THE ORIGINS AND EVOLUTION OF THE BRA

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ABSTRACT

This thesis marks the first biography of the evolution of the bra from a designer and patternmaker's perspective. Although the bra has a very long history, it only became a truly iconic garment in the latter half of the Twentieth Century. To some extent this transformation was driven by rapid social and economic changes, but the evolution of this highly technical garment is also inextricably linked to developments in technology which have led to improvements in materials, design and manufacture. Initially these developments were related to designing a three-dimensional product from a two-dimensional flat patternmaking process, but more recently the advent of the moulded bra has offered opportunities to create a seamless three-dimensional garment without the need to construct a flat pattern, and this has enabled both increased design possibilities and raised the prospect of a better fitting product.

Through an investigation of the origins of underwear in general, and the bra in particular, this thesis reviews secondary source historical data to chart major changes in design, patternmaking, and technology from the first recorded uses of underwear to the current challenges facing bra designers and patternmakers in an increasingly globalised industry. This historical review culminates in the identification of two distinctly diverging trends in current bra design and manufacture, both of which face significant challenges in terms of training new designers and producing better sizing and fitting protocols. The two primary source studies which emanate from this historical review contribute new knowledge to each of these diverging directions in bra design.

The first study provides an entirely new approach to the teaching, and subsequent current commercial practice of flat patternmaking for what many regard as the 'traditional' cut-and-sewn variety of bra. This study culminates in a new way of producing, learning and teaching the art of flat patternmaking, enabling underwear design graduates to leave university with the core skills they need to survive in a fast moving global industry. The second major study investigates the salient challenge of providing an excellent fit for both major types of bra across globally diverse and perhaps ethnically different body types. Consequently, it employs cutting-edge three-dimensional body scanning technology to demonstrate how the design, sizing, and

fitting of both cut-and-sewn and moulded varieties of garment might be significantly improved in the future. Both primary source data studies therefore stand at the beginning of the future evolution of the most technically complex garment in human history, the not so humble bra.

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DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my work.

Name: Kristina Woo Kyung Shin, M.A.

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Date: 9 September 2009

CHAPTER 1
THE CONTINUING BIOGRAPHY OF THE BRA

1.1 A Biography of the Bra

This thesis constitutes the only biography of the bra from the perspective of a professional designer and patternmaker. As such, it concentrates on the structure, form, and design of this iconic garment, and those other garments throughout history, both underwear and outerwear, that have influenced its continuing and future development. However, unlike a personal biography which has a fixed end, the story of the bra continues to develop, and consequently this thesis not only deals with the development of the bra through history, but also identifies emerging technological trends which have separated bra design and construction into two distinctly divergent lines. The oldest of these involves an approach to bra design based on flat-patternmaking for the cut and sewn variety of the garment. This involves following certain measurement protocols, drawing and cutting flat pieces of cloth, producing a flat pattern, and then joining the pieces together to form a three-dimensional product. The second approach has more recent origins, and involves the use of three-dimensional moulding and bonding technology to produce the sleek, and slim fitting moulded bra. This thesis makes at least two entirely new contributions to knowledge, one in each of these areas, and finally demonstrates how new technological developments can provide impetus for future design and fit innovations.

Having identified these divergent strands, the first contribution to new knowledge introduces an entirely novel patternmaking approach which makes the undergraduate teaching of bra patternmaking to industry standards possible. In so doing, it provides a means of taking the technical skills involved in flat patternmaking into a new era where many more student and industry patternmakers will be able to create novel designs from scratch, rather than relying on the common practice of pattern copying currently so prevalent in the industry. The second contribution to new knowledge uses cutting-edge three-dimensional scanning technology to illustrate a significant issue facing the global bra industry, that of providing a good fitting garment for a wide range of ethnic body types. As such, it suggests that current sizing and measurement protocols require urgent review as consumers increasingly demand greater levels of comfort and fit. Finally, the thesis provides potential solutions by way of a review of current sizing and measurement protocols and through the use of the rapidly developing scanning technology. In considering the impact of new technologies on the future development of the bra, the final chapter continues the theme that the design of this garment remains subject to a wide range of influences, and clearly demonstrates that developments today, as well as in the past, are often as much driven by technology as by fashion trends.

1.2 The Concept of Underwear

The biography of the bra begins in chapter 2 which examines the origins of the concept of underwear. In reviewing the literature available on the early evolution of underwear from 600,000BC to 1000AD, the author explores two major theories put forward to explain why underwear developed. One theory suggests that underwear began as outerwear which gradually migrated to being worn as a layer underneath outerwear for largely functional reasons (Ewing, 1971). The author identifies differing viewpoints even within this broad explanation, with some commentators suggesting that the concept of underwear began in ancient civilisation from a sense of status (Saint-Laurent, 1968), whilst others (Tobin, 2000) suggest that the underwear concept only became significant from the end of the 19th Century. The second major theory argues that underwear came into being for largely utilitarian reasons prior to the Middle Ages, and identifies five core functions of underclothes which only developed in total after the Renaissance (Cunnington and Cunnington, 1992). These two theories and the associated themes are revisited in the final chapter where the author concludes that the origins of underwear can in fact be traced back to ancient civilisations, but that these largely utilitarian origins rapidly evolved into other more ‘fashion’ and status related functions when farming replaced the hunter-gatherer lifestyle. In other words, the less utilitarian functions of underwear began to develop when human beings started to settle in one area, rather than pursuing a more nomadic lifestyle. Significantly, this chapter also traces the origins of underwear technology back to some of the earliest hominids who managed to survive the long, harsh era of Würm glaciation by developing and improving both shelters and clothing (Clark, 1969). The survival of these early hominids provides evidence that they possessed the rudimentary tools, probably made of bone, and stitching made of leather or fibre strips, required for joining animal furs together to make garments which were then probably layered for added warmth. The theme of technological developments driving innovations in underwear design continues as a golden thread throughout the thesis.

1.3 The Evolution of Underwear

Chapter 3 provides a synopsis and review of the evolution of underwear from 1001AD to the early 1900s emphasising the fundamental role undergarments played in creating whatever was regarded as the fashionable silhouette of the era. In so doing, it argues convincingly for the impact of outerwear design on underwear development and demonstrates the need to consider outerwear developments in tandem with any historical review of the evolution of underwear in general, and the bra in particular. Acknowledging that the concept of underwear probably had humble beginnings as a layer underneath outerwear, with a hygienic or protective functionality, this chapter demonstrates that underwear itself gradually gained an identity of its own, initially through supporting and complementing developments in outerwear fashion. In chapter 2 the advent of rudimentary tools for cutting, separating, and joining furs and other materials marked the beginnings of flat patternmaking whereby a series of flat pieces of cloth or fur were joined together to create a three-dimensional shape which provided a better fit for the human body. The theme of developments in technology is continued in this chapter with a wider range of materials in use during the Middle Ages, including linen, cotton, cambric, and nainsook, which ultimately meant that materials which were more conducive and comfortable to wear as undergarments became more widely available. Later in the period covered by this chapter, the advent of international trade accelerated the availability of these and other materials, including dyes, and stiffening and fastening devices. As these gradually became more accessible to the general populace, particularly during the industrial revolution, a wider range of undergarments were made possible to the extent that the earliest technological forerunners of the now familiar underwired and moulded bras are clearly in evidence from the 18th Century onwards. By the 1900s, underwear in general, and the bra in particular, developed into more sophisticated forms which not only served the utilitarian functions of support for the body and personal hygiene, but also became garments of status and enhanced sexual attraction in similar ways to outerwear.

