line). The measurements are different between the two conditions; the OBCC with the bra on is greater. The OBCC measurement for breasts of different shapes (pert versus ptotic), in different positions (bra on, bra off, breasts lifted or under gravity, standing versus lying) would all change the resultant calculated bra size.

Table 1 International bra size conversion chart (www.lingeriemart.com/Corporate_info/International_size_chart.htm)

Australia	US	UK	France	International
10AA	32AA	32A	85A	70 A
10A	32A	32B	85B	70 B
10B	32B	32C	85C	70C
10C	32C	32D	85D	70D
10D	32D	32DD	85DD	70DD
12AA	34AA	34A	90A	75 A
12A	34A	34B	90B	75 B
12B	34B	34C	90C	75C
12C	34C	34D	90D	75D
12D	34D	34DD	90DD	75DD
12DD	34DD	34E	90E	75E
14AA	36AA	36A	95A	80 A
14A	36A	36B	95B	80 B
14B	36B	36C	95C	80C
14C	36C	36D	95D	80D
14D	36D	36DD	95DD	80DD
14DD	36DD	36E	95E	80E
16AA	38AA	38A	100A	85 A
16A	38A	38B	100B	85 B
16B	38B	38C	100C	85C
16C	38C	38D	100D	85D
16D	38D	38DD	100DD	85DD
16DD	38DD	38E	100E	85E

Bra size calculation

In order to investigate the effects of respiration on bra size estimation, two measurements (OBCC and UBCC) were recorded three times each per subject during two respiratory states: end voluntary inspiration and relaxed voluntary expiration (minimal accessory muscle effort). The mean of the three measurements per subject per condition was used in further analysis. To achieve these respiratory states, the subjects were asked to ''breathe in and hold'' and to ''gently breathe out and hold'', respectively. The same trained assessor (DEM) took all measurements using a metal tape measure, which was kept level across the subject's back. The tape was held firmly but not tightly and did not indent the breast tissue. The OBCC was measured level with the most prominent part of the breasts, with the subjects standing and braless so that the breasts were dependent. The UBCC was measured level with the inframammary fold, while the subjects stood braless with the breasts held raised by the subject's hands to expose the inframammary fold. Band size was then calculated using the standard method of bra size estimation. This involved adding the most common recommended arbitrary number, which ranged from 2 to 6 inches as reported in a search of 26 websites of bra size measurement, to the UBCC measurement. An arbitrary number of 4 inches was added to an even UBCC measurement and 5 inches to an odd UBCC measurement. For example, a UBCC of 28 inches resulted in a 32-inch band size (28 + 4). Cup size was also calculated using the standard method of bra size estimation, which was based on the difference between the OBCC measurement and band size. For example, an OBCC–band size difference of 1 inch equated to an A cup, whereas a 2-inch difference equated to a B cup.[1 5 6]

The breast hemi-circumference[7] was also recorded for each subject, measured from the medial to lateral mammary folds, while the subjects were braless and supine with their shoulders abducted to 45°. The tape did not indent the breast tissue during measurement. The breast hemi-circumference measurement was recorded to enable later comparisons between the bra size calculated using this method and the standard method relative to the subject-reported bra size (ie the size of a comfortable bra regularly worn by each subject).

The methods used to measure the OBCC, UBCC and breast hemi-circumference proved to be highly reproducible, with intraclass correlation values, calculated using the method described by Vincent,[20] of R = 0.999 (OBCC), R = 0.999 (UBCC) and R = 0.998 (breast hemi-circumference) for within-day reliability assessments.

Statistical analysis

Mean (SD) was calculated for the OBCC and UBCC measurements in the two respiratory states (inspiration and expiration). A Kolmogorov–Smironov test (with Lillefors' correction) was used to test all data for normality, and non-parametric tests were used if the data violated the assumption of normality. Paired t tests were then used to determine any significant ($p \leqslant 0.05$) differences in the chest circumference measurements for the two respiratory states. Bra band sizes calculated in inspiration and expiration were compared against the subject-reported band sizes using Wilcoxon's signed ranks tests to determine the effects of respiratory state on band size calculations. The subject-reported cup size was compared with the cup sizes calculated using the breast hemi-circumference methods, and Wilcoxon's signed ranks tests were used to determine any significant difference in cup size calculations. All statistical analyses were conducted using SPSS V.11.5.

