UTILISATION OF 3D BODY SCANNING TECHNOLOGY AS A RESEARCH TOOL WHEN ESTABLISHING ADEQUATE BRA FIT

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ABSTRACT

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Aims

- Profile the relationship and differences in bust size, position and shape in a sample of UK bra consumers using 3D anthropometric body scan data.
- Evaluate the presentation of bra sizing by retailers and identify areas of miss communication to characterize effective application to the bra market.
- Collate and validate criteria for achieving adequate bra fit and quantify the physical impact on the bust size, shape and position.

Methods

Three quantitative methods were applied rich data to achieve the research aims. Profiling the variation in bust size shape and positioning within a bank of 3D Body scanning data into Bust height, Breast size, Bust Spread, Breast Drop and Breast Symmetry using the 30th and 70th percentiles as category dividers. Evaluating variation found in bra sizing and fit information provided by retailers and the deviation from the British Standard guidelines and Laboratory fit trials to assess the application of retailer bra fit criteria with grades in four categories; Underband, Cup Volume, Underwire and Bra Strap to a sample of UK bra consumers.

Findings

The findings from this research indicate potential for 3D Body Scanning Technology as a tool to quantify the relationships and differences in five bust characteristics. The technology is applicable in profiling the relationship between the bust and the body. The research presents a new method for measuring breast size which accounts for the prominence independently from the circumferential measurements. . Variation is found among retailers and researchers in bra sizing strategies in the baseline for the size range and the inclusion or exclusion of 'FF' causes greater variance above an F cup. The application of a bra fit criteria has a medium to large statistically significant impact reducing the areas where the fit is too big or small and increasing the cases where the bra fit is adequate. Post Hoc analysis revealed a medium to large negative affect on the bra fit small and bra fit too big classifications and a large positive effect on the bra fit adequate score when tested. Underband category findings are consistent with current research which suggests consumers are more likely to wear a bra which is too big in the underband.

Recommendations

The research built on previous findings while identifying gaps in the field of research. Further research is recommended into the variation in bra sizing which has been highlighted by this research. A recommendation is to link bra pattern cutting and grading to bra size communication to customers. This is seen as key to reducing communication of sizing to the consumer. Current bra fit advise is inadequate in assisting the consumer in selecting adequate support from a bra. Professional fitting is recommended to support this. A key recommendation from this work is that future Bra fit criteria applied to research should include a Bra cup neck edge category. Bra styling should also be considered as the correct size is not sufficient to achieve adequate fit.

CONTENTS

Abstract II

Contents III

List of Figures VI

List of Tables VII

Glossary of Terms IX

1 The Importance of Bra Sizing and Fit 1

2 Literature review 6

2.1 Review topic 1 - Breast shape an d profiling 6

2.1.1 Differences affecting fit 11

2.1.2 Breast Size Categories 13

2.1.3 Summary of review topic 1 16

2.2 Review topic 2 – Bra sizing and fit 17

2.2.1 Bra sizing 17

2.2.2 Consumer selecting the correct size 22

2.2.3 Bra support 23

2.2.4 Summary of review topic 2 24

2.3 Review topic 3 – 3D Body Scanning Technology for Bra Research 24

2.3.1 Reliability of 3D body scanning and the breast 24

2.3.2 Breast measurement protocols 26

2.3.3 Summary of review topic 3 29

3 Methodology 30

3.1 Phase 1 - Bank of 3D body scan data 32

3.1.1 Reliability of 3D body scan data and protocols 32

3.1.2 Sampling strategy/Inclusion criteria/sample analysis 33

3.1.3 Cleaning process 35

3.1.4 Variables and the experimental approach 36

3.1.5 Profiling methodology 37

3.2 Phase 2 Bra size charts and Survey 4

3.2.1 Bra size charts 5

3.2.2 Bra survey 5

3.2.3 Variables and the Experimental approach 6

3.3 Phase 3 - Bra fit criteria and fit trials 6

3.3.1 Bra fit criteria 6

3.3.2 Laboratory fit trials 8

3.3.3 Pilot studies 8

3.3.4 Bras 10

3.3.5 Sampling strategy/Inclusion criteria/sample analysis 11

3.3.6 Variables and the Experimental approach 12

3.3.7 Ethical practice 13

3.3.8 Limitations 13

4 Results 14

4.1.1 Descriptive statistics on sample 14

4.1.2 Profiling 1 – Bust height 14

4.1.3 Profiling 2 – Bust size method 1 15

4.1.4 Profiling 2 – Bust size method 2 17

4.1.5 Profiling 3 – Bust spread 20

4.1.6 Profiling 4 – Breast drop 21

4.1.7 Profiling 5 – Breast symmetry 22

4.1.8 Breast profiling summary 23

4.2 Bra sizing ... 23
4.2.1 Bra sizing knowledge ... 26
4.3 Bra fit Criteria ... 27
4.3.1 Descriptive statistics on sample ... 30
4.3.2 Bra fit criteria analysis ... 31
4.3.3 Overall bra fit scores ... 34
4.3.4 Observations of no bra scans ... 35
4.4 Symmetry ... 36
4.5 Physical impact of bra fit on the bust ... 36
5 Discussion ... 41
5.1 Bra Sizing ... 41
5.2 Bra fit criteria ... 43
5.3 Physical impact of bra fit on the bust ... 44
6 Conclusions ... 46
7 Recommendations ... 49
References ... 51
Appendices ... A-1
APPENDIX A. Literature Review Supporting Tables ... A-1
APPENDIX B. Supporting Documents - Methodology ... B-1
APPENDIX C. Ethical practice follow up report ... C-7
APPENDIX D. Supporting Tables - Methodology ... D-1
APPENDIX E. Supporting Tables – Results and Discussion ... E-10
APPENDIX F. Supporting Figures – Results and Discussion ... F-1

LIST OF FIGURES

Figure 1 Bra sizing measurements (La Senza, 2011) 18

Figure 2 Phases of the Methodology 31

Figure 3 Bust arc width [W103] used to calculate % distribution front and back 37

Figure 4 Front neck to bust Left and right [Scanner reference W144] – From the front neck point to bust point 39

Figure 5 Bust Girth [scanner reference W102] –bridges over the hollows 39

Figure 6 Underbust Girth [scanner reference W106] – A horizontal plane is fitted 39

Figure 7 Bust prominences left/right [scanner reference W106/W106] – The long left and right measurements are taken from a point between the bust over the contours to the side seam 1

Figure 8 Bust girth and bust to bust [scanner references W102 and W86] – tape measure point one bust point to the other 2

Figure 9 Side neck to underbust (scanner reference W53) 3

Figure 10 bra colour worn contrasted with the participants skin tone resulted in missing data 10

Figure 11 Initial Girth Correlations of the database sample 15

Figure 12 the weak correlation between bust and underbust and the front bust percentage distribution 18

Figure 13 Participants with the same distance between bust points but different ratios of bust spread 21

Figure 14 Neck to underbust [W53] –From side neck point to underbust over the bust contours 22

Figure 15 Underband score distribution... 32

Figure 16 Cup volume score distribution 33

Figure 17 Slices at the bust and underbust height of comparative scans 36

Figure 18 Participant 0828 visuals of body shape when improved bra fit is applied 37

Figure 19 Undefined points for the scan of 0831 caused by the cup volume being big . 38

Figure 20 Bra cup neck edge Adapted from: http://thelingerieaddict.com/wp-content/uploads/Image-71.jpg 44

Figure 21 Amended from Source: Office for National Statistics, Annual Population Survey 2010.. B-5

Figure 22 Normal distribution of the bust to bust data F-1

Figure 23 Underwire score distribution F-3

Figure 24 Bra strap score distribution...F-4

LIST OF TABLES

Table 1 Profiling Categories... 4

Table 2 Bra sizes supplier for the research 11

Table 3 Correlation between average bust prominence and the difference between Bust Girth and Underbust Girth (cm) 19

Table 4 Summary of breast profiling 23

Table 5 Bra size denotations across retailers.. 24

Table 6 Bra calculation across research base 26

Table 8 Participants selection of their upper body underbust category and underband size (grouped 28-34 and 36-40)... 27

Table 9 Re-coding according to the three categories.. 28

Table 10 Participant 086822's recoded responses and total scores for each criteria in their own bra and the fitted bra... 28

Table 11 bra fit criteria.. 29

Table 12 Highlighted case where the underband rating is too small 33

Table 13 Aspects of the bra where significant variation was observed between bras.... 35

Table 14 Friedman Test results - Profiling 1 Bust Height 38

Table 15 Friedman Test Results - Profiling 2 Bust size 1.. 39

Table 16 Friedman Test Results - Profiling 3 bust spread 40

Table 17 Friedman Test Results - Profiling 4 Bust Drop 40

Table 18 Ptosis grades (Kim et al., 2005) A-1

Table 19 Eight breast shape factors (Zheng et al., 2007) A-1

Table 20 Bra size calculations across retailers D-1

Table 21 Age categories applied to the bank of scan data D-10

GLOSSARY OF TERMS

Due to the specialist nature of this work, a number of technical and medical terms have been collated into a glossary to assist the reader. The definitions refer to the use of these terms in the context of this work and the author understands that other definitions may exist outside of their own discipline.

Inframammary fold (noun) – The lower fold of the breast where the breast tissue meets the breast wall, in the context of this research the height of the inframammary fold is discussed in relation to its distance from the Suprasternal notch, the nipple point and also the lowest contour of the breast.

Breast Ptosis (noun) – Drooping of the breast, Ptotic (adjective) used to describe the level of drooping as defined by the height of the nipple point in relation to the inframammary fold and the lowest contour of the breast.

Mastalgia (noun) – Breast pain.

Macromastia (noun) – The medical term for the pain or discomfort felt as a result of having disproportionately large breasts.

Suprasternal notch (noun) – An indent at the base of the front neck at the top of the sternum. It is a static point frequently used to take breast related vertical measurements from, also known as the Jugular notch.

Acromian placement (noun) – The position that the highest point of the shoulder sits, referred to as forward or backward to suggest the angle which the shoulder point sits in relation to the body.

Underbust measurement (noun) – A circumferential measurement taken on a horizontal plain around the body, level the inframammary fold.

Underband size (noun) – The underband size is an ordinal inches (“) value used in the bra industry to categorise a range of underbust measurements.

1 THE IMPORTANCE OF BRA SIZING AND FIT

Medical studies have highlighted links between correct bra size, fit and pain, specifically in the area of the back and shoulders (Casselman, 2005; British Chiropractic Association, 2009) defining bra sizing and fit as a current and relevant research area. Prior research is limited in defining discomfort caused by bra fit or quantifying problems with bra fit. Shin (2007) and Chen, et al. (2010) focused on self reported perceptions of problems with bra fit but fall short of identifying the causes or quantifying problems. Scurr (2007) categorises breast pain (mastalgia) in her work into three types, cyclical (related to the menstrual cycle,) non cyclical and exercise related. Scurr (2007) focused predominantly on exercise related mastalgia and the breast health research team have developed the knowledge base on the biomechanics of the breast (White, Scurr, & Smith, 2009) and the impact of bra support on reducing breast movement as well as advances in the understanding of bra fit, sizing and measurements (Brown, et al., 2012; White & Scurr, 2012) which strengthen the importance of current and future breast support research (Scurr, 2007). The focus of the sports science research strengthens the case for further multi discipline development in the research field as biomedical work on everyday bra fit is limited. Research frequently attributes discomfort and pain in the neck, shoulders and back to inadequate bra fit (Chen, LaBat, & Bye, 2010) with an emphasis on inadequate support being a cause however specific relationships between bra fit problems, support and discomfort remain unresolved. Research relating to the provision of adequate bra fit is essential in improving consumer bra fit and reducing the discomfort and pain which can be caused by bras which do not support the bust.

It has been proposed that the physical fit of a bra can be determined by a set of criteria which can affect the physical shape and position of the bust (Wood et al, 2008; McGhee et al, 2010). Bra fit criteria and advice have been discussed on a basic level by both Academic (McGhee at al, 2010) and Industry publications (Marks and Spencer, 2011.) These criteria appear to be lists of advice from single or unreferenced sources (Marks and Spencer, 2011) independent of each other without coherence and have not been analysed or developed into an appropriate framework applicable to both industry and academia. The benefit of a bra fit criteria can be as a checklist for achieving adequate bra fit in order for the bra to provide support. The development of a criteria based on retail bra fit advice could be utilised by the consumer to follow in order to achieve the fit recommended for them by the retailer. Criteria of bra fit developed by Choice Magazine (2005) has been utilised and validated by McGhee & Steele (2010) with an intra-rater reliability of r=0.92. It is applied as a validated criteria in research by McGhee et al. (2006) (2010) and is currently the only academically published and validated bra fit criteria. The Choice magazine criterion (2005) does not cover all aspects of bra fit referenced in retailer literature strengthening the premise that the Industry and Academic criteria are developed independently of each other. This study aims to bridge the gap between retailer and academic bra fit criteria, collate and validate criteria through fit trials testing the application of bra fit criteria to the human body. This validation is to be conducted in conjunction with trials of utilising 3D body scanning technology. The perceived benefits of this are to assess the advice which is provided to consumers by the UK retail market regarding adequate bra fit, areas where insufficient information is provided can be highlighted to make recommendations to the industry. If sufficient information can be provided to the consumer regarding how to achieve adequate bra fit then this could improve the consumer's ability to self administer bra fit and improve the support they receive from everyday bras.

This research builds on an exploratory study into the importance of bra sizing and fit, expanding on its focus and allowing its recommendations to be explored. Key findings recommended expansion of the acquisition and analysis of 3D body scan data in relation to bra fit and sizing. This is possible due to the large scan database, software developments and growing research application of the scanner within the Department of Clothing Design and Technology (MMU) (Apeagyei, 2010). Providing satisfactory clothing fit is a challenge due to variation that exists in body shapes even within one designated size (Simmons et al., 2004)) and variation of physical characteristics can impact on perceptions of bra fit problems and problems with upper body movement restriction. In order to cater for size and shape variation this variation needs to be quantified and profiled in order to assess the needs of the consumer. Once variation is quantified then the bra industry can use this information for the development of bras which cater for the consumer. Aspects of variation linked to age and lifestyle changes could be used by brands to develop styles which alter the natural unsupported shape and provide the preferred shape and positioning by their consumer sector.

Comparisons have been drawn between breast volume measurement using 3D body scanning technology and classic techniques used for medical purposes by Kavocs et al. (2007). Four different methods were compared; 3D laser scanning, nuclear magnetic resonance imaging (MRI), thermoplastic casts and Anthropometric methods. A Key finding was that the four methods compared measured different breast areas and are therefore analysed based on measurement precision only, as direct comparison is not possible. In this respect 3D body scanning was found to represent a replicable non invasive method of breast measurement extraction which is comparable to the accuracy of classic techniques. It also presents a new alternative for quantitative evaluation of bust symmetry, shape, contour and distance measurements for bra fit analysis. Size and shape are parameters which can be measured and also profiled numerically; the focus of this study is on the quantifiable parameters of Standring (2005) and Wood et al, (2008) such as body fat composition and symmetry. Once profiling tools have been developed then application of these and other tools to large scale samples can be recommended for development of profiling tools for wider research applications.

Studies on this research area appear to focus on the 18-25 year age categories as a result of convenience sampling. Frequent references are made throughout literature to variation that is present in bust size, shape, positioning and density due to changes throughout a woman's life which affect the support structure of the breast (Scurr, 2007.) This strengthens the importance of research covering a wider range of participants.

3D anthropometric data acquired at Manchester Metropolitan University (MMU) is accessible and although still a result of convenience sampling covers a wider sample of UK consumers in addition to the University's 18-25 student population. Beyond medical investigations related to issues regarding the female body form and structure, consumer and industry awareness of bra sizing and fit is growing. Recently this has been recognised as a relevant area worthy of academic research due to an increase in awareness of bra sizing and fit issues. A recent study by McGhee & Steele (2010) found at the time of their study that no published study had physically assessed the bra fit of women and systematically evaluated their ability to independently select the correct sized bra against a known correctly fitted bra size. This research focuses on the variables which impact the application of adequate bra size by the consumer.

The recent multidisciplinary work on bra fit highlights the importance of bra fit to a multitude of areas this justifies the development of work from a clothing technology viewpoint which utilises the methods and approaches proven by other disciplines. Aspects of discomfort and pain can be reduced by adequate bra fit but in order to achieve this fit the consumer needs support and advice from retailers. This research hopes to disseminate the advice they provide and assess whether it is sufficient to provide the fit and support the consumer requires.

The background literature defined key areas where there are gaps in current research that could link the medical use of 3D body scanning technology for breast research to the application of the technology to consumer bra fit. 3D body scanning technology has presented advancements in the effective acquisition and analysis of body shape data for application to the medical, biomedical and clothing disciplines. Sources agree that variation exists in breast size, shape, positioning which needs to be catered for by the bra market. 3D body scanning technology presents a quick and precise measurement extraction option for bra fit research to profile the variation that exists which can give retailers in depth information on consumers' everyday shape which could be applied to bra pattern development and the development of garments which closely fit the female torso. Inadequate bra fit can cause discomfort and reduced support, the consumers' ability to select a bra which provides adequate support is aided by the size and fit advice provided by retailers.

The research Aims break the research title 'Utilisation for 3D body scanning technology as a research tool for establishing efficient bra fit' into the main phases defined by the literature. The first aim comprises of evaluating the potential and limitations of using 3D body scanning technology to profile and quantify physical variations in the bust and the body as highlighted in the literature which include bust size, position and shape. Sizing was highlighted as a problem area for the communication of bra fit to the consumer and consistency of information and procedures within the literature is an area which has not previously been evaluated. Aim 2 outlines the evaluation of current UK sizing calculations and characterising effective communication to the bra market. The literature review suggests variation exists and evaluation of this variation is required to define key areas where misinterpretation can occur. The next phase is to pilot the use of 3D body scanning technology to assess bra fit, this links back to the use of the technology for aim 1 but also to highlight limitations and the parameters within which the technology can be used effectively. This is to be in line with the development of a bra fit criteria and fit assessment. This systematic approach encompasses three key aspects of Utilising 3D body scanning technology for bra fit research while challenging existing bra fit paradigms. The paradigms in bra knowledge that exist currently centre on the basic understanding of bra sizing by the consumer. There is an understanding that there is a standard calculation to determine correct bra fit and that adequate bra fit can be determined a bra fit criteria. These paradigms will be tested as if they are false assumptions or have any aspect of miscommunication they are seen by the researcher as potential obstacles to improving consumer bra fit.

AIMS

- Profile the relationship and differences in bust size, position and shape in a sample of UK bra consumers using 3D anthropometric body scan data.
- Evaluate the presentation of bra sizing by retailers and identify areas of miss communication to characterize effective application to the bra market.
- Collate and validate criteria for achieving adequate bra fit and quantify the physical impact on the bust size, shape and position.

2 LITERATURE REVIEW

The structure of this literature review divides into three main sections. Review topic 1 on breast profiling breaks down literature on defining breast size, shape and the breast in relation to the rest of the body. Medical studies relate to breast health research and predominantly breast surgery for reduction augmentation or correcting aesthetic anomalies. Review topic 2 covers bra sizing and fit which analyses literature on the impact of bra fit on the breast, reviewing literature on bra sizing calculations and the impact of bra fit on the wearer, which includes areas of bra discomfort and the effects of bra support. This area includes aspects of sports science research which covers support and breast movement during exercise and medical studies linking pain to bra fit. These three sections summarise the current work under the main title of 3D body scanning technology and bra fit. As bra fit is a topic which spans disciplines, literature is included from medical, sports science, clothing, technology and consumer based research. The final review topic, review topic 3 covers existing use of 3D body scanning technology for bra research focuses on the application of 3D body scanning technology to the breast and torso region, as well as breast volume measurement which is a specific aspect of breast size which is difficult to profile, and the limitations of the technology within the scope of this research area. This section brings together comparable studies in order to justify further specific developments in the area of applying 3D body scanning as a research tool for measuring the parameters of bra fit.

2.1 REVIEW TOPIC 1 - BREAST SHAPE AN D PROFILING

Agbenorku et al. (2011) profiled breast shape in very general terms as being a gentle downward vertical flow from the suprasternal notch to the nipple-areola and mildly convex from the nipple-areola to the inframammary crease. The suprasternal notch is a point at the front base of the neck and according to Agbenorku et al. (2011) a downward flow is expected to the nipple-areola, this definition assumes the nipple point is the fullest point of the bust. The inframammary crease also known as the inframammary fold, is crease beneath the breast where the breast tissue meets the rib cage. This very general definition does not identify any differences of shape which can exist within the description.

In Grays Anatomy (Standring (Ed.), 2005) breast shape is categorised into hemispherical, conical, variably pendulous, piriform (pyriform/Teardrop shape), thin and flattened. Although these shape classifications are not often used in a retail environment to describe the breast shape they are fundamental to the terminology used by breast surgeons. These categories are simply listed without further definition or classification. Another source (McGhee & Steele, 2011) designated the shapes ‘pert’, ‘broad’ and ptotic. These and Gray’s (2005) terms lack traceable definition which makes them applicable to this study but difficult to directly relate and validate against the data. Differences in shape could impact on the support required and the needs of the bra wearer.

Breast shape and size is said to be influenced by 6parameters, Genetics, Ethnicity, Dietary factors (which incorporates body fat composition), Age, parity (symmetry and asymmetry) and hormonal (Standring (Ed.), 2005; Wood et al., 2008). These parameters alone suggest a diverse range of variables impacting the shape and size of the breasts throughout the female population. Scurr (2007) updates this list with whether women have undergone surgical procedures on the breast. Breast surgery represents one of the lifestyle choices which directly impact breast size and shape. Berry et al (2011) attribute some variation found in their research to breast surgery, cultural, geographic and psychological factors which although are not among the 6 parameters it could be argued that geographical could be incorporated into Genetics as neither Berry et al (2011) Standring Ed. (2005), or Wood et al. (2005) have justified or validated their parameters it is difficult to discuss the merit of their categories. Published literature falls short of identifying tools and procedures for profiling differences and relationships caused by these parameters. Scurr (2007) suggests that these parameters will affect the supporting structure of the breast and as a result the shape and size. This is key to applying quantitative measurement parameters to classify the variation and to measure the amount of difference that each parameter or variable is responsible for.

Brown et al., (2012) recruited a convenience sample of 93 participants with an average age of 27.5 (SD 5.6years) an average height of 1.67m (SD0.6m) and an average Body Mass of 65.6kg ($SD 11.0\text{kg}$) and merged recognised methodologies to extract anatomical data and analyse relationships with breast size. Brown et al., (2012) concluded that there were anthropometric differences and differences in Body Mass and BMI between smaller and larger breasted women.

Agbenorku et al. (2011) focused on profiling normal values of young adolescent breast to provide a guideline. The age range of 16 to 22 years with a mean of 17.43 years, a limitation of these findings is that the standard deviation is not quoted with the central tendency giving no guide as to the spread of the data across the 438 person sample. Although the study accepts the need to record Age, height and body weight among other clinical information this data is not used in the analysis or mentioned as potential confounding variables or controlled for in the statistical analysis. The only discussion on this area was that age had no impact on bust height this is a claim which is hard to substantiate among a small sample age range.

Agbenorku et al. (2011) documented all manual measurement protocols clearly and there is an acknowledgement that prior studies in the area have all followed different protocols. This is however not recognised in the discussion section which claims adolescent breasts appear to have a 2-4cm higher nipple position than more mature breasts. This claim cannot be substantiated until the differences between the protocols adopted in comparable studies are analysed. Any impact the protocols have on the data extracted impacts the validity of the findings. The study suggests further investigation into a negative relationship between nipple height and age is required.

Fitzal et al. (2007) looked at quantitative assessment of breast symmetry among cosmetic surgery patients. Their aim was to determine quantitative measures for breast symmetry after breast surgery had been conducted. This study was prompted by experience as they judged that too much variation of opinion existed in current subjective assessment methods. The theory behind the ‘breast symmetry index’ developed by the authors was that the mathematical properties (area, circumference, nipple position) of one breast subtracted from the other could be used to describe the percentage variation between the two, if there is no difference in shape and size between the two breasts the symmetry is perfect. 27 participants who had undergone surgery on their breasts had clinical frontal and side pictures taken of their breasts and the inter reliability was tested by five experts and five non experts using the breast symmetry index method. Correlation was evaluated between subjective summary scored by 33 participant, five experts and five non experts and the breast symmetry index scale as further evaluation. They determined there was a strong positive correlation between symmetry analyses using a breast symmetry index and professional observation. The breast symmetry index subtracted the distance measures of one breast from the other and determined that <30% is good symmetry and >30% is bad aesthetic symmetry. The use of the percentiles to break down results into categories is consistent with the work by Chen et al. (2010) to classify levels of variation. Fitzal et al. (2007) identified limitations of the study as its inability to define more variation categories than good or poor. They identified this as a limitation of the technology's 2D nature suggesting 3D technology could further break down the difference.

The researcher sees a further limitation in that the samples used by both Chen et al., (2010) and Fitzal et al., (2007) are not representative of the population that is being looked at therefore the use of percentiles only breaks down the variation found in the sample. In order for the application of these parameters to be applicable to the population, expert opinions could be brought in to validate the categories. The context of this study is in post-cosmetic surgery assessment however it presents justification for using mathematical breast size and shape calculations to look at breast profiling.

Ptosis or breast droop is a physical characteristic which defines the relationship between the nipple level and the inframammary fold level. Ptosis is a shape and position characteristic which can be seen on the unsupported breast. There are 4 ptosis grades collated by a 2007 study (Kim et al., 2007). These range from none where the nipple and most of the gland are above the inframammary fold to Major where the nipple is at the lower breast contour (the lowest curve of the breast) and below the inframammary fold (Appendix A.0, A Table compiling the Ptosis grades defined in Kim et al's., 2005 study.) These categories use the ratio between one, two or three variables to classify Ptosis, the ratio is used as a profiling tool.

The study discussed the limitations of photographic images as the magnification of the images used were not standardised and a scale was not applied to the image to allow for direct measurements to be extracted. The author suggests this as a limitation but if a scale was applied to these images direct measurements could be calculated. Ratios between The height of the Nipple point, the Inframammary fold and the lowest contour of the breast were used to categorise ptosis into one of four grades. Without the use of absolute measurements to put them into context, it is possible that there are relationships between other breast characteristics which this medical study does not investigate. The context of the article is breast surgery assessment only. This provides an interesting area to analyse as the tools could be applied to other aspects of breast assessment. This study identifies ratios and relationships as a statistical tool for the analysis of breast parameters.

Medical studies on breast size and shape are rooted in breast surgery research and as a result the ‘ideal’ shape and size is discussed as this is what is aimed for when conducting breast surgery. The general consensus is that the ‘ideal’ bust is full, without ptosis (breast droop) and that has good symmetry. Berry et al., (2011) acknowledge this ‘ideal’ could be the result of advertising and globalisation of the ideal female figure and that it is subjective they use quantitative methods to record measurements and calculate ratios explained by their sources. Berry et al., (2011) record variations in breast implant size and shape and discuss these in relation to proportions and ratios. The numerical tools of the research are directly applicable to profiling variation in breast shape and size in this current study, measurements of the breast will be taken in replacement of measurements of an implant.

Agbenorku et al., (2011) recommend that in order to profile the shape of the breast the overall height, body weight, breast shape, ptosis and projection must be noted. This gives a profile of the situation of the breast among the rest of the body as well as a profile of shape. Size and shape are principles which can be measured can also be profiled numerically; this presents a focus for this study on the quantifiable parameters of Standring (2005), and Wood et al (2008). Once profiling tools have been developed then application of these and other tools to large scale samples can be recommended.

This is a key limitation in the current literature base and suggests as Brown et al. (2012) recommended that further research could be conducted into the relationship between anthropometric variables and breast support. McGhee and Steele (2011) in their research on Bra volume and breast size highlight that breast shape may be as important as volume. The study determined that a range of breast volumes could be attributed to one bra size defining limitations to a sizing system which just incorporates breast size.