1.4 The Birth of the Modern Bra

Chapter 4 considers the evolutions and origins of what might be regarded as the modern bra which is marked by the fact that the garment now takes on functions in addition to those of hygiene, having to provide the ability to lift, mould and shape the breasts, rather than merely providing support. Drawing on the context of the previous two chapters, the author progressively focuses on the development of the modern bra and demonstrates how this particular evolution is marked by changes in society, including the role of women, developments in marketing strategies, and the arrival of new technological advances which had a significant impact on bra design and production techniques. Once again, the author demonstrates the importance of technological advances in both materials and flat patternmaking techniques in driving the evolution of the modern bra as both a functional and aesthetically pleasing undergarment. The author argues that all five functions of the bra identified in chapter 2 are driving change to varying degrees during this era, and arguments related to the relative impact of fashion, status, and utilitarian needs, identified in chapters 2 and 3, once again come into play. For example, during the periods spanned by each war, utilitarian factors clearly acted as major drivers for changes in female fashion, but each post-war period brought about a growing sense of liberation for society as a whole, and women in particular, which is mirrored in the more elaborate and feminine designs of underwear associated with the two post-war periods. The theme of rapid technological change, brought about in part as a result of two World Wars and the large-scale introduction of females into the workforce, brought with it significant changes to the range of materials, colours, and techniques available to designers.

1.5 Conflict and Divergence

The 1960s was a time of significant change and a number of social, political, and technological changes had a profound impact on the development of the modern bra. Various changes in the role of women in society which had their origins in the two World Wars, an increasingly fast-changing and innovative fashion scene, and changes in feminist attitudes to the bra itself over four or five decades, brought about substantial changes in attitudes towards both underwear and outerwear during this period. As a consequence of these factors, the bra often took centre stage in reflecting some of these momentous changes. For example, this era began with the advent of the feminist ‘burn the bra’ movement which, by the end of the era, had gone through a number of revolutions including the bra-less look, the T-shirt bra, sports bra, padded and uplifting bras, nursing bras and so-called ‘training’ bras for young girls. The theme of developing technology which runs throughout the earlier chapters is continued at an even greater pace with significant improvements in materials technology and innovations related to flat patternmaking and three-dimensional moulding technologies partly driven by the wider variety of bra designs demanded by consumers. To some extent, this era is marked by what Rubin (2007) calls the twin social and individual pressures of modesty and rebellion, but it is also marked by growing interest in a healthy lifestyle, and an emphasis on environmentally friendly materials. Technological advances in moulding, textiles, and bonding technology meant that it was now possible to produce a truly lightweight, seamless, and sleek breast supporting bra which could be worn under the fashionable, light, figure-hugging T-shirts. Whilst technology remained a major influence on bra design development, this chapter recognises that not all innovations were accepted by the consumer. However, from the perspective of a designer and patternmaker, the bra had now entered an era where two distinct lines of development began to emerge. These involve a divergence between two methods of bra design, patternmaking, and construction; the two-dimensional flat pattern and the cut and sewn variety of modern bra versus the development of the seamless moulded bra. This divergence, based on the evolution of two distinct types of technology, provides the twin themes which outline future trends in bra design and patternmaking, and the cutting-edge primary source research into both divergent lines described in chapters 8 and 9.

1.6 Trends in Modern Bra Technology

Chapter 6 reviews the history and development of moulding and bonding technology, ultrasonic and seamless knitting technology, together with the development of eco-friendly textiles and smart materials. All of these technologies are now central aspects of bra design in particular, and the intimate apparel industry in general. The flat pattern designed cut and sewn bra is now amongst the most sophisticated and technically challenging garment designs in history, with many modern bra designs involving a very large number of flat pattern pieces which are sewn together to provide a comfortable, supporting, and fashionable undergarment. The further development of this strand of bra design development is considered in detail in chapters 7 and 8. However, running alongside the sophisticated and highly technical nature of flat patternmaking, the advent of moulding and bonding technology now enables manufacturers to create a 'natural' look by removing the need for seams and stitches, initially from around the bra cup, and eventually from the rest of the garment. The result is a bra which is comfortable, smooth, durable, lightweight, and thin, facilitated by technology which reduces production costs by providing fast production and efficient material utilisation. The advent of these new technologies clarified and deepened the division between the two divergent directions for bra designers identified in the last chapter. Both of these directions are explored in detail in the final four chapters of the thesis.

1.7 The History of Bra Patternmaking

Having identified the two distinct and divergent directions for bra design and patternmaking, this chapter reviews the patent history and development of the first and oldest approach, that of flat patternmaking for the cut and sewn product. This review of bra patents demonstrates that what the author calls the 'dark art' of flat patternmaking for the cut and sewn bra, has made significant technical breakthroughs in the last one hundred years or so. The most significant of these is the ability to create a supportive three-dimensional bra cup from a flat pattern. Unlike the moulded product which is restricted often to synthetic materials that are suitable for the currently available bonding methods, a wide range of materials is available for the ever popular cut and sewn bra, and this is perhaps one reason why they are still the most popular bra product on the market. Demand for natural fibres, and feminine lacy bra products, and particularly the use of an underwire for support, has ensured continuation of the demand for the cut and sewn variety of bra design. The review of 1,671 patents undertaken in this chapter demonstrates that cup and bra shaping methods involving the use of darts, style lines, pleats and gathers, which have now been employed for over one hundred years, remain at the core of professional courses offered at university or within the industry. This is because the skills of designing and patternmaking for a flat patterned cut and sewn bra are technically challenging and very few graduates currently leave university with the skills required to produce an adequate flat pattern for this bra product. This assertion provides the basis for the primary source research undertaken and reported in the next chapter. However, despite the differences in terms of design, manufacture and suitable materials, the salient issue confronting both methods of bra production remains one of obtaining an accurate fit, particularly relevant given the wide variety of body shapes and sizes that both products must encompass. This issue is taken up in the primary source research which constitutes chapter 9 which explores further technological advances related to three-dimensional body scanning.

1.8 Flat Patternmaking and a New Approach

Having identified the development of the bra from its humblest origins, and illustrated the key role of technology in this evolutionary process, consideration now turns to the most salient issues facing today's bra designers and manufacturers, the question of developing the skills necessary to produce a good fitting three-dimensional garment from a flat patternmaking process, and, in chapter 9, the problems of obtaining a good three-dimensional fit for a variety of ethnic body types.

For some decades flat patternmaking has been regarded as a 'dark art' with most skilled patternmakers serving long apprenticeships to acquire the necessary technical knowledge to produce innovative new designs from flat patterns. To some extent, this has been the result of industry motivated secrecy promoted in the interests of protecting brand 'secrets'. One consequence of this secrecy has been the lack of available information on modern flat patternmaking techniques for the bra, and a lack of skills amongst those who are responsible for teaching graduates of underwear design at university level. The research conducted and reported by the author in this chapter addresses this issue, and presents an entirely novel approach to flat patternmaking for the bra which moves away from what have become traditional copy or ‘knock-off’ methods of patternmaking. In so doing, this research provides a template for educators within and beyond the industry to ensure that flat patternmaking for the modern bra is brought into the new Millennium. The new method is more logical and easier to learn, accurate in terms of maintaining the consistency of size and fit, considerably faster in the industry setting, and more suitable for both custom made and mass produced garments than traditional methods. As such this study has brought the long-term lack of patternmaking innovation to the attention of educators and the industry and clearly identified the potential benefits of adopting this approach to teach new students, and update industry practices.

In the course of research into flat patternmaking practice, the author identified several major technical issues relating to patternmaking and fit in what is now a global intimate apparel industry. These involve the failure of current bra sizing systems and offer a significant opportunity for new technology to once again drive bra design and development. The failure of current bra sizing systems and the potential for three-dimensional body scanning technology therefore form the subject of the second major primary source study reported in the next chapter.

