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Breast Size and Anthropometric Changes through Brassieres

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ABSTRACT

The objective of this research is to investigate breast size from a comprehensive perspective, which encompasses physical size and aesthetic preference, and identify how women expect to change their breast size and shapes by wearing an everyday bra. Forty-five females are invited to an onsite measurement session. The breast size is evaluated by body scanning and a short questionnaire. Each subject is requested to choose a brassiere that gives her a desired effect, and the impact of those brassieres is analyzed in relevant to breast size.

There was a reasonable agreement among a cup indicator, breast volume, and a subjective judgment. However, cup indicators were limited to capture breast size in an approximate sense, but could not be effective enough to assign an exact bra size to an individual. Participants' subjective judgments coincided with breast volume. After wearing the brassieres, breast size increased; breast volume and full bust girth significantly grew. Bust points were relocated inwards and upwards, and there were statistically significant effects of breast volume on these changes in breast size and shape.

Keywords: breast size, bra cup size, breast volume, effect of brassiere, 3D body scan

Introduction

A female breast requires unique consideration related to physical activity, appearance, self-image, sexuality and motherhood. Interest in breast research has increased and diversified accordingly by a variety of experts from multiple disciplines, which include medical science (Caruso, Guillot, Nguyen & Greenway, 2006; Kovacs et al., 2007; Loughry, Sheffer, Price, Lackney, Bartfai, & Morek, 1987), sports engineering (McGhee & Steele, 2010a; McGhee & Steele, 2010b) and apparel engineering (Chen, LaBat & Bye, 2010; Lee, Hong & Kim, 2004; Zheng, Yu & Fan, 2007).

Though research interest varies by fields, breast size plays a critical role in all applications. For example, the issue of breast size is complicated by social and cultural contexts. Breasts have become sexualized in popular culture and media, and large breasts are perceived as more feminine (Einon, 2012; Fidelis, Oliveira, Giraldi & Santos, 2017). At the same time, females with large breasts experience problems such as breast pain or a backache during exercise (Hadi, 2000) and social embarrassment (Green, 1996). Therefore, it is necessary to investigate breast size from a comprehensive perspective that encompasses aesthetic preference influenced by sociocultural

impacts as well as physical size related to physiological comfort.

Aiming to provide comprehensive understanding of breast size, the current research estimated breast volume and carried out contrastive analyses of physical breast size and aesthetic preference. The research continued investigating the effect of a brassiere on breast size and shapes that research subjects favored to have. Based on empirical data and statistical analysis, this research provided quantitative evidence and verification to support an improved understanding of breast size and the role of brassieres. These findings will help product developers identify expectations that consumers have for their daily bras.

Literature review

Breast size can be measured by volume and mass, but the dominant method in most research so far has been a use of volumetric measurements. Established in 1935 by the Warner's company (Fields, 2007), the current bra sizing system focuses on girth difference between full bust and underbust, which determines what is known as cup size. The cup sizing system, therefore, is based on a volumetric approach to estimate breast size, but depending on shapes of the breasts, it may result in inconsistent volume intervals between sizes. This issue has been addressed by previous researchers (Chen, LaBat & Bye, 2011; McGhee & Steele, 2011; Pandarum, Yu & Hunter, 2011) as a major obstacle limiting a scientific use of cup size in academia and industry.

Due to size inconsistency and incompleteness in the cup sizing system, there have been attempts to find a more accurate and precise way to evaluate breast size. One such method is to estimate breast volume, which is a common approach in mammoplasty. Several techniques have been tried to acquire breast volume such as magnetic resonance imaging (Inui, Murase & Tsutsumi, 2012; Kovacs et al., 2006), body scanning (Lee, Hong & Kim, 2004; Chen & Wang, 2015), thermoplastic casting (Caruso, Guillot, Nguyen & Greenway, 2006), water replacement (McGhee & Steele, 2011), breast squeezing (Grossman & Roudner, 1980), and linear measurements (Qiao, Zhou & Ling, 1997). Among these, body scanning is believed to be most practical and reliable (Kovacs et al., 2007), and is actively implemented in underwear research (Lee, Hong & Kim, 2004; Pandarum, Yu & Hunter, 2011; Zheng, Yu & Fan, 2007).