2.1.1 DIFFERENCES AFFECTING FIT

Chen et al. (2010) identified that differences in body shapes provide obstacles to achieving adequate bra fit. Chen et al. (2010) utilised 3D body scanning technology to attain measurement data and applied angle classification software before the data was inputted into Statistical Package for the Social Sciences (SPSS) for analysis. The participants were put in ranked order against each of the pre-defined categories. Shoulder slope, bust, back curve and acromian placement (the position that the highest point of the shoulder sits) and divided into 3 groups using the 30th and 70th percentiles. The 30% with the lowest were grouped into square shoulder slope, large bust, round back and backward acromian placement; the other two groups were set accordingly.

Statistical significance was tested for and post hoc analysis performed. Chen et al. (2010) recognised that the use of 3D body scanning technology and the use of algorithms to determine body shapes represent a promising option for classifying the relationship between body shapes and achieving adequate bra fit. The study identified the Female Figure Identification Technique (FFIT) as one of the advances in this area.

The FFIT is an integrated 3D body scanner and software technique derived from Simmons et al. (2002) research on classifying body shapes and validated by Simmons et al. (2004). Bust, waist, hip, high hip, abdomen and stomach measurements are extracted using [TC]^2 3D body scanning Technology to classify female bodies into one of 9 predetermined categories based on a combination of 5 variables. The mathematical variables used absolute differences between measurements, the ratio of one measurement to another and the difference between one measurement and the average of the others to quantify the shape classifications. The opportunities and limitations of linking this research to bra fit are not highlighted by Chen et al. (2010) and the researcher sees this as a limitation.

Chen et al. (2010) reviews the work conducted by Simmons (2002), and Devarajan, Istook (2004)and presents a limitation as being missing data on shoulder slope, bust prominence and back curvature which Chen et al. (2010) states are key upper body shape characteristics. The researcher does not support this claim as the research conducted by Simmons et al. (2002; 2004) focuses on overall female body shape classification and not specific upper body shape classification, this could be a recommendation rather than a limitation. Chen et al. (2010) do not present any strong justification for the selection of these particular physical characteristics in relation to bra fit. There was limited published literature available at the time but Lee et al. (2004) and Nicoletti et al. (2009) had discussed a relationship between physical characteristics and bra fit briefly. It is possible a limitation of Chen et al.'s (2010) work was a focus primarily on fashion and apparel literature rather than across disciplines and medical research.

Chen et al. (2010) assessed shoulder slope, bust prominence, back curvature and acromian placement characteristics to perceptions of bra fit among a sample of 18-25 year old participants (n=103). The central tendency and standard deviation are not quoted which does not support the claims in the conclusions that the study applies statistical methods. The statistical methods applied must be carried out with caution and with more statistical accuracy if applied to further research. Chen et al (2010) concluded that there is a relationship between body size and shape variation and variation in perceived bra fit perceptions.

This mixed method study classified correlation between physical characteristics and perceptions of bra fit acquired through a qualitative questionnaire. The study used two way interactions to determine the combination of figure classifications and questionnaire responses to draw conclusions based on angles. They identified a correlation between backward acromian placement and fewer problems associated with bra support and concluded 'this group of participants likely had small breasts which require less support'. A correlation existed between bust prominence and problems associated with bra fit.

The effect size of each variable on the dependant variable 'problems associated with bra fit' is not identified statistically. Chen et al. (2011) conducted a later study with similar methodology to the 2010 study, on bust prominence related to bra fit problems. Although not detailed in either study the undertaking of further research on this characteristic suggests the previous study may have influenced the further research choice. The key findings of the 2011 study (Chen et al.) are identified as being a positive correlation between round back curvature and satisfaction with bra support. However Chen et al. (2011) Identified that bust prominence presents the greatest influence and exploring and presenting the data a different way may have revealed this. Justification for this claim is limited though as causes for findings are mentioned but not presented in analysis.

The study developed the use of percentiles as a statistical method to profile body characteristics and conduct two way interaction analyses with a questionnaire to report findings on the effect of specific body characteristics on bra fit perceptions. Although the conclusion suggest a relationship between these characteristics and bra fit. It is unclear why these particular characteristics were selected and the specific statistical relationships. This highlights the need for further anthropometric size and shape profiling and justified analysis.

The current base of research on differences effecting bra fit identifies merits of multidisciplinary work strengthening the justification for methodologies of a clothing based studies. (Chen, LaBat, & Bye, 2010) It identifies that these methodologies and analytical tools could be strengthened by applying supporting methodologies from a medical viewpoint ((Lee, Hong, & Kim, 2004; Nicoletti, Scevola, & Faga, 2009).

2.1.2 Breast Size Categories

Millsted & Frith (2003) conducted a qualitative study on 'being large breasted' and conducted semi structured interviews of 8 white European women aged 20-25 who volunteered to discuss their experiences of having large breasts. It was recorded that the snowball recruitment method using recommendations and social networking was suitable for a population of large breasted women who had a strong opinion on the subject. The study does not document the actual bra size of the participants which limits the validity of the findings as they lack a context for comparison with other work.

If categories of large and small breast are not quantified relatively and the study does not apply effective inclusion criteria for participants this could impact on the reproducibility of the findings. The participants are included as they feel themselves that they are large breasted which in itself validates their inclusion within the context of the study however does not quantify the bust in relation to the rest of the body. A key limitation of this study as with Chen et al.'s (2010) study was a lack of clear inclusion criteria in their methodology and therefore the opinions are not set in context of actual breast size determined by measurement extraction.

In the opinion of the researcher qualitative breast research should be supported by quantitative measurements to set the context of the opinions recorded. Breast size can be numerically determined by measurements and documented. If self reported bra size is used in place of this inaccuracies could occur and findings must be reported tentatively (Brown, et al., 2012).

Breast size is often segmented by retailers according to two categories of bra cup size, the top and bottom end of this scale are often referred to as normal size and plus size. The cup sizes that are used are A-D and DD+. This is a very general method of clustering sizes based on the initial development of bra sizing which has not been updated and the designation of cup size is not standardised across retailers or internationally (Wright, 2002).

In sports bra research the split occurs between the B and C cup sizes and smaller breasts are categorised as A-B and larger sizes as C and above. White et al. (2009) recorded a marked difference between the structure of the support required to reduce breast movement during exercise for smaller breasts and larger breasts when this criteria is used to cluster categorise bra sizes. Breast movement in smaller breasts is thought to be more effectively controlled by compression bra designs, larger breasts may require more support that is offered by encapsulation bras. White et al.'s (2009) findings contracts this and find that when compared to no bra support wearing a compression or encapsulation sports bra reduced breast movement by 56.6% and 56.4% respectively in a sample of female participants (n=8) with a mean age of 24.8 (SD 6.4years) underband size 34 [1.85] and a D cup size participants. This does not suggest any significant difference in the level of support for what can be described as the larger size category in sports research. In retailer literature Marks and Spencer (2011) define different fitting criteria for DD+ cup sizes indicating that there are different requirements in providing support.

Medical studies use the term 'macromastia' to denote disproportionately large breasts. Macromastia is categorised separately from large breasts in Wood et al.'s 2008 study by some of the following clinical symptoms being present; Neck, thoracic spine and shoulder pain, breast pain, headaches, grooving and associated pain caused by bra straps or inflammation of the skin folds that are not attributed to any other diagnosed cause.

This is a very loose definition when linking to clothing research and is often used when conducting reduction surgery on the breast where an amount of perception is present on the part of the patient. A four stage methodology was applied in Wood et al.'s study to ensure that the inclusion criteria was covered by the 30 participants between 18-26years who had self reported thoracic spine (the central section of the spine) pain and the participants perceptions of the pain they were experiencing. An assessment of bra fit according to a bra fit criteria and estimation of breast size using international guidelines were conducted. Out of the study 26 participants provided complete data sets that met the inclusion criteria.

The study found little meaningful correlation between breast size and thoracic spine pain intensity in this area or thoracic spine pain and bra fit. Only one specific aspect of pain was analysed which suggests a need for further research into aspects of breast specific pain or discomfort thought to be caused by the bra. A study by Nicoletti et al. (2009) looked at macromastia in relation to whether breast reduction is considered functional or cosmetic. The study comprised of a review of current methods of assessment of breast size from a view to creating a criterion for who is invoiced for the costs of breast reduction surgery therefore giving a specific classification for breast size in relation to breast reduction to reduce pain.

Nicoletti et al. (2009) considered the breast as a variable in overall body proportion not just an independent measure. The study highlights the international nature of the topic by referencing the American Medical Association and the Italian Society of Plastic, Reconstructive and Aesthetic Surgery (SICPRE,) whose criterion is used to base these decisions on. Existing US regulations (2009) state that when 500g of breast tissue or above is removed per breast or if postural disorders are observed it is classified as functional and the reduction is fully funded. The study considered that a 500g reduction on a small frame and height will be very different to the impact to a large frame and height and apply ratio to the equation. Based on the researchers experience and prior anthropometric data (from 1986 to 2004) they conclude that the ratio of preoperative suprasternal notch (indent just below the throat) to nipple distance to total height could be used. A ratio of between 3.95 and 5.31 with a mean of 4.60 was used to determine that a ratio ≤5 was considered function breast reduction and >5 was cosmetic. Therefore a ratio of clavical notch to nipple distance to height of ≤5 is considered to be a large breast. This provides a more accurate objective evaluation of the breast in relation to the rest of the body which is applicable to the current research relating to profiling relationships in breast size and shape by looking at the breast as proportional to the rest of the body.

This links together the type of methodologies used by Chen et al. (2010, 2011) in their purely statistical approach and Fitzal et al. (2007) in their purely experience based approach. In the UK this assessment is conducted on an individual case basis (NHS, 2010) which suggests the need for further standardisation of breast size assessment internationally.

The strength of qualitative research on sensitive and personal topics such a bra fit is highlighted by studies. A limitation can be the lack of physical measurement and inclusion parameters to provide context for findings. This gap has been identified as an area worth further investigation to strengthen the quantitative base for qualitative research. Breast size as a proportion of overall body size and methods for defining this are areas which require more research.

2.1.3 SUMMARY OF REVIEW TOPIC 1

Parameters for measuring difference in bust prominence, bust size and the relationship between physical characteristics and bra fit have been trialled. Within the medical, biomedical and apparel disciplines methodologies exist but vary greatly between studies and connections to an overall breast shape assessment are limited to reviewing asymmetry (Fitzal, et al., 2007; Kim et al., 2007; Chen et al., 2010; Agbenorku et al., 2011).

The relationship directly between breast measurements, between the breasts and overall body measurements represent a method of quantifying the variation found within a sample. Percentiles present a statistical option for profiling the difference found within a sample once key measurements and protocols are established (Chen et al., 2010).

Cluster categories for breast size are grouped as either small or large, methodologies are centred on the use of the alphabet bra size system and centre on cup size only to cluster sizes but other anthropometric measurement based systems are being used in a medical context (Nicolett et al., 2009). Further profiling research with defined parameters could strengthen the existing body of research.

2.2 REVIEW TOPIC 2 – BRA SIZING AND FIT

This section outlines a review of the impact that a bra has on the breast and incorporates literature that relates to Bra sizing and the effects of bra fit on support. Studies which closely relate to this research define the relationship between breast volume and bra size, bra knowledge, fit and breast support. Literature suggests an international interest in breast shape and size across medical and clothing disciplines and a need for clear methodological approaches to profile the differences that exist.

2.2.1 BRA SIZING

Scurr (2007), in an article justifying breast biomechanics as a credible research area states that bra sizing incorporates independent measurements of the chest girth and cup size. Dundas et al. (2007) support this by describing cup size as the calculated difference between underbust girth and breast girth. Turner and Dujon's (2005) medical study applies the concept of cup size weight but takes into account the relative underband measurement and calculates cup size as a ratio of underbust to bust. The aim of their study was to evaluate cup size calculating as a method for predicting the weight of tissue to be removed during breast surgery to achieve a relevant smaller cup size.

Wright (2002) graphically analysed the bra size measurement extraction and calculation process which is similar to that advised by many UK bra retailers on their websites (Charnos, 2011; La Senza, 2011; Lepel, 2011; Marks and Spencer, 2011; Playtex, 2011; Ultimo, 2011). The basis of the bra size calculation is the underbust girth measurement is taken, if it is an odd number then 5inches are added. If it is an even number then 4inches are added. The bust girth measurement is taken (inches). The difference is then used to calculate the cup size. The measurements are illustrated as shown in Figure 1.

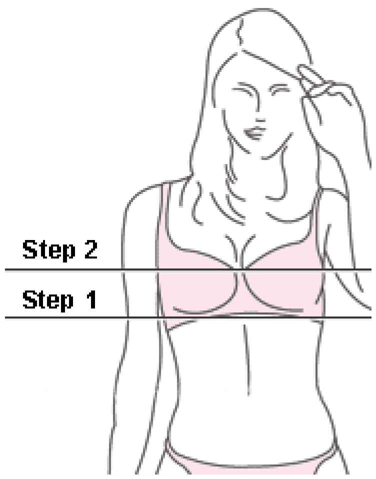


Figure 1 Bra sizing measurements (La Senza, 2011)

Step 1 - Underband (inches) = Underbust Girth (if even add +4 inches. If odd add +5 inches)

Step 2 - Cup size (Alphabetical denotation) = Bust Girth – Underband, Incremental difference (inches) assigned a letter.

Example: Underbust Girth = 30 Inches, Bust Girth = 38 Inches
Underband = 34 Inches (30 +4)
Cup size = 4 Inches (38-34)
Bra size = 34C (cup based on a sizing system which starts with AA as the -1 point on a scale)

The British Standard Institution (1999) states guidelines on the size denotations and intervals that are to be used on bra sizing. The standard advises that the bra size be calculated using the underbust and bust measurement and that the cup size be the difference between these two measurements. It is interesting to note that the British Standard Institution do not advise adding to the underbust before the calculation. This is in line with only one retailer mentioned in Mintels 2010/2011 lingerie reports (utilised in this study as an inclusion criteria, discussed further in the Methodology section.) Eveden Ltd (2011) advises that the Underband should be the underbust measured in inches, the advice is then to use trial and error to achieve the correct cup size utilising fitting advice. The British standard guidelines are also the only publication to recommend a sizing system based on centimetres rather than the traditional inches sizing which is consistent with international sizing.

The calculation is said to have direct correlation with a quantifiable weight of breast tissue. Tables in the study (Turner & Dujon, 2005) show a correlation between cup size and breast tissue weight to be removed during breast reduction surgery, the calculation for underbands of 32-34 inches uses a weight of +115gms per cup size. For greater underband sizes (36-38, 40-42, 44-46) an extra +100gms is added respectively. This is consistent with what Scurr (2007) suggests about cup size being relative to underbust size. This also supports the theory that plus size bra cup sizes (DD+) require increased support as more support is required to balance the respective weight increase**.**

Wright's (2002) study focuses on the point in the bra sizing calculation where the measurements are rounded to the nearest integer. As if the measurements are rounded two times in the calculation there is an argument for decreased accuracy. The study trials the same measurement method but with the measurements rounded to the nearest integer at the initial taking of the measurement which results in double rounding, once when the underbust is measured and once when it is made even (as currently advised by retailers.) This is compared graphically to the calculations being completed with +5inch added to the underbust initially. If the underbust calculation gives an odd number then the underbust is reduced -1inch. The first calculation, due to the use of double rounding has the potential to cover a 3 inch variation in the cup size designated; this suggests a need for greater accuracy when calculating a size based on circumferential measurements. Although this study makes conclusions drawn in relation to comparability to the professional eye of an experienced bra fitter it still has relevance in the basic measurements that are used as a starting point for independent bra fitting. Through the literature search it was found that a number of academic publications suggest that trial and error is the best method to achieve bra fit (Shin, 2007). This is supported by the finding that a number of Bra retailers do not include the bra size calculation on their size charts or published bra size advice (Charnos, 2011; Lepel, 2011; Playtex, 2011). Others suggest that it is a guide only and recommend being professionally fitted for a bra (Marks and Spencer, 2011). It must also be noted that some of the brands included in the Mintel 2010 and 2011 reports (Playtex, 2011) do not sell directly to the customer but through retail distributors which could impact on the inclusion of sizing guidelines on their website. The inclusion of fitting advice on their website does go against this argument by directing comments to the customer.

> "…to make sure you are wearing the best bra for you please visit a lingerie stockist for a professional fitting" (Playtex, 2011).

This suggests that bra retailers feel there could be inadequacies in the bra sizing calculation and its application to providing sufficient fit to the bra consumer.

Chen et al (2011) discuss differences in the calculations used to denote bra sizes and compare Wright's (2002) method against a retailer and a method developed by Washington state university cooperation Extension Service in 1986 which utilises a chest measurement taken above the bust as the base for the underband measurement. Calculations were each used to test whether the participants were wearing the correct size along with self administered bra fit questionnaires. This study highlights the variation in sizing as a result of the calculations advised to the consumer. This is conflicting sizing even before variations between the fit of different retailers is taken into account.

Based on conclusions similar to those described above Zheng et al (2007) worked on developing a new bra sizing system based on anthropometric 3D body scan data from a sample of 456 female subjects using random sampling and stratifying by region in China to ensure a representative sample of the Chinese female population. 3D body scanning technology was utilised to extract measurements from the participants without wearing a bra. The existing and new sizing method are compared for accommodation rate (how much of the population the sizing system accommodates) a limitation of this methodology is that Zheng et al. note that differences exist between manual and 3D body scanning measurement methods but does not make the reader aware of this when applying 3D body scanned measurements to a calculation designed for manual measurements. Zheng et al. state that bras stretch to a range of underbust measurements and as a result the existing underbust labelling is acceptable. It could be proposed that this is the justification for questioning the application of 3D body scan measurements to a manual methodology.

The researchers presented 103 measurements that could be relevant to the breast shape and used principle component factor analysis to decide on 8 primary factors to profile the sample variance. Factor 1- overall body build of which underbust girth was most closely correlated (0.940%) and factor 2 – volume of the breast of which breast depth to width ratio was the easiest measurement to extract most closely correlated (0.9396%) accounted for 43% of the total variance. The p value is not quoted so it is not known whether this strong positive correlation is statistically significant, these factors have a top and bottom end and incorporated overall body size, breast size, position and shape. Breast shape breakdowns include wide, firm, narrow, low, round and flat the resulting sizing system is based on the two principle factors and groups the variance which is essential for the creation of a sizing system which covers a population. The resulting sizing system uses the underbust measurement as extracted by a 3D body scanner in cm with intervals of 5cm. The breast depth width ratio is used to denote the cup size which still uses an alphabet classification. The study demonstrates possibilities for the application of 3D body scanning technology to bra sizing research and provides baseline factors for numerical breast shape classification.

This study relates to the Chinese population only but could provide a template for international sizing development. This research defined key measurement variables and principle factors that can be used to profile the variation in breast size and shape within a population.

Which? Magazine conducted a review of the fit service provided by a number of bra retailers in 2010 which caused a reaction in the industry which resulted in the lingerie and swimwear seminar entitled ‘shaping up for lingerie and swimwear - defining the challenges, exploring the solutions, held by the Association of Suppliers to the British Clothing Industry (ASBCI, 2010). The report suggested that the fitting procedures on the high street are inadequate to provide for the variation in breast size and shape of the UK consumer. The Which? (2010) methodology involved participants above a DD UK cup size aged 25-75; this demonstrates a focus on the plus size consumer only.

2.2.2 CONSUMER SELECTING THE CORRECT SIZE

McGhee and Steele's 2010 study was the first study to assess the consumer's ability to select the correct bra size using 3 different methods and verify this against professional fit criteria. Participants selected their bra size after utilising trial and error, the chest circumference method (as discussed in 2.2.1) and the breast hemi-circumference method. Reliability for each method was established with inter class correlations of R=0.94 and R=0.96 respectively. A common theme found was that there was positive correlation between the fit characteristics of the bra the participants selected through trial and error and the participants own bra, even when this fit was not correct to the bra fit criteria. This could suggest consumer have the ability to reliably select the same fit but lack the knowledge to fit against the criteria required for adequate bra fit. There was a significant difference observed between the size selected by the three methods and the size determined by the professionally fitted criteria. The conclusions of the study suggest that an increase in knowledge could improve bra fit but does not identify any specific short fallings of the bra sizing systems utilised. It does raise the question; if the methods are reliable there is something wrong with the sizing systems themselves or the calculations.

McGhee et al (2010) develop the recommendations from the prior study (McGhee & Steele, 2010) to investigate the impact of knowledge on self administered correct bra fit. Using parallel groups of physically active adolescent females they measured the effects of an education booklet on bra knowledge over a 4 month period. The study aimed to determine whether an education booklet could improve the bra knowledge and fit and level of breast support of bras worn by adolescent female athletes. Data collection included four methodologies to collect the level of bra knowledge, bra fit, level of breast support and discomfort during exercise. Bra fit was assessed through a bra fit criteria (Choice Magazine, 2005). Findings at baseline for both groups suggest a general need for improvement in bra fit knowledge and the ability to choose and fit a bra appropriate to their size and level of support required. Results linked improvements in bra knowledge to improvements in the ability to fit a correct bra independently with the appropriate level of support. A limitation of this and other studies is the use of only self administered qualitative data collection. Although this is the first study to use a professional fit criteria to administer and validate bra fit, a limitation of this study is the exclusion of participants for which the size was not available and participants with breast shape or size could not be correctly fitted by the test bras. No conclusions about the bust shape or size of the participants were drawn nor were these investigated further.

In a later study McGhee and Steele (2011) quantify bust volume in their study on bra size study. This is the first study to directly relate breast volume data and correctly fitted bra size determined by a professional bra fitter. McGhee and Steele discuss in their 2011 paper on Bra volume and breast size that breast shape may be as important as volume and the study determined that a range of breast volumes could be attributed to one bra size.

2.2.3 Bra support

The functional role of a bra is to support the weight of the breast (Shin, 2007). One of the normal elements of garment fit is garment ease; extra room is added to ensure the body can move in a garment. In bra fit garment ease is reversed and fabric is reduced below the body measurements to create support through tension or negative ease which is approximately 10-15cm less than the ribcage circumference (Shin, 2007). The components and stretch properties of the bra fabric are integral to this tension and support. Published findings (Wood et al., 2008) have linked the age of bras to the support given. The structure of the bra is supported by the fabric and components that make it up; if these deteriorate over time the support is reduced.

An everyday best selling bra from UK retailer Marks and Spencer was tested in a laboratory trial testing for a relationship between breast support and breast movement. The Everyday bra was compared to no bra and two sports bras when testing to see the effects of support on reducing breast movement when running. The study (White et al., 2009) determined that the everyday bra reduced breast movement by 41.3% compared to no bra. In contrast the sports bras reduced movement by an average of 56.5%. This study was conducted using participants with above C cup sized breasts, these participants could be considered as having larger than average breasts making this a plus size study. This study has implications for everyday bra research to increase the support and reduce movement of the breast in everyday wear through a correctly fitting bra.

2.2.4 Summary of review topic 2

Differences exists in the calculation and communication of bra sizing (Chen et al., 2011) which could have an impact on the consumers experiencing of selecting adequate fit from a bra. This presents an area where there is a gap in the current knowledge relating to effective communication. This needs to be clearly defined in order to characterise the application of size information to the bra market. There is an established link between bra fit knowledge and bra fit so clarity of information to the consumer could be an important area.

2.3 Review topic 3 – 3D Body Scanning Technology for Bra Research

The application of 3D body scanning technology to the torso and breast region was focused on specifically whilst citing limited texts in the wider area of 3D body scanning technology. 3D body scanning technology is to be reviewed to give an context to its application as a research tool and alternative options for this research area The scope of this research does not cover an in depth analysis of the general application or development of 3D body scanning technology as this is covered by academic research.

2.3.1 Reliability of 3D body scanning and the breast

Manual measurements follow anatomical reference points and landmarks and use these to label features of the bust and breast (Agbenorku et al., 2011; Brown, et al., 2012). 3D body scanning technology uses geometric landmarks of the point cloud data instead of anatomical landmarks to locate points on the body, an example is the nipple point defined in manual measurements is not found using 3D body scanning technology Han and Nam (2010) discuss this and raise the issue of the bust point that is defined as the furthest point of the bust may not be where the anatomical nipple point is.

The scanner picks up the furthest vertical and horizontal protrusion within set parameters. This point is defined as the fullest point of the bust (bust point) not the nipple, for the purpose of clothing the fullest point of the bust is more appropriate as clothing must fit the body surface and does not depend strictly on the matching of anatomical points, this does not however provide a landmark from which to calculate Ptosis as this is relative to the nipple as a reference point.

There is limited available literature on the limitations of 3D body scanning technology for breast measurement extraction which could be due to the limited research in this area at this time. It could also be a result of the new technology being privately owned and developed. The measurement algorithms for the scanner and protocols for the participants positioning and breathing are not widely published.

Preliminary validation of point cloud data from a 3D body scanner against CT scans has been conducted (Lerch & Anthony, 2008). The findings indicated a light 3D body scanner has percentage differences of 2% when compared to a CT scan of length and cross sectional measurements. This does not however discuss the impact of confounding variables on the scan data as differences between measurements of the body extracted from participants standing and lying down are influenced by gravity.

Initial research into the application of 3D scanning technology for clothing fit has been conducted (Apeagyei, 2010). This study implies 3D body scanning technology is a valuable tool to capture and analyse aspects of body size and shape. The study highlights the potential for 3D body scanning technology to reduce the occurrence of invalid, unreliable and subjective measurement procedures. This is synonymous with the findings in section 2.2.1 Bra sizing which highlight the need for a more accurate and reliable size measurement system.

Research linking 3D body scanning technology to bra fit is limited but one Chinese study (Na et al., 2011) looking into the impact of the apex positioning on a bra. The study trials measurement parameters for research on the breast area in relation to bra fit. Na et al., (2011) do not provide detailed descriptions of how the measurements are taken only the measurement names used by the scanner software (Appendix D-II) these can be used as a guide for research in the area. The study found a statistically significant strong variation in breast depth of 18.28% within one bra size (34B) suggesting variation of breast shape. The study utilises 3D body scanning technology to compare the effects of different bra fit on the breast height, Distance between Bust points, Depth and width of the breast. A limitation of this study is that it does not document the limitations of the technology or the algorithms for measurement extraction, it is important to understand the technology in order to ensure reliable and valid analysis.

Mckinnon and Istook (2002) highlight the threat of variations in subject respiration on the data integrity of 3D scanned measurement data. The study first looked at validating the 3D scan extracted measurements against manual measurements taken at the same time. The scan measurements taken of the control group were accurate to an average of 0.89cm in scans taken consecutively. When compared to manual measurements taken at the same time the average difference between the scan and physical measurements was 1.93cm.

This study highlights the variation between algorithms used for extracting measurements between methods. This technology presents a new level of precision in anthropometric measurement extraction but is not directly comparable to manually extracted measurements and this must be understood when applying the technology. Mckinnon and Istook (2002) analysed the effect of respiration on the accuracy of extracted measurements.

They note that there are variations in breathing patterns of participants. These differences were seen when participants breathed from the diaphragm or more from the chest cavity. These variations skewed the results both negatively and positively when comparing inhaling and holding and exhaling and holding against breathing normally. The study concluded that the recommendation to breath normally provided optimum reliability versus advising the participants to breathe out and hold or breathe in and hold. This study utilised [TC]² white light scanning technology and validates the protocols currently adopted by Manchester Metropolitan University with the use of this technology.

2.3.2 Breast measurement protocols

Lee et al., (2004) conducted a Korean based study on the sensitive topic of measuring women's nude breasts using 3D scanning technology. The methodology detailed the application of combining 3D scanned images when the breast tissue is pushed up and to the side to give a fold line in the skin at the natural edge of the breast. The aim was to define a protocol centred on the anatomical base of the breast and utilised a folding line method to locate the boundary for the breast as a basis for their calculation.