1.9 Bra sizing: Current Inadequacies and Future Possibilities

This chapter addresses the second salient challenge facing the modern bra design and construction industry, and investigates, using differences in body measurements between Asian and Caucasian consumers as an illustrative sample, the potential offered by new three-dimensional body scanning technology. In so doing, it demonstrates that the industry has so far failed to keep pace with globalisation of its product and sizing, and that the new technology is probably the next exciting development in terms of bra design and patternmaking for both the cut and sewn and the moulded versions of the product. Taking the question of whether there are any significant differences in body measurements between Asian and Caucasian women, this chapter reviews current measurement protocols and uses state-of-the-art body scanning technology to challenge current approaches to design and production. In concluding that the demands of bra mass production in a labour intensive industry has led to many consumers (particularly Asian women) suffering inadequately fitted garments which fail to meet some the five core functions of the bra identified in chapter 2, it identifies a far more complex picture of necessary body measurement protocols than has hitherto been recognised. In so doing, this chapter demonstrates a potentially exciting future for three-dimensional body scanning which could eventually bring about significant change to both body measurement protocols and bra sizing systems for both major methods of bra design and construction.

1.10 Looking Backwards and Moving Forwards

The final chapter of the thesis reviews the major findings from both the secondary source historical information and the findings of the two major primary source data studies and suggests possible solutions, largely provided once again by developments in technology, that might facilitate further evolutions of the now not so humble bra. Bringing together the lessons learned from history, particularly the historical significance of developments in technology, the author identifies how the bra industry can move forwards from a position which many have suggested (e.g. Saint-Laurent, 1968; Rubin, 2007) marks the end of bra patternmaking evolution. The current dilemma over the divergent trends in bra design and construction can be resolved by returning to the five core functions of underwear identified by Cunnington and Cunnington (1992) as the utilitarian functions of protection from cold weather and hygiene, and the non-utilitarian functions of supporting the outer costume, class distinction, and sex appeal. Underpinning these core functions, particularly in terms of bra design and construction, is the enduring quest to produce a truly global product which provides the best possible fit for consumers of all body types and new scanning technology promises to ensure that this aspect is now given appropriate attention.

CHAPTER 2
THE EARLY EVOLUTION OF UNDERWEAR FROM 600,000BC TO 1000AD

2.1 Introduction: The Concept of Underwear

The idea of wearing underwear is so natural for people living in the 21st Century but understanding how the concept of underwear evolved is not quite so simple. For example, did underwear evolve purely as a result of an enduring fashion trend, or were there more practical and possibly hygienic reasons, such as protecting outerwear from bodily fluids like sweat and other more intimate human secretions? Alternatively, did underwear perhaps evolve as additional protection from weather and other extreme conditions? This chapter will review the development of prehistoric costume and is broadly divided into two parts. The first part will review the background and development of the necessary clothing technology related to prehistoric costume and the second part will review the nature of prehistoric clothing from 3,500BC to 400AD. The former date is the time when the first known civilisation, the Sumer, evolved in Mesopotamia.

2.1.1 The Origins of the Concept of Underwear

Ewing (1971) takes the view that underwear began as outerwear which gradually migrated to being worn as underclothing for largely functional reasons. Whilst accepting that underwear existed in some form before the concept of 'fashion' began, she argues that it did not really acquire any significance, or any history, until the late Middle Ages. Tobin (2000) disagrees with this viewpoint, suggesting that the concept of underwear became significant only from the end of the 19th Century. However, Saint-Laurent (1968) provides an alternative viewpoint, suggesting that the concept and existence of underwear began in ancient civilisation around 3000B.C. from a sense of status, and not for hygienic purposes or protection from extreme weather. This idea is supported by the fact that, for example, Ancient Egyptian clothing was used as a symbol of wealth and power in society, and as a consequence, numerous layers of clothing, often decorated with elaborate trims, were worn to express status. Higher 'class' men wore a loincloth under their tunic, which was later developed into an under-skirt, and higher class women wore two tunics. Saint-Laurent (1968) identifies this layering process as instrumental in bringing about the concept of undergarments and suggests that, as society became more complex and sophisticated, these original simple undergarments developed to serve many different purposes and functions.

2.1.2 Underwear as Utilitarian Garments

Cunnington and Cunnington (1992) argue that the only likely function of underclothes before the Middle Ages was utilitarian even though these early garments were almost certainly not as effective as today. They identify five core functions of underclothes which they consider really only developed after the Renaissance:

i. Protection of the body from cold weather.
ii. Support of the shape of the outer costume.
iii. Hygiene.
iv. Sex appeal.
v. Class distinction.

Barbier and Boucher (2004) classify women's underwear into three different categories based on functionality: lingerie, corsetry and hosiery. They identify lingerie as mainly for hygiene purposes, sexual attraction, and comfort. Corsetry is identified as providing support for the outerwear costume shape, as well as to preserve female morality. Hosiery functions as an enhancer of aesthetic qualities and reflects industrial improvements. Barbier and Boucher (2004) also argue that the three major functions of hygiene, body support, and sexual attraction/aesthetics remain relevant to modern underwear. Surprisingly, the hygiene function, which is now an important requirement for social and individual welfare in modern society, did not become a social issue until the early 19th Century, and the levels of support available from foundation garments and the corsetry of modern days did not exist before the 20th Century. Prior to that, 'support' involved manipulating body shape into what was regarded as the fashionable shape of the time. The prevailing fashionable shape was generally achieved by changing the size of three body areas: the waist, the bust and the hips and the potentially serious harm inflicted on the wearers of tightly-laced corsets was generally ignored by women who wanted to be fashionable until the late 19th Century.

2.1.3 Summary

Clearly, there remains some disagreement amongst historians of underwear about both the origins and original purpose of underwear. However, it is not only the evolution of the concept of underwear which is complex because the motivation for clothing in general is not entirely clear. Boucher (1987) posits a theory which combines every possible scenario suggesting that men first adopted clothing as protection from the climate, and then gradually began regarding it as a symbol of social status, reserving some clothing for special occasions, and endowing other garments with some mystical or magical significance. In other words, the functions of costume reflect the development of human civilisations. This view is broadly shared by Gorsline (1978) who suggests that the loincloth and the tunic are the ‘originators’ of all clothing. He also emphasises the importance of strict social stratification in ancient times when perhaps power and wealth helped to precipitate certain fashion changes, whilst an overall style might survive for thousands of years. However, the alternative view is held by Saint-Laurent (1968) who maintains that the evolution of early clothing has no certain pattern or ties with the culture, sexuality, or sensuality of society, and is more likely to be entirely utilitarian.

2.2 The Beginnings of Clothing Technology for Prehistoric Costume

2.2.1 Background

Prehistory can be operationally defined for our purposes as referring to any given period of human existence before which there is literacy, and textual records (White, 2003). The first direct ancestor of the modern human, Homo sapiens, appeared around 120,000 years ago and populated Africa, Asia, Europe and Australia about 40,000 years ago. However, 420,000 year old remains of a bipedal hominid, Australopithecus Anamensis, were found on the shores of Lake Rudolf (now Lake Turkana) in Kenya in 1972. These hominids are thought to have survived the long, harsh era of Würm glaciation by developing and improving both shelters and clothing. To that extent they must have possessed the rudimentary tools, probably made of bone, required for joining animal furs together to make garments. The development of human consciousness and an aesthetic sense probably began to evolve around 100,000 years ago and is evidenced by the discovery of tools and by the beginning of burial practices (O'Brien, 1999). Some of the decorative artefacts discovered dating to the end of this Ice age indicates an evolution of both social status, and a social hierarchy, together with the emergence of a symbolic plane of beliefs and values (Williams, 1999). It is also believed that these humans formed societies in which a small number of rulers, nobles, priests and warriors would have absolute power over a greater number of 'ordinary' people. This might account for the beginnings of clothing as a means of distinguishing between those of higher and lower social status.