RESULTS

Effects of respiration on bra size calculations

Figure 2 shows the mean (SD) UBCC and OBCC values measured during inspiration and expiration for the 16 women. Table 2 shows the bra sizes calculated from these measurements compared with the subject-reported bra sizes.

The mean UBCC and hence the calculated band size were significantly greater when measured during inspiration compared with during expiration (t = 4.3, p = 0.001; fig 2). The calculated band size difference between the two respiratory states ranged from 0 to 6 inches, with a mean (SD) difference of 1.9 (1.8) inches. This between-respiratory state difference in band size would equate to an average error of one band size, with a potential of up to four band sizes in error if respiratory state was not standardised. Interestingly, band size calculated during inspiration matched the subject-reported band size within one size error for only three of the 16 subjects (18%), who specifically stated that they wore loose-fitting bras, and for four subjects (25%) when measured during expiration. Consequently, the subject-reported band sizes were significantly different from the band sizes calculated for both inspiration (Z = −3.3, p<0.001) and expiration (Z = −2.8, p = 0.005).

The OBCC values, and consequently cup size calculations, were also significantly different (t = 3.5, p = 0.003) in the two respiratory states. The between-respiratory state difference in OBCC value was on average 1 inch—that is, a mean (SD) of 0.75 (0.86) inches, range 0–2 inches— greater during inspiration relative to expiration, which equated to one-cup size error. As band sizes were overestimated, relative to subject-reported band sizes, when using the standard bra size calculations in inspiration and expiration, cup sizes were consequently underestimated (ranging from 1 to 4 cup sizes in inspiration and 0 to 4 cup sizes in expiration; table 2).

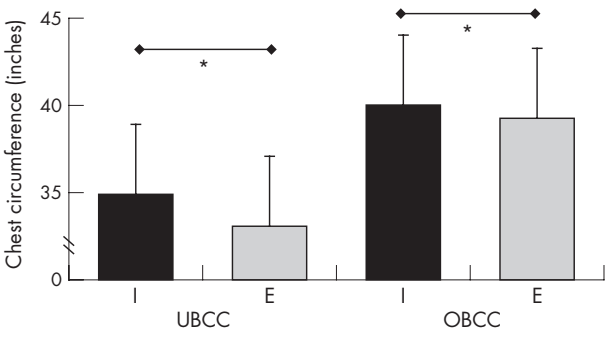

Figure 2 The mean (SD) under-bust chest circumference (UBCC) and over-bust chest circumference (OBCC) values measured during inspiration (I) and expiration (E) for the 16 women (* indicates a significant between-respiratory state difference at p<0.05).

Table 2 Subject-reported bra sizes compared with bra sizes calculated for each subject using the standard method of bra sizing (based on chest circumference values measured during inspiration and expiration) and using the breast hemi-circumference method

Subject no	Subject-reported bra size	Bra size calculated during inspiration	Bra size calculated during expiration	Cup size calculated using the BH method
1	16J	20F	20E	**J**
2	12C	16AA	**12C**	**C**
3	12D	20AA	16A	**C**
4	12C	**14**A	**14C**	**B**
5	16C	**16C**	**14C**	F
6	14D	18AAA	16A	**D**
7	14C	18AA	**14D**	**D**
8	12C	16A	16A	E
9	10D	14AA	12A	**D**
10	16D	22A	20A	**E**
11	10E	16AA	12AA	**F**
12	14C	18AAA	12AA	**C**
13	12E	**14**B	14B	**D**
14	14D	18A	16A	**E**
15	14C	18AA	18AA	**C**
16	18C	26AA	26AA	F

The bolded values are calculated sizes that matched the subject-reported bra size to within one size error.
BH, breast hemi-circumference.