A limitation of this study was the use of only small breasted participants 80A (UK 34AA/A). The limited range of sizes limits further application without further piloting as it is currently an untested protocol for measuring the nude breast of sizes other than 34AA/A. In contrast a later study conducted in Germany by Kovacs, et al. (2007) sampled from patients awaiting breast reduction surgery and therefore the larger end of the spectrum of bra sizing. Lee at al., (2004) describe a limitation of their work themselves as the impact of having to compensate for breast sagging in their methodology which adds complication and therefore room for error.

Wang and Zhang (2007) investigated a gap they saw in breast knowledge which they saw as a need for a library of breast size and shape data. They also factored in the complication that one person can have several breast shapes dependant on the bra they wear as the breast tissue is malleable. Wang and Zhang (2007) saw developments in 3D body scanning as a technology advancement that makes developing a library of breast characteristic information possible.

Scans of nude breast were captured but it was felt that the breast configuration in this setting is not ideal for fashion or bra development as it does not reflect the breast held in an attractive or social ideal position and therefore does not represent the shape that the garment is fit to. In the case of bras, the fit physically impacts on the shape of the bust tissue. Deformation software was applied to the torso in order to replicate the effect of a bra on the bust tissue. Hypothetically this demonstrates the possible effect of applying different types of bras to the body.

Limitations of this research are that the deformation is constructed using software and does not therefore present the basis for a library of breast shapes within a population. The realistic variations that exist in the support provided by a bra due to the fabric and components are not considered. How much the breast tissue can be moved in relation to the body and whether different breast sizes and shapes could impact on this is not considered. This research does however have positive implications on the made to measure bra market as patterns can be developed to try to achieve the deformations created in the virtual environment. This research presents a new approach to using 3D body scanning to measure the breast which with further work could be instrumental to both profiling the impact of bras on the breast and manipulating the malleable breast tissue in a virtual environment.

Manual anthropometric measurements are collected internationally in breast research (Araco, et al., 2006; Wood et al., 2008; White et al., 2009; Chen et al., 2011; McGhee & Steele, 2011). One recent example is Agbenorku et al's (2011) study to develop standardised methods of measuring female breast to determine shape categories. The research specifically focuses on West African adolescents but cites comparable international findings with an older sample. This suggests the authors intend their findings to be internationally relevant.

The study discusses the theory that any protocol which attempts to record the shape of the breast must note the further parameters which affect the relative positioning and ratio of the breast to the rest of the body. The parameters outlined include height, body weight, shape, volume, relative position of the trunk and the other breast (symmetry), ptosis, projection, quality of the breast skin and any pathological morphology of the breast. One limitation of the study is that in the results and discussion only a few specific measurements are pulled out and therefore the study does not apply these parameters outlined to the reported findings. Manual and 3D body scanning present the only two methods of breast measurement where the relative anthropometric body measurements can be taken using the same method so that relationships between the breast and the rest of the body can be analysed. Breast Volume measurement

In 2007 researchers in Germany (Kovacs, et al., 2007) compared breast volume measurement techniques. In order to test the theory that 3D body surface imaging represents a new and less invasive alternative to classical breast measurement techniques. The classical techniques were grouped into 5 categories, Volume calculations based on 2D photographs, Archimedean methods (based on Archimedes theory of water displacement), nuclear magnetic resonance imaging (MRI), thermoplastic casting (based on cast materials applied to a seated participant and left to harder, resulting in a shape which can be filled with water to determine volume) and Anthropomorphic measurements (calculations based on anthropometric measurements.)

Three of these techniques, Anthropomorphic, MRI and Thermoplastic casting are compared with volume calculated (cc) from 3D body scans using Raindrop Geomagic Studio 7 Software (Raindrop Geomagic, Durham, NC, USA.) The key finding for this study was that all the techniques consider different areas when calculating the volume which impacts on the resulting measurements which makes the techniques difficult to calculate. The study concluded that in relation to accuracy MRI and 3D body scanning technology are the most accurate and consistent measurement methods.

A later study (Kayar et al., 2011) compared a different 5 techniques. The Grossman-Roudner Device is a series of volumetric discs to measure volume of the breast manually this method is recommended by the study as being the standard method of breast volume measurement. 3D body scanning technology was not compared in this study. There is no cited justification for it not to be included; one suggestion for this could be that the technology was not available to the researcher. As it was not a rejected methodology in this study it is perceived that it is a viable option.

2.3.3 SUMMARY OF REVIEW TOPIC 3

McKinnon & Istook (2002) recommend that when applying [TC]² white light scanning technology to research participants breathe normally to provide optimum reliability.

Na et al., is the first study to apply 3D body scanning technology to test the fit of a trial bra on the breast height, Distance between Bust points, Depth and width of the breast and found significant results. This presents justification for further research in this area.

The scanner picks up the furthest vertical and horizontal protrusion within set parameters. This point is defined as the fullest point of the bust (bust point) not the nipple, this does not provide a landmark from which to calculate ptosis as this is relative to the nipple as a reference point, this is one aspect that cannot be profiled with 3D body scanning technology.

3 METHODOLOGY

Literature suggests aspects of unintentional miscommunication between the retailer and the consumer on the topic of bra sizing and fit, inhibiting the consumers' ability to select a bra which provides adequate fit. An increase in consumer knowledge is seen as a key area of development (McGhee, Steele, & Munro, 2010; White & Scurr, 2012). This is currently a growing area for research with developments being made from both social and natural science approaches, the researcher acknowledges the importance of the qualitative aspects of this highly sensitive and personal topic and perceives there to be a need for further development in this area once a strong quantitative base is established.

It is appreciated that rich qualitative data is valuable in a topic that evokes a very personal and often emotional response (Freeman, 2008) but without grounding in, or subsequent support from quantitative findings there is limited context to support and validate the findings.

The literature review has highlighted that there are limitations in a qualitative research on this topic area as there is a lack of quantitative context to some of the observations and experiences documented (Millsted & Frith, 2003) an aim of this research is to being to build on and support this quantitative body of work. The scope of this study and the newness of combining disciplines into this topic was seen as a good starting point for an Msc research project which future development could be built upon. Within the proposed timeframe a framework for quantitative data acquisition and analysis is most practical and could provide some of the support for further comprehensive qualitative investigation that is limited at this time. A positivist approach to this research has been adopted, with a view to support the body of research which quantifies bra fit problems in order to strengthen the base on which to build future mixed method and qualitative research in the area.

The three phase framework covers the quantitative methodology structured to achieve each aim of the research.

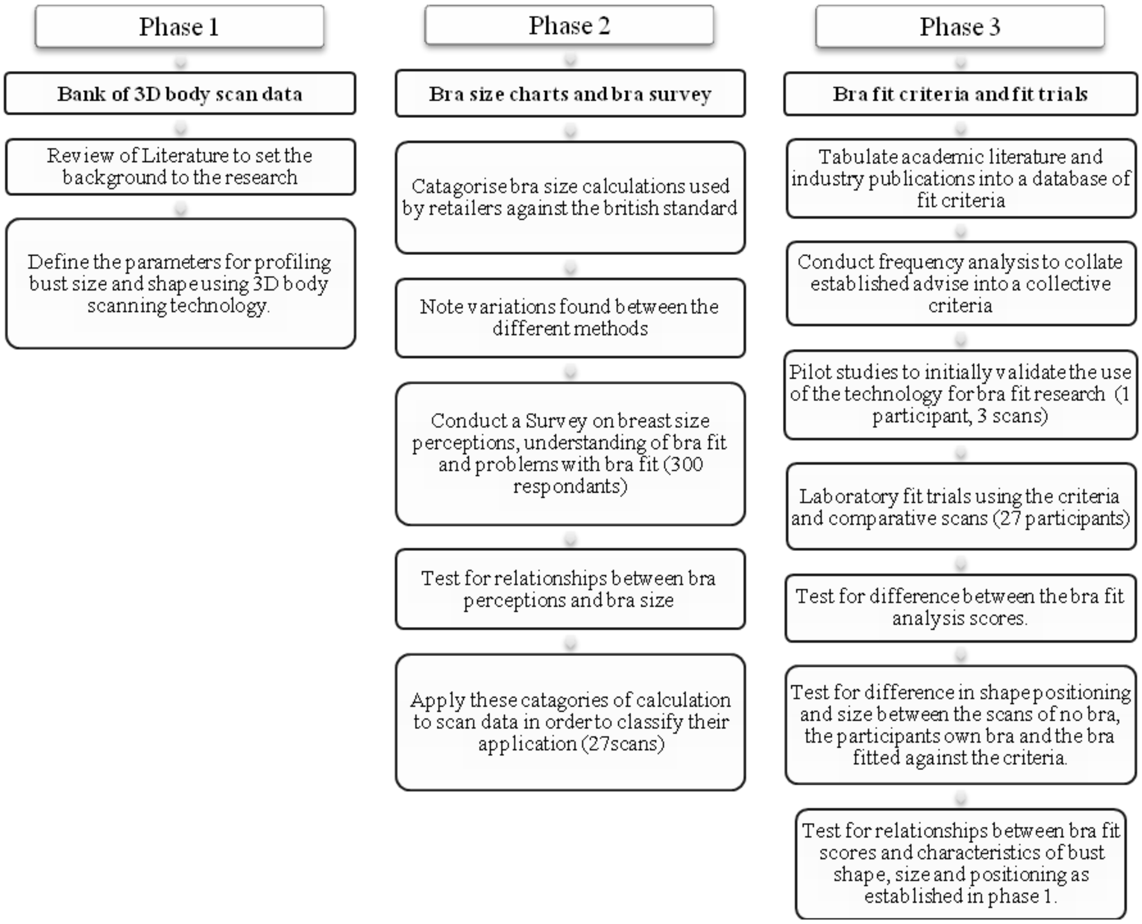


Figure 2 Phases of the Methodology

3.1 PHASE 1 - BANK OF 3D BODY SCAN DATA

Phase 1 covers aim 1 to Profile the relationship and differences in bust size, position and shape in a sample of UK bra consumers using 3D anthropometric body scan data. In order to put this in context a systematic literature search was conducted using broad search terms ‘bra’ ‘breast’ ‘fit’ ‘siz*’ ‘shape’ ‘3D scan*’ were searched in international academic databases. Variations on wording using a thesaurus were searched to ensure articles were not unnecessarily excluded; international spelling variations and truncation were used to include variations which occur with international literature searches.

A research question proposed by the literature was; are there differences in bust size, position and shape that can be profiled using 3D Body scanning technology. The first stage was to adapt statistical methods and parameters as defined by literature and apply these to a bank of 3D body scan data. One area of the bra sizing section of the literature links to profiling of the breast. Bra sizing is said to be measurable using the difference between the bust girth and the underbust girth with a calculation. The following hypothesis centres on the girth proportions which relate to the measurements commonly extracted when conducting bra size calculations.

H0a – The relationship between bust girth and underbust girth within the sample is responsible for all of the variance in bust size and suitable as the only measure for bust size.

H1a – The relationship between bust girth and underbust girth within the sample is not responsible for all of the variance in bust size and suitable as the only measure for bust size.

3.1.1 RELIABILITY OF 3D BODY SCAN DATA AND PROTOCOLS

The [TC]² white light body scanner situated at Hollings Faulty at Manchester Metropolitan University (MMU) is identified through the literature review as being an appropriate data acquisition tool for this research as it is applicable to both clothing and breast research. The use of this specific scanner for clothing research has been verified by Apeagyei (2010).

The scanner is calibrated regularly using a cylinder and set of calibration balls which are hung and scanned to ensure the accuracy and validity of the scanner system. The researcher conducted this calibration before commencing the acquisition of new scan data and as per the guidelines set this is conducted on a regular basis to ensure the validity and reliability of the bank of scan data retained.

The participant positioning is standardised throughout the scanner process with positioning tools within the scanner cubical and instructions given to participants by the scanner technicians. Foot placement guides are visible on the floor to standardise the foot placement of the participants. The participants are instructed to roll their shoulders back and hold out their arms straight and level with the hand guides in the scanner. The participants are instructed to breath normally these guidelines are inline with Mckinnon and Istook's work on the effects of foot placement and breathing on 3D body scan data (2002).

The scales used to weigh the participants were calibrated with weights before every session with 2 10kg weights being put onto the scales systematically to check and calibrate the scales. The anthropometric tape measure is checked against a metal rule prior to each scanning session to ensure that it has not stretched with use.

All equipment was cleaned prior before and after use by each participant. Three scans were taken in the everyday bra as a baseline; they were averaged out to a mean score when wearing that bra.

All of the predefined protocols linked to the use of the 3D body scanner were followed as per the guidelines outlined by the university. This ensured that the bank of scan data and the new data collected were comparable and to eliminate confounding variables.

3.1.2 Sampling strategy/Inclusion criteria/sample analysis

Three primary sampling strategies were employed, Convenience, snowballing and applying a post hoc inclusion and exclusion criteria to an existing dataset, these non stratified techniques were in line with the timeframe and resources for this research project. The sampling strategies utilised were also in line with relevant studies (Agbenorku et al., 2010). The 3D body scanning facilities at Manchester Metropolitan

University are used to create a library of 3D body scans through convenience sampling body scan sessions. The use of the scanner for project work within the faculty has built up a wealth of scans which are being consolidated into a 3D scan data bank. Access to the bank of scan data from MMU's 3D body scanner sessions was obtained through ethical guidelines and the ethical regulations for the use of this data were checked and adhered to at every stage of the research.

Data protection regulations were adhered to and at any point when the anonymously stored data was transferred or stored outside of the 3D body scanning database it was password protected. Participants sign a declaration stating 'I consent to the storage of this data for the purpose of further study' when taking part in the 3D body scanning procedure as per MMU regulations which enables the use of this anonymously stored data for further similar research.

Open calls for scan participants go out through the university's networking systems, although participants from other occupations are included the nature of the convenience sampling means it is largely composed of the student population. This limits generalisation of any demographic conclusions that can be drawn from this sample as it is not representative of a more general population.

Participants are asked to wear a normal everyday bra, (participants are not scanned without a bra) this inclusion criteria is applicable to this research as it ensures that the participants are bra consumers. The demographic information collected and extracted in line with ethical procedure to protect anonymity forms a 'User ID' which is a four digit chronological number which links to the order in which participants have gone through the scanning process and a further four characters denoting Age, Gender and Ethnicity. This provides two of Standring's (2005) principles for analysis, Age and Ethnicity, and presents two aspects of inclusion criteria which can be applied to the data. The data is initially collected using convenience sampling and post hoc inclusion criteria were applied when the data was extracted from the database.

The initial data set accessed comprised of both male and female scan data which was split after the cleaning process and before analysis for this research. Exclusion from the study included participants under the age of 18 as initial breast growth is generally completed by the age of 18-20 and their inclusion would have broadened the range of this small scale research project to include pre-pubescent factors, this is in line with current research (Brown, et al., 2012; Chen, LaBat, & Bye, 2010; White, Scurr, & Smith, 2009). Three cases were filtered out before any analysis as they did not satisfy the condition (0219 did not provide their age, cases 0102 and 0695 are <18).

Cases with missing data for weight and height were excluded on a case by case basis as these were often the result of an administrative error rather than the participant not providing the information. 0759 was one participant with a data entry error on height setting it below normal parameters at 16.5cm which skewed the data the original copy of this data could not be located and as such the height of this case was excluded from analysis.

Although the scanner presents no recorded danger to pregnant women the scanner guidelines recommend that participants do not take part if they are pregnant unless they have consulted and had approval from their doctor. The researcher is not aware of any pregnant participant's scans being retained as part of the database. The exclusion of participants who are currently pregnant is in line with comparable research (Chen, LaBat, & Bye, 2010) (Brown, et al., 2012) as the temporary hormonal changes to the body and on the bust during this time can impact on the validity of findings. Further exclusion criteria specified in breast health research recommends that participants have not given birth or breast fed in the last year or undergone any breast surgical procedures (Brown, et al., 2012) (White & Scurr, 2012). These criteria could not be applied as this data is not available for analysis from this source.

3.1.3 CLEANING PROCESS

The extracted data must go through a manual cleaning process conducted by trained 3D body scanning technicians, to ensure any errors are picked up before the data is extracted into a workable data set, this includes manual corrections to scan errors, removal of poor quality scans which occur due to movement and incorrect positioning by participants. In most cases duplicate scans represent a difficulty in extracting a good scan first time so a repeat scan is conducted or when a number of scans are taken as a baseline for paired sample tests. In order to create the database one good clean scan from every participant who has been through the process was selected. On occasions when multiple scans were captured on one participant at different time periods rather than on the same day, the most recent scan was selected as the scope of this study is limited by time. With this premise in mind the most recent duplicate without error is retained for the database, however all scans with duplicates are manually checked for errors which may have been missed by the scanning technician. Common scan problems are corrected manually and stored with the automated suffix ‘ptmod’ (point modified) so that the point modification can be identified from the original scan and any errors can be gone over and corrected from the original unaltered scan. A single clean scan was retained for each participant that has been scanned to be stored in the new database.

3.1.4 VARIABLES AND THE EXPERIMENTAL APPROACH

The bank of scan data is comprised of participants scanned in their underwear and can therefore profile variation experienced in a bra retail environment as bra measurements are taken over the consumer’s existing everyday bra (White & Scurr, 2012). Guidelines for calculating bra size advise that measurements be taken of a correctly fitting bra. White and Scurr (2012) suggest that retailer protocols ignore standard requirements for the bra worn when measuring and that in order to test the method that retailers advise, the measurements should be taken over the participants own bra regardless of whether it fits correctly, is unpadded or underwired, this is comparable with the sample used in this study.

The first stages of statistical tests were run on the direct measurements that can be extracted by the 3D body scanner in line with the measurements taken in comparable studies (see Appendix D- II.). Direct comparisons between findings of this and previous studies were drawn with caution as variation exists between manual and 3D body scanned measurements (Kayar et al., 2011). Studies using 3D body scanning technology do not define the algorithms for automatic measurement extraction which limits the direct comparability of measurement data. (Chen et al., 2010,2011; Lee et al., 2004) data protection imposed by the software developers could have an impact on the accessibility and distribution of this methodological data.

Length measurements and girth measurements were checked for normal distribution (see Appendix F-I). Data was checked for normality and outliers prior to correlation being checked, in the case of outliers, they have been removed if there is just validation for this only, correlation was checked for linearity and homogeneity of variance before parametric statistical tests were conducted to ensure the data is suitable for these tests. Missing data is to be excluded only if the data is required for specific analysis as the data has gone through a manual cleaning process and does not include any cases with a large number of faults as concluded by the trained scanning technician.

Correlation coefficients were defined using Cohen's (1988) method, weak: r=0.10-0.29, medium: r=0.30-0.49 and strong: r=0.50-1.0 and the confidence level is reported as being below 0.0005 or 0.001. For all analysis the alpha level was set to $p<0.05$ to be in line with current bra fit research (White & Scurr, 2012) but reported as 0.0005 or 0.001 where applicable.

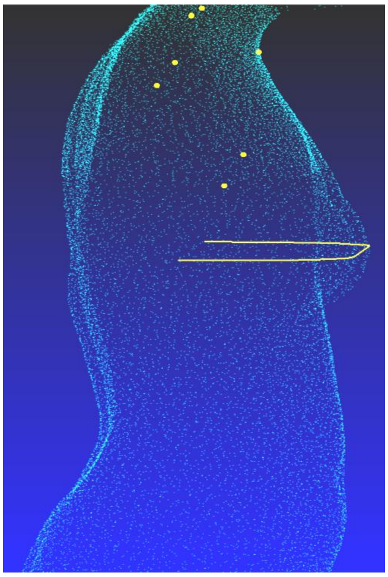


Figure 3 Bust arc width [W103] used to calculate % distribution front and back

3.1.5 PROFILING METHODOLOGY

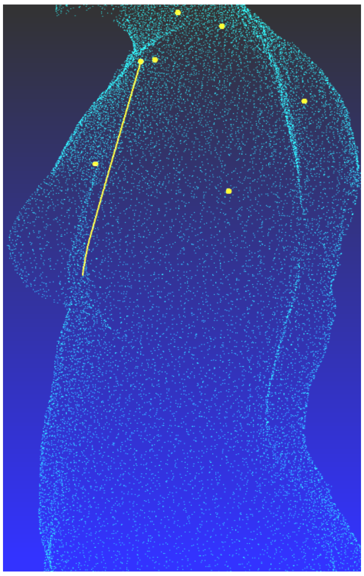
Ratios as used in Nicolleti et al.'s (2009) research were applied to represent the relationship between breast shape aspects, these and other relative calculations synonymous with previous research were utilised as the base for profiling breast proportions and their relationship to the body as a whole (see Appendix D-III.) Percentiles of 30% and 70% were applied to the data to profile each Ratio or Difference between measures within a category following Chen et al.'s (2011) statistical reasoning that the majority will fall around the central tendency and the extremes will lay at either end of the spectrum.

The selected profiles are based on studies highlighted in the literature review and comparable measurements are presented in a table (see Appendix D- II.)

The scanner picks up left and right variations however these could be impacted by how the participants are standing, the scanner procedures are designed to limit the affects of these but when looking into any aspect of symmetry difference between left long and right long shoulder height (new variable Difference_ between_shoulder_heights=W13 RLongShoulderHeight-W13LLongShoulderHeight), the average variation had to be controlled for to limit the impact of how the participant is standing if any variation was found.

Adapting Nicoletti et al.'s, (2009) method of using suprasternal notch to nipple distance and height as tool to denote the proportion of the bust to height. This presented bust height profiling as an area which could be defined by the technology. The scanner has an automatic algorithm set to locate the front neck point and the bust point at the fullest point of the bust based on geographical points on the surface of the body. The bust height profile is a ratio profile calculated as the ratio of the average front neck to bust to overall height.

Correlation between bust height and total height was tested for to ensure that there was not a relationship between total height and neck to bust (scanner reference W144) which would impact the results. When profile 1 bust height was established correlation was checked for again against total height to ensure it was independent.



1. Bust height	Ratio	$\dfrac{\text{Height (Manually taken)}}{\text{Average Front neck to bust (left and right calculated from scanner reference W144 Figure 4)}}$	High, Average, Low

Figure 4 Front neck to bust Left and right [Scanner reference W144] – From the front neck point to bust point

Correlation between bust girth, BMI and other girth measurements are tested for the measurements detailed in traditional bra size calculations are Bust girth taken over the fullest part of the bust bridging the gap between the bust points and Underbust girth taken horizontally level around the body. Bust size 1 is calculated as the difference between the bust and underbust girth.

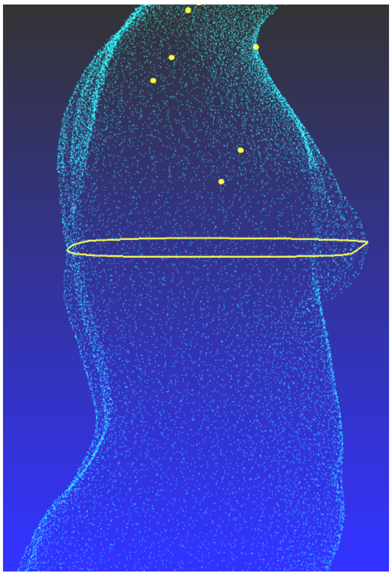


Figure 5 Bust Girth [scanner reference W102] – bridges over the hollows

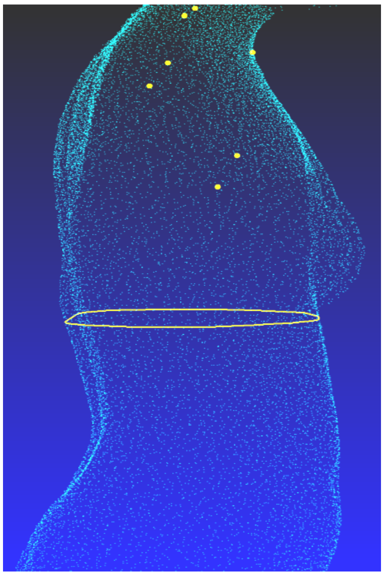
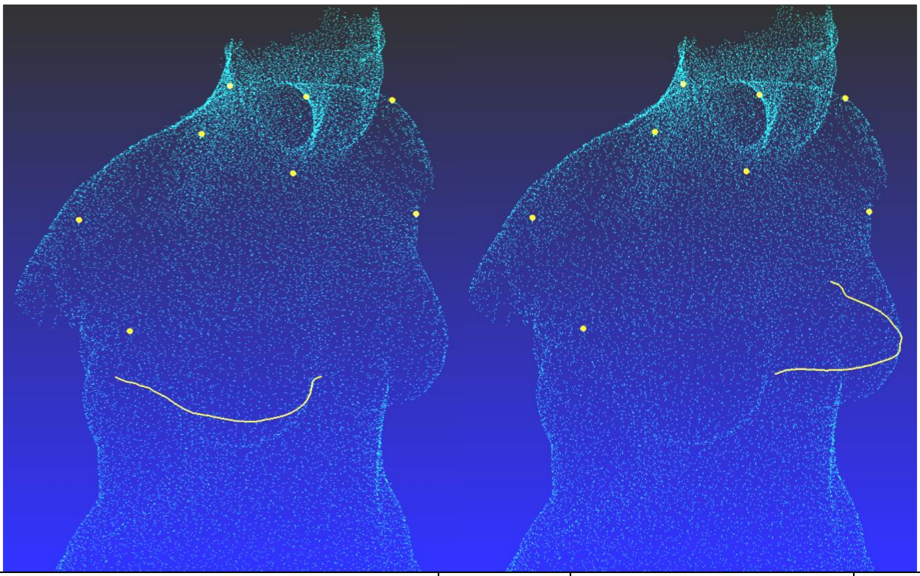


Figure 6 Underbust Girth [scanner reference W106] – A horizontal plane is fitted

2. Bust size 1 traditional method	Difference	Bust girth (scanner reference W102 Figure 5) –Underbust girth (scanner reference W106 Figure 6)	Small, Average, Large

As there is speculation in the literature review about the validity of the difference between bust girth and underbust girth as a breast size measure. Correlation is checked and the variance is tested to identify the amount of variance of difference between bust and underbust girth is accounted for by bust girth. Further analysis of the confounding variables which could be overlooked when using girth measurements to calculate breast size was conducted. 3D body scanning technology presents an option for profiling front and back distribution separately.

The average bust arc is taken and the percentage of the overall bust girth that is made up of the front bust is calculated to give a proportion. The correlation between the difference between bust and underbust and the percentage front bust distribution is used to give an indication of whether bust size 1 the traditional method can be used as an indicator for the percentage of the bust girth which is at the front. The co-efficient of determination is used to identify how much of the difference in front bust percentage can be attributed to the difference picked up by the traditional sizing method.

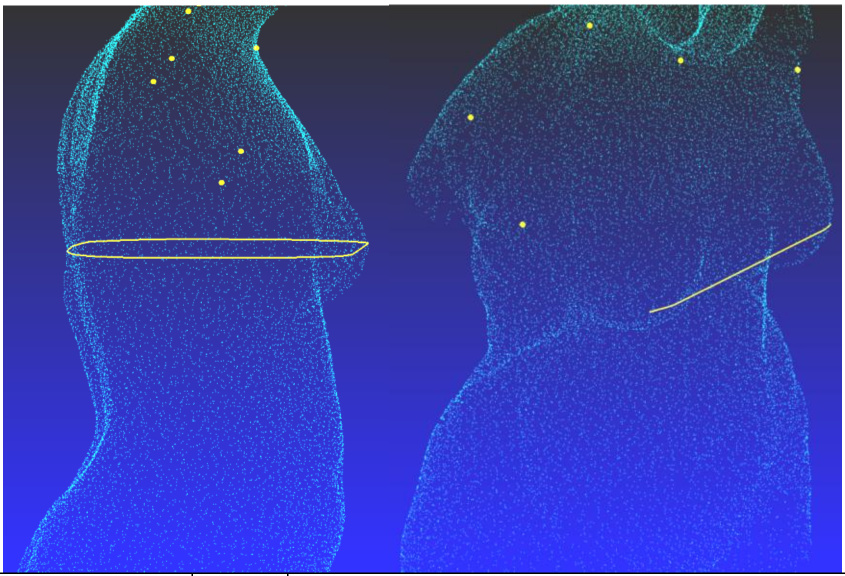


2. Bust size 2 experimental method	Average	Average bust prominence	Small, Average, Large

Figure 7 Bust prominences left/right [scanner reference W106/W106] – The long left and right measurements are taken from a point between the bust over the contours to the side seam

In order to utilise the traditional sizing method for the purpose of illustration the bust girth and underbust girth are converted into inches for the selection of analysis focused on bra sizing. Correlation is tested for between the two profiling methods and again when the bra sizing calculation is applied to bust size 1 – the traditional method to see if this has any impact on the correlation.