A brassiere primarily functions as an external support to a breast. It often serves to re-shape bustline (Inui, Murase & Tsutsumi, 2012; Jian & Wei, 2007) and/or to control breast movement (McGhee & Steele, 2010a; Zhou, 2011). A fashion bra is worn primarily for aesthetic concerns; it changes breast dimensions or shifts the bustline into a more attractive shape (Davis, 2013). According to previous research (Frederick, Peplau & Lever, 2008), 70% women were discontented with their breast. Of those women, 33% were dissatisfied with its shape, 28% with small size and 9% with large size. On the other hand, a sports bra is expected to support and restrict breasts during physical activities (Lawson & Lorentzen, 1990). This restriction is achieved by encapsulating and fastening the breasts with an appropriate amount of force (Zhou, Yu & Ng, 2013).

In order to achieve the intended purpose of a brassiere, it is very important to ensure its size and fit, but an accurate evaluation of breast size is not trivial. It has been a longstanding challenge for manufacturers and retailers to establish a consistent fit in brassieres. Popular retailers provide their customers with professional bra fitters to assist with bra fitting, and there are bra fitting checklists recommended by professionals (McGhee & Steele, 2010b). Despite diverse efforts, an accurate fit is still elusive; more than 80% women are wearing an incorrect bra size (McGhee & Steele, 2010b; Wood, Cameron & Fitzgerald, 2008). According to Wood, Cameron and Fitzgerald (2008), considerable difference existed in size estimates when breasts were measured by experts and general consumers. The size difference was up to 3 cup sizes,

and large-breasted women had a greater tendency to underestimate their breast size. In addition, a right fit is a subjective decision made by each individual and is difficult to be quantified and standardized (Yu, Fan, Ng & Harlock, 2014). When a brassiere does not fit correctly, it does not support breasts and causes much discomfort to a wearer (Lawson & Lorentzen, 1990; White, Scurr & Hedger, 2011).

The objective of this research is to compare and analyze breast size from different perspectives and identify how women expect to change their breast size and shapes by wearing an everyday bra. Forty-five female subjects were invited to an onsite measurement session. Since quite a number of women are dissatisfied with their breasts (Frederick, Peplau & Lever, 2008), it was assumed that women would favor a daily bra that resolved their personal dissatisfaction associated with breast size and shapes. Each subject was requested to choose a brassiere that gave her a desired effect, and the effect of the brassiere on breast size and shapes was analyzed. The effect was also investigated to see how it relates to breast size.

Research question

Breast size was quantified by three different methods. The impact of brassieres was measured by comparing breast anthropometry with and without the brassiere selected by subjects. Three research questions were established as follows and summarized in Figure 1 with a list of relevant measurements.

R1. How does breast size vary depending on different measurement methods? Is there any agreement between the methods?

Three different approaches were taken to measure breast size. The first method was to calculate a conventional cup size from underbust and full bust girths. The second method was to calculate breast volume from body scan data. Lastly, a subjective judgment was collected by a questionnaire asking whether subjects considered their breasts to be small or large.

R2. Is there a significant change in breast anthropometry when wearing a brassiere?

Breast anthropometry information was collected before and after wearing a brassiere. Breast volume, full bust girth, and underbust girth were measured and compared to indicate dimensional changes. The distance between right and left bust points (bust span) and the height of a bust point location were calculated and used for morphological comparisons.

R3. Is there any significant relationship between breast size and the anthropometric changes?

The anthropometric changes created by a brassiere were analyzed to confirm whether the expected role of brassieres was affected by breast size.

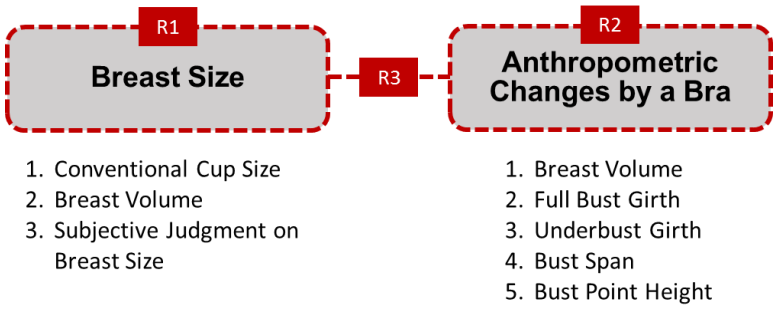

Figure 1. Schematic description of research questions

Experimental method

Based on quantitative data empirically collected, this research investigated breast size, identified user expectations for an everyday bra, and analyzed how the role of brassieres was affected by breast size. Conventional cup size and breast volume were calculated from body scans to identify physical size of breasts, and subjective judgments on breast size was gathered from subjects via a questionnaire to indicate their preference. Anthropometric changes after wearing an everyday bra were observed and analyzed to find its relevance to breast size.