Effects of measurement method on bra size calculations

Bra size calculated using the standard bra sizing method matched the subject-reported bra size (cup and band size together, matched to within one cup and band size of error) for only four of the 16 subjects (25%) when measured in expiration and for 1 (6%) of the subjects when measured in inspiration. However, cup size calculated using the breast hemi-circumference method matched the subject-reported cup size in 6 (38%) subjects and matched to within one-cup size of error in another 7 (44%) subjects—that is, 82% of subjects in total. There was no significant difference between the subject-reported cup size and the cup sizes calculated using the breast hemi-circumference method (Z = −1.6, p = 0.101). By contrast, cup size calculated for both inspiration and expiration using the standard method were significantly different from the subject-reported cup size (Z = −3.3, p = 0.001). In both respiratory states, cup size was underestimated compared with the subject-reported values (table 2).

DISCUSSION

Effects of respiration on bra size calculations

The difference in bra size calculated at end voluntary inspiration compared with expiration confirmed the notion that variation in respiratory state is another potential source of error in bra sizing when using the standard method of bra size calculation. As both the UBCC and OBCC values changed with inspiration and expiration, the average relative difference equated to an error of one band size and one-cup size. Although this is a small difference on average, the range from 1 to 6 inches could cause a more substantial error, confirming

the need for respiratory state to be standardised during bra size measurement. Interestingly, the subject-reported band sizes were smaller than the sizes calculated for 15 (95%) subjects during inspiration and 12 (75%) subjects during expiration. This confirmed the results of Greenbaum *et al*,[6] implying that the large-breasted women in the present study chose bras with tight bands.

As band sizes were overestimated in both respiratory states, cup sizes were consequently underestimated. The cup size discrepancy was greater during inspiration (ranging from 1 to 4 sizes in inspiration and 0 to 4 in expiration), with the greatest discrepancy with the self-reported size in the subjects with larger ptotic breasts or broad breasts. In agreement with Greenbaum *et al*,[6] it is postulated that cup size might have been underestimated because cup size was measured with the breasts dependent (fig 1) rather than with a bra on. A breast-dependent method was used in the present study to avoid variation in the OBCC caused by the breasts possibly hanging at different heights owing to subjects wearing different bras. It is therefore important to educate women not to breathe in and hold their breath during bra size measurement or else a D cup breast may well be calculated to be AA, as was the case for subject 3 (table 2).

Effects of measurement method on bra size calculation

The bra sizes calculated by the standard method were significantly different from the subject-reported bra size, irrespective of respiratory state. Although the discrepancies were less in expiration than in inspiration, it must be determined whether the standard bra sizing method assists or hinders women in selecting the correct size bra. The discrepancies were substantial, even when considered as component parts of band and cup size—that is, self-reported band size matched the band size (to within one size error) calculated using the standard method for only 1 (6%) subject in inspiration and for 4 (25%) subjects in expiration (when an arbitrary number of 4 and 5 inches was added), with discrepancies of 4 and 5 sizes. Furthermore, cup size matched (to within one size error) only 1 (6%) subject in inspiration and 4 (25%) subjects in expiration, again with discrepancies of 4 to 5 cup sizes.

Pechter[7] recommended the breast hemi-circumference method to calculate cup size and the raw UBCC to determine band size, with no arbitrary additions as the variations in this arbitrary number can vary the band size by several sizes. As cup size is a measure of breast volume, it appears logical to specifically measure the breast rather than the OBCC, as in the standard method of bra sizing. The present results are consistent with Pechter[7] as cup size calculated using the breast hemi-circumference method matched within one-cup size of the subjects' self-reported cup size for 82% of subjects, with no significant difference between the two measurements. Retrospective video observations of the other 18% of subjects supported the breast hemi-circumference sizing method to be the correct estimate of cup size. A direct measurement of breast volume would have been preferable to confirm this notion, but was unavailable during this study.