The decision to use the ratio rather than absolute measurements for bust spread profiling was to take into account the size of be bust as the potential indicator for distance between bust points. Ratio instead profiles the relationship between the bust and the body eliminating bust size as a confounding variable.



3. Bust spread	Ratio	Bust girth (scanner reference W102 Figure 5Figure 5) ——— Bust to Bust (scanner reference W86 Figure 8)	Close, Average, Spread

Figure 8 Bust girth and bust to bust [scanner references W102 and W86] – tape measure point one bust point to the other

The breast drop is calculated as the ratio of side neck to bust to side neck to underbust. Ratio is used instead of absolute measurement to profile the height of the fullest point of the bust in relation to the rest of the breast tissue, not just the length.

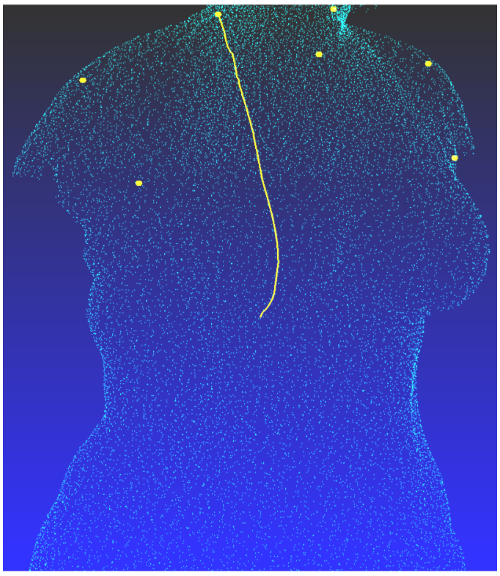


Figure 9 Side neck to underbust (scanner reference W53)

4. Breast Drop	Ratio	Side neck to underbust (scanner reference W53 Figure 9 Side neck to underbust (scanner reference W53)) ――――――――― Side neck to bust (scanner reference W51)	High, Average, Low

BMI is calculated as Weight (kg)/Height² and categories were assigned according to the world cancer research fund calculator as Underweight <18.50kg/m², 18.50kg/m² ≤ Healthy Weight ≤ 24.90kg/m², 25.00kg/m²≤ Over Weight ≤ 29.90kg/m², Very overweight≥ 30.00kg/m². (World Cancer Research Fund, 2011).

The breast symmetry is tested using a Wilcoxon signed rank test to test the difference between related measures in data. The non parametric test is applied as the data is not normally distributed for all profiling aspects.

Applying these predetermined measurements and equations to the data enabled the sample to be profiled into categories**Error! Reference source not found.**(Table 1 Profiling Categories.)

Profile category	**Type**	**Measurement (cm)/Calculation**	**Profile categories**
1. Bust height	Ratio	$\frac{\text{Height (Manually taken)}}{\text{Average Front neck to bust (left and right calculated from scanner reference W144 Figure 4)}}$	High, Average, Low
2. Bust size 1 traditional method **OR** 2. Bust size 2 experimental method	Difference **OR** Average	**Bust girth (scanner W102 Figure 5) –Underbust girth (scanner reference W106** Figure 6) **OR** Average bust prominence()	Small, Average, Large **OR** Small, Average, Large
3. Bust spread	Ratio	$\frac{\text{Bust girth (scanner reference W102 Figure 5Figure 5)}}{\text{Bust to Bust (scanner reference W86 Figure 8)}}$	Close, Average, Spread
4. Breast Drop	Ratio	$\frac{\text{Side neck to underbust (scanner reference W53 Figure 9 Side neck to underbust (scanner reference W53))}}{\text{Side neck to bust (scanner reference W51)}}$	High, Average, Low
5. Symmetry	Difference	Difference between Left and right profiles – 1.Bust Height, 2.1 Bust Size, 2.2 Bust Size, 4. Breast Drop.	Average, Asymmetry (difference greater than 0.79cm to allow for body positioning variations.

Table 1 Profiling Categories

3.2 Phase 2 Bra size charts and Survey

Evaluate the presentation of bra sizing by retailers and identify areas of miss communication to characterize effective application to the bra market.

3.2.1 Bra size charts

The methodology for this section focuses on the classification of bra sizing calculations which are advised to consumers by retailers in order for them to calculate their recommended bra size. The selection criteria for retailers used in this process was defined by their inclusion in the 2010/2011 Mintel Underwear reports, classifying them as key current retailers (n=9) making up the UK bra market and representative of the information available to UK bra consumers in addition to the calculations referenced by White and Scurr (2012) and Wright (2002) The calculations are categorised by their variation from the size recommendations given by the British Standard (British Standards Institution, 1999).

3.2.2 Bra survey

3 tiered convenience sampling was employed to target a range of age groups in a survey conducted during 2010-2012; a small section of this survey has been accessed for use in this study. Three replicas of the survey were created with no variation in the questions or how they were phrased, they were piloted and question wording and answer options were amended as a result. A large print version which was easier to read was targeted at older participants through social lunch groups for ladies 55+ accessed as an older age convenience sample, on receiving the questionnaire participants had the option to pass copies on to people they know which merged into snowball sampling. This strategy was thought to be applicable as awareness and interest in bra sizing and fit is growing (Mintel, 2011). This strategy was also employed on a train with a group of commuters who worked with people aged 29-55; they were given a number of copies to distribute. Social networking was employed through the use of the social networking site facebook, a group was created for people with an interest in bras to join and complete the surveys. All responses were anonymous but a contact email was given for participants interested in taking part in further related research. The inclusion and exclusion criteria were as Phase 1 of the research to ensure comparability.

This survey was also given to the participants of Phase 3 of the research the bra fit trials and kept separately from the initial responses keyed with the scan ID code for direct comparable measurement data to test hypotheses.

Pressure was being exerted on the central tendency in the Underband size results by one response (ID 966705261) stating an underband size of 85, this is a Metric not Imperial Bra size and as such converted to Inches and replaced to be inline with the rest of the sample and give a more representative average.

3.2.3 VARIABLES AND THE EXPERIMENTAL APPROACH

Limitations have been highlighted in the use of self reported bra sizes, descriptive statistics were reported on whether respondents who have been fitted for a bra in the last 12 months, feel they could be wearing the wrong size and their perceptions of their upper body shape and correlations between the above responses and bra size.

Correlation is applied to test the relationship was tested for between the participants' perception of their upper body shape and the bra size that they wear. The sample size was not big enough to classify bra size against upper body shape directly against each other without breaking the statistical assumptions of the chi-square test for independence. As such the responses for upper body shape and bra size were split into upper body underbust shape and upper body cup shape and underband and cup size respectively to test upper body shape as an indicator for both the underband and cup volume aspects of bra size. Spearman's rank correlation was applied and chi square test for independence if suitable significant correlation was found.

3.3 PHASE 3 - BRA FIT CRITERIA AND FIT TRIALS

Collate and validate criteria for achieving adequate bra fit and quantify the physical impact on the bust size, shape and position. Phase 3 is made up of the development of a preliminary bra fit criteria used in laboratory bra fit trials, and the procedure behind the bra fit trials to be conducted.

3.3.1 BRA FIT CRITERIA

This section of the review comprises of a tabulated Bra fit criteria. The criterion is an amalgamation of the bra fitting advice available to consumers in order for them to ascertain adequate bra fit and must be representative of the majority of information that is provided for them by retailers to ascertain whether this is sufficient to provide adequate bra fit (Appendix E-III). This criterion is categorised by contributing bra components and bra fit principles as defined in both retailer and academically published literature. These components are in line with the Choice Magazine criteria (2005) utilised and verified by relevant studies in the research area (McGhee & Steele, 2006; 2010; 2011). The most frequently used terms and phrases were collated into the bra fit criteria to define criteria which was representative of the overall advice that consumers are given. The methodology selected for this analysis is frequency of the appearance of words and terms within the data set if a word or phase is used in two or more retailers advice it was included. Variations of terms have been utilised to collate similarities and therefore validate criteria which exist beyond variations in terminology.

This criterion covers both retailer and academic aspects and as such is the first criterion which comprehensively applies to both the theoretical academic research and practical bra fit advice supplied by the retailer to the consumer. The criteria were formulated into a checklist against which the participants own bra and the fitted bra were rated against component categories; underband, cup volume, underwire, straps and rated as either too small, adequate, too big. The criteria were entered into SPSS (version 19). The compute variable tool was applied in each category (underband, cup volume, underwire and bra strap) to calculate an overall score for that component within the too small, Adequate or too big classifications. This resulted in a score of 0 to 1 indicating the number of conditions within that classification that have been met. Tests for relationships were conducted to determine whether the application of the bra fit criteria is sufficient to achieve adequate bra fit. The categories of the criteria were scored individually then compared to determine whether there is a relationship between the fit score in one of the categories and the overall fit score as well as the fit score between different categories. This practice is based on McGhee and Steele's (2010) use of a bra fit criteria in their 2010 and 2011 research.

3.3.1.1 Bigger size advice

On reviewing the literature it became apparent that one retailer (Marks and Spencer, 2011) distinguished between the fit requirements of A-D and DD+ bra cups. The relationship between the DD+ only criteria and the overall inclusive size criteria is defined to determine whether there is a significant difference in the criteria for larger cup sizes which needs to be considered when follow up primary research is conducted.

3.3.2 Laboratory fit trials

Phase 1 of the Methodology assesses the application of the current University protocols and 3D body scan database to bra fit research. Phase 3 goes beyond the current protocols and pilots the specific application and procedures to the application of this technology for bra fit research. The effects of applying the theory based fit criteria to the human body will be assessed using structured laboratory fit trials. The fit trials were comprised of comparison scans of participants. One unsupported, one with the participant's everyday bra support and one with the bra support fitted in by an independently trained fit expert using the bra fit criteria developed in this study. This methodology is adapted from that used in sports bra research (White et al., 2009) to test for relationships between the breast and different conditions. Specific anthropometric body measurement data were extracted for analysis following the definitions and parameters adapted in phase 1 to satisfy aim 3 to evaluate the physical impact of adequate bra fit on the wearer.

3.3.3 Pilot studies

A number of pilot studies were conducted to trial the use of the technology for bra fit and define the parameters for use of this technology for bra fit research, pre-empt potential issues prior to data collection and note ethical considerations in the field of data collection and storage. Through the pilot study on the extraction and analysis of bra fit data, efficient automatic measuring parameters were defined which could then be used to classify equations and definitions for specific application of the 3D body scanning tool to bra fit research. A measurement extraction profile (MEP) was modified from an existing profile on the system to include bust specific measurements required to satisfy the first aim to critically evaluate 3D anthropometric body scan data to profile variation of bust size, position and shape in a sample of UK bra consumers. This MEP could then be applied to satisfy the third aim, to collate and validate criteria for achieving adequate bra fit and evaluate the physical impact on the wearer. The use of this MEP is designed too satisfy the second part of this aim by defining the parameters the use of this technology. The MEP for this research was based on an existing MEP defined for the national Size UK study and used for all standard research conducted at

Manchester Metropolitan University to ensure that this research has current relevance to National clothing standards and current 3D body scanning research.

3.3.3.1 Scanner limitations

One issue was pre-empted prior to piloting after training on the scanner technology was completed. The scanner literature details some of the limitations of the technology applicable to this research one of which was the suitability of the underwear worn during the process. A number of the bras acquired for use in this study were a dark purple colour. White light scanners do not acquire data when participants wear black underwear as the light is absorbed by the black as such the dark purple bras presented a risk to data acquisition. This theory was piloted against a range of skin tones to ensure that the bra colour did not impair sufficient data collection. On very pale Caucasian skin the scanner failed to collect sufficient data of the breast region see Figure 10 bra colour worn contrasted with the participants skin tone resulted in missing data'. In the sizes where only the purple colour was available, the same style and size of bra was acquired in a baseline colour (cream) which would be workable with lighter skin tones. As the colour is not black there are amendments to the calibration of the body scanner could have been made in order to allow for more dramatic contrast if a replacement bra had been unavailable. The replacement bra was selected as the most suitable solution to this problem as it was the quickest method and could be pre empted and planned for rather than having to make alterations on the day. It also eliminated any perceived discomfort that could be caused to the participant by the suggestion that they were an anomaly and required a change in scanner setting in order to be scanned. The scanner process is by nature a sensitive procedure as it requires the participant to be in a near naked state, the researchers observation was that a quick problem free scan causes the least discomfort to the participant.

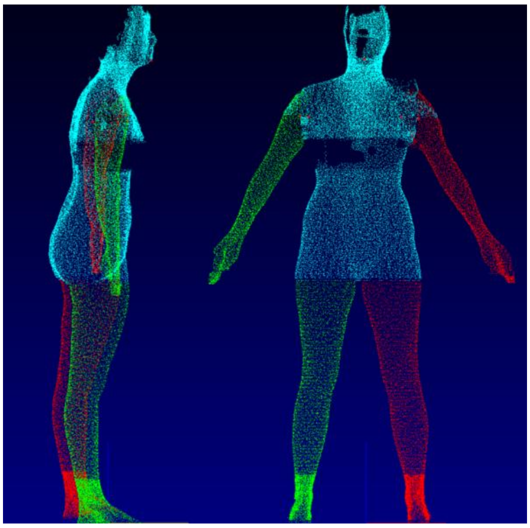


Figure 10 bra colour worn contrasted with the participants skin tone resulted in missing data

3.3.3.2 Body Slices as an analysis tool

Visual slices through the body can be taken at 0.5cm intervals to display cross sections; this visual tool is not as precise as the measurement extraction from the scanner which can extract a measurement to 0.000001cm. As the slices are not as precise as the measurement data they could reduce the precision of the conclusions drawn if displayed without the supporting measurement information. As a visual display tool it is applicable for bra fit research as it displays visual shape variations of the bust cross section when different bras are worn. Precision could be improved when displaying a specific extracted measurement point by taking two cross sections at 0.5cm intervals closest to the measurement and taking an average line between them.

3.3.4 Bras

A size set of bras was provided by Courtaulds for use in this study as a baseline everyday bra representative of one that can be purchased commercially on the UK market. This is a readily available style to purchase and as such does not infringe on the confidential development by Courtaulds or Marks and Spencer. The style is an unpadded 3 part cup underwired style retailed by Marks and Spencer and covering both the standard (A-D) and plus size (DD+) size ranges. The style of bra is consistent with that used by White & Scurr (2012.)

	A	B	C	D	DD	E	F	G	GG	H
32	32 A	32 B	32 C	32 D	32 DD	32 E	32 F	32 G		
34	34 A	34 B	34 C	34 D	34 DD	34 E	34 F	34 G	34 GG	34 H
36	36 A	36 B	36 C	36 D	36 DD	36 E	36 F	36 G	36 GG	36 H
38	38 A	38 B	38 C	38 D	38 DD	38 E	38 F	38 G	38 GG	38 H
40	40 A	40 B	40 C	40 D	40 DD	40 E	40 F	40 G	40 GG	40 H
42	42 A	42 B	42 C	42 D	42 DD	42 E	42 F	42 G		
44					44 DD	44 E	44 F	44 G		

Table 2 Bra sizes supplier for the research

The pilot study supported findings in literature (Wood et al., 2008) that suggest everyday bra's worn can be affected by the age and laundering which affects the structure and support given by the bra. It has been considered that options exist to overcome this obstacle in this primary strategy. The first option was asking participants to select a size from the provided range of bras for their 'everyday bra scan' or taking the age of the bra into consideration during analysis. Asking participants to select a bra as in McGhee and Steele's (2010) study would have influence on the comparison as it would force them to go against their normal bra selecting procedures and the resulting bra may not be representative of one that they would wear. Using the participants own bra gives an accurate observation of the support they receive from their bra on an everyday basis and ensured this methodology was in line with other comparable studies (Chen et al., 2010; White & Scurr, 2012) and phase 1 of this study.

3.3.5 SAMPLING STRATEGY/INCLUSION CRITERIA/SAMPLE ANALYSIS

Convenience and snowball sampling were employed. Prior participants who completed a questionnaire during an undergraduate study conducted on the importance of bra sizing and fit and who expressed an interest in taking part in future bra fit research were contacted. The email sent to participants was approved by the ethics committee (Appendix B-IV). Social networking was again employed in the creation of an event. Participants were advised that they were free to bring along anyone who had an interest in the research topic. An observation by the researcher was that there was a great interest in taking part which supports literature suggestions that this is a growing topic of consumer awareness and interest (Mintel, 2011).

3.3.6 Variables and the Experimental approach

The variables in the bra fit criteria make up a bra fit score for each of the bra support scenarios, differential between the two fit scores were tested for. The first stage was to test the application of the bra fit criteria. Two versions of the data were input into SPSS (version 19) for analysis. Version A was input with two cases for each participant and the conditions were split using the split variable 'bra worn' the split the data into condition 1 'own bra' and condition 2 'fitted bra'. This allowed for the creation of bar charts to display the data initially to look for overall patterns in the date. The second version, version B was input with one case for each participant with a separate variable for each condition in order to test repeated measures for the 'own bra' and fitted bra condition to test for direct application. As the fit criteria scale uses both positive and negative ends of the axis with adequate as a zero point, spearman's correlation cannot be applied. Due to the scale applied using both positive <1 and negative <0 end of the scale to denote problems with bra fit being too big and too small with adequate being a neutral point; Spearman's correlation cannot be effectively applied to this scoring system to test the relationship. Related measures tests were applied and then post hoc analysis was carried out to determine causality.

The application of a paired sample T-Test was inappropriate due to the distribution of the data not being normally and a sample size of <30 (26 participants with both sets of data.) This data set enabled the application of non parametric related measures tests such as the Wilcoxon signed rank test. The signed rank test measured the number of times a score is higher, lower or the same at repeated measures which in the case of this research is the own bra and the fitted bra.

The 3D Body scanning technology presents opportunity to for visual displays of data through body slice tools and point cloud screen shots. These have been used to demonstrate key findings and limitations and to visually display bust size variation and proportional shape.

A Friedman test is used to analyse the 3D body scan data and test for differences across the three conditions 'unsupported', 'own bra' and 'fitted bra'. The non parametric test is applicable due to the sample size.

3.3.7 *ETHICAL PRACTICE*

Due to the sensitive nature of this work full ethical approval was sought and granted by the Manchester Metropolitan University ethics committee for all methods employed. Approved ethical procedures and paperwork for the use of 3D body scanning technology for clothing research are established within MMU (see appendices for paperwork). Bra fit trials have not previously been conducted at the facility and as such a Risk assessment was conducted and data protection and anonymity were controlled for in the procedural set up, a full follow up report (Appendix C) was presented to the ethics committee following this research to assess the use of this paperwork and procedure for future bra fit research at the University.

3.3.8 *LIMITATIONS*

The primary limitations of this study are that the subject area specifically is not widely published. This is manageable as it is a newly emerging research topic with industry and academic interest growing and a wide variety of publications which are closely related to the research area. The Clothing Design and Technology department is well equipped and supported by academics in the area of 3D body scanning for clothing. The researcher's prior bra fit experience ensures that this limitation is reduced as prior knowledge on this area exists.

An immediate limitation of using secondary data is that it is extracted according to a University protocol and is therefore not specific to this topic area, subject specific data such as stage of the menstrual cycle or lifestyle choices which relate to the breast cannot be obtained. Standard questions related to the scanning protocol include Age and Ethnicity which presents and opportunity to look into these parameters outlined by literature (Standring (Ed.), 2005; Scurr, 2007; Wood et al., 2008; Berry et al., 2011), during the scanning process weight and height are collected, although this does not give the level of biological accuracy that Brown et al.'s (2012) method does, it gives a recognised indication of BMI (Body Mass Index.)

4 RESULTS

The results section of this study presents the data and breaks down the results from the three phases on the methodology linking to each research aim. The first aim of this study was to profile the differences in bust size, position and shape in a sample of UK bra consumers using 3D anthropometric body scan data. The first research question to be raised by this aim was; are there differences in bust size, position and shape that can be profiled using 3D Body scanning technology?

4.1.1 DESCRIPTIVE STATISTICS ON SAMPLE

Once exclusion criteria are applied the data set contains 242 female participants between the ages of 18-80 with a mean age [standard deviation (SD)] of 27.5 [11.8years], weight 61.3 [11.7kg], height 163.5 [7.2cm]. The distribution of the data for weight and height is normal. Age is only slightly skewed with predominantly normal distribution. The ethnicity of this sample is not normally distributed however it is similar to the distribution found within the UK population, 'A British white' and 'B white other' making up 79% (n=245) against 85% (n=61,378,000) for the UK national statistics, (see Appendix B-0 for the full table of percentages.)

4.1.2 PROFILING 1 – BUST HEIGHT

Chen et al. (2011) and Nicoletti et al. (2009) justify the profiling of the bust in proportion to the body in order to define the overall impact of breast size on the consumer, Nicoletti et al. highlight the importance of differentiating between the impact the same size bust may have on a bigger or smaller frame.

There is only a weak strength relationship between total height and the length of the front neck point to right bust and the front neck point to left bust (r_s=0.26, $p<0.0005$/r=0.23, $P<0.0005$ respectively). This supports Nicoletti et al.'s (2009) reasoning that variation in breast size alone is not strong enough justification to evaluate breast size; size must be profiled in relation to the overall proportions of the body. The ratio of front neck to bust (average) to total height has a weak positive correlation (r_s=0.14, $p<0.05$) which does not suggest a strong relationship between bust height and total height. This supports the use of breast height as a profiling tool as it is independent of overall height as a parameter for measuring the bust.

The ratios in this study are taken when wearing a bra and as such are not directly comparable to Nicoletti et al.'s (2009) benchmarks for small and large preoperative breasts. Chen et al.'s (2010) percentile method was applied to break down the variation of bust height ratio's (measure used [W20] bust height) in the sample into average, high (70th) and low (30th) to classify the bust height within the sample in relation to the rest of the body. These are set at 7.83<high≤10.53, 7.83≥average≥7.12, 5.55≤low<7.12 within this population. This technique requires normal distribution to ensure that the majority of the sample fall into the average category but is resistant to some outliers as it centres the average population in one group and groups the extreme ends of the scale into an upper and lower scale.

4.1.3 Profiling 2 – Bust size method 1

Initial exploration of the data revealed indications of strong positive relationships between bust girth, BMI and other Girth measurements (**Error! Reference source not found.**.) This demonstrates links between overall girth measurements and BMI.

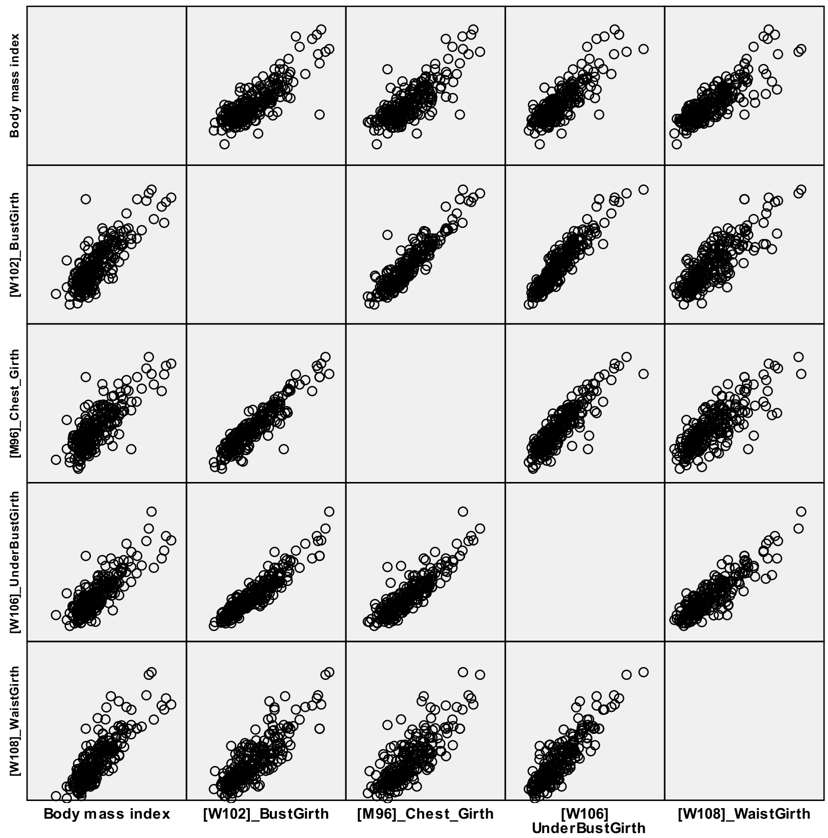


Figure 11 Initial Girth Correlations of the database sample

Difference between bust and underbust is a traditional measure to calculate bust size, this is defined as profiling 2.1 bust size 1. During preliminary data exploration BMI was tested for as a parameter which impacts differences in breast size. There is only a weak positive relationship between the difference between bust and Underbust and BMI (r_s =0.28, p<0005, r_s^2=0.08%) this indicates that only 0.08% of the variance in bust size as measured by Difference between bust and underbust is accounted for by BMI.

The mean girths in the sample of 247 participants [SD] were a bust girth of 94.62cm [9.40] an underbust girth of 79.22cm [7.98], the hypothesis was explored with initial findings that there is a strong positive correlation between bust girth and underbust girth (r_s=0.92, $p<0.0005$, r_s^2=85%) however when this is classified into correlation between the bust Girth and the difference between the bust and underbust the relationship weakens (r_s=0.57, $p<0.0005$, r_s^2=32%) but is still a strong relationship (Cohen, 1988).

Bust girth only accounts for 32% of the variance in the difference between bust girth and underbust. This strengthens the justification set by the literature for further analysis on the bust size as an independent variable from the overall body girths and BMI as differences may exist.

An initial Hypothesis drawn from the Literature:

H0a – The relationship between bust girth and underbust girth within the sample is responsible for all of the differences in bust size and suitable as the only measure for bust size.

H1a – The relationship between bust girth and underbust girth within the sample is not responsible for all of the differences in bust size and suitable as the only measure for bust size.

It presented an opportunity to utilise further capabilities of the scanning technology which is to account for the front and back distribution of the Girth measurements using the [W103] Bust Arc width.

3D body scanning technology can break down the distribution of the bust girth measurement based on automated side seam placement (Ashdown, Choi, & Milke, 2008). Based on areas defined by the literature review the profiling focuses on the bust in relation to the rest of the body and on existing methods which are used as the base for bra sizing and size definitions.

4.1.4 PROFILING 2 – BUST SIZE METHOD 2

An average bust arc width of 49.85cm [5.80] was found within the sample, any variation in the front bust measure that cannot be accounted for in the overall Bust girth measure goes against the bra sizing assumption that an increase in bust girth against the underbust girth denotes an increase in cup size.

In order to calculate the distribution the bust arc to the bust it was computed as a percentage. When the girth measurements are broken down into the percentage of front and back distribution, there is only a weak positive correlation between front bust percentage distribution and bust girth ($r_s=0.17$, $p<0.01$) which does not suggest that as bust girth increases the percentage of front distribution increases. The bra cup size calculation utilises the difference between the [W106] Underbust Girth and [W102] Bust Girth. However when explored there is only a weak positive correlation ($r_s=0.26$, $p<0.005$) between the difference between these measurements and the front percentage distribution of the bust girth measurement, the co-efficient of determination (r^2) is 0.07% which does not account for the variance in the percentage distribution.