Participants

Forty-five female subjects were invited to an onsite measurement session. They were selected through convenience sampling and participation was completely voluntary. Offline information about the research was spread across the university, and interested individuals were encouraged to contact researchers for participation. Participants were college students with an average age of 20.8 (± 3.0) years majoring in Apparel and Textiles. Their breast size was ranged between B and F cups based on the conventional cup sizing system.

Due to a wide variety of personal preferences as well as individual size and fit issues, there was no standard brassiere offered in the experiment; subjects chose their favorite brassiere. Prior to visiting a laboratory, they were requested to select a favorite everyday bra among what they owned based on its functional capability such as support and comfort. The choice of brassiere was totally up to the subjects' individual preference and there was no condition restricting their choice of brassiere. Focusing on the effect of the self-selected brassiere, experiments were designed to compare and analyze anthropometric changes regardless of types of brassiere chosen by the subjects.

Measurement

The subjects were body-scanned in a straight standing position without wearing a brassiere using the TC^2 3D body scanner NX16 (TC^2, Cary, NC), and bust girths were extracted from the scan files. Since the conventional cup sizing system was originally defined in an imperial unit (*e.g.* inch), cup sizes were obtained based on inch measurements. Considering that each underwear company relies on its own formula for cup size calculation, cup sizes were calculated as follows in this study. Full bust and underbust girths were measured from the widest level around the breast and the lowest position of a breast root, respectively. The underbust girth measurement was processed to the nearest even number to obtain what is known as band size. By subtracting the band size from the full bust girth, a numeric cup indicator was acquired and used in replacement of an alphabet letter for quantitative analysis (*e.g.* ~1 equals to an A cup and ~2 equals to a B cup).

Breast volume was calculated in cm^3 after processing individual body scans with

GeoMagic Design X (3D Systems, Rock Hill, SC) for 3D image analysis. A breast on the non-dominant side of each subject was selected for analysis because breast size is asymmetrical and can be affected by use of a dominant arm (Loughry et al., 1987). To obtain accurate breast volume, a breast boundary and a base were carefully determined as follows. The breast cup was separated from the torso based on the boundary suggested by previous researchers (Zheng, Yu & Fan, 2007). The lower breast boundary was defined along the visible shape of the breast root. The upper boundary was decided by five areas: the axillary folds, the location of the bust point and suprasternal notch, the curvature of the cleavage, and body contour lines created by coronal and sagittal planes (Zheng, 2007). Then, the breast base was custom-made through reconstructing a virtual chest wall (Kovacs et al., 2006), which was created by filling the cavity on the torso surface that was developed when the breast cup was removed from the scan. Accordingly, the breast base conforms to the inherent shapes of the torso. This breast base was separated again from the torso along the breast boundary previously defined and applied to close the opening on the hemispheric breast cup for volume calculation (Peterson & Suh, 2019).

A questionnaire was prepared to gather each participants' personal opinions of breast size. The participants were asked to rate their breast size, on a scale of 1 to 5, with the numbers representing the value "too small", "slightly small", "appropriate", "slightly large", to "too large", respectively. The survey was designed to indicate participants' attitude toward their breast size regardless of factual data. Several additional questions were included in the questionnaire to describe the selected brassieres and the participants' preference as well as demographic information.

Body scanning was repeated with the subjects wearing a selected brassiere, and anthropometric changes created by the brassieres were analyzed by comparing the body scans before and after wearing the brassiere. Bust girths and breast volume were obtained in the same manner as in the first scan. Bust span and bust point height were compared to determine how much the breast was reshaped by the brassiere. The bust point was placed on the most prominent spot on the breast contour, and therefore it sat on the full bust girth. This may not reflect the exact location of a nipple, but it is how the bust point is recognized visually over clothing. Major areas related to the measurements are illustrated in Figure 2.