2.2.2 Utilitarian 'Fashion'

Fashion frequently relates to lifestyle, and proof of that statement can be found throughout history, even in prehistoric time. Clark (1969) describes the raw materials used for clothing in prehistory as being related to the climate and activities of everyday life. In the Palaeolithic period, the 'Old Stone Age' from 600,000 to 8,000 BC, men were hunter-gathers and their clothing was generally made from fur and hide. In the Mesolithic period, the 'Middle Stone Age' from 8,000 BC to 3000 BC, the changing climate from cold to milder temperatures, meant that people started enjoying a more stable year-round food supply and began settling in one place rather than leading a more nomadic existence and following herds for hunting. Although Mesolithic man still wore fur and hide garments, they began domesticating animals and growing plants and this was a time of transition, from the hunting and gathering lifestyles of the Old Stone Age, to the farming lifestyle of the New Stone Age. Table 1 summarises the timeline associated with this important period of transition when prehistoric man is changing from hunter-gatherer to farmer in various regions of the world. By the Neolithic period, the 'New Stone Age' from 3000BC to 1000 BC, Neolithic man probably had to find other means to produce clothing because the supply of fur from hunted and domesticated animals was almost certainly insufficient for an ever-growing human population. This certainly impacted upon the development of clothing technologies because not only were communities more static, they were now sophisticated tool producers.

Table 1: Regional Transition Timeline from Hunter-gatherer to Farmer

Region	Timescale for the development from hunting to farming
West Asia (Mesopotamia and the Zagros region)	12,000BC-9,000BC
East Asia	By 3,000BC
Europe	8,000 – 200BC
Africa	10,000BC – 500AD
North America	8,000BC
Mesoamerica	7,000-1,000BC
South America	6,500BC
Australia/ Pacific Islands	10,000BC – 1,000AD

Table 2 below demonstrates when most historians identify prehistory as ending in various regions of the world in terms of the operational definition given earlier in this chapter. Soon after prehistoric men began to settle in one place and pursue a farming lifestyle, they began to develop an aesthetic sense and started recording their thoughts and everyday events. Inevitably, this means that more information about the development of both lifestyles and clothing is available from the marked end of prehistory in various parts of the world.

Table 2: The End of Prehistory around the World

Region	Prehistory ends at:
West Asia (Mesopotamia and the Zagros region)	Cuneiform, 6050 BC
East Asia	2000 – 200 years ago depending on the region
Europe	Roman conquest, 1st Century BC
Africa	Egyptian hieroglyphics, 2550 BC
North America	European conquest, 15th & 16th Century AD

Mesoamerica	Maya writing, 550 BC
South America	European conquest, 15^{th} & 16^{th} Century AD
Australia/ Pacific Islands	Arrival of Europeans in the 18^{th} Century

(Source: White, 2003)

2.2.3 The Impact of Early Fibre Science and Technology

Human inventions have improved the quality of life and made a significant impact on the speed of human development throughout history. For example, the use of fire by early hominids from around 500,000BC, the production of stone tools from 250,000BC, and the development of blade tools from 30,000BC (O'Brien, 1999). However, one of the most overlooked but nonetheless important inventions in human history must be the sewing needle. Sewn clothing considerably extended human physical capability to withstand harsh environments, in particular severely cold climates. The earliest materials used for sewn clothing for hunter-gathers from the Palaeolithic period were fur and hide from animals, and this demonstrates the crucial nature of using clothing to remain mobile and keep warm during this period. There is some evidence that the needle, some with very fine eyes, has been in use since 26,000BC in central and Eastern Europe (Lambert, 1987). These were undoubtedly initially used with thread made from animal sinews and hairs before spinning technology was developed.

2.2.3.1 Early Evidence of Spinning Technology

Whilst the invention of thread is often regarded as the 'steam' of the Industrial Revolution (Barber, 1994), there is indirect evidence of spinning technology in the form of a string skirt or tasselled girdle from the 'Venus of Lespugue', one of the most elaborate Upper Palaeolithic female statues from 25,000BC (Figure 1). String skirts or tasselled girdles appear to be fundamental to women's clothing from this time period and were usually associated with the childbearing or marital status of the wearer. According to Barber (1994) this is currently the first significant evidence that clothing reflected a wearer's social status rather than being produced for purely utilitarian purposes. At around that time people sometimes adorned their fur and hide garments with beads of shell, tooth, and bones to indicate the social status of the wearer. For example, the discovery of a 23,000-year-old hunter who wore beaded fur clothes in an area east of modern day Moscow shows evidence of use of needles as well as ‘class’ distinction (Lambert, 1987). Furthermore, there is also some direct evidence of the early existence of spinning technology with the discovery of spun and piled cordage from as long ago as 15,000 BC.

Figure 1: The front and back view of the ‘Venus of Lespugue’.
Source: Musée de l’Homme, 2006

2.2.3.2 Spinning and Weaving Technology

Spinning and weaving technology were fully utilised in the Neolithic period. The plain weave (plaited) matting found in Spirit Cave, Nevada, dates from 7,424 BC (+ or - 70 years) and demonstrates a degree of sophistication in weaving technology. The weaving technique used for the matting which was also discovered in the cave is considered to be extremely rare and highly developed, and was probably made with a loom (Tuohy and Dansie, 2006). Spinning and weaving technology possibly drove the revolution in the use of materials with linen being the oldest fibre used in both spinning and weaving followed by hemp and flax. Weft-twined cloth found in a cave at Nahal Hemar, Israel dating from 6,500 BC was made out of linen, whereas warp-faced woven tape found in Çatal Hüyük, an early Neolithic town site in south central Turkey, from 6,000 BC was made out of mostly flax and other so-called ‘bast’ fibres. There is some evidence of cotton being cultivated in Mesoamerica around 4,300BC which suggests the possibility of the use of cotton in weaving. In addition to the above, a dish showing a ground loom discovered in Badari and dating from 4000BC (Figure 2) supports the revolutionary invention of a loom as early as the Neolithic period (Barber, 1991 & 1994).

Figure 2: Neolithic Egyptian dish showing a ground-loom.
Source: Petrie Museum, University College London: UC9547, 2006

However, the discovery of the so-called Tyrolean Ice Man or Ötzi, (dating from 3,350 to 3,120 BC), in a receding glacier high in the Austro-Italian Alps in 1991 shows that many of these developments were probably regional. Remarkably, no woven material was found with this body despite the fact that this man lived during the time when the New Stone Age started. Instead, his clothing consists of a cap, hide coat, grass cloak, leggings, belt, loincloth and a pair of shoes. The threads used for the stitching were made of animal sinews. However, his well preserved clothing does demonstrate what prehistoric leather and hide clothing were like at that time (Figure 3).

Figure 3: Reconstruction of Ötzi with clothing and equipment.
Source: South Tyrol Museum of Archaeology, 2006

Other discoveries in China demonstrate that just a few centuries later (around 2,800 to 2,700BC) approximately 5,000 miles away from where the Ötzi was found, weaving technology was already well developed and even further elaborated with the use of silk.