In order to apply the bra size calculation adopted by White & Scurr (2012) and Wright (2002) for this stage of analysis the measurements had to be converted into inches. After applying the calculation an average difference between Bust and Underbust of 15.08cm [3.49] was found within the sample, to establish the bra size the underband size of the participants is calculated using the White & Scurr (2012), Wright (2002) method of bra size calculation which is applicable as the measurements are taken over a bra. Caution must be taken when directly comparing findings using this method as the measurements are extracted using 3D body scanning technology rather than the manual method documented. Once the measurements are converted from centimetres to inches (using Microsoft Excel) the 247 participants have a median bust Girth of 36.6 Inches with a median difference between bust and underbust of 5.93 Inches once the measurements have gone through the calculation (**Error! Reference source not found.**) a median Underband size (White & Scurr, 2012; Wright, 2002) of 36 and cup size B is identified.

The median it taken rather than the mean as the data is now ordinal date rather than interval as the markers for Inches are not as accurate for extracting precise body measurements and do not fall at mid points of the data intervals.

The calculation for bra cup size is reliant on the relationship between the [W106] Underbust Girth and [W102] Bust Girth however bra cup size is only a denotation of size for the breast tissue (Shin, 2007) and accommodates only the front bust distribution, if cup size calculations only use overall girth measurements it presents the question that they could not account for independent variation of the front bust and as a result increase the inaccuracy highlighted by McGhee et al. (2010), White & Scurr (2012) and Wright (2002).

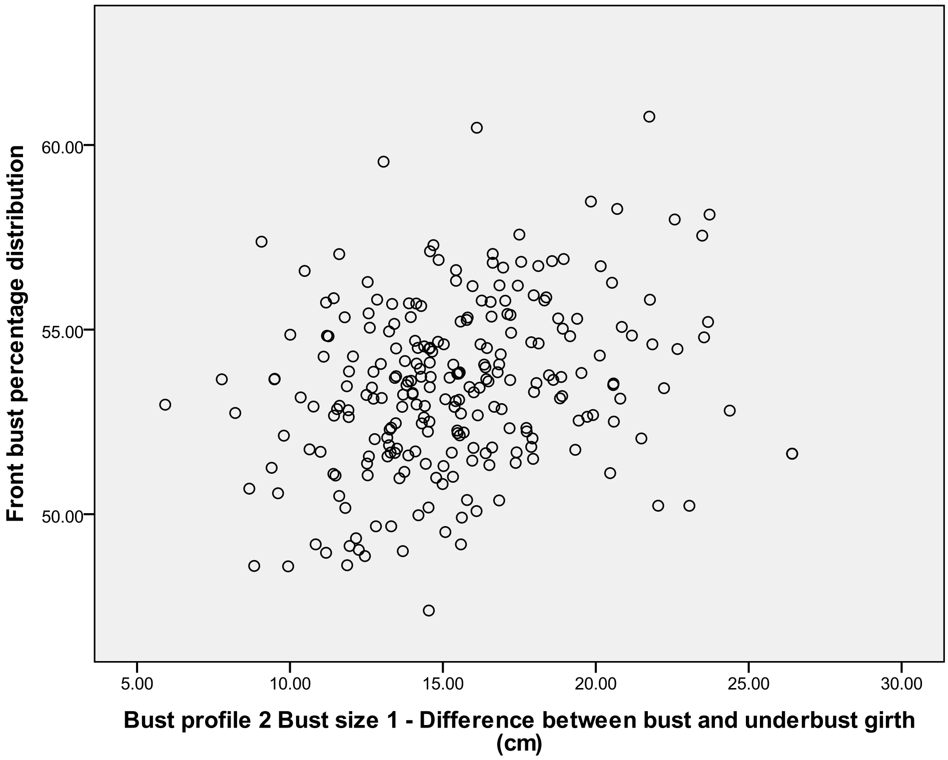


Figure 12 the weak correlation between bust and underbust and the front bust percentage distribution

The graph shows weak correlation between the difference between bust and underbust and the front bust percentage distribution. This does not support bra sizing 1 (the traditional method) as an indicator for the front bust percentage distribution.

The front bust percentage distribution alone cannot be used to profile the size of the bust as it only looks at the percentage of the overall bust girth which is positioned at the front of the body between the two side seams.

Table 3 Correlation between average bust prominence and the difference between Bust Girth and Underbust Girth (cm)

			Difference between bust and underbust (cm)	Average bust prominence (cm)
Spearman's rho	Difference between bust and underbust (cm)	Correlation Coefficient	1.000	.555**
		Sig. (2-tailed)	.	.000
		N	247	247
	Bust prominence average	Correlation Coefficient	.555**	1.000
		Sig. (2-tailed)	.000	.
		N	247	247

**. Correlation is significant at the 0.01 level (2-tailed).

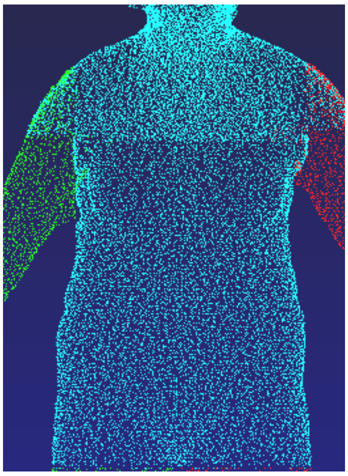
There is a strong positive correlation between average bust prominence and the difference between Bust Girth and Underbust Girth (cm) =0.56, $p<0.0005$, $r_s^2=31\%$ the correlation weakens when the bra size calculation is applied (the correlation between Cup size using the Wright/White and Scurr Method and Bust prominence average), reducing the coefficient of determination (r_s^2) by 9%. This indicated that applying the bra size calculation and grouping the measurement into cups could reduce the predictability of determining the adequate size to fit the bust. This is a feature of sizing system limitations and not a limitation of the sizing system itself as measurements have to be grouped to create a commercial sizing system which covers as much of the differences as possible with the smallest number of sizes. Although it has limitations, variations on the bra size calculation are utilised by researchers to quantify breast size (Brown, et al., 2012; Haake & Scurr, 2010; Turner & Dujon, 2005) to reduce miscommunication due to variations of the bra size calculation the relationship between direct measurements are segmented into percentiles this is consistent with Berry et al.'s (2011) method for profiling breast implant for augmentation surgery.

The 30th and 70th percentile for the difference between Bust and Underbust are 13.47cm and 16.82cm respectively to profile variation as small average and large. This measure is inline with current research and therefore more applicable, the aim of this research is to evaluate the 3D body scanning technology as a tool for bra fit research as such bust prominence presents a new opportunity for breast profiling and is presented as an alternative to Bust size through difference calculation. As the arguments for bust prominence (Chen, LeBat, & Bye, 2011) and difference between underbust and bust girth (Brown, et al., 2012; Haake & Scurr, 2010; Turner & Dujon, 2005) are both discussed in this and previous research they have both been included as two categories of Breast size in the profiling. Going forward, further investigations into the validity and reliability of these two profiling methods are recommended.

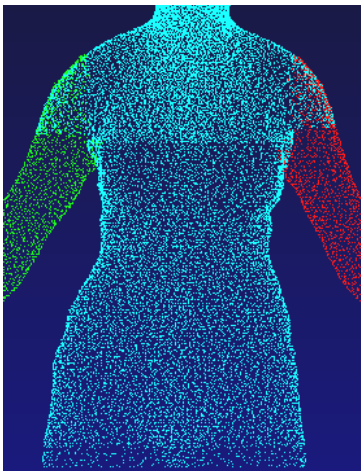
4.1.5 Profiling 3 – Bust spread

The distance between bust points (Mean=19.37, SD 2.27) indicate the spread of the breasts, there is a medium strength positive correlation between front neck to bust line and the distance between the bust points (r_s=0.455, p<0.0005) indicating a potential relationship between the vertical length of the breasts and the spread of the bust. The bust spread is an aspect that can be profiled using 3D body scanning technology and calculated as the ratio of the distance between bust points to the bust girth profiles it within the parameters of the overall bust.

The decision to use the ratio rather than absolute measurements was to take into account the size of be bust as the potential indicator for distance between bust points and to instead profile the relationship between the bust and the body. Figure 13 shows participants 0828 (left) and 0829 (right) who demonstrated a similar distance between bust points (20.63cm and 20.44cm respectively) but different bust spread ratio (4.90 and 4.46) the 30th (4.63) and 70th (5.13) percentile are used to profile the variation within this sample. Using this classification Participant 0828 has a bust spread profile of Average and 0829 has a bust spread profile of Spread which profiles the bust spread in relation its position within the body.



0828 Breast spread profile – Average



0829 Breast spread profile - Spread

Figure 13 Participants with the same distance between bust points but different ratios of bust spread

4.1.6 Profiling 4 – Breast drop

Ptosis is an area which cannot be comprehensively assessed using 3D body scanning technology as it relates to the positioning of the nipple. The location of the nipple point is not synonymous with the scanners automatic identification landmarks, as in Han & Nam's (2010) study the fullest point of the bust is identified as the bust point as the scanner is calibrated for clothing research on a body with underwear (see0.) The scanner can profile an aspect of breast drop as it takes surface body measurements from the side neck point to underbust over the curve of the bust. The drop of the bust can be calculated by the ratio of Side neck point to bust to neck to underbust [W53] – although the description for this measurement point is Neck the algorithm for this measurement is set to be taken from the side neck point (Figure 14.) This calculation represents the vertical position of the fullest point of the bust in relation to the overall vertical bust shaping.

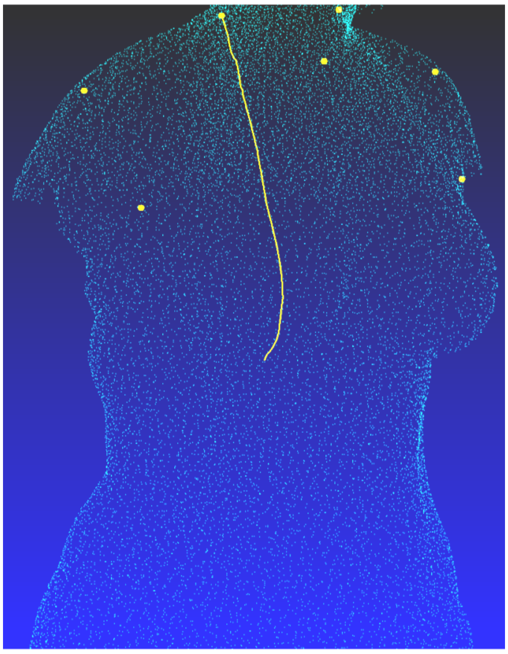


Figure 14 Neck to underbust [W53] –From side neck point to underbust over the bust contours

Using the percentile method the breast drop profiled as the ratio as the average between 'W53L_ Neck2UnderBust / W51L_ SideNecktoBust' and 'W53R_ Neck2UnderBust / W51R_ SideNecktoBust' to calculate side neck to bust as a proportion of side neck to underbust. The percentiles broke down breast drop into; $1.12 \leq \text{Low} < 1.27$, $1.27 \leq \text{Average} \leq 1.34$, $1.34 < \text{High} \leq 1.56$.

4.1.7 Profiling 5 – Breast symmetry

The difference between the left and right bust height indicates support for Agbenorku et al (2011) finding that within their sample a mean difference of 1.3cm (range 0.5-4.5cm) is normal variation between the left and right breast height. Chen et al. (2011) apply Bust prominence as a measure in breast size profiling which is one aspect used to assess symmetry (Berry, Cacchiara, & Davies, 2011). A Wilcoxon signed rank test to test for difference between related measures, was applied as the data is not normally distributed. The test determined that there was no significant difference between the front neck to left and right bust at fullest point ($z=0.36$, $p=0.72$ with a small effect size $r=0.02$) that there was no significant difference between the right and left bust prominence ($z=1.82$, $p=0.07$ with a small effect size $r=0.12$) and that there was no significant difference between right and left breast drop ($z=2.34$, $p=0.02$ with a small effect size $r=0.15$) in the sample of women wearing bra's see 0 for further height symmetry analysis on participants without a bra. As previously discussed shoulder height can influence bust height, therefore only variation above the mean difference in shoulder height among the sample, 0.79cm (with a maximum difference of 4.10cm and a minimum of 0.00cm) is considered significant.

4.1.8 BREAST PROFILING SUMMARY

The breast profiling measures are collated into a table with five categories and a three point grade for each category.

Breast profiling	Small/Close/High	Average	Large/Spread/Low
1. Bust height (ratio of height to front neck to bust)	10.53≥High>7.83	7.83≥Average≥7.12	7.12>Low≥5.55
2. Bust size 1 traditional method (difference between bust girth and underbust girth **OR** 2. Bust size 2 experimental method (average bust prominence)	5.92cm≤Small<13.47 cm **OR** 18.86cm≤Small<23.60cm	13.47cm≤Average≤16.82cm **OR** 23.60cm≤Average≤27.19cm	16.82cm<Large≤26.42cm **OR** 27.19cm<Large≥34.88cm
3. Bust spread (ratio of bust to bust, to bust girth)	7.57≥Close>5.13	5.13≥Average≥4.63	4.63>Spread≥3.89
4. Breast Drop (Ratio side neck to bust to side neck to underbust)	1.12≤Low<1.27	1.27≤Average≤1.34	1.34<High≤1.56
5. Symmetry	Cannot be defined within a sample of bra wearing participants. This will be applied to the sample of scans taken on unsupported breasts.		

Table 4 Summary of breast profiling

4.2 BRA SIZING

Evaluate the presentation of bra sizing by retailers and identify areas of miss communication to characterize effective application to the bra market. Bra sizing calculations and their distance from the British standard recommendation are shown (Table 5,) which demonstrates the differences in underband size and cup size from the British Standard recommendations (British Standards Institution, 1999). The differences found in academic literature (Table 6) is also documented as three different Underband calculations and four different cup size calculations were found.

British Standard	60±2cm/24in **60 A**	65±2cm/26in **65B**	70±2cm/28in **70C**	75±2cm/30in **75D**	80±2cm/32in **80E**	85±2cm/34in **85F**	90±2cm/36in **90G**	95±2cm/38in **95H**
La Senza	Below size range	30A/ 30C	32B/ 32D	34C/ 34DD	36D/ 36E	38DD/ 38F	40E/ 40**FF**	42F/ 42G
CUK Clothing	28A	30B	32C	34D	36D	38DD	40E	42F
Eveden	Below size range	Below size range	Below size range	28	30	32	34	36
Ultimo	Below size range	30B	32C	34D	36D	38DD	38**FF**	38G
Ann Summers	28A	30B	32C	34D	36D	38DD	40E	42F
George	28/30AA or 28/30B	28/30A or 28/30C	32B/ 32D	34C/ 34DD	36D/ 36E	38DD/ 38F	40E/ 40G	42F/ 42G
Triumph	Below size range	30AA	32B	34C	36D	38DD	40E	40F
Marks and Spencer	28AA	30A	32C	34DD	36E	38G	40 Cup size above size range	42 Cup size above size range

Table 5 Bra size denotations across retailers

Bra Research Calculations	**Source**	**Manual/3D body scanner**	**Method**
Underband size	(Brown, et al., 2012; McGhee & Steele, 2006; McGhee & Steele, 2010) (White &	Manual, Anthropometric tape Manual, Anthropometric	Underbust (in) is taken level with the inframammary fold and a sizes allocated as below: 30in>24 to 26, 32in >26 to 28, 34in >28 to 30, 36in >30 to 32,38in >32 to 34 When the participant is not wearing a bra. Underbust (in) is taken level with the

	Scurr, 2012; Wright, 2002) (Washington State University and Cooperative Extension Service, 1986)	tape Manual	inframammary fold and a sizes allocated as below: 30in>24 to 26, 32in >26 to 28, 34in >28 to 30, 36in >30 to 32,38in >32 to 34 When the participant is wearing a bra. The chest is measured (inches) at the underarm point: Even number = Underband size Odd number +1 = Underband size
Cup Size	(Brown, et al., 2012; McGhee & Steele, 2006; McGhee & Steele, 2010) (White & Scurr, 2012) (Wright, 2002)	Manual, Anthropometric tape Manual, Anthropometric tape measure over the participants own bra Manual, Anthropometric tape measure	Breast girth (in) around the fullest part of the bust. The difference between Breast Girth and Underbust size, allocated as below: 1in = A cup, 2in = B cup. 3in = C cup, 4in = D cup, 5in =DD cup, 6in = E, 7in =F, 8in=G etc. When the participant is not wearing a bra. Breast girth (in) around the fullest part of the bust. The difference between Breast Girth and Underbust size, allocated as below: -1in = AA cup, 0in = A cup, 1in = B cup, 2in = C cup, 3in = D cup, 4in = E cup, 5in =F cup, 6in = FF, 7in =G, 8in=GG. When the participant is wearing a bra. Breast girth (in) around the fullest part of the bust. The difference between Breast Girth and Underbust size is denoted with a letter, allocated as below: -1in = AA cup, 0in = A cup, 1in = B cup, 2in = C cup, 3in = D cup, 4in = DD cup,

	(Washington State University and Cooperative Extension Service, 1986)	over the participants own bra Manual	5in =E cup. When the participant is wearing a bra. Bust measured around the fullest point. The difference between the bust measurement and underband size is denoted with a letter, allocated below: 0-½ in= AA cup, ½-1in = A cup, 1-2in = B cup, 2-3in = C cup, 3-4in = D cup. When the participant is wearing a bra.

Table 6 Bra calculation across research base

4.2.1 BRA SIZING KNOWLEDGE

Within the bra survey responses there is a statistically significant strong correlation between perceived upper body shape and bra size worn in both the underband ($r=0.55$, $p<0.0005$) and cups size ($r=0.74$, $p<0.0005$) categories.

		Cup Size grouped A-D DD+		
		A-D	DD+	Total
Small bust	Count	83	1	84
	Expected Count	45.6	38.4	84.0
	% within Upper body Cup categories	98.8%	1.2%	100.0%
	% within Cup Size grouped A-D DD+	46.6%	.7%	25.6%
Average bust	Count	83	34	117
	Expected Count	63.5	53.5	117.0
	% within Upper body Cup categories	70.9%	29.1%	100.0%
	% within Cup Size grouped A-D DD+	46.6%	22.7%	35.7%
Large bust	Count	12	115	127
	Expected Count	68.9	58.1	127.0
	% within Upper body Cup categories	9.4%	90.6%	100.0%
	% within Cup Size grouped A-D DD+	6.7%	76.7%	38.7%
Total	Count	178	150	328
	Expected Count	178.0	150.0	328.0
	% within Upper body Cup categories	54.3%	45.7%	100.0%
	% within Cup Size grouped A-D DD+	100.0%	100.0%	100.0%

Table 7 Participants selection of their upper body cup category and bra cup size (grouped A-D DD+)

A chi square test reveals that participants selection of their perceived Bust shape (small, average, large) shows significant association with the category of bra size they wear (A-D, DD+) $X^2=183.05$, $df=2$, $p<0.005$, Cramer's $V= 0.75$, $p<0.0005$.

Table 8 Participants selection of their upper body underbust category and underband size (grouped 28-34 and 36-40)

		Underband Categories (28-34 and 36-40+)		
		28-34	36-40+	Total
narrow ribcage	Count	107	6	113
	Expected Count	76.5	36.5	113.0
	% within Upper Body Underbust categories	94.7%	5.3%	100.0%
	% within Underband Categories (28-34 and 36-40+)	48.2%	5.7%	34.5%
average ribcage	Count	95	48	143
	Expected Count	96.8	46.2	143.0
	% within Upper Body Underbust categories	66.4%	33.6%	100.0%
	% within Underband Categories (28-34 and 36-40+)	42.8%	45.3%	43.6%
wide ribcage	Count	20	52	72
	Expected Count	48.7	23.3	72.0
	% within Upper Body Underbust categories	27.8%	72.2%	100.0%
	% within Underband Categories (28-34 and 36-40+)	9.0%	49.1%	22.0%
Total Count		222	106	328
Expected Count		222.0	106.0	328.0
% within Upper Body Underbust categories		67.7%	32.3%	100.0%
% within Underband Categories (28-34 and 36-40+)		100.0%	100.0%	100.0%

A chi square test reveals that participants selection of their perceived Underbust body shape (narrow ribcage, average ribcage, wide) shows significant association with the category of bra size they wear (28-34, 36-40+) $X^2=90.20$, df =2, $p<0.005$, Cramer's V= 0.52, $p<0.0005$. This suggests that participants wear the cup size that they feel matches their body shape.

4.3 BRA FIT CRITERIA

Collated bra fit advice supplied to consumers by UK bra retailers has been presented as a criteria enabling fit analysis to be conducted using the criteria as a checklist (for the full table and breakdown of the criteria which were selected see Appendix E-III.). The table below (Table 11) demonstrates the procedure of calculating the criteria into a score and applying the fit criteria as an analysis tool. Initially criteria are used as a check list where if a characteristic is apparent during the fitting process it is given a Yes and 1 point is given. For criteria where two or more criteria make up one score (e.g. cup volume too small) the mean score was taken into the next stage of calculation so if 1 characteristic was present but the other was not this would be graded a 0.5.

Once all the criteria have a yes or no for each aspect the points are recoded so that they can be used to calculate a final score. Each category, ‘too small, adequate and too big are defined differently to give a repeatable bra fit score which is representative of the overall fit defined by the criteria. The table below (Table 9) demonstrates the definition and nominal value assigned to the yes and no answers given by the participants

Table 9 Re-coding according to the three categories

	Too Small		Adequate		Too Big	
	Definition	Assigned value	Definition	Assigned value	Definition	Assigned value
Yes	>0	-2	=1	1	>0	2
No	=0	0	<0	0	=0	0

Each participants bra fit score can be defined in each category using the sum of these coded scores. The below table shows participant 086822’s scores for each criteria and the total fit score for that criteria.

Table 10 Participant 086822's recoded responses and total scores for each criteria in their own bra and the fitted bra

Participant 086822	Own Bra	Fitted Bra
Underband Small	0	0
Underband Adequate	0	1
Underband Big	2	0
Total Underband Score	2 Too big	1 Adequate
Cup Volume Small	-2	0
Cup Volume Adequate	0	1
Cup Volume Big	0	0
Total Cup Volume Score	-2 Too small	1 Adequate
Underwire Small	0	-2
Underwire Adequate	1	0
Total Underwire Score	1 Adequate	-2 Too small
Bra Straps Small	-2	0
Bra Straps Adequate	1	1
Bra Straps Big	0	0
Total Bra Strap Score	-1 A little small	1 Adequate

The only currently validated bra fit criteria was developed by choice magazine (2005) validated by McGhee and Steele (2010) and applied since by White and Scurr (2012) which gives a pass or fail classification for the bra without defining variation in each category, these criteria are not completely representative of the bra fitting advice provided by UK retailers by the bra market. The criteria compiled for this study is made up of the most frequently accruing bra fitting advice available to UK consumers.

Table 11 bra fit criteria

Bra Fit Criteria	Too Small	Adequate	Too Big
Underband	The underband is cutting into the back, Yes=1	1. The underband is horizontally level around the body, Yes=1 2. The underband does not ride up, Yes=1	The underband is riding up at the back, Yes=1
Cup Volume	1. The cup edge is cutting into the breast tissue causing double busting, Yes=1 2. The breast tissue is spilling out of the cup at the front and/or the underarm, Yes=1	1. The breast is fully encased within the cup, Yes=1 2. The breasts fill the cup without over spilling, Yes=1 3. There is a smooth line between the cup edge and the bust tissue, Yes=1	There are wrinkles in the bra cup, Yes=1
Underwire	The underwire is digging into the breast tissue, Yes=1	1. The underwire lies flat against the body, Yes=1 2. underwire follows the line of the bust, Yes=1 3. The underwire is not digging in or resting on the breast tissue (at the front or underarm, Yes=1	
Bra Straps	1. The Straps are digging in, Yes=1	1. You can comfortably fit 2 fingers between	The Straps are falling off the shoulders,

<table>
<tr><td></td><td colspan="2">2. The straps are too far apart at the back, Yes=1</td><td colspan="2">the straps and the body, Yes=1
2. The bra straps are parallel or slightly V shaped at the back, Yes=1</td><td colspan="2">Yes=1</td></tr>
<tr><td>Total Score is re-coded according to the values given</td><td colspan="2">Yes>0, No=0, Yes scores are given a nominal value of -2, No scores are given a nominal value of 0</td><td colspan="2">Yes =1, No<1, Yes scores are given a nominal value of 1, No Scores are given a nominal value of 0</td><td colspan="2">Yes>0, No=0, Yes scores are given a nominal value of 2, No scores are given a nominal value of 0</td></tr>
<tr><td>Bra fit score</td><td colspan="2">Using the codes above an overall bra fit small score can be given for this aspect of the bra.</td><td colspan="2">Using the codes above an overall bra fit adequate score can be given for this aspect of the bra.</td><td colspan="2">Using the codes above an overall bra fit big score can be given for this aspect of the bra.</td></tr>
<tr><td>Grades of score</td><td>Too small =-2</td><td>A little small =-1</td><td>Nearly Adequate =0</td><td>Adequate fit =1</td><td>A little too big=3</td><td>Too big =2</td></tr>
</table>

4.3.1 DESCRIPTIVE STATISTICS ON SAMPLE

On initial observation there was missing data for weight and height for one participant (871) and incorrect data for (864) these cases were manually checked against the hard copies of data filled out by the technicians. The data file excluding the missing data contains scan information for 25 female participants between the ages of 22-66 with a mean age [standard deviation (SD)] of 34.08 (13.81 years), weight 63.06 (12.06kg), height 163.90 (6.51cm.) The distribution of the data for height is nearly normal however for Weight, Age and Ethnicity do not have normal distribution which impacts on the tests that can be conducted and the conclusions that can be drawn from this sample. However as this is the first time this methodology has been applied for 3D body scanning bra fit research it is suitable for trialling the methodology.

This process excluded 2 participants from analysis as one did not take part in the bra fitting process as the size they wore was not available in the range (0865) and one participant was wearing a strapless bra on arrival at the fit trial (0861) which prevented a full ‘bra score small’ and ‘bra score adequate’ being calculated, ‘bra score big’ does not contain a bra strap category and therefore is analysed, as bra size small, adequate and large are not directly comparable measures this case is included for the bra size large category as there is no missing data.

4.3.2 BRA FIT CRITERIA ANALYSIS

Two versions of the data were saved using SPSS (version 19), A version with two cases presented for each participant, one under condition 1 – own bra and one under condition 2 – fitted bra was saved which contained only one variable per measure but with the cases duplicated over a split variable ‘Bra Worn’ so that the bra fit scores could be presented graphically using a split bar chart to demonstrate the distribution of the ratings at the own bra and fitted bra condition to give an overall representation of how the data falls.

A version with only one case per participant and a variable for each of the two conditions was saved, for example Underband small score own Bra and Underband small score fitted bra to test repeated measures of the bra fit criteria to a participants own bra and then a bra fitted to the criteria.

The bar charts present an initial overview of the distribution of the data and highlight potential discussion points and aspects for statistical testing, it is noted at this point that the bar charts show only the overall distribution and no conclusions about the application of the bra fit criteria to the fitting process can be drawn from them at this stage. The analysis was conducted using paired sample tests which directly rank a participants score under the ‘own bra’ condition against their score under the ‘fitted bra’ condition.