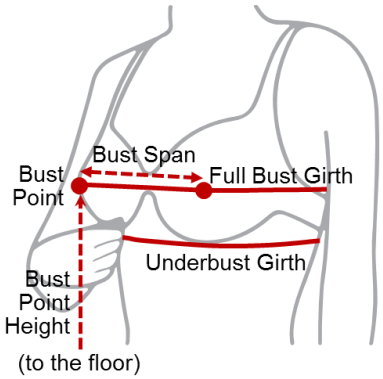

Figure 2. Measurement locations on a subject body

Statistical analysis

For the first research question, one-way ANOVA was used to compare the average breast volume among different cup size and personal judgment groups. Scheffe's post hoc test was followed for further analysis. Paired t-test was selected for the second research question and determined the statistical significance of anthropometric changes after the selected brassiere was worn. To answer the third question, the relationship between breast volume and anthropometric changes was analyzed with linear regression. Statistical power was verified based on the effective size calculated from the collected data. SPSS Statistics 24 (IBM, North Castle, NY) and G*Power 3.1 (Heinrich Heine Universität Düsseldorf, Dusseldorf, Germany) software packages were used.

Result and discussion

Every subject selected a brassiere with two shoulder straps. Forty-three participants picked wired bras, while only two chose wireless ones. Various cup structures were chosen, including molded, seamed, padded, lined, and unlined cups; the selection ranged in different cup styles covering breasts fully to halfway. Major reasons that subjects chose the brassieres for were comfort (51%), lifting performance (51%) and movement control (47%). Components in brassieres reported to be problematic in general were shoulder straps (44%), followed by cups (33%), underwires (29%) and underbust bands (16%). Outside of ranking shoulder straps first, the ranking of problematic bra components corresponded with previous findings that overly small cup size (73%), underwire shape (69%) and an overly large underbust band (50%) were the most frequent problems caused by ill-fitted brassieres (McGhee & Steele, 2010b).

Breast size

The descriptive analysis of size measurements taken without a brassiere is summarized in Table 1. The average cup indicator was 4.5 (± 1.2), and breast volume was 313.5 (± 153.6) cm^3 on average. Among the three different methods of breast size measurement, breast volume acquired from 3D scans is considered the most scientific and reliable size indicator. However, the average breast volume appeared considerably smaller than what was reported in other studies: 436 cm^3 (Loughry et al., 1987) and 547 cm^3 (Lee, Hong & Kim, 2004). This may be due to the method used to define the breast base. Since this study employed a curved breast base (Kovacs et al., 2006; Peterson & Suh, 2019), which was generated from each individual's own ribcage curvature, it would naturally yield less volume than other measurements calculated with a flat breast base.

Table 1. Body size and breast size measured without a brassiere

	Height (cm)	Weight (kg)	Full bust girth (cm)	Underbust girth (cm)	Cup indicator (none)	Volume (cm^3)
Mean	165.6	60.6	91.6	77.6	4.5	313.5
Std. Dev.	73.0	8.0	7.4	6.3	1.2	153.6
Min.	152.4	45.4	77.9	66.0	2.0	90.6
Max.	182.9	74.8	107.1	94.2	6.0	712.7

The distribution of cup indicators and breast volume is plotted in Figure 3, and the average breast volume for each cup indicator is shown in Table 2. Breast volume gradually increased as the cup indicator became larger. One-way ANOVA indicated that there was a statistically significant difference in breast volume depending on cup indicators (F=5.266, p=.002). This supports a rationale behind a cup indicator that has been widely adopted in underwear market. The statistical power was calculated to be above 0.80 with the given number of participants.