Furthermore, there are also some well preserved woven wool garments dating from the Bronze Age (from 2,100 to 1,000 BC). These discoveries have fuelled debate about when man began using wool as a fibre, particularly since domestication of wild animals started with dogs as long ago as 10,000BC followed by domestic cattle in the Sahara region of Africa around 8,000BC. However, there is no strong evidence of the use of wool for clothing or other purposes prior to the Bronze Age, although Zeuner (1963) suggests that wool probably came into use soon after sheep were domesticated. Ryder (1983) supports Zeuner's idea by suggesting that the absence of preserved wool samples might be the result of biodegradation and does not necessarily rule out the likelihood of its existence prior to that time. Clothing found at two different burial sites in Denmark dating from the early Bronze Age (1,370 BC) shows spinning and weaving technology was certainly used with wool at this time. This clothing consists of a string skirt, a sleeved bodice, a tunic with a belt, two head dresses and two girdles with metal discs as adornment. A female body found with these garments confirms that this clothing is probably a Bronze Age woman's attire. Figure 4 shows the reconstruction of this clothing worn by a model whose height is similar to the discovered female body. This type of clothing clearly reflects the social status of their buried owner as major social changes are reflected by a significant shift in the treatment of the dead (O'Brien, 1999).

Figure 4: Reconstructed female attire from the Bronze Age.
Source: The National Museum of Denmark, 2006

The string skirt worn by this Bronze Age woman shows marked similarities to the string skirt depicted on the 'Venus of Lespugue' (Figure 1) 20,000 years earlier, and suggests how slowly fashions changed in prehistory.

2.2.3.3 Silk and Cotton

In contrast, it seems that silk and cotton are relatively young fibres when compared to wool, linen, hemp, and flax (Barber, 1991). A silkworm cocoon, artificially cut, found in the Yang-Shao Neolithic layers (2,000BC) of His-yin-ts'un, Shansi Province shows the earliest use of silk (Cheng, 1960). Silk textiles were also found in a tomb in Athens, Greece dating from the late 5th century BC and the weaving techniques indicate their origin is almost certainly China. The earliest evidence of the use of cotton is a thread found in the Indian sub-continent dating from about 1,500BC. It seems likely that trading and migration between early civilisations might have accelerated the pace at which prehistoric garments evolved into relatively more sophisticated fashion items where a range of materials were more likely to be combined in one outfit. For example, a male costume found in marshes dating from the Iron Age consists of long and short trousers, a tunic and some cloaks. This case is interesting because leather shoes and a fur cape were found together with the woven costume items at the same site.

2.3 Prehistoric Clothing from 3,500BC to 400AD

It is known that at least four primal Eurasian civilisations arose around the Nile, the Euphrates-Tigris, the Indus and the Whang-Ho rivers (Williams, 1999) and Table 3 shows the first known civilisations in different regions of the world.

Table 3: First Civilisations from Different World Regions

Region	First civilisation
West Asia (Mesopotamia and the Indus region)	4,000 to 1,800BC
Egypt	3,500 to 2,180BC
Mediterranean and the Gulf region	2,000 to 1,000BC
China	1,700 to 1,050BC
South America	1,400BC to 1000AD
Mesoamerica	1,200BC to 700AD

2.3.1 The Ancient East

The development of clothing from the ancient East (South-West Asia) has been identified as a focal area by costume historians, despite the difficulties of pinpointing precise influences by different peoples, because this area was where the first human civilisations probably took shape (Boucher, 1996). The Sumer is generally regarded as the first civilisation to evolve from the two great river valleys of the Near East, the Euphrates-Tigris in Mesopotamia, and the Nile in Egypt. A map of the ancient Near East is shown in Figure 5 and identifies many of the key areas discussed in this chapter.

Figure 5: Map of Ancient Near East. Source: Boucher, 1996

From the middle of the third millennium the development of costume in the Middle East showed dual tendencies characteristic of costume in all times. These were draping, in the costume produced by the natives, and cutting and sewing, in the hemmed garments brought by invaders (Boucher, 1996).

2.3.2 The Sumer (Valleys and Plains)

Mesopotamia has become known as the 'Cradle of Civilisation', this being an area where the vast majority of early biblical recording occurs. The first known civilisation was the Sumer (3500-2006 BC), which then evolved into Babylonia (1792-539 BC), Assyria (1115-612 BC), Phoenicia and Egypt, as well as other civilisations in the area west of India and Afghanistan, and south of the Black Sea

(Pistolese and Horsting, 1970).The Sumerian civilisation is the oldest known and information about Sumerian costume has been collected from statues, bas-relief and other objects which have survived from the time. Of particular relevance to this thesis, is the existence of one terracotta Sumerian statue of an otherwise naked woman, wearing a loincloth, and what appears to be a relatively modern form of brief, dating from 3000BC (Figure 6). This statue is generally cited as the first evidence of the wearing of underwear in history and is normally taken as marking the starting point for underclothing history (Ewing, 1971; Saint-Laurent, 1968).

Figure 6: Sumerian terracotta from 3000BC. Source: Louvre, 2006

The status of the woman depicted in this terracotta is believed to be a slave because higher quality garments have since been discovered for higher status people. The main Sumerian costume was constructed from 'Kaunakès' cloth, a sheepskin or goatskin with long tufts of hair on the outside. It was used by both men and women from 2900 to 2500 B.C. Figure 7a shows the 'Kaunakès' worn by Ebihil, superintendent of the Ishtar temple at Mari from 2400BC and Figure 7b shows female statues wearing 'Kaunakès'.

a) Ebihil b)Princesse De Bactriane

Figure 7: Ebihil, superintendent of the Ishtar Temple at Mari from 2400BC (a) and Statuette de Femme Vêtue d'un Kaunakès, Appelée 'Princesse De Bactriane' (b). Source: Louvre, 2006

There are two types of garments which use Kaunakès; a skirt and a long woollen shawl. A whole garment works separately as a skirt or loincloth and a cloak or cape. Resemblances to the Sumerian's primitive costume can also be found in Central Asia between 3400 and 2400B.C. as well in the Celts' woollen cloak which was also woven using skin with long dangling strands between 1440 and 1150B.C. Kaunakès as a cloth imitating skins continued into the Middle Ages and became a symbol of power as a result of the particular arrangements of the tufts and decoration.

2.3.3 Babylonia and Assyria (Valleys and Plains)

Babylonian and Assyrian costume adopted primitive, thick, yet richly decorated Sumerian costume into a more fitted sheath-like garment, more suitable for the hot climate. In Babylon there were even guilds for linen and woollen weavers and men wore long or medium length tunics with wrist-length sleeves and a slit on the chest fastened by two cords with woollen tassels. Higher ranking men, such as a king or high court official, wore the shawl folded into a band over the tunic. The length of the fringe generally indicated the persons rank in the society.

2.3.4 Syria and Phoenicia (Eastern Mediterranean and Black Sea)

Costume in the coastal countries (Mesopotamia, Syria and Arabia) was often composed of elements from Cretan, Hittite, Mesopotamian and Greco-Roman costume, probably because the coastal region was heavily engaged in trade and transport. Phoenicia (the territory of modern-day Syria, Lebanon and Israel), with ample sources of the dye for purples, became the first urban centre of trade and communications from the 16^{th} Century B.C. From as long ago as the third millennium B.C., men were dressed in a short tunic-undergarment of linen. This costume became widespread throughout Asia Minor and was referred to in Greek as being made from 'chiton' meaning 'linen material'. Women from this time wore a shawl draped like a cloak over a long linen tunic whereas the clothing worn by the coastal people consisted of a shawl decorated with long fringes, a short skirt or loincloth, a short or long gown and a scarf over the chest. The typical costume from Syria and Phoenicia shows bold stripes and borders with flower motifs in a mixture of colours. In the second millennium BC men wore the loincloth-skirt with fringes, tassels and bands, and the sleeveless Sumerian style robe with a fringe. Both garments were influenced by Egypt. Ionian women wore the long tunic-gown with a greater fullness of fabric than hitherto and sometimes this was finely pleated in an Egyptian style, or it was arranged in several tiers in the Cretan style. In the first millennium B.C., men and women's costume consisted of two contrasting types; one is the draped Sumerian garment identified above and the other is the sewn garment, generally a short tippet or tunic, with an opening.