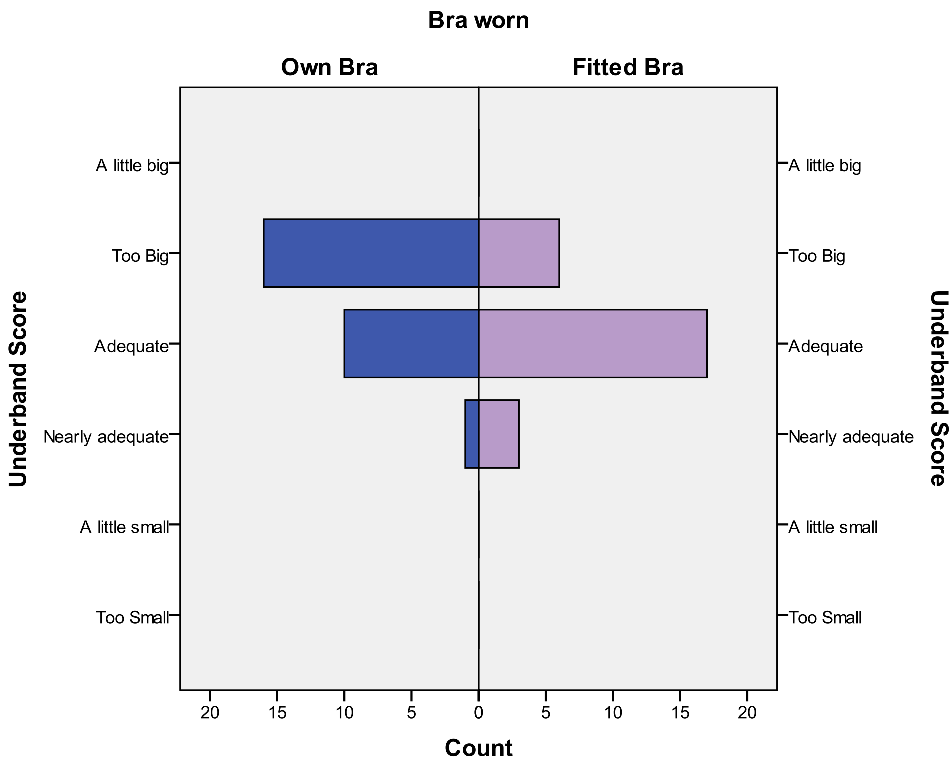


Figure 15 Underband score distribution

The bar chart shows that the number of counts for too big ratings is lower when the criteria are applied. The overall distribution shows that the number of counts for the adequate rating is higher. This suggests a relationship between the application of the bra fit criteria and the Underband score, to test whether this is as a result of the application of the bra fit criteria a repeated measures test will be conducted. An initial observation was that only 1 participant (n=26) had an underband which was registered as too small under the criteria that the underband is cutting into the back tissue, when checking the data it was found that this was when the participant was wearing the fitted bra. The observer noted that the smaller of two underbust sizes was selected for this participant as when questioned the participant did not feel discomfort and the fitter felt that the tighter underband gave better support. This case is highlighted in the below frequency table (Table 12). As this was a conscious decision taken by the trained bra fitter, this anomaly was classified as nearly adequate (not all adequate criteria are satisfied, Table 11) in order to give a viable group for analysis and enable statistical analysis to be carried out.

Underband too small - The underband is cutting into the back

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	52	96.3	98.1	98.1
	Yes	1	1.9	1.9	100.0
	Total	53	98.1	100.0	
Missing	System	1	1.9		
Total		54	100.0		

Table 12 Highlighted case where the underband rating is too small

A number of cases ranked as too big in the underband in the fitted bra, post hoc analysis revealed that this was due to the underband size being unavailable. Although the size the participant wore was available when they arrived at the fit trial, according to the criteria a tighter underband is required, as this meant that their size was unavailable. In these cases the bra fitted where applicable conducted cross grading fitting, where the next size of underband was worn on the tightest hook and the cup size was graded accordingly to give the closest possible fit for analysis. Although more effective than not fitting the participant this still resulted in a large fit score in the underband category which skews the results.

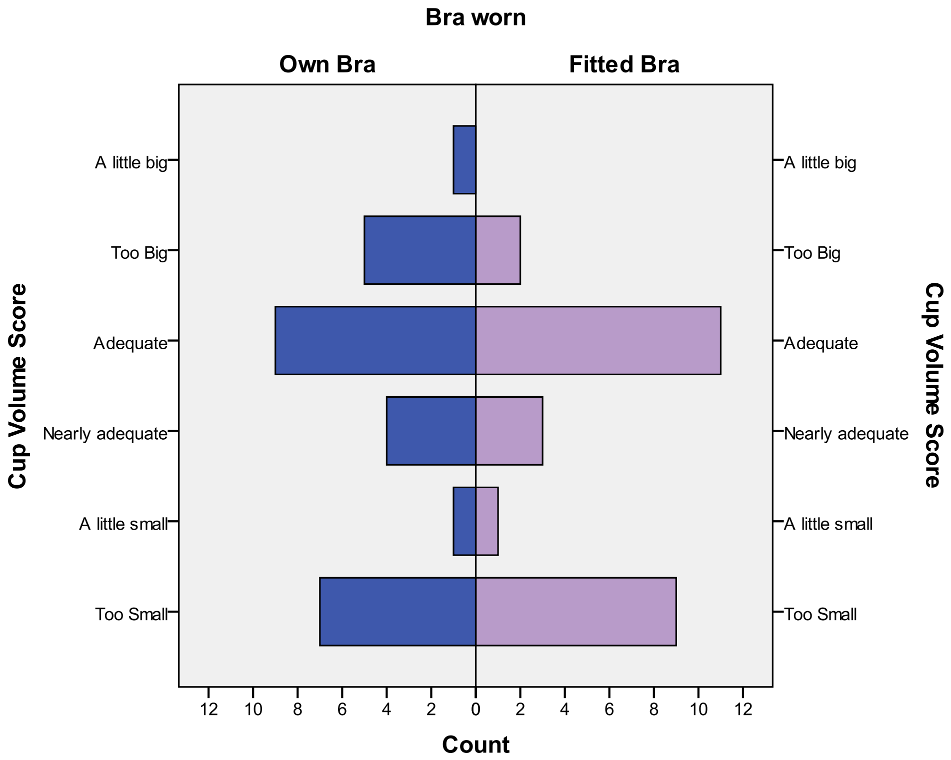


Figure 16 Cup volume score distribution

The cup volume score appears sporadic with little consistency of improvement between the fitted bra score and the own bra score which indicates a need for testing the aspects of the criteria which make up the cup volume score and also the relationship between these criteria aspects.

4.3.3 OVERALL BRA FIT SCORES

The overall bra fit scores in the categories of ‘too small’, ‘adequate’ and ‘too big’ were tested using a Wilcoxon signed rank test, to an alpha level of $p<0.05$.

The bra fit score small was smaller (scored closer the adequate) in 14 of the 25 cases when the fitted bra was worn, the test determined that the finding was statistically significant ($z=-2.02$, $p<0.05$) with a medium effect size ($r=0.40$). The bra fit score big was also smaller (scored closer to adequate) in 18 out of 26 paired cases when the fitted bra was applied, showing a statistically significant negative finding ($z=-3.21$, $p<0.05$) with a large effect size ($r=0.63$). The bra fit score adequate was larger (more of the adequate criteria were observed) in 19 out of 25 paired cases when the fitted bra was worn which was a statistically significant finding ($z=-3.17$, $p<0.05$) with a large effect size ($r=0.63$.) This suggests that the application of the bra fit criteria during the fitting process reduces the number of observations that indicate the bra is too small or too big and increases the number of observations that indicate the bra is adequate. To further investigate the impact on the specific characteristics of the bra fit each component score is tested in the two conditions (**Error! Reference source not found.**.)

Statistically significant variation observed	No statistically significant variation observed
Underband Adequate - The Underband is horizontal around the body, $z=-2.98$, $p<0.05$, $r=0.58$	Underband too small - The underband is cutting into the back, $z=1.00$, $p=0.32$, $r=0.20$[1]
Underband Adequate - The underband does not ride up, $z=-2.50$, $p<0.05$, $r=0.49$	Cup volume too small - The cup edge is cutting into the breast tissue causing double busting, $z=-1.16$, $p=0.248$, $r=0.23$
Underband too big - The underband is riding up at the back, $z=-2.50$, $p<0.05$, $r=0.49$	Cup volume too small - The breast tissue is spilling out of the cup at the front and/or underarm, $z=-0.82$, $p=0.41$, $r=0.16$
Underwire too small - The Underwire is	Cup volume adequate - The breasts are fully encased

[1] As noted in the initial findings this judgement to apply a tighter fitting underband was made by the researcher and this score has been amended for overall score analysis.

digging into the breast tissue, z=-2.32, p<0.05, r=0.46	within the cup, z=-1.13, p=0.26, r=0.22
Underwire adequate - The underwire lies flat against the body, z=-2.67, p<0.05, r=0.52	Cup volume adequate - The breasts fill the cup without over spilling, z=-0.38, p=0.71, r=0.07
Bra straps too small - The straps are digging in, z=-2.00, p<0.05, r=0.39	Cup volume adequate - There is a smooth line between the cup edge and the bust tissue, z=0.00, p=1.00, r=0.00
Bra straps adequate - You can comfortably fit 2 fingers between the straps and the body, z=-3.16, p<0.05, r=0.63	Cup volume too big - There is wrinkling visible in the cup, z=-1.00, p=0.32, r=0.20
Underwire adequate - The underwire is not digging in or resting on the breast tissue at the front and/or underarm, z=-1.94, p<0.05, r=0.38	Underwire adequate - The underwire follows the line of the bust, z=-1.60, p=0.11, r=0.31
Bra straps adequate - The bra straps are parallel of slightly 'V' shaped at the back, z=-2.24, p<0.05, r=0.45	Bra straps too small - The straps are too far apart, z=0.00, p=1.00, r=0.00

Table 13 Aspects of the bra where significant variation was observed between bras

4.3.4 OBSERVATIONS OF NO BRA SCANS

The parameters for automated extraction of the underbust height result in the measurement being extracted at a height much lower when no bra is worn. A sizeable distortion can be seen visually on the slice. Visually analysing this on the raw point cloud data reveals an error in the automatic measurement Extraction procedure. The underbust slice on this scan is being extracted to include part of the bust tissue (Figure 17), the technology is designed for extraction when wearing underwear and as such this could skew the extraction, visual checks of the no bra scans are to be conducted to limit any anomalies which can occur.

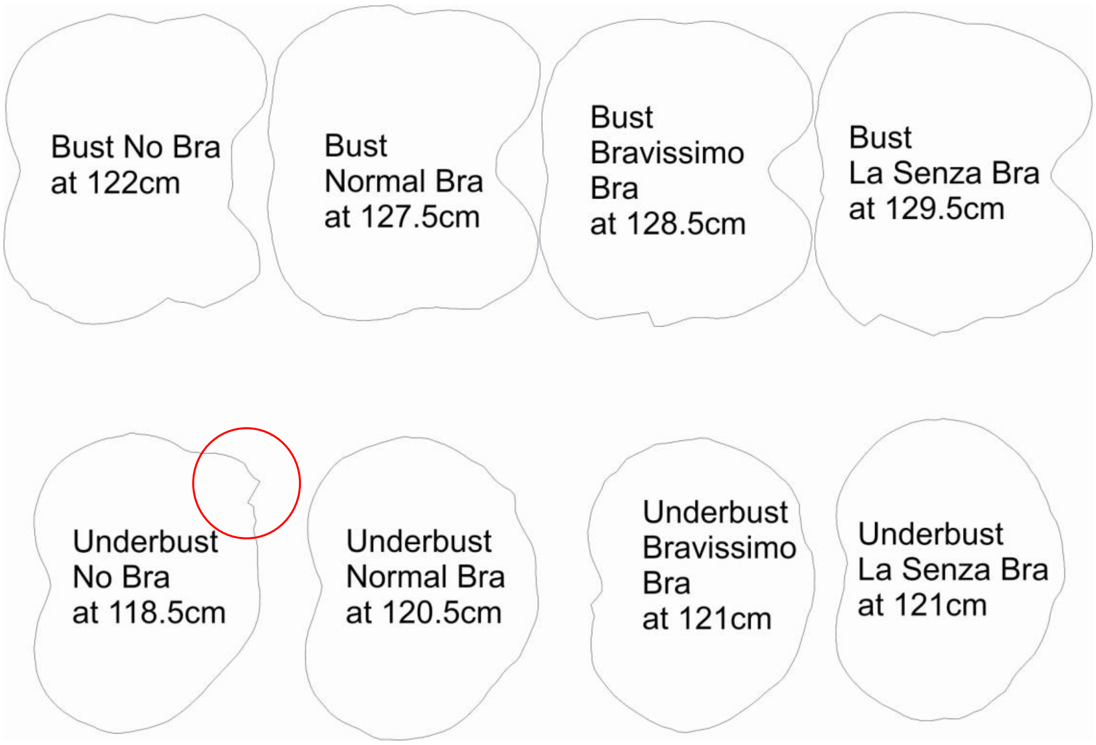


Figure 17 Slices at the bust and underbust height of comparative scans

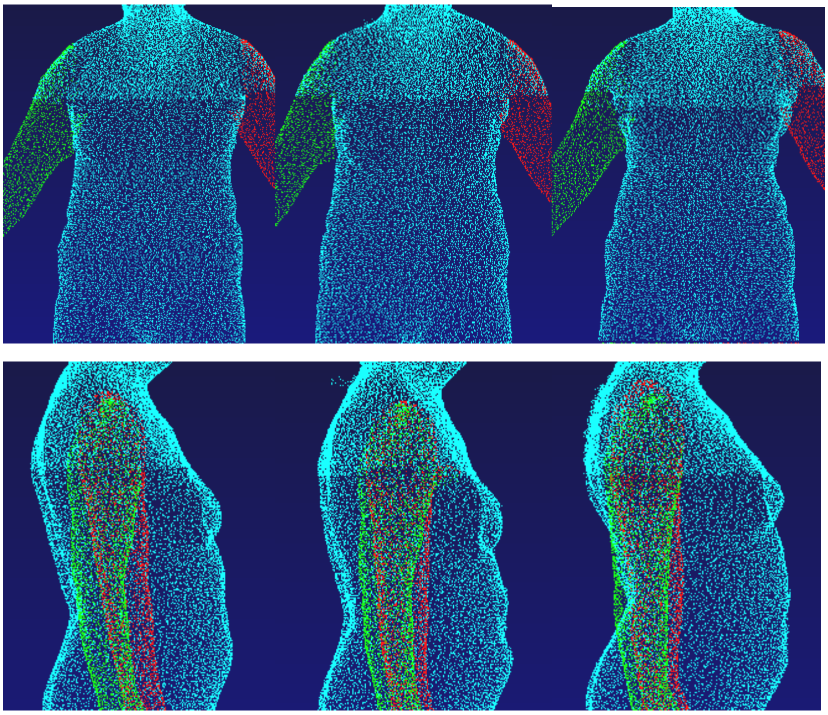
4.4 SYMMETRY

Profiling parameters were not set in the first phase of methodology as no significant variation was found, as such symmetry and asymmetry is analysed using experimental measures to look for patterns in the data. When unsupported, a Wilcoxon signed rank test revealed a statistically strong negative pattern between the left and right bust height ($z=-2.46$, $p<0.05$ with a large effect size $r=0.51$) based on the left height being smaller than the right height. This means that although measures have not been put in place to profile symmetry a statistically significant difference has been found between left and right bust height.

4.5 PHYSICAL IMPACT OF BRA FIT ON THE BUST

Fit improved in all of the bra fit categories in only one case (0828), this does not include cases where the bra fit of the participants own bra was already adequate in one category and remained adequate when a fitted bra was applied. Visually a difference can be seen on the 3D body scan point cloud data output (Figure 18) and a change in the profile categories can be seen.

Figure 18 Participant 0828 visuals of body shape when improved bra fit is applied



Unsupported Everyday Support Fitted Bra Support

Profile 0828	Unsupported	Everyday Support	Fitted Bra Support
1. Bust Height	Low	Low	Low
2. Bust size 1 Bust size 2	Small Average	Small Average	Average Large
3. Bust Spread	Average	Average	Spread
4. Bust Drop	Low	Low	Low

The bust size 1 and 2 increase as the fitted bra increases the prominence of the bust, this can be seen visually on the side profile scan image. The fitted bra also alters the breast spread profile, increasing the distance between the breasts.

A limitation of the use of 3D body scanning technology for bra fit was the scanners inability to precisely detect when the bra cup was too big. This criteria was defined by wrinkling or looseness in the cup which is a characteristic which cannot be picked up by the scanner and in the two cases when the cup volume of the fitted bra was found to be too big (0827, 0831) the scanner did not extract a clean scan, for case 0827 a good scan could not be extracted and this scan was removed from analysis. For case 0831 the uneven surface distorts the points of the scan around the bust area (Figure 19,) this scan was manually checked to ensure extraction points were not affected before including it in analysis. It could be possible with further work to classify these scan distortions as a profiling tool to pick up when the cup is too big but further work is required before this can be implemented.

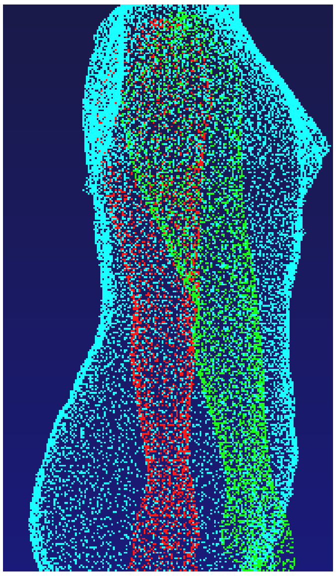


Figure 19 Undefined points for the scan of 0831 caused by the cup volume being big

The results of a Friedman Test on Profile 1 Bust height (Table 14 Friedman Test results - Profiling 1 Bust Height) indicate that there was a statistically significant difference in the ratio of bust height to Height across the three conditions, Unsupported, Everyday Support and Fitted Support x^2 ((df=2, n=21) = 14, p<0.005). Inspection of the median values showed an increase in the ratio of bust height as a proportion of Height from the Unsupported condition (Md = 6.61, Low) to the Everyday support condition (Md=7.14, Average) and a further increase under the Fitted Support condition (Md=7.15, Average.)

Friedman Test - Ranks

	Mean Rank
Ratio Bust Height Unsupported	1.38
Ratio Bust Height Everyday Support	2.10
Ratio Bust Height Fitted Support	2.52

Test Statistics[a]

N	21
Chi-Square	14.000
df	2
Asymp. Sig.	.001

a. Friedman Test

Table 14 Friedman Test results - Profiling 1 Bust Height

The results of a Friedman Test on Profile 2 Bust size 1 (Table 15 Friedman Test Results - Profiling 2 Bust size 1) indicate that there was a statistically significant difference in the bust size calculated as the difference between the bust and underbust measurements across the three conditions, Unsupported, Everyday Support and Fitted Support x^2 ((df=2, n=23) = 18.09, p<0.0005). Inspection of the median values showed an increase in the bust size from the Unsupported condition (Md = 13.71, Average) to the Everyday support condition (Md=15.76, Average) and a further increase under the Fitted Support condition (Md=16.64, Average.)

Friedman test - Ranks

	Mean Rank
BustSizeProfiling1NoBra	1.30
BustSizeProfiling1OwnBra	2.17
BustSizeProfiling1FittedBra	2.52

Test Statistics[a]

N	23
Chi-Square	18.087
df	2
Asymp. Sig.	.000

a. Friedman Test

Table 15 Friedman Test Results - Profiling 2 Bust size 1

The results of a Friedman Test on Profile 2 Bust size 2 indicate that there was no statistically significant difference in the bust size calculated as the average bust prominence across the three conditions, Unsupported, Everyday Support and Fitted Support x^2 ((df=2, n=23) = 5.48, p=0.065).

The results of a Friedman Test on Profile 3 Bust Spread (Table 16 Friedman Test Results - Profiling 3 bust spread) indicate that there was a statistically significant difference in the bust spread calculated as the ratio of distance between bust points and bust girth, across the three conditions, Unsupported, Everyday Support and Fitted Support x^2 ((df=2, n=23) = 17.48, p<0.0005). Inspection of the median values showed an increase in the bust spread ratio from the Unsupported condition (Md = 4.50, Spread) to the Everyday support condition (Md=4.85, Average) and a further increase under the Fitted Support condition (Md=5.08, Average.) As the ratio increases this means the amount of the bust girth which is taken up by the distance between bust points decreases and they are closer together.

Friedman test - Ranks

	Mean Rank
Ratio Bust To Bust To Bust Girth Unsupported	1.30
Ratio Bust To Bust To Bust Girth Everyday Support	2.22
Ratio Bust To Bust To Bust Girth Fitted Support	2.48

Test Statistics [a]

N	23
Chi-Square	17.478
df	2
Asymp. Sig.	.000

a. Friedman Test

Table 16 Friedman Test Results - Profiling 3 bust spread

The results of a Friedman Test on Profile 4 Bust Drop (Table 17 Friedman Test Results - Profiling 4 Bust Drop) indicate that there was a statistically significant difference in the bust drop calculated as the ratio of distance between side neck point to bust average and side neck point to underbust average, across the three conditions, Unsupported, Everyday Support and Fitted Support x^2 ((df=2, n=23) = 9.74, $p<0.05$). Inspection of the median values showed an increase in the bust size from the Unsupported condition (Md = 1.23, Low) to the Everyday support condition (Md=1.30, Average) but not a further increase under the Fitted Support condition (Md=1.29, Average.)

Friedman test - Ranks

	Mean Rank
Ratio SNP To Bust To SNP To Under Bust Unsupported	1.48
Ratio SNP To Bust To SNP To Under Bust Everyday Support	2.35
Ratio SNP To Bust To SNP To Under Bust Fitted Support	2.17

Test Statistics [a]

N	23
Chi-Square	9.739
df	2
Asymp. Sig.	.008

a. Friedman Test

Table 17 Friedman Test Results - Profiling 4 Bust Drop

As the profiling is based on a sample of participants with everyday support it is expected that the unsupported bust would rate on the lower and more spread end of the scales however the difference that both conditions of support have on the resulting profile provides retailers with a tool to test trial bras in their impact on the bust profile.

5 DISCUSSION

This section comprises of the discussion of key findings from the study and emphasises the practical application of the research.

5.1 BRA SIZING

This study has identified differences in bra sizing calculations from the British standard recommendations (1999) and also comparable retailers in both underband and cup size. This suggests that there is a lack of standardisation in the industry. The differences found in academic literature (Table 6) is also documented as three different Underband calculations and four different cup size calculations were found.

One of the first initial findings is that the denotation ‘FF’ is not employed in the British Standard or among 4 of the 8 retailers. This means that there will be more variation among the sizes above ‘F’ as half of the retailer’s referenced use ‘FF’ and the other half use ‘G’ for the same intervals from ‘F’. The intervals recommended by La Senza (2011) and George (2011) cover a wider range of measurements. This means the variation can be between 3 cup sizes dependent on whether the underband measurement is at the lower or upper end of the size denotation. Variations exist in the baseline for the calculation which is the underbust and the amount of variance that denotes the first size which is either A or AA this suggests miscommunication in the bra sizing and calculation system which recommends further research to establish the precise amount of variance.

Some initial findings stemmed from the researcher gaining a greater understanding of the research topic directly relating to bra pattern technology, and a potential miscommunication of sizing denotations and the calculations advised to consumers for bra sizing and ultimately bra fit. Bra patterns are graded and amended in millimetres (mm) as a small amendment can have a dramatic affect on the shape of the malleable breast tissue (Hardaker & Fozzard, 1997; Na et al., 2011; Shin, 2007). A number of the UK sizing systems are calculated in Inches (“) (Ann Summers, 2011; Marks and Spencer, 2011) and ones that are not calculated in Inches (John Lewis, 2011; La Senza, 2011) are still size designated using the Inch sizing systems. This presents a margin for error and a possible gap between the patterns used to construct bras and the consumer selecting what will fit them adequately.

The finding that there was a strong association between bra consumers perception of their upper body shape and both the bra size and underband size they wear is interesting as it relates to their self perception and buying behaviour. The practical application of this in a retailer bra fitting scenario is that if a consumer understands their body shape they will carry this understanding through to size selection and could improve their ability to select a correctly fitting bra. This supports McGhee et al.'s (2010) findings that education improves bra knowledge and as a result bra fit through self selection.

This study does not suggest that there is anything wrong with bra sizing or that it needs to be standardised, the key point in this study is that there are differences and that these need to be accurately conveyed to the consumer so that they can apply this information to bra size selection.

The related measures test found statistically significant changes in the overall bra fit through the application of the bra fit criteria this indicates that bra fit can be improved by applying the criteria during the fitting process.

There is however a paradigm shift when validating the criteria as the existence of a criteria or overall bra fitting advice is on the assumption that perfect bra fit can be achieved. The observations of the researcher during this process suggest that styling of a bra and availability of sizes can impact on the applicable criteria. The Bra fit criteria and advice from retailers analysed does not distinguish between different styles of bras. For example participant 086124 was wearing a strapless bra and therefore the bra straps section of the criteria did not apply to them. 19.2% (n=26) of participants were fitted into cross graded bra's this means that the underband size which would fit them according to the criteria was unavailable in the trial style and the next underband size was worn on the tightest adjustment, as the cup size is proportional to the underband size, one cup smaller was worn (Hardaker & Fozzard, 1997; Shin, 2007). This accounts for all counts (n=6) of the Too Big underband scores on the fitted bras. One success of the scoring system developed for this research is that it can be used to identify and highlight specific aspects of the bra which is not fitting correctly. This information is extremely useful to consumers and also to bra retailers.

The researcher recommends future distinctions should be made that a criteria is set against a particular style of bra. Two styles which presented problems being rated against the criteria were moulded cups and strapless bras, a limitation of the choice magazine criteria (2005) is that it is only applicable to one style of bra. The bra style selected for this research was not considered a limitation as it was a style representative of a best selling style which can be purchased on the UK bra market and covers both the standard A-D and DD+ size range. The BMI scores of the participants do not indicate that they are an extreme of body size or below the age set by the inclusion criteria.

5.2 BRA FIT CRITERIA

In the underband category findings were consistent with previous research. The number of counts for too big ratings is lower when the criteria are applied. The overall distribution shows that the number of counts for the adequate rating is higher when the criteria are applied during the fitting process. This suggests a relationship between the application of the bra fit criteria and the Underband score,

There were no counts of underband too small when participants are wearing their own bra but 16 participants in the sample (n=29) where the underband scored as too big. This is consistent with McGhee and Steele (2010) and White and Scurr's (2012) finding that the most common underband fitting mistake is that the underband is too loose, not too tight.

Cup volume demonstrated an inconsistent level of improvement through the bra fitting process. The bra fitter noted that bras were being scored in the too small criteria for cup volume when the cup volume was adequate or too big in all other aspects except for the bra cup neck edge (**Error! Reference source not found.**) which was digging in to the breast tissue. This was due to the styling and cut of the bra being unsuitable for the participant, which challenges the paradigm that correct bra fit, can be achieved through fitting. If the style of the bra is not correct than adequate bra fit is not possible, this is an area which requires further development.

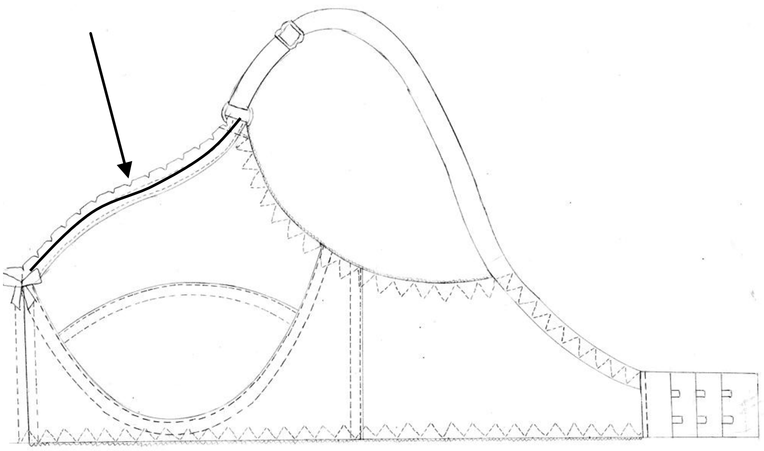


Figure 20 Bra cup neck edge Adapted from: http://thelingerieaddict.com/wp-content/uploads/Image-71.jpg

This study presents the first bra fit criteria in academic research which can be used to grade different aspects of a bra and provide information to the consumer and bra fitter on what is and is not correct about the bra fit. This information could be used to improve bra fit understanding and resulting bra fit.

Observations of the scanning technology and protocols revealed key areas which need to be monitored during the 3D body scanning process when applying the technology to bra fit. Extraction of the underbust measurement must not include any breast tissue, this must be manually checked prior to the scanning procedure. The use of bra's which are close to the participant's skin tone improves the chances of extracting a clean scan first time. The posture of the participant should be monitored through the scanning process. This is an area where there are protocols to ensure correct posture however there is an element of participant co-operation as the participant is on their own in the scanning booth.