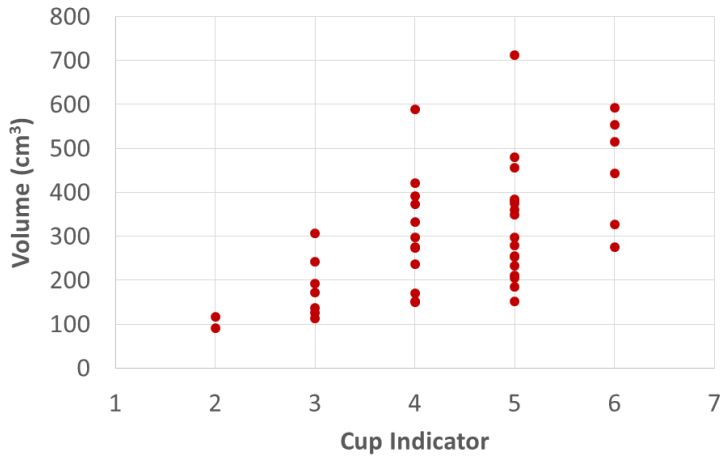

Figure 3. Cup indicator and breast volume

Table 2. Average breast volume by cup indicator

Cup indicator	N	Average breast volume (cm^3)	
2	2	103.96	a
3	7	184.39	a
4	12	305.40	ab
5	17	327.54	ab
6	6	450.95	b

* Superscripts a and b indicate Scheffe's homogeneous subsets

However, a post hoc test (Table 2) did not suggest clear difference between neighboring cup indicators. No statistical difference was reported for the breast volume between cup indicators from 2 to 5 and from 4 to 6. Significant volume difference was found only between very small sizes (cup indicators of 2 and 3) and a very large size (cup indicator of 6). There was a considerable amount of volume overlap between neighboring cup indicators, which would hinder people from determining an exact cup size. Despite the overall statistical significance, cup size classification was not delicate enough to distinguish nearby sizes. These findings support the claims of previous researchers (Chen, LaBat & Bye, 2011; Pandarum, Yu & Hunter, 2011) that current cup sizing system needs to be improved to better represent breast size.

Regarding subjective judgments on breast size, the average rating was 3.0 (± 0.9) out of a 5-point scale. More than half of participants (58%) answered that their breast size was appropriate. The rest (42%) was dissatisfied with breast size because it was small (22%) or large (20%). This response parallels previous findings related to overall body image satisfaction (Swami, Cavelti, Taylor & Tovée, 2015). The subjective judgment showed a strong positive relationship with breast volume (Figure 4, F=9.410, p<.000), but the relationship was not significant enough with bust girth (Figure 5, F=2.865, p=.035). Based on the high enough statistical power (0.95), it could be concluded that personal preference on breast size were based on factual breast volume within the given subject group.

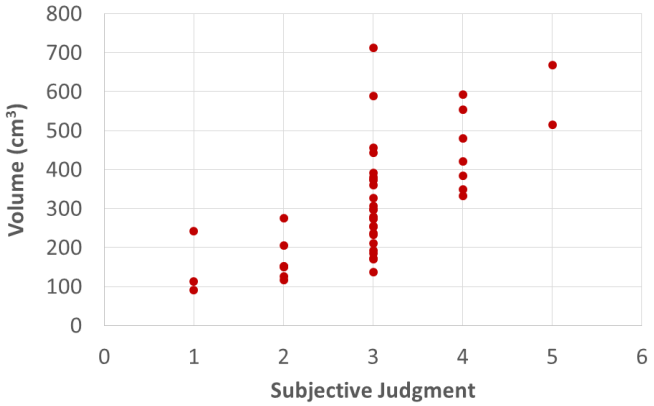

Figure 4. Subjective judgment and breast volume

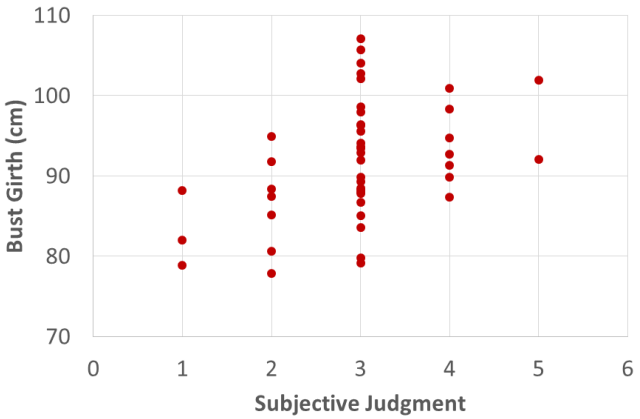

Figure 5. Subjective judgment and full bust girth

Table 3 shows the average breast volume and full bust girth for each subjective judgment level. An 'appropriate' breast size was estimated to be 314.83 cm^3 in breast volume and 93.04 cm (36.63 inch) in full bust girth. Homogeneous subsets determined by post hoc tests suggested that breast volume was clearly classified by small and large sizes. A rough agreement was reached among the participants that a volume below 315 cm^3 was regarded as a small breast, and a volume above 315 cm^3 was considered a large one. It must be noted that this observation came from American university students in their late teens and early twenties. The findings may be different in other studies depending on the factors such as age or sociocultural backgrounds (Song & Ashdown, 2013).