2.3.5 Anatolia, Armenia, the Caucasus, Persia, Afghanistan and Baluchistan (mountain countries)

By the beginning of the second millennium, the Steppe people, armed with new weapons and mounted on horses, left their Russian and Asiatic homes and settled on the plains of the Middle East. This Aryan invasion brought about significant changes in costume. A warmer sewn costume consisting of a tunic with sleeves was introduced by the northern settlers. Persians adopted this mountain dwellers' tunic and converted it into a long under-tunic or caftan, the 'candys'. The Persians introduced long trousers, 'anaxyrides', to the Middle East in about 400 to 360BC and these probably also originated from the Steppe nomads.

2.3.6 Steppe Nomads (Irano-Indian Regions)

The Steppe nomads (Huns, Scythians, Alans and Sarmatians) wore fur and leather clothing; a tunic, long trousers, a pair of boots and a tall fur or felt cap. The Scythians wore a pointed hood, jacket, tunic, trousers and long tunic with long sleeves usually with a belt. It is from this that the caftan originated. The tunic was worn by both men and women with different decoration according to gender. Trousers became an essential garment for nomadic horseman and the migration of primitive horsemanship from South Russia into Central Europe at the end of the Stone Age around 2500 B.C. coincides with the adoption of trousers as costume. The ancient Middle East costume can therefore be characterised as a mixture of the original Sumerian style draped garment (loincloth, shawl and cloak) with the new flowing, yet fitted type (tunic and gown over trousers) from the mountain dwellers and invaders from the Steppes of Central Asia. This new part-fitted costume became the mark of warriors, or of the wealthy and governing classes and later these garments spread to Europe and developed in more fashionable form.

2.3.7 Mycenae, Crete and Cyprus

Cretan civilisation started around 3400B.C. Initially influenced by Egypt and Babylon, Cretan civilisation developed its own distinctive costume from the second millennium (Evans, 1931) using materials like wool and flax along with fur and skin, and external trade spread this Cretan costume widely. Men wore a simple loincloth in the same shape as the Egyptian ‘shenti’ except the lower corner of the fold fell down in front into an oblique point, often weighted by a net of pearls. Occasionally two loincloths or a loincloth and a cache-sexe were worn together, and this loincloth developed into a closed garment which was then converted into a pair of short trousers and worn in the Cyclades. Loincloths and shorts were held at the waist by a wide leather belt as Cretan men were proud of their wasp waists. There was also a protection robe or ‘cassock’, which was only used for religious and symbolic events where high ranking men would wear a long gown decorated with rich embroidery.

Women’s costume at this time is characterised as being close-fitting, echoing the loincloth tied around the waist which they wore like a short skirt, although still significantly longer than the male version. A belt was used to hold the loincloth as well as a dagger and from the beginning of the 18th Century B.C., a skirt, a bodice, a long cloak or a short cape and a head-dress became everyday attire for women. New forming and decorating techniques such as pleats, flounce, and embroidery were added and the tightly fitted skirt shape, supported with a belt at the waist and reaching to the ground with fullness, resembles the Crinolines of 19th Century Europe. Together with the men's wear, these flounced tier skirts spread throughout the Eastern Mediterranean. The origin of these flounced skirts, often overlaid with a rounded apron, is believed to be the Sumerian 'Kaunakès'. One interesting and unique item of costume, depicted as being worn by goddesses or priestesses for ritual practice, also appeared at this time. This unique item was the corset which left the breasts completely exposed, and accentuated a slim waist. Figure 8 is a picture of the 'snake goddess', a polychrome terracotta figurine from Knossos, wearing ceremonial dress, yet indicating typical Minoan attire. Cretan woman also wore the first models of hats in the history of fashion.

Figure 8: Snake goddess from the late Minoan period from 1800BC.
Source: Heraklion Museum, 2006

2.4 Costume from Africa/Egypt

Egyptian costume was always quite simple and remained largely consistent from about 3200 to 1500B.C. This clothing was characterised by the use of a draped costume of linen material, and the use of the same style for both sexes. The loincloth or 'shenti' was worn by both sexes as was the sleeveless long tunic which created an elongated silhouette. The sleeved tunic or 'calasiris', was added to Egyptian costume from the 16^{th} Century B.C. when a wider range of colours came into common use. The 'calasiris' was composed of a short, tight bodice with long close-fitting sleeves, and openings at the back and front fastened by thin cords, and worn with a wide skirt sewn into the bodice, with horizontal folds/pleats. Linen was the material of choice probably because of its availability and its characteristics of being light, cool and durable. At this time, wool was considered as impure by Egyptian religion and, rather like parts of Asia, was normally not used. The shawl was generally worn by women and a cloak was worn by men. Figure 9 shows the changing styles of loincloth worn by the King and high officials and the loincloth/chastity belt worn by female slaves.

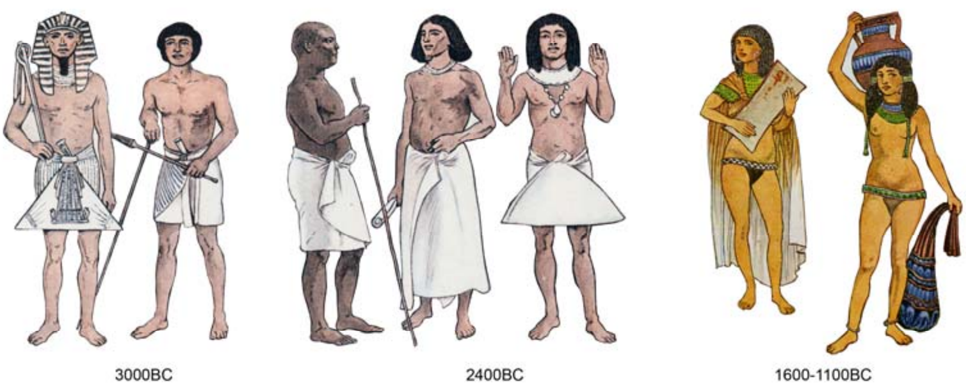


Figure 9: Loincloth worn by Egyptians. Source: Bruhn and Tilke, 1955

2.5 Central Mediterranean

There were two clear guiding principles for ancient Greek and Roman costumes:

i. No rules for dimensions. Only the height of the wearer was considered, and a rectangular shape was adopted.
ii. Only drapes. No cutting and sewing.

2.5.1 Greece

At the end of the 5thCentury B.C., the woollen fabric industry in Greece was well developed from shearing to dyeing the wool. Linen was also imported from Syria as a pleated textile. Greek costume was composed of a rectangular cloth which could be worn as either a tunic or cloak. Each arrangement of this garment was named differently depending on the occasion and the gender of the wearer.