5.3 Physical impact of bra fit on the bust

The profiling tools developed in this study are basic statistical breakdowns of some aspects of breast size and shape data which can be extracted. Further work on these definitions could be conducted using subject specific expert knowledge to classify the shapes into categories before applying them to 3D body scan data. Once defined the categories can be used in bra fit assessment when a certain characteristic is desired, for example uplift or a pushed together effect is desired.

Overall the 3D body scanning technology did not prove a useful tool for quantifying bra fit as a number of the aspect of the bra fit criteria cannot be adequately identified using the scanner and no new tools specifically linking to bra fit where identified.

It was interesting to note that observer and participant observations were that the style of bra used for the fit trials had a sloped shape and participants felt that it did not give them a ‘lift’ as they thought, although the findings show that the overall bust height increased as a result of applying the bra the bust drop indicates that the shape of the bra gives a slope with a prominent but low (in proportion to the rest of the bust) point rather than a rounded shape.

Where the scanner does present interesting findings is in the profile of the bust once the bra has been fitted. The practical application of this could be for the research and development department of a retailer or supplier to test the shape a new product gives. It could also be used to assess the shape a best selling style gives to replicate it through future ranges. The strength of using 3D body scanning technology for this purpose is that it is a quick and non invasive method of data acquisition; data can be reviewed after a period of time and reassessed. The technology can be used to asses the shape a bra gives over a large sample of sizes and shapes such as part of a wearer trial.

A key Finding at this stage is that bra fit impacts Breast size when breast size is measured as the difference between bust and underbust but not when measured as the average bust prominence, one limitation of the bra calculation highlighted by White and Scurr (2012) was that retailers do not follow the advice to measure over a correctly fitting bra and this was a limitation in the application of the sizing method. Breast prominence as measured using 3D body scanning technology initially appears to present a breast size measurement option which is not affected by bra fit. Further research is recommended into the application of Breast prominence as a measure for breast size.

6 CONCLUSIONS

The relationship between breast measurements and overall body measurements represent a method of quantifying the differences found within a sample. Percentiles presented a statistical option for profiling the differences found within a sample, once key measurements and protocols were established. A Five point profiling tool has been developed for 3D body scanning technology using the bank of scan data which categorises 1. Bust Height, 2. Two methods of Bust size, 3. Bust spread, 4. Bust drop and an initial look into profiling Symmetry.

The profiling tool developed in this study supports current research that proportion and the breast in relation to the rest of the body is an important aspect when classifying shape and size characteristics. This tool could provide the basis for developing a 3D body scan system to assess size and shape characteristics of a sample of consumers. This satisfied aim 1, to profile the relationship and differences in bust size, position and shape in a sample of UK bra consumers using 3D anthropometric body scan data. It also demonstrated further practical applications for this technology in bra fit trials.

As the profiling tool is based on a sample of participants with everyday support it was expected that the unsupported bust position would be lower and more spread. Both of the bras applied had an impact on the bust profile which was not as predicted. The overall profile of the bust and participant observation was that the fitted bra gave a spread out and sloped shape with a low bust point. This suggests that 3D body scan profiling could be applied to the testing of trial bras and their impact on the bust position and shape on a large sample of consumers. The researcher recommends the adaptation of these profile markers so that they are in line with expert definitions and can be applied to test whether the product meets consumer and retailer expectations in relation to the positioning and shape it gives the bust of a range of consumers.

The bra fit criteria collated for this research project was defined by the most frequently accruing bra fitting advice available to UK consumers. It therefore represents a general view of the bra fit information and advice UK consumers receive. The findings suggest that the direct application of the information give statistically significant improvement to overall bra fit it does not supply all the information the consumer needs. The findings suggested that not all bra's and consumers can be fitted correctly with information alone and that other factors influence the resulting bra fit. Advice on bra styling and how to fit different types of bras, for example strapless, plunge and ballonet is recommended. The addition of bra cup neck edge to fit criteria is recommended as this aspect can act independently to other bra cup volume criteria.

This study presents the first bra fit criteria in academic research which can be used to grade different aspects of a bra and provide information to the consumer and bra fitter on what is and is not correct about the bra fit. This information could be used to improve bra fit understanding and resulting bra fit.

Where the 3D body scanner presents interesting findings is in the profile of the bust once the bra has been fitted. The researcher was able to quantify differences in the shape and positioning of the bust using the 3D body scanning technology. This presents an interesting new avenue for the assessment of bra shape and the impact of the bra on the bust. The practical application of this could be for research into the shape a range of products give. This satisfies aim 2 to collate and validate criteria for achieving adequate bra fit and quantify the physical impact on the bust size, shape and position.

The literature review highlighted criticisms that the bra size calculation is inadequate in advising consumers the correct bra size for them. Miscommunication of information to the consumer and variations caused by measurement procedures were considered as possible problem areas for the presentation of clear information.

Review topic 2 of the literature review found that variation exists in the calculation and communication of bra sizing (Chen et al., 2011) which could have an impact on the consumers experiencing of selecting adequate fit from a bra. The bra sizing table presented in the Results section also demonstrates the need for clear retailer specific measurement and calculation information to be conveyed so that the consumer can understand differences in how the bra sizes are calculated so that they can apply this information to bra size selection. This study does not support the understanding that there is a standardised bra sizing calculation and supports clearer communication to the consumer of retailers' individual sizing calculations and methods to improve understanding.

A key finding is that bra fit has a statistically significant impact on breast size, when breast size is measured as the difference between bust and underbust (bust size 1) but not when measured as the average bust prominence (bust size 2). White and Scurr (2012) say that when calculating bra size it is advised that measurements be taken over a correctly fitting bra however they note that retailers do not always follow this advice. If the fit of the bra worn when taking the measurements has an impact on the breast size calculation it suggests that there could be a weakness in the current use of this sizing system. This satisfies aim 2, to evaluate the presentation of bra sizing by retailers and identify areas of miss communication to characterize effective application to the bra market,

Breast prominence as measured using 3D body scanning technology initially appears to present a breast size measurement option which is not affected by bra fit. This is the first study to highlight the use of bust prominence as a potential indicator towards a new method of bra size calculation as it is not affected by the bra worn when taking the measurements. Further research is recommended into the application of Breast prominence as a measure for breast size.

7 RECOMMENDATIONS

The Methodology section of this study highlighted limitations of using the existing bank of scan data for bra fit research and the potential for in depth analysis when more background data is acquired. A recommendation is that further supporting procedures be developed in this area to further bra fit research using the 3D body scanning facilities at Manchester Metropolitan University. It is recommended that one aspect of future research focus on long term breast size and shape principles such as Age and hormonal changes as the principles of size and shape analysis could be applicable to a longitudinal study. 3D body scanning technology could be used to track shape and size variations using repeat scans of one participant which span a time frame to track changes over a period of time. A longitudinal study could be conducted for the purpose of documenting changes in breast shape and size over a short period of time to track hormonal and cyclical breast changes or over a long period of time to monitor the long term effects of bra fit or the impact of hormonal changes such as menopause or pregnancy.

From an ethical viewpoint the scan database is anonymously stored however the application of the suffix no bra after a scan could have ethical implications for the participants feelings on the process. A recommendation is for further coding to be applied to replace the wording. NB for no bra FB for fitted bra OB for Own bra, to the uninformed user of the scan database this could have less potential for negative personal feelings towards this particular aspect of the scan process.

The Literature and Methodology highlighted variation between manual and 3D body scan measurements of the bust, a recommendation of this study is that further research be conducted on the reproducibility and validity of 3D body scanner extracted underbust and bust measurements and the application of bra size calculations to these measurements.

This research has highlighted the potential for the application of a bra fit criteria to achieve adequate bra fit and a recommendation for further research and development of style specific bra fit criteria with recommendations on how to achieve adequate bra fit.

Nicolleti et al.'s (2009) work on categorising breast size combined the type of purely quantitative methodologies used by Chen et al. (2010, 2011) in their statistical approach and the experience based qualitative methods of Fitzal et al. (2007) in their purely experience based approach. During this study the researcher has highlighted the value of qualitative and experience based approaches once a strong quantitative foundation is in place. A recommendation from this research is that both the topics of profiling variation in bust size, positioning and shape and the topic of bra fit criteria be researched using a mixed method approach to give depth to the development of research in this area.

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APPENDICES

APPENDIX A. LITERATURE REVIEW SUPPORTING TABLES

A Table compiling the Ptosis grades defined in Kim et al's., 2005 study.

Ptosis Grade	Definition
0=None	Nipple and most of gland are above inframammary fold
1= Minor	Nipple at Inframammary fold
2= Moderate	Nipple is below inframammary but above lower contour of breast
3= Major	Nipple at lower breast contour and breast below inframammary fold

Table 18 Ptosis grades (Kim et al., 2005)

A table consolidating the breast shape factors compiled through Zheng et al.'s 2007 study.

No.	Description	Top end of the range	Bottom end of the range
Factor 1	Overall body build	Fat	Thin
Factor 2	Volume of breast	Large	Small
Factor 3	Inner breast shape	Wide and firm	Narrow and low
Factor 4	Outer breast shape	Wide and firm	Narrow and low
Factor 5	Overall height proportion	Tall	Small
Factor 6	Orientation of the breast	Spreading	Close
Factor 7	Gradient of the upper breast	Spreading	Close
Factor 8	Lower breast shape	Round	Flat

Table 19 Eight breast shape factors (Zheng et al., 2007)

APPENDIX B. SUPPORTING DOCUMENTS - METHODOLOGY

I. 3D BODY SCANNER ETHICS PROCEDURE STEP BY STEP V2.DOC 13/05/2013 12:07

SCANNER ETHICAL PROCEDURE

1. Outline the scanning procedure using the step-by-step guide and explain the consent process.

Subjects have the scanning process explained to them and are referred to a step-by-step guide detailing the process from start to finish. This process and a copy of the consent form are provided for the subject to read prior to scanning.

2. Complete the subject records database

The database is available on a single computer in room 9, which has the required program (Filemaker) to enable it to be run. The database can only be accessed with a password and is used to store personal details of the subject, these are currently name; age; ethnicity; gender; contact (either phone or email); postcode and the manual measurements not taken by the scanner.

Completion of the database fields generates a unique code that is used to name the scan file and retain anonymity of the scan subject.

3. Print and sign the consent form (Subject and Scanner Technicians)

During steps 4-6 of the database a consent form is printed out, which subjects are then cautioned to read and sign as an agreement to go through the scanning process. This consents to them being scanned and also for their scan to be used anonymously in teaching and research at the Manchester Metropolitan University. The form is then counter signed by both the scanner technicians who are present throughout the scan process.

4. Using a private changing cubicle, change into underwear then don a dressing gown

Subjects are directed to a private lockable changing cubicle and provided with a dressing gown. It is explained they must remove all outerwear and then don the dressing gown before being measured manually (see below) and entering the scanning booth. Due to the nature of the scanner it is explained underwear must be close fitting and not black in colour. If subjects have incorrect underwear they are provided with some, which is more appropriate; Women are instructed to place the briefs over their own whilst being scanned, Men are provided with close fitting underwear, which they wear in place of their own.

5. Manual measurements will be taken prior to scanning

To enable full analysis of the scan data both weight and height measurements are collected. These are taken manually in accordance with detailed methods, which are available for the subject to view during and prior to giving consent. Other clearly defined manual measurements may be taken as projects dictate, these will also be explained to the subjects and a detailed definition will be provided for reference by the subject.

6. Enter the Scanner booth, close curtain and then remove dressing gown and place outside of cubicle, redrawing the curtain.

Prior to entering the scanner booth the scan position is explained to the subject and a definition provided for their reference. The subject is then instructed to enter the scanning booth and draw the curtain to, remove the dressing gown and hang it outside the scanner. Privacy is maintained by placement of a screen and the necessity to only open the curtain a fraction when placing the dressing gown outside of the cubicle.

Whilst the subject is in the scan booth and before the scan is activated the technician will input the unique code on the consent form to name the scan file. This retains the anonymity of the subject but allows for the scan to be matched with the other details when analysing the data.

7. Stand in the scan position and when instructed press the button on the tip of the right handhold. Remain in the scanning booth until the scan is complete and a usable image is collected. (Approx 2mins)

The subject adopts the scan position and presses the button to activate the process when they are ready and relaxed in the scan position. Once the scan has been captured it is checked on screen and if a rescan is necessary this is communicated to the subject. Once a suitable scan is captured then the subject places the dressing gown on and returns to the changing cubicle to get dressed.

8. Leave scanner booth and get dressed in the cubicle

On completion of the scan the subject re-enters their changing cubicle and dresses in their original clothing, borrowed underwear is deposited in a suitable container by the subject and will be laundered before being reused. Similarly dressing gown are laundered once they have been worn a number of times.

Once scanned the subject is given the option of having their scan data printed showing a front and side view and displaying their measurements and body shape.

9. Note

At no point is the subject undressed whilst in view of the scanning technicians or other subjects. A minimum of two scanning technician must be present at all times. The subject is free to withdraw from the activity at anytime even though the consent form has been signed. At no point will the information from the subject details database and the scan data be held on the same computer. All data is backed up on an external hard drive and kept in a fire proof safe with controlled access.

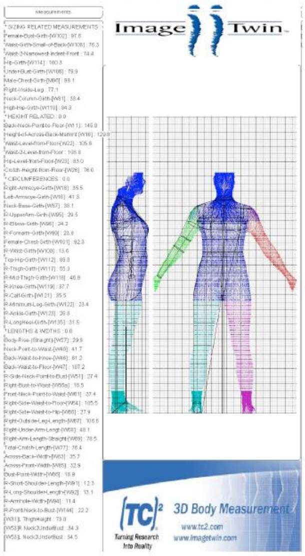
II. Body Scan Information Sheet

BODY SCAN INFORMATION SHEET

Manchester Metropolitan University

The body scanner provides a unique opportunity for you to have your body captured in 3D and for measurements to be extracted. This data can be used to create an avatar to your dimensions and to classify your body shape. You may also like to return to the scanner to record any body size/ shape changes over a longer period of time.

Sample Scan Measurement Output



Scanning process:

- On arrival you will need to complete a consent form and the scan process will be explained
- Using a private changing cubicle, you will undress down to your underwear then don a dressing gown.
- Prior to scanning a number of manual measurements will be taken.
- You will then enter the private scanner booth, close the curtain and remove your dressing gown
- Your scan will be captured and once processed you will leave the booth in your dressing gown to get dressed.
- A copy of your scan and list of measurements will be provided.

What should I wear:

- Underwear should be close fitting and Not Black or shiny fabric, as they will cause data loss in the scan. Most suitable colours are beige, grey, light blue.

Women - close fitting bra and briefs in non-shiny fabric

Men - close fitting briefs.

No loose fitting boxer shorts

Jewellery and hair:

- Stud earrings may be worn
- No bracelets, long earrings, watches or glasses
- Long hair must be tied up away from the neck.

Ethics:

- Subjects can withdraw at anytime from the scan process without reason
- Data will be kept privately and will be anonymous (scans are individually coded)
- Scan images will be used anonymously for research and teaching at MMU
- Two technicians will be present during the scanning process
- All data is collected in accordance with our Ethics Step by Step procedure

More details of the scanner can be found at http://www.hollings.mmu.ac.ukbodyscanner/

Macintosh HD:Sim Scanner Files:01C Scanner Guidance Documents:Scan Info Sheet 3.doc 08/09/2011

III. ETHNICITY DISTRIBUTION OF THE UK POPULATION 2010

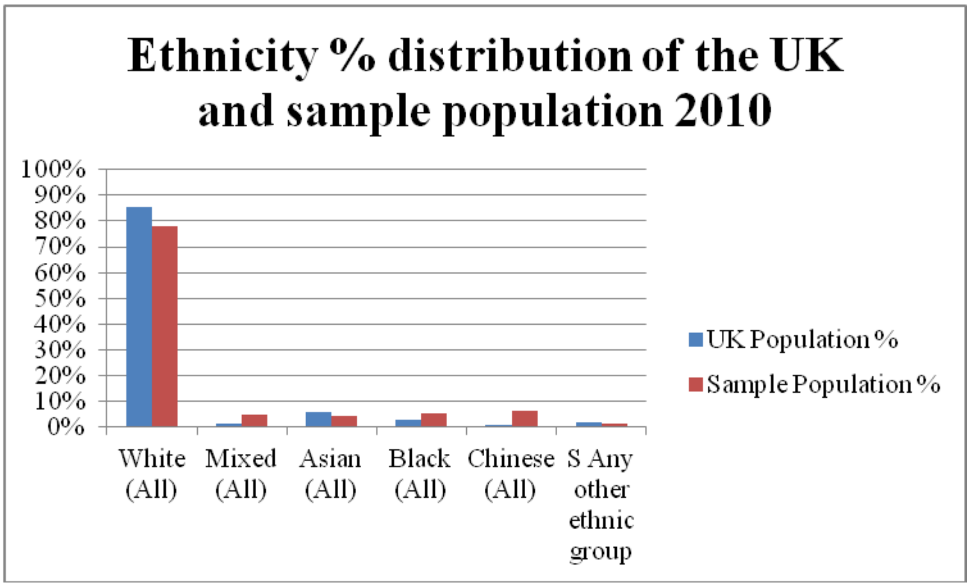


Figure 21 Amended from Source: Office for National Statistics, Annual Population Survey 2010

IV. APPROVED EMAIL SENT TO PRIOR PARTICIPANTS

Email sent to prior bra fit research participants who expressed an interest in participating in further research regarding bra fitting and body scanning. Sent on 20.08.2011 between 17:18 and 17.46

Dear,

Thank you once again for your participation in the study on Bra Sizing and Fit. It has now been a year since you took part and as this research was a great success, the findings are going to be published in an international academic journal.

At the time you expressed an interest in being part of further research and due to the successful foundation the previous study presented I am now looking further into using 3D body scanning as a tool to research bra fit. This safe, non-contact method provides speed and precision in measuring. It is also able to generate accurate body size and shape information, which often helps consumers to select sized garments that fit better. I will be able to provide you with a copy of the output data (complete body measurement and body shape information). As usual, anonymity is assured to all participants.

If you would be interested in knowing more about taking part please let me know. If not then thank you for your time and I really appreciate your previous participation.

Kindest regards,

Natasha Mitchell

Postgraduate Researcher

APPENDIX C. ETHICAL PRACTICE FOLLOW UP REPORT

REPORT ON ETHICAL PROCEDURE WHEN APPLYING 3D BODY SCANNING TECHNOLOGY TO BRA FIT RESEARCH

Natasha Mitchell, Department of Clothing Design and Technology, 2011-2013

This report summarises and reviews the application of new ethical protocols for research into bra fit and 3D body scanning at Manchester Metropolitan University. The report is compiled by Natasha Mitchell for the attention of the Ethics committee on completion of the Msc by research project entitled 'Utilisation of 3D body scanning as a research tool when establishing adequate bra fit'

WORKING DOCUMENTS

The working documents submitted to the committee in 2011 included

1. Bra recruitment poster
2. Bra fit information sheet and consent form
3. Brief schedule for fit trials

KEY AREAS WHERE NEW PROTOCOLS WHERE ADAPTED

The two key areas where new protocols where adapted were the optional 3D body scans taken where the participants breasts were unsupported and when the participants took part in the bra fitting part of the trial. These two aspects were integral to the bra fit research being carried out. The unsupported scan was used to provide a baseline on which bra fit support could be assessed and also gave the researcher the opportunity to test the capabilities of the 3D body scanner for assessing unsupported breast shape. The bra fit trial was based on a retailer style bra fit with an observer as per university guidelines. All aspects of the procedures were explained to the participants fully and the participants were given the opportunity to ask questions or opt out of part of the process at any time.

RECOMMENDATIONS FOR FUTURE RESEARCH IN THIS AREA

One recommendation is that existing 3D body scan protocols should be followed for all types of 3D body scan research and adapted where required to specific research applications. If additional elements are included and a participant goes through a number of processes then the participant's 3D body scan reference number should be used to ensure consistent anonymous identification.

Participants which go through any procedure which differs to that of normal scanner protocols must have there scans identified with a suffix as it may exclude their inclusion into the bank of scan data used for research within the university. Discrete coding should be used to identify any additional parameters which exclude the inclusion of the data in the bank of scan data. The suffixes 'no bra', 'own bra' and 'fitted bra' were used, it is recommended that these be amended to 'NB', OB and FB to avoid drawing unnecessary attention to the saved data before it is moved from the scan data base to a secured server. These suffixes also appear on the participants print out sheets so it is again important to be discrete about the conditions of the scans.

One aspect which was key to ensuring the participants felt safe and comfortable was sectioning off an area of the body scanning room to ensure a personal booth space was possible for the bra fitting. At no point did the participant appear without a bra in front of the technicians or other participants, returning to their own changing cubicle to change into a different bra.

Overall the acquisition of this data was carried out with integrity and openness and complied with the Universities ethical procedures. The researcher recommends the adaptation of these working documents for future research in this area.

APPENDIX D. SUPPORTING TABLES - METHODOLOGY

I. INITIAL OBSERVATIONS ON BRA SIZE ADVICE VARIATIONS AMONG RETAILERS

British Standard	**60A**	**65B**	**70C**	**75D**	**80E**	**85F**	**90G**	**95H**
La Senza	-	30A/ 30C	32B/ 32D	34C/ 34DD	36D/ 36E	38DD/ 38F	40E/ 40**FF**	42F/ 42G
CUK Clothing	28A	30B	32C	34D	36D	38DD	40E	42F
Eveden	-	-	-	28	30	32	34	36
Ultimo	-	30B	32C	34D	36D	38DD	38**FF**	38G
Ann Summers	28A	30B	32C	34D	36D	38DD	40E	42F
George	28/30AA or 28/30B	28/30A or 28/30C	32B/ 32D	34C/ 34DD	36D/ 36E	38DD/ 38F	40E/ 40G	42F/ 42G
Triumph	-	30AA	32B	34C	36D	38DD	40E	40F
Marks and Spencer	28AA	30A	32C	34DD	36E	38G	40+	42+

Table 20 Bra size calculations across retailers

II. BRA RESEARCH MEASUREMENTS TABLE

Bra research Measurements	**Source**	**Manual Anthropometric/ 3D body scanner and method**	**Measurement used in the study**
Suprasternal notch to nipple distance	(Brown, et al., 2012) (Agbenorku, Agbenorku,	Manual/motion capture. Manual application of 5mm retro reflective markers and 8 calibrated motion capture cameras. Manual -Measured with a tape +/-0.5cm to the centre of the nipple.	W144R_FrontNecktoBust (right) W144L_FrontNecktoBust (left) W145_CFrontNeckToBustLine

	Iddi, Amevor, Sefenu, & Osei, 2011) (Kim, Reece, Beahm, Miller, Atkinson, & Markey, 2007)	Reference photo which is not scaled so points are used in reference to each other as vertical levels. The measurement is taken from a line level with the Suprasternal notch to a line level with the centre of the nipple height	Front Neck to bust level (W8_FrontNeckBaseHeight-W20_Bust_Height)
Nipple to inframammary crease	(Agbenorku, Agbenorku, Iddi, Amevor, Sefenu, & Osei, 2011) (Kim, Reece, Beahm, Miller, Atkinson, & Markey, 2007)	Manual - Measured with a tape +/-0.5cm to the centre of the nipple. Reference photo which is not scaled so points are used in reference to each other as vertical levels. The measurement is taken from the centre of the nipple height to the end point of the inframammary fold height using the side	

		view photograph.	
Nipple to vertical midline	(Agbenorku, Agbenorku, Iddi, Amevor, Sefenu, & Osei, 2011)	Manual - Measured with a tape +/-0.5cm to the centre of the nipple. Midline is the intersection point between the vertical suprasternal notch and the horizontal inframammary line	
The level of lowest visible point of the breast to nipple height	(Kim, Reece, Beahm, Miller, Atkinson, & Markey, 2007)	Reference photo which is not scaled so points are used in reference to each other as vertical levels. The measurement is taken from a line level with the lowest visible point of the breast to a line level with the nipple height.	Bust_ Height_ to_ Underbust_ Height (W20_Bust_Height - W21_Underbust_Height)
The level of lowest visible point of the breast to inframammary fold	(Kim, Reece, Beahm, Miller, Atkinson, & Markey, 2007)	Reference photo which is not scaled so points are used in reference to each other as vertical levels. The measurement is taken from a line level with the lowest visible point of the breast to a line level with the end point of the inframammary fold using the side view photograph.	
Bust	(Wang &	3D body scanner - Not	W102_ Bust Girth

Bust circumference	Zhang, 2007) (Na, Xin, Yi, Yu, & Ye, 2011)	provided 3D body scanner - Not provided	W103_BustArcWidth Front bust to bust ratio
Underbust	(Wang & Zhang, 2007)	3D body scanner - Not provided	W106_ Under Bust Girth
Waist Midriff girth	(Wang & Zhang, 2007) (Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided 3D body scanner - Not provided	W108_WaistGirth
Hip	(Wang & Zhang, 2007)	3D body scanner - Not provided	W114_HipGirth
Neck	(Wang & Zhang, 2007)	3D body scanner - Not provided	W90_NeckWidth
Shoulder	(Wang & Zhang, 2007)	3D body scanner - Not provided	
Bust point Distance Distance between two BP points	(Wang & Zhang, 2007) (Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner- Not provided 3D body scanner- Not provided	W86_BusttoBust
Bust point height Height of chest point	(Wang & Zhang, 2007) (Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided 3D body scanner - Not provided	[W20]_Bust_ Height 3D body scanner
Underbust	(Wang &	3D body scanner - Not	[W21]_Underbust _Height

height	Zhang, 2007)	provided	
Waist height	(Wang & Zhang, 2007)	3D body scanner - Not provided	W22_Waist_Height
Hip Height	(Wang & Zhang, 2007)	3D body scanner - Not provided	W23_HipHeight
Neck Height	(Wang & Zhang, 2007)	3D body scanner - Not provided	W8_FrontNeckBaseHeight
Shoulder Height	(Wang & Zhang, 2007)	3D body scanner - Not provided	W9R_SideNeckHeight and W9L_SideNeckHeight and Difference_ between_ shoulder_ heights (W9R_ Side Neck Height - W9L_ Side Neck Height)
Pitch of breast radial	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	
Depth of breast	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	
Sp1 shoulder scope	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	
Sp2 shoulder scope	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	

Distance neck-side point to BP point	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	W51R_SideNecktoBust W51L_SideNecktoBust
Distance middle point of shoulder to BP point	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	
Horizontal circumference of breast	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	
Upperbust circumference	(Na, Xin, Yi, Yu, & Ye, 2011)	3D body scanner - Not provided	M96_Chest_Girth

III. BRA RESEARCH CALCULATIONS TABLE

Bra Research Calculations	**Source**	**Manual/3D body scanner**	**Method**
Body Mass Index (BMI) Quetelet's Index (QI)	(Brown, et al., 2012) (den Tonkelaar, Peeters, & van Noord, 2004)	Manual Manual	Weight (kg) dived by height (m) squared (km/m²) Weight divided by height squared (kg/m²)
Underband size	(Brown, et al., 2012; McGhee & Steele, 2006; McGhee & Steele, 2010)	Manual, Anthropometric tape	Underbust (in) is taken level with the inframammary fold and a sizes allocated as below: 30in>24 to 26, 32in >26 to 28,

			34in >28 to 30, 36in >30 to 32, 38in >32 to 34 When the participant is not wearing a bra.
	(White & Scurr, 2012; Wright, 2002)	Manual, Anthropometric tape	Underbust (in) is taken level with the inframammary fold and a sizes allocated as below: 30in>24 to 26, 32in >26 to 28, 34in >28 to 30, 36in >30 to 32, 38in >32 to 34 When the participant is wearing a bra.
	(Washington State University and Cooperative Extension Service, 1986)	Manual	The chest is measured (inches) at the underarm point: Even number = Underband size Odd number +1 = Underband size
Cup Size	(Brown, et al., 2012; McGhee & Steele, 2006; McGhee & Steele, 2010)	Manual, Anthropometric tape	Breast girth (in) around the fullest part of the bust. The difference between Breast Girth and Underbust size, allocated as below: 1in = A cup 2in = B cup 3in = C cup 4in = D cup 5in =DD cup 6in = E