Table 3. Average breast volume and bust girth by subjective judgment levels

Subjective Evaluation	N	Average breast volume (cm^3)		Average full bust girth (cm)	
1. Too small	3	148.40	a	83.03	a
2. Slightly small	7	168.53	a	86.61	a
3. Appropriate	26	314.83	ab	93.04	a
4. Slightly large	7	444.62	b	93.60	a
5. Too large	2	591.18	b	97.00	a

* Superscripts a and b indicate Scheffe's homogeneous subsets

Anthropometry with and without a brassiere

Anthropometric information was extracted from the second body scan to estimate cup indicator, breast volume, bust girths, and bust point location. The estimations were compared before and after the selected brassiere was worn. A descriptive analysis on breast size change is given in Table 4. The subjects had an increase in breast size after the brassiere was on, and significant increases were verified by paired t-tests.

Table 4. Breast size measured before and after wearing the selected brassiere

	Full bust girth (cm)		Underbust girth (cm)		Cup indicator (none)		Volume (cm^3)	
	before	after	before	after	before	after	before	after
Mean	91.6	94.1	77.6	77.4	4.5	5.5	313.5	382.8
St.Dev.	7.4	6.9	6.3	6.0	1.2	1.4	153.6	131.3
Min.	77.9	80.9	66.0	66.1	2.0	2.0	90.6	126.6
Max.	107.1	107.2	94.2	92.9	6.0	9.0	712.7	679.2

As shown in Table 5, a statistically significant size increase was found in every measurement except underbust girth: breast volume (t=4.529, p<.000), full bust girth (t=8.193, p<.000), and cup indicator (t=6.711, p<.000). The statistical power stayed above 0.99 in all t-tests with the given number of participants. Although more than half of the participants' subjective judgment on breast size was 'appropriate' (Table 3), the average breast volume significantly increased from 313.5 cm^3 to 382.8 cm^3 after wearing a brassiere. Full bust girth also significantly grew by 2.45 (± 2.01) cm (0.96 inch) on average, while underbust girth did not change (Table 5). This much increase in full bust girth equal to a one cup size going up in the conventional sizing system, and this was supported by the fact that the cup indicator increased by 1.05 (± 1.03) on average. Breast size increase was more than previous research (Cha, 2012), where bust girth increased only by 1.48 cm (0.58 inch) on average when a brassiere was designed and fitted to a wearer by the researcher.

Table 5. Paired samples t-test with and without brassieres

		Paired Differences						
					95% Confidence Interval of the Difference			
	df	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	Sig.
Full Bust Girth	45	**2.45**	2.01	0.30	1.85	3.05	**8.193**	**.000**
Underbust Girth	45	-0.23	1.76	0.26	-0.76	0.30	-0.890	.378
Cup Indicator	44	**1.05**	1.03	0.16	0.73	1.36	**6.711**	**.000**
Breast Volume	45	**69.39**	102.77	15.32	-38.51	100.26	**4.529**	**.000**
Bust Span	44	**-2.39**	1.65	0.25	-2.89	-1.89	**-9.617**	**.000**
Bust Point Height	44	**2.01**	1.95	0.29	1.42	2.60	**6.836**	**.000**

In addition to breast size increases, there was a notable change in breast shape as well. The distance between two bust points was reduced by 2.39 (± 1.65) cm (0.94 inch) (t=-9.617, p<.000), and the location of the bust point moved up by 2.01 (± 1.95) cm (0.79 inch) (t=6.836, p<.000) after the brassiere was worn. The statistical power was above 0.99 in both t-tests with the given number of participants. This change illustrates the effect of a typical push-up bra. The brassiere pushed breasts medially and superiorly so that the breasts were reshaped inwards and upwards. The amount of medial support was larger than the previous result of 0.92 cm (0.36 inch) (Cha, 2012), but vertical support was at a similar level to the previous experimental result (McGhee & Steele, 2010a), where 2 cm (1 inch) elevation was reported.