The chiton was essentially a belted tunic, which could be either short or long, and was worn by both sexes and also served as an undergarment. For example, soldiers wore a cuirass on top of the chiton and a wider tunic, worn as a cloak for men, was called the 'himation' or 'chlaine'. The 'peplos', a traditional Greek women's garment fastened by two fibulae, looks similar to the chiton but Greek women seamed the side of the tunic together to ensure personal modesty. Women also wore the male cloak, and added the pharos, a lightweight linen cloak. In terms of underwear, Greek women wore a narrow breast band called an 'apodesme', which flattened the breasts and restricted their movements. Contini (1965) claimed that this 'then-brassiere' was used in order to look slimmer rather than supporting the breasts or aiding better movement. This evolved into a thin red ribbon called 'anamakhalisters' and 'mastodetons', which grew over a short period of time to the size of a scarf. An early stomach flattening garment, the 'zona' was developed during the same period. This garment wrapped around and flattened the stomach and was initially worn by both sexes.

2.5.2 Rome (510BC – 330AD)

Rome at this time was a small town under the Etruscan civilisation which flourished in Tuscany between 800B.C. and 300B.C. Rome expelled Etruscan overlords and founded a republic in 510B.C. Etruscan women initially followed Greek fashion, but over time developed their own fashion which emphasised a tight-waist by wearing full, bell-shaped skirts. At this time both men and women started to develop and adopt a variety of new fashions. The Romans wore a wide range of costume which nonetheless can be classified into two types of garment:

The first type was a tight fitted undergarment called the ‘indumenta’ which was the tunic introduced from Greece and generally worn by men. Essentially, two pieces of cloth were sewn together at the sides so that wearers needed to slip the garment over their heads to put it on and then tie it around the waist. When it had wide sleeves it was called a ‘dalmatic’, and when a hood was added, it was called a ‘caracalla’. The second type was a draped outer garment called the ‘amictus’. The ‘amictus’ was what has commonly become known as the ‘toga’, a special Roman cloak. The ‘toga’ was cut in a circle about eight feet in diameter and decorated with a band or bands which indicated the owner’s social status.

Originally, Romans did not wear trousers, but this changed as a result of experience gained during their foreign campaigns, and they later adopted the use of trousers for riding and hunting. These were called the ‘gallic bracae’ and they resembled riding breeches and were initially worn for warmth and protection by Roman soldiers stationed in the north of the empire. Women wore similar garments to the male tunic and ‘toga’ but tended to wear a wider and flatter belt than their male counterparts. The breast-band was added to the fitted loincloth as an undergarment and aristocratic Roman women wore short tunics of luxurious silk decorated with gold fringes. Techniques of decoration such as braids, fringes and embroidered trims flourished at this time due to the influence of imported oriental fashion.

Underwear garments increased in number and became increasingly sophisticated and complicated in design from the 3rd Century B.C. A band called a ‘taenia’ was worn under the breast in the same way as the Greeks. Some breast bands were designed to prevent growth. For example, the ‘fascia’ was for small girls and was probably designed partly for this purpose. Others were designed to flatten full breasts. For example, the ‘mamillare’ was for grown women and were worn as disciplinary measures. The ‘mamillare’ that were made from leather were gradually replaced by ‘strophium’. The ‘strophium’ resembled a scarf and supported the breasts without suppressing them. A ‘capitium’, which was a bigger and softer version of the strophium, was worn by the lower classes. The originally Greek ‘zona’, a girdle-like skirt, and the ‘cestus’, another girdle-like garment covering from the breast to the groin, were also worn. Roman women wore a knee-length sleeveless under-tunic, a corset-like garment called the ‘capitium’, a belt called a ‘cingulum’ and an underskirt called a ‘castula’. The Roman bikini was worn by gymnasts and later the Greeks were to adopt this garment as a bathing suit. There are substantial numbers of mosaic images showing female athletes wearing a bikini from a roman villa in Sicily (Figure 10). This villa was built between the late 3rd century BC and the early 4th century AD. The upper part of the bikini was called the ‘fascia pectoralis’ and the lower piece, the ‘subligatur’.

Figure 10: Mosaic image from the Villa Romana del Casale, Piassa Armerina, in Sicily. Source: Roux, 2006

It is clear from these images and others that the bikini was also worn as underwear and commonly used to practice gymnastic activities. Figure 11 shows the mosaic image of a Roman female who is wearing the bikini top as underwear.

Figure 11: Mosaic images of a Roman woman wearing underwear from Villa Romana del Casale in Sicily. Source: Roux, 2006

2.5.3 Byzantine: The Greek Speaking Roman Empire (330 to 1025AD)

The Byzantine Empire is a continuation of the Roman Empire after Constantine founded a new imperial capital at Byzantium. The city is now called "Constantinople". Constantine converted to Christianity and made this the Roman state religion. Its history is a story of constant gains and losses of territory. Perhaps as a consequence of this, fashion got richer in materials, colours and trims (Gorsline, 1978).

2.6 Europe

Europe was also affected from the earliest times by incessant migratory movements. The Celts emerged as an agricultural people during the first millennium BC when the Bronze Age was at its peak in Central Europe. 'Celts' was the name given by the Greeks and Romans to the peoples of Europe north of the Alps. Then the Celts began to expand towards Western Europe from 1100BC to the 5th Century AD. In the course of their advance, the La Téne civilisation of Celts settled throughout the whole of Europe.

Celtic men and women wore a semi-fitted tunic with long or short sleeves which was basic attire from the Nordic and Mediterranean world. The shirt or chemise, worn only as body linen, appears in the 4th Century AD under the name of camisia and was derived from the tunic, replacing the loincloth originally worn under the tunic. Cloaks, hooded capes and Roman style draped shawls were worn together with breeches, long wide seated trousers, in the case of men. The first significant change in western clothing came about in the 4th Century AD and the major new influences came from the east. From the 3rd Century AD to the 6th Century AD Nordic migration swept over Central Europe, then the Eastern Indo-Europeans overthrew the Gothic Empire. All these 'Barbarians' dressed in sewn garments fitting closely to the body, short tunics, and long or short breeches in various colours. These developments which occurred over a considerable period of human history meant that very gradually a firm foundation for costume had been established in Europe, and set the scene for the real history of underwear which began around the early Middle Ages (1000AD-1200AD). Figure 12 summarises the timelines of history from 600,000BC to 1000AD which are described in this chapter.