It is imperative that standardised procedures are used to facilitate valid and reliable chest circumference measurements. This includes standardising breast position during measurement, using a raw UBCC value without adding any arbitrary number because of the high variability in arbitrary numbers recommended by different manufacturers, and standardising the level at which the band measurements are taken around the chest. This level should be at the inframammary fold, with ptotic breasts lifted during this measurement. A correctly fitted band should not be too tight or ''cut in'' to the torso, but should be firm enough so that the band does not shift up during upper limb movement, and the posterior band should sit level with the inframammary fold.

What is already known on this topic

- Large-breasted women are poor at selecting a correct-fitting bra.
- Ill-fitting bras can lead to musculoskeletal problems in these women.
- There is a lack of consistency among bra manufacturers with respect to band length and cup volume.

What this study adds

- This study highlights the possible contributors to bra-fitting and sizing errors such as variations in instructions provided by different bra manufacturers and variations in respiratory state.
- We suggest an alternate method of bra sizing that could assist women in selecting the right size bra to minimise bra-related musculoskeletal problems.

Bands that are too loose can cause the straps to bear excessive pressure. Ultimately, bra sizes need to be standardised among all manufacturers and among all styles. Currently, cup volumes and band lengths are not always consistent among manufacturers or even within different styles of bras made by the same manufacturer. That is, an accurately measured 14C is not always a 14C.

Three different breast shapes were evident in the present study; (i) pert (n = 1), (ii) ptotic (n = 11), and (iii) broad (n = 4). Bra size calculations using the standard method matched the subject-reported bra size in only pert-breasted subjects, whereas the breast hemi-circumference method resulted in more matches, irrespective of breast shape. It is speculated that this was related to the more homogeneous shape of the breasts when the subjects were supine compared with the standing position. The supine position is required for measurement by the breast hemi-circumference method for large breasts, whereas the standing position is required for the standard method. While standing, the ptotic breasts were hanging at a lower level and were more varied in shape compared with the pert and the broad breasts.

CONCLUSION

As respiration significantly affected bra size, respiratory state should be standardised during bra size measurement. It is recommended that women reach relaxed end expiration while chest circumference measurements are being recorded. The high number of discrepancies between bra sizes calculated using the standard method of bra sizing and the subject-reported bra size highlights the lack of credibility of the current standard bra sizing method, particularly for larger-breasted women. It is therefore recommended that a new valid and reliable bra sizing system be developed to assist women select correctly fitting bras. Such a method should specify the posture, breast position and respiratory state during measurement, as well as a standardised procedure for calculating cup size and band sizes. As the common aims of sports medicine are to promote physical activity and improve posture to alleviate musculoskeletal symptoms, assessing and educating female patients with respect to the importance of bra fit should be inherent components of the treatment process, particularly in large-breasted, inactive female patients.

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COMMENTARY 1

In this study, the authors examine the variation in bra size by the traditional method when under-bust and over-bust chest circumference measurements are taken at end expiration versus maximal inspiration. Their findings support the conclusion that ''sighs do matter'', such that respiratory state should be standardised during measurement of bra size. They also rightly recognise that the traditional method of bra sizing is inaccurate at best, with little validity attributable to the method of determining cup size by the relationship of under-bust chest circumference, or band size, with over-bust chest circumference. Studies such as this may hopefully yield improved methods of bra measurement and increased comfort for bra wearers.

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COMMENTARY 2

With a paucity of literature available investigating the effectiveness of bras in limiting breast motion and related breast pain, the current research suggests that a well-fitting bra can limit such breast motion and related breast pain. As has been highlighted in this paper, it is currently believed that most women are not wearing the correct bra size, and this is matched with the belief that many women are not being fitted for their bras when purchasing. If better techniques in bra measurement were implemented, and bra manufacturers then standardised their measurements in their bra design, perhaps women would have more confidence in the bra-fitting practice and may then be more likely to wear bras of correct size.

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