Influence of breast size on anthropometric changes

Another interesting finding of the research was that anthropometric changes were affected by the breast size. There was a statistically significant tendency that small-breasted women had a more increase in breast volume (F=17.311, p<.000) than large-breasted women. It was also observed that a padded bra was not selected by those participants whose breast volume was more than ~600 cm^3 (Figure 6). The coefficients were estimated to be –0.358 for breast volume and 181.73 for the constant, and both were statistically significant at a 0.001 confidence level. The statistical power was as high as 0.98 in this analysis.

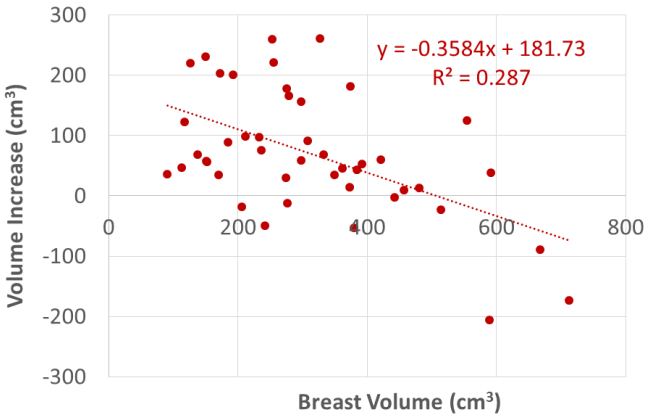

Figure 6. Breast volume and its increase

This tendency was consistent with the bust girth increase (Figure 7, F=7.372, p=.009) as well. The coefficients were –0.104 for bust girth and 11.94 for the constant, and they were statistically meaningful at a 0.01 confidence level. As seen in Figures 6 and 7, for a few subjects with large breasts, size reduction was observed both in volume and girth, which was understood to be the effect of either a compression bra or a minimizer bra. Statistical power stayed at 0.86 and it supported that this finding was valid under the given number of participants.

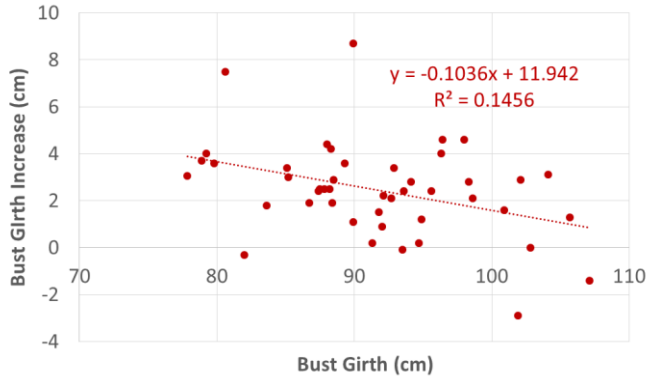

Figure 7. Full bust girth and its increase

There was an influence of breast size on anthropometric changes in terms of reshaping effects. The bust point was elevated significantly more in large-breasted subjects (Figure 8, F=7.188, p=.010), but the relationship was not significant enough with bust span decrease (Figure 9, F=3978, p=.053). The large-breasted subjects lift their breasts more upwards since a big breast is more likely to take a sagged shape than a small one. Statistical power was 0.86 within the given number of participants.