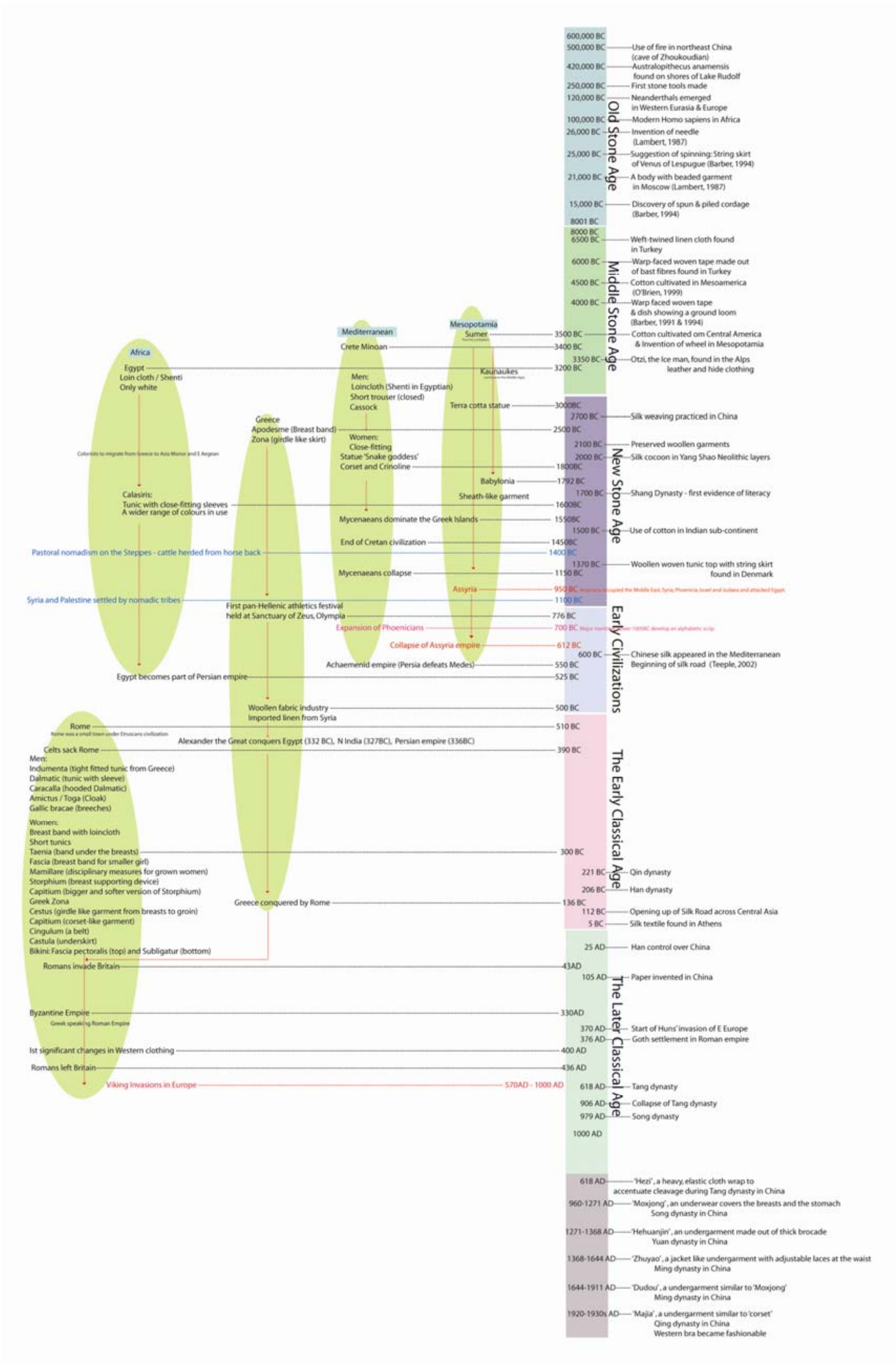


Figure 12: Timelines from 600,000BC to 1000AD.

2.7 Summary

2.7.1 The Early Evolution of Underwear

The concept of underwear did not exist at the dawn of human history back in 600,000BC and it remains a difficult task to pinpoint the authentic starting point of the concept and use of underwear. Gorsline (1978) suggested the loincloth and tunic as the 'originators' of all clothing whereas Saint-Laurent (1968) suggested that the origin of clothing is originally based on physiological needs and eventually developed because of man's desire to alter his own image. As a result, individual and societal needs for psychological comfort through self expression and self adornment became major reasons for adopting clothing rather than just physiological or survival needs. This explanation is consistent with the current view that modern underwear is not only hygienic but also serves aesthetic purposes by extending and improving the body image and shape.

Social changes and developments throughout the history of the region where the particular fashion arose and disappeared are important, and the foundation for the development of both fashion and underwear clearly depended on the following factors:

- Developments as a result of farming and the domestication of animals.
- The invention of needles, spinners and looms.
- The development of spinning and weaving technology.
- Trade and transport effects.
- The impact of expansion and war.

Understanding the evolution of the history of both fashion and underwear relies heavily upon archaeology for source material. The first era of clothing is found in artefacts, cave painting, pottery art, and preserved pieces of cloth with perhaps the first written reference to underwear in history being the fig leaves made for Adam and Eve by God in the bible.

Despite the difficulties of drawing firm conclusions from archaeological data, there are three garments which can nonetheless be regarded as particularly significant in this respect amongst other prehistoric costumes (Saint-Laurent, 1968; Ewing, 1971; Carter, 1992):

i. The garment which can be regarded as the forerunner of the modern brief depicted on a remnant of Sumerian terracotta dating from 3000BC (Figure 6).
ii. The bell shaped skirt with a tightly fitted bodice worn by a Cretan snake goddess dating from 1800BC (Figure 8).
iii. The Roman women's breast-band with short pants or briefs for exercise dating from 400AD (Figure 10).

Figure 13 shows these three artefacts on the world map, together with the approximate time of their arrival.

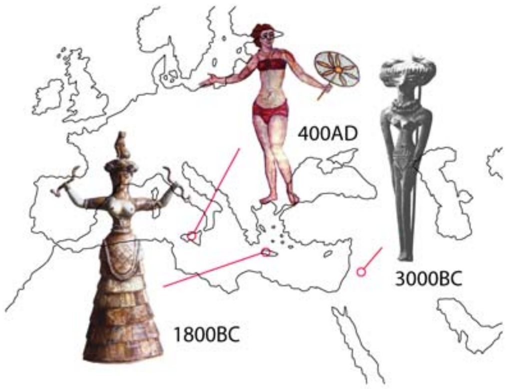


Figure 13: Artefacts depicting garments resembling modern underwear.

Speculation over the loincloth worn by the Sumerians in 3000BC as a primitive form of modern brief, the breast band 'apodesme' worn by Greek women in 2500BC as a primitive form of modern brassiere, the tight bodice worn by Cretan women in 1800BC as a primitive form of corset, and the bell shaped multi layered skirt worn by Cretan women in 1800BC as a primitive form of petticoat/crinoline, cannot be supported as to date. Consequently, there is no conclusive evidence of the existence of the concept of underwear in prehistoric costume.

2.7.2 The Concept of Underwear for 'Fashion'

The Oxford English Dictionary (2006) defines underwear as clothing worn under other clothes, and next to the skin, whereas Blair (1992) defines underwear as an overall term for clothing worn close to the body and under outer garments. The concept of underwear is strongly related to its functions (Barbier and Boucher, 2004; Calasibetta, 2003; Cunnington and Cunnington, 1992) and the functions of underwear throughout history can be summarised as follows:

i. To provide class distinction.
ii. To provide protection from the cold.
iii. To support the shape of the costume.
iv. To support the body.
v. To provide enhanced personal hygiene.
vi. To enhance sexual attraction.

Amongst these core functions, class distinction is probably the main driving force behind the evolution of underwear from its most basic early functions as protection from weather and providing personal hygiene, because this was deeply rooted in costume from the ancient East, especially Egypt, where social status was demonstrated by wearing many layers of clothing (Saint-Laurent, 1968; Cunnington and Cunnington, 1992). This particular class distinction is perhaps not applicable in the 21st Century because underwear is now regarded as a matter of personal taste, and good quality, well designed underwear is reasonably priced.

2.7.3 The Utilitarian Possibility

Barbier and Boucher (2004) make the assumption that the first underwear/bodyline for the female was a menstrual device equivalent to modern sanitary towels. It is possible that the hygiene function of underwear existed in prehistoric time. Unfortunately records of menstrual aids are rare as most cultures and societies regarded menstruation as taboo or a forbidden subject even up to relatively recent times. In that respect, the development of women's underwear might suggest a bigger role for hygiene than in men's underwear, in particular to protect women's outerwear from menstrual and other bodily secretions. Whatever the salient driving forces for the development of underwear were, there is little doubt that its development has come a long way throughout human history, starting with the humble string skirt from 15,000BC (Figure 1), the concept of underwear has slowly formed and provided a foundation for further development around the time of the Greek speaking Roman Empire and Byzantine Empire, in 400AD when the first really significant changes in Western costume began.

This chapter has reviewed the development of prehistoric costume, identifying that this process can be broadly divided into two parts. Having considered the background and development of the necessary clothing technology related to prehistoric costume, and