	(White & Scurr, 2012) (Wright, 2002)	Manual, Anthropometric tape measure over the participants own bra Manual,	7in =F 8in=G etc. When the participant is not wearing a bra. Breast girth (in) around the fullest part of the bust. The difference between Breast Girth and Underbust size, allocated as below: -1in = AA cup 0in = A cup 1in = B cup 2in = C cup 3in = D cup 4in = E cup 5in =F cup 6in = FF 7in =G 8in=GG When the participant is wearing a bra. Breast girth (in) around the fullest part of the bust. The difference between Breast Girth and Underbust size is denoted with a letter, allocated as below: -1in = AA cup 0in = A cup 1in = B cup 2in = C cup 3in = D cup 4in = DD cup 5in =E cup

	(Washington State University and Cooperative Extension Service, 1986)	Anthropometric tape measure over the participants own bra Manual	When the participant is wearing a bra. Bust measured around the fullest point. The difference between the bust measurement and underband size is denoted with a letter, allocated below: 0-½ in= AA cup ½-1in = A cup 1-2in = B cup 2-3in = C cup 3-4in = D cup When the participant is wearing a bra.
Breast Mass estimation	(Brown, et al., 2012; Haake & Scurr, 2010; Turner & Dujon, 2005)	Manual, using bra size calculations as above.	115g per cup for underband sizes 32-34 and 215g per cup for underband sizes 36-38 In addition to Turner and Dujon (2005) Brown et al (2012) cross graded the cups for a 30inch underband size.
Waist to hip ratio (WHR)	(den Tonkelaar, Peeters, & van Noord, 2004)	Manual	Waist circumference divided by hip circumference
Height to 'clavicular notch to nipple' distance ratio	(Nicoletti, Scevola, & Faga, 2009)	Manual	Not Provided

IV. AGE CATEGORIES APPLIED TO QUESTIONNAIRE AND BANK OF SCAN DATA

New code	Label (Age)
0 –	Under 18
1 –	18
2 -	19-24
3-	25-28
4 -	29-33
5-	34-38
6-	39-44
7-	44-55
8-	55+

Table 21 Age categories applied to the bank of scan data

APPENDIX E. SUPPORTING TABLES – RESULTS AND DISCUSSION

I. LENGTH MEASURES TAKEN FROM THE BANK OF SCAN DATA

		[W20]_Bust_ Height	[W21]_Underbust _Height	[W51]R_ Side Neck to Bust	[W51]L_ Side Neck to Bust	[W86]_Bust to Bust
N	Valid	243	243	243	243	243
	Missing	0	0	0	0	0
Mean		118.1562	111.2107	26.7752	26.5692	19.3760
Median		118.3400	111.7200	26.4700	26.3100	19.3100
Std. Deviation		6.57358	6.43159	2.87921	2.85255	2.28832
Percentiles	25	114.1400	106.8200	24.8400	24.7500	17.8700
	50	118.3400	111.7200	26.4700	26.3100	19.3100
	75	122.4200	115.4400	28.6100	28.2300	21.0100

II. GIRTH, ARC AND PROMINENCE MEASUREMENTS TAKEN FROM THE BANK OF SCAN DATA

Statistics

		[W101]_ Chest Girth	[W102]_ Bust Girth	[M97]_ Chest Arc Width	[W103]_ Bust Arc Width	[W104]_ Bust Girth Contoured	[W105]R_ Breast Prominence	[W105]L_ Breast Prominence	[W106]_ Under Bust Girth	[W107]_ Front Underbust Girth	[W108]_Waist Girth	[W109]_ Front Waist Girth
N	Valid	243	243	243	243	243	243	243	243	243	243	243
	Missing	0	0	0	0	0	0	0	0	0	0	0
Mean		91.5632	94.6167	46.2692	50.6077	96.5505	25.4166	25.5968	79.2167	39.2233	76.3112	36.8799
Std. Deviation		9.85789	9.39965	5.49358	5.78570	10.21980	3.40062	3.39800	7.97889	4.42635	9.62715	4.82413
Range		98.05	48.23	28.74	28.11	60.18	20.56	17.83	47.98	26.48	53.02	26.53
Percentiles	25	85.4500	87.1100	41.9600	45.9900	88.6800	22.9100	23.3700	73.4000	35.9800	69.2300	33.2700
	50	89.9300	92.9600	45.5100	49.8500	94.8800	25.2000	25.3600	77.4600	38.9300	73.9400	35.6200
	75	95.9900	100.8000	50.1600	54.1300	102.8300	27.6700	27.7800	83.3700	41.5000	81.1300	39.2100

III. ADEQUATE AND INADEQUATE BRA FIT ADVICE

Retailer Literature	Academic Literature	Bra Fit Criteria
Underband		
"Underband is sitting **horizontally around the body** - you should be able to **fit two fingers under the band comfortably**" (Marks and Spencer, 2011) "The underband should be snug but enabling you to **fit two fingers in the under-band at either side**… The underband should be **even all the way round the body**, so the **back of the bra is parallel with the front of the bra**." (Charnos, 2011)	'**Too tight. Flesh bulging over top of band**, subjective discomfort "feels too tight"…**Too loose: Band lifts when arms are moved above head**, posterior band not **level with inframmammary fold**' (McGhee, Steele, & Munro, 2010)	<u>Too small</u> The underband is cutting into the back <u>Adequate</u> The underband is horizontally level around the body. The underband

"The underband should be snug but enabling you to **fit two fingers in the underband at either side**… The underband should be **even all the way round the body**, so the **back of the bra should be parallel with the front of the bra**." (Lepel, 2011) "The band of the bra should **be firm on you** as this is where all the support of the bra comes from. The band should be **level all the way around your body**, as a guide you should only be able to **fit 2 fingers inside the band** when you are wearing the bra." (Playtex, 2011) "If a bra is fitting correctly you **may experience 'back fat' or overhang**. To get the support you need…" (Playtex, 2011) "The underband of your bra should fit **comfortably in the middle of your back** and **not rise up or down**…" (La Senza, 2011) "The horizontal band of your bra should sit **flat against your body**…(it) **should sit level front and back**. It **should not ride up at the back** fastening at all" (Ultimo, 2011) "Band is **level all the way round**, **without riding up at the back**… Underband is nice	'**Too small - Back of the bra cutting into the back** and cutting bulging' (Wood, Cameron, & Fitzgerald, 2008) '**Too big - Back of bra riding up** towards the neck' (Wood, Cameron, & Fitzgerald, 2008)	does not ride up. <u>Too big</u> The underband is riding up at the back

and **snug**." (Horrell, Bloom, Jeffery, & Barron, 2007) '**The underband arches up the back**. This is usually caused by the **underband being too big**…or it may be the bra is **too old and has lost its elasticity**.' (Marks and Spencer, 2011) 'If the **back of your bra is riding up** then it means that the **band is too big** and you should go down a size.' (Playtex, 2011) '…**indents on your shoulders** this is a common sign that the bra is not fitting correctly and the likely cause is the **band being too big**.' (Playtex, 2011) "BACK BAND RIDING UP… (or) is it (the underband) being pulled further down your ribcage? If the underwire is being dragged down to where your ribcage is slightly narrower, this is a sign that you are wearing too small a band size." (Horrell, Bloom, Jeffery, & Barron, 2007)		
Cup Volume		
"**Bust is contained fully within cup**" (Marks and Spencer, 2011) "**Your breasts should fill the cups without bulging over the top or 'double-busting**'." (Charnos, 2011)	'**Too big. Wrinkles in cup fabric**…**Too small. Breast tissue bulging above, below or at sides**.' (McGhee, Steele, & Munro, 2010)	<u>Too small</u> The cup edge is cutting into the breast tissue causing double busting. The breast tissue

"**Your breasts should fill the cups without bulging over the top or being squeezed**." (Lepel, 2011) "The breasts should be **fully encased** within the cups of the bra, **so you do not have any overspill at all**." (Playtex, 2011) "The breast should **fit in the cup perfectly** creating a **smooth line between the skin and the fabric**" (Ultimo, 2011) "Cup fits with **no bulging or gaping at the top**." (Horrell, Bloom, Jeffery, & Barron, 2007) ***DD+ Advice*** 'The cups should **fully encase the breasts** (except at the top if it's a low cut style) and the underwire should **sit flat against the chest at the front and sides**.' (Marks and Spencer, 2011) '**The cups are too small** – commonly known as **double busting**. This happens when the bust is not fully encased in the cup, and it **spills out at the front and/or under the arm**, giving the impression of four busts under tops.' (Marks and Spencer, 2011) '**Cups wrinkling or sitting away from the breasts**.	'Too small **- Bust bulging over the top**… **Bust bulging at the underarm**' (Wood, Cameron, & Fitzgerald, Breast size, bra fit and thoracic pain in young woemn: a correlational study, 2008) '**Too big** – Is the **cup wrinkled**…Cups of bra sitting **high at the underarm**' (Wood, Cameron, & Fitzgerald, Breast size, bra fit and thoracic pain in young woemn: a correlational study, 2008)	is spilling out of the cup at the front and/or underarm. <u>Adequate</u> Breasts are fully encased within the cup. Breasts fill the cup without over spilling. There is a smooth line between the cup edge and the bust tissue. <u>Too big</u> There are wrinkles in the cup fabric.

This is a sign that the cups are **too big** for the breast size.' (Marks and Spencer, 2011) "If you have **puckering in the cup**, this means the **cups are too big**" (Playtex, 2011) "The bust should not **spill over the top of the cup**. If it does you are wearing the **incorrect cup size**." (La Senza, 2011) "centre front **lifting away from the body**" (Horrell, Bloom, Jeffery, & Barron, 2007) "Does any **breast tissue bulge out at the top of the cup**? This means the cup is **too small**." (Horrell, Bloom, Jeffery, & Barron, 2007) "If there are **creases** in your **cups** you might want to **try going down a cup size**." (Horrell, Bloom, Jeffery, & Barron, 2007)		
Cup neck edge		
'If you look sideways onto the mirror the bra should **sit flat against your chest**, there should be **no digging in on the breast** at all.' (Playtex, 2011) "the cup fits **snugly everywhere but is gaping where the cup meets the strap**, it could be that **the bra is finishing too high up the chest** for you."		<u>Too small</u> The frequency is not high enough to validate inclusion.

(Playtex, 2011)		<u>Adequate</u> The frequency is not high enough to validate inclusion. <u>Too big</u> The frequency is not high enough to validate inclusion.
Underwire		
'…The wires should always sit **around the breast**…and they should lie **flat against the body**.' (Marks and Spencer, 2011) '**Seams or wires** are not **digging into/resting on any breast tissue (front or under the arm)**' (Marks and Spencer, 2011) 'Your breast should **fit into each cup within the wire casing**.' (Charnos, 2011) (Lepel, 2011) "The underwire should then **follow the line of the bust**, and **sit behind the breast tissue, not on it**…	'Incorrect shape. **Underwire sitting on breast tissue laterally (under armpit) or anterior midline**, subjective complaint of discomfort.' (McGhee, Steele, & Munro, 2010)	<u>Too small</u> The underwire is digging into the breast tissue. <u>Adequate</u> The underwire lies flat against the body. The underwire follows the line of the bust. The underwire is

To check this you can push the end of the underwire, if you press it and it is hard you know it is sitting on the rib cage and fitting correctly. ” (Playtex, 2011) “The underwire should **lay flat against the breastbone**.” (La Senza, 2011) “Underwire sits **flat against the ribcage**… Breast tissue is completely **encased in underwire**… Underwire follows the **natural crease of the breast**.” (Horrell, Bloom, Jeffery, & Barron, 2007) ‘Underwires are **lifting away from the bust at the bottom of the cup**, This happens when the cup size is **too small**.’ (Marks and Spencer, 2011) ‘It is important that wire positions are checked during the fitting as discomfort (at the sides of the breasts) can cause health issues…’ (Marks and Spencer, 2011) “If you **push the underwire and it is soft and making your breast move, it means that the wire is sitting on the breast tissue**.” (Playtex, 2011) “The underwire should never **dig into** your **breast tissue** and should fit **snugly under the arm**.” (La Senza, 2011)		not digging in or resting on the breast tissue (at the front or underarm.) <u>Too big</u> The frequency is not high enough to validate inclusion.

"Is there any **underwire digging into the breast tissue**? If so, you might well need a **larger cup size**." (Horrell, Bloom, Jeffery, & Barron, 2007)		
Straps		
'**Straps are secure but not tight**. If you **remove bra straps, bra continues to support the breast**' (Marks and Spencer, 2011) 'Straps should be tightened so that you can only put **two fingers between the strap and the body**.' (Marks and Spencer, 2011) 'The straps should be **adjusted to between the shoulder and the elbow**.' (Charnos, 2011) (Lepel, 2011) 'The shoulder straps should be **distributing the weight of the bust**…you should only be able to fit **2 fingers under the straps**.' (Playtex, 2011) "Straps are **parallel** or slightly **v shaped at the back**… Straps do not **dig into the shoulders**." (Horrell, Bloom, Jeffery, & Barron, 2007) 'Strap discomfort. This is a common issue when **straps are over tightened** to try to **pull up the cup**	'**Too tight**. **Digging in**, subjective complaint of discomfort, **carrying too much of the weight of the breasts**…**Too loose, Sliding down off shoulder** with no ability to adjust the length.' (McGhee, Steele, & Munro, 2010) '**Too big - Shoulder straps slipping down the shoulder**' (Wood, Cameron, & Fitzgerald, Breast size, bra fit and thoracic pain in young woemn: a correlational study, 2008)	<u>Too small</u> Straps are digging in. Straps are too far apart at the back. <u>Adequate</u> You can comfortably fit 2 fingers between the straps and the body. Bra straps are parallel or slightly V shaped at the back. <u>Too big</u> The straps are sliding off the shoulders.

for more support.' (Marks and Spencer, 2011) '**the shoulder straps slipping off**' (Playtex, 2011) "**Shoulder straps digging in**" (Horrell, Bloom, Jeffery, & Barron, 2007) "It they are **too far apart at the back (an upside down V)**, it could mean that your **bra band is too small and overstretching**." (Horrell, Bloom, Jeffery, & Barron, 2007)		
Centre front		
'Centre front of bra should sit **flat against the chest**' (Marks and Spencer, 2011) 'The centre front should **lay flat and separate your breasts**.' (Charnos, 2011) (Lepel, 2011) "...middle of the bra (**the centre gore**) **should sit flat against the chest wall and separate the breasts**" (Playtex, 2011) "**Should sit flat**…**between between your breasts where it should neither dig in nor lift away from the body**." (Ultimo, 2011)	'**Too loose, Not all in contact with the sternum**' (McGhee, Steele, & Munro, 2010) 'Too big **- Centre of front sitting away from body**' (Wood, Cameron, & Fitzgerald, Breast size, bra fit and thoracic pain in young woemn: a correlational study, 2008)	Synonyms: 'not at all in contact', 'sitting away' 'Chest', 'Sternum' Justification for inclusion – 100% consistency between sources

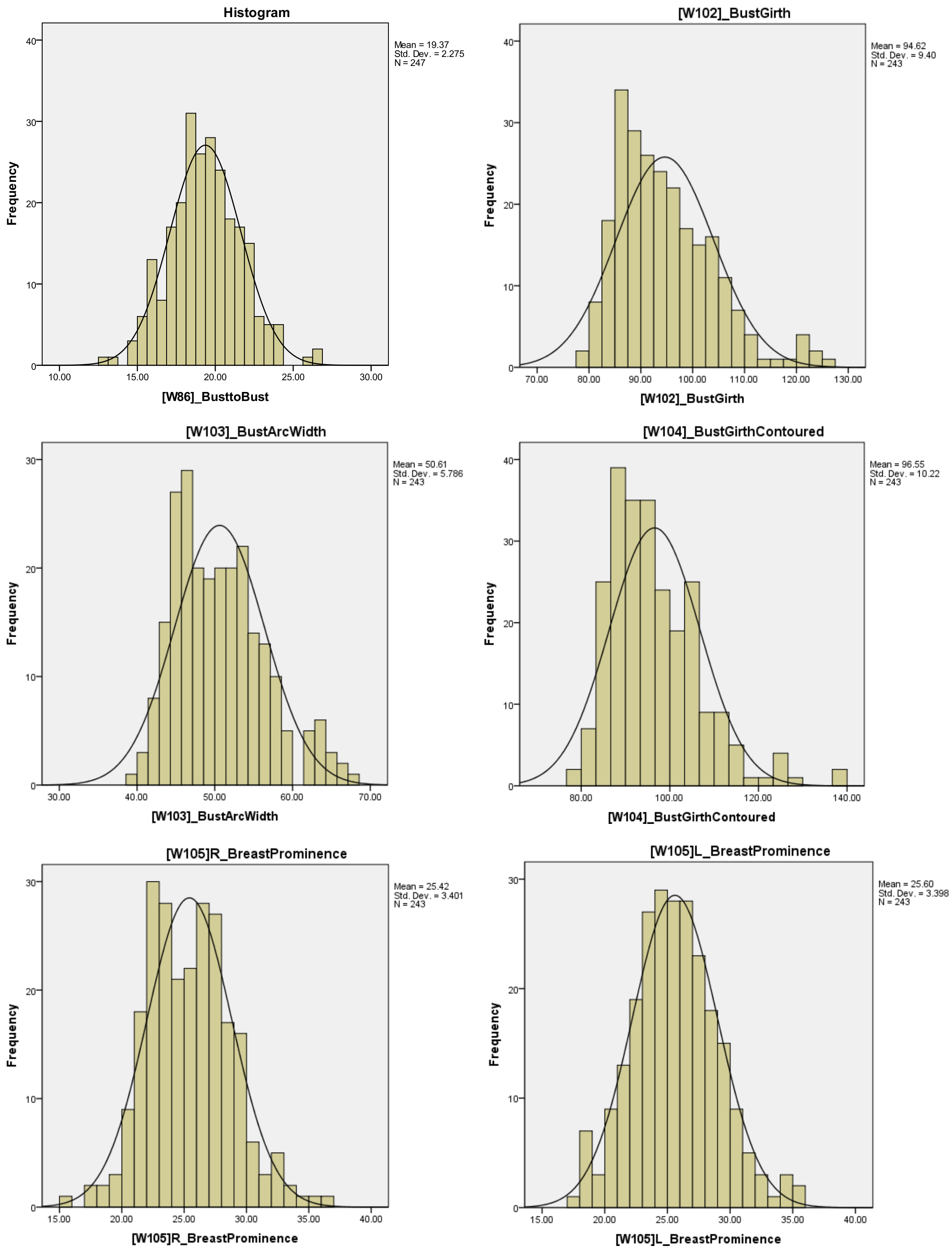
"**Centre front sits flat against the body**." (Horrell, Bloom, Jeffery, & Barron, 2007)		Bra fit criteria: <u>Too small</u> <u>Adequate</u> Sitting flat against the chest and separating the breasts. <u>Too big</u> Lifting away from the chest wall.
Bra fastening		
'Always fit your bra on the **last hook**.' (Charnos, 2011) 'When you try your new bra make sure you secure it to the **loosest hook and eye**…' (Playtex, 2011)		Synonyms: Last hook, Loosest hook Justification for inclusion – 100% consistency Bra fit criteria: Secure the bra on the last hook and eye.
Other		

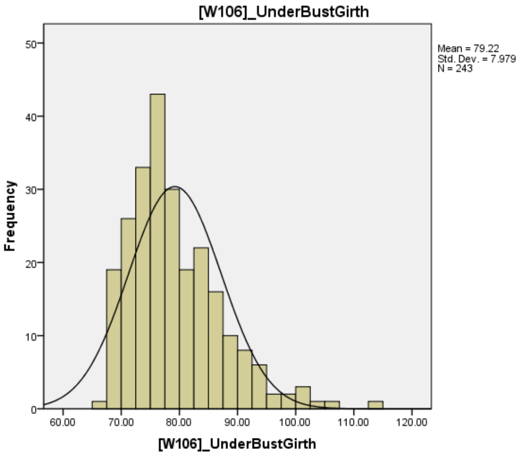
DD+ Advice 'You should be able to **move your arms back and forwards with out hitting the sides** of your **breasts**.' (Marks and Spencer, 2011)		This is not referred to in comparable literature. Further analysis is needed before this advice is included.

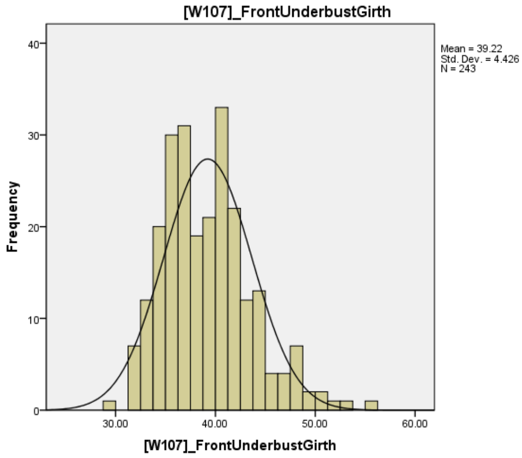
APPENDIX F. SUPPORTING FIGURES – RESULTS AND DISCUSSION

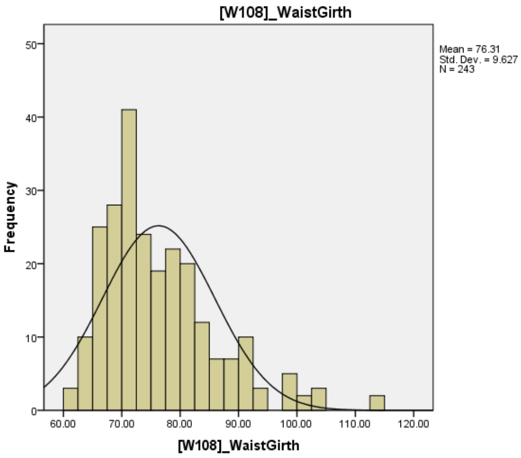
I. GRAPHS SHOWING THE DISTRIBUTION OF THE 3D BODY SCAN DATABASE DATA

Figure 22 Normal distribution of the bust to bust data




[W106]_UnderBustGirth
Mean = 79.22
Std. Dev. = 7.979
N = 243
Frequency
[W106]_UnderBustGirth


[W107]_FrontUnderbustGirth
Mean = 39.22
Std. Dev. = 4.426
N = 243
Frequency
[W107]_FrontUnderbustGirth


[W108]_WaistGirth
Mean = 76.31
Std. Dev. = 9.627
N = 243
Frequency
[W108]_WaistGirth

II. UNDERWIRE AND BRA STRAP COMPARISON CHARTS

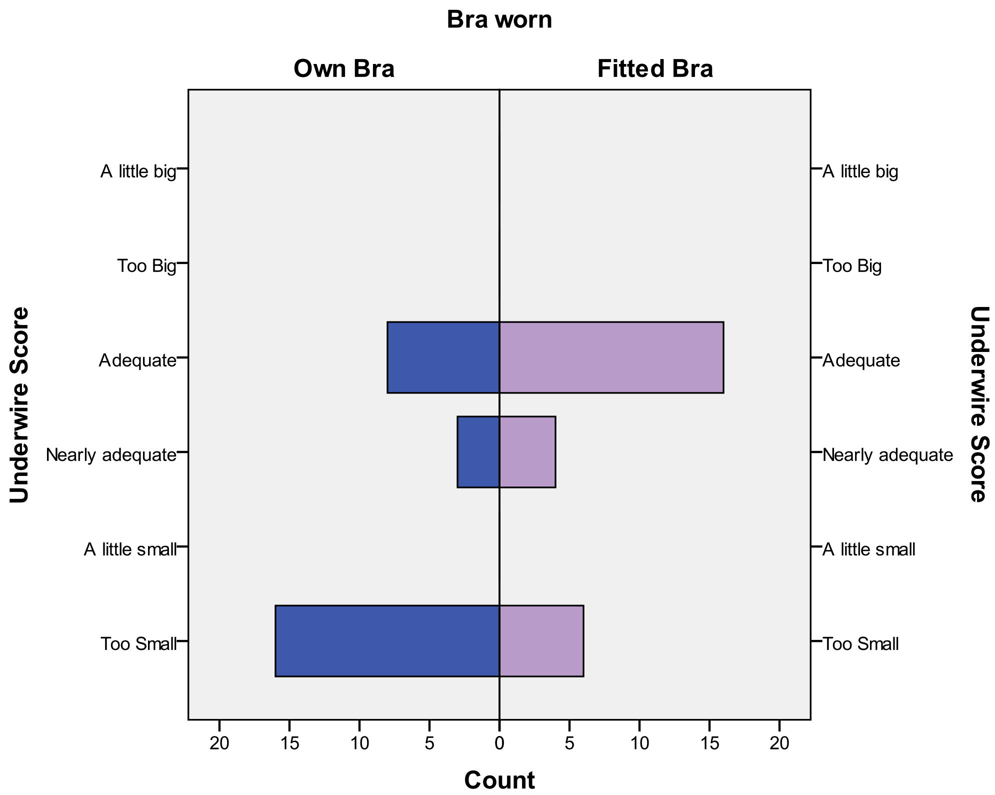


Figure 23 Underwire score distribution

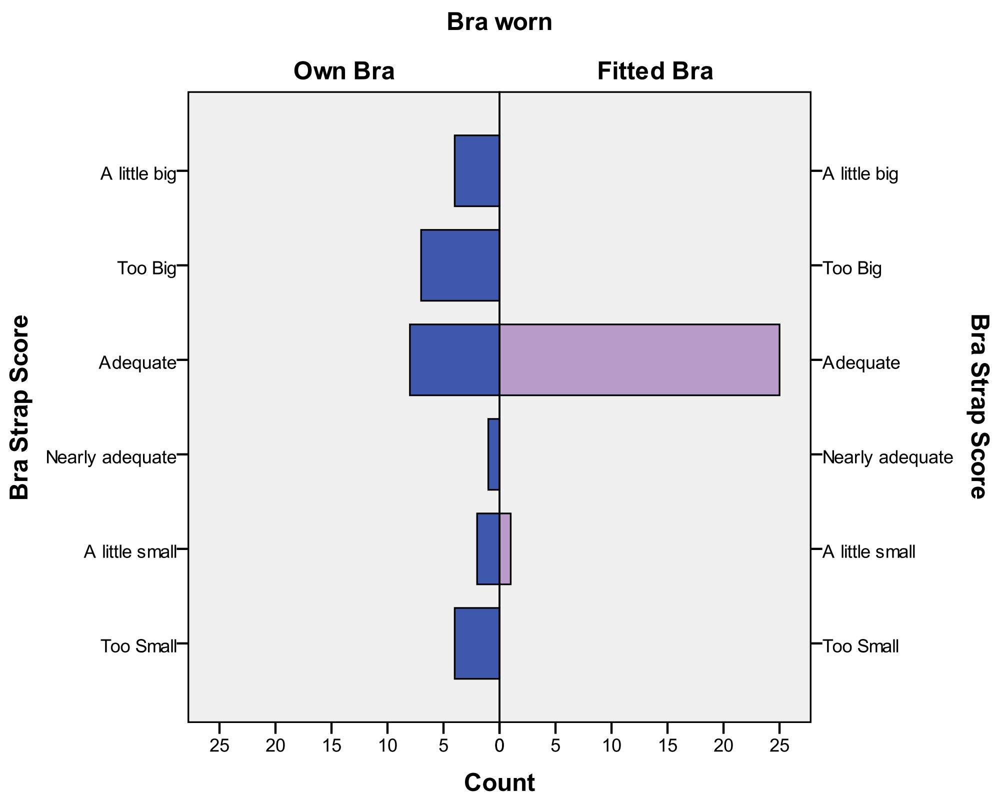


Figure 24 Bra strap score distribution