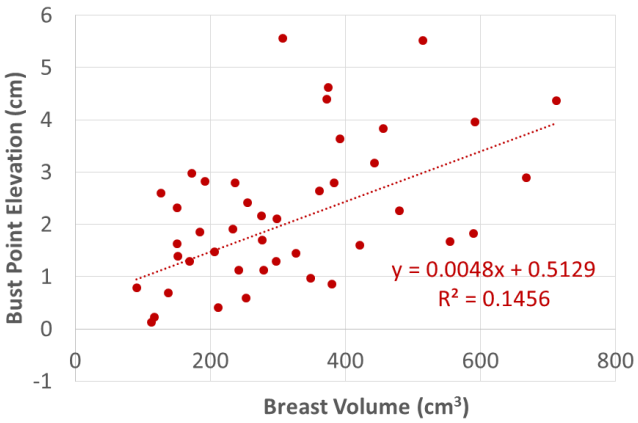

Figure 8. Breast volume and bust span reduction

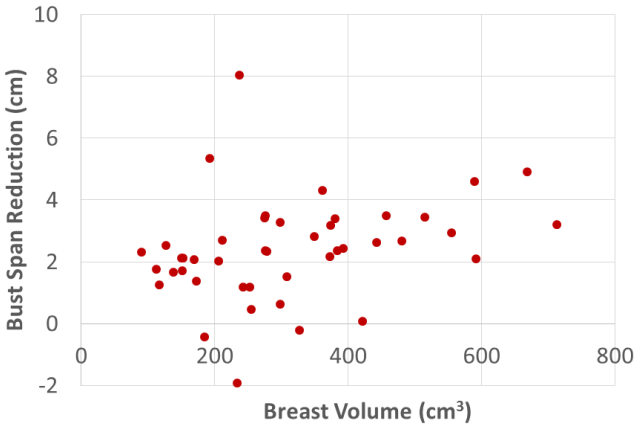

Figure 9. Breast volume and bust point elevation

Conclusion

Through on-site measurement sessions and surveys with 45 female subjects, breast size and the role of a brassiere were investigated. Breast volume was calculated from 3D scans, and cup size indicators were acquired from the girth difference between full bust and underbust. Subjective judgments on breast sizes were collected via questionnaire. By comparing breast measurements before and after subjects wore brassieres, anthropometric changes were observed and used to quantify the impact of a brassiere favored by the participant.

Overall, there was a statistically significant agreement among a cup indicator, breast volume, and a subjective judgment. The average breast volume was 313.5 cm^3, which was considered an appropriate size by research subjects. The average cup indicator was 4.5. Participants' subjective judgments coincided with breast volume rather than bust girth. However, the conventional cup sizing system was limited in its delicacy where neighboring sizes could not be distinguished clearly. This implies that the cup sizing system could be used to capture breast size in an approximate sense, but may not be effective enough to assign an exact bra size to an individual.

The impact of brassieres was demonstrated by significant anthropometric changes in breast volume, full bust girth, bust span, and bust point height. Breast size

increased by 2.45 cm (0.96 inch) in full bust girth, while underbust girth did not change. Consequently, cup size grew one level up on average, and the following breast volume increase was 69.39 cm^3. Changing breast shapes, the brassieres gathered breasts inwards by 2.39 cm (0.94 inch) and pushed breasts upwards by 2.01 cm (0.79 inch). Those anthropometric changes were as expected, but it was meaningful that a numerical amount of the change was identified based on the empirical data collected directly from human subjects. These numerical results could be interpreted as of the level of change in breast size and shapes expected for an everyday bra, since participants selected the favorite brassieres based on their personal preference.

As the last part of the study, it was confirmed that these anthropometric changes depended on breast volume. It might be expected, but was empirically proven that small-breasted participants had a greater increase in breast size through brassieres that lager-breasted ones. On the contrary to this, there were more shape changes associated with large breasts. The elevation of bust points was significantly greater with the participants with large breasts. A practical conclusion drawn from this finding is that a bra product may need to be engineered differently to satisfy the preferences of diverse size groups. For example, the bra cups of a padded bra may need to be designed and graded into different sizes and shapes in a way to accommodate different demands of small- and large-breasted people.

This investigation involves a few limitations in terms of its scope and method. The subjects were recruited by convenient sampling, and therefore the research findings would be meaningful for the limited groups of people, who are American college students. To respect individual preference, the experimental bras were not controlled by the researcher, but selected independently by subjects. Therefore, the observed anthropometric changes were created by different bra styles, and this made further in-depth analysis on bra design difficult. The size label of the selected brassieres was inconsistent and incomparable among diverse manufacturers. The subjects were not visually exposed to the researcher wearing the underwear only, and visual fit assessment was not implemented in the current research due to privacy issues. The researcher could not verify if a subject has chosen the brassiere in a right size.

However, based on empirical data and statistical analysis, this research provides quantitative evidence and verification to enrich an understanding of breast size and the role of brassieres in everyday lives. The findings are expected to establish concrete technical foundations to engineer bra designs in order to better meet the expectations of consumers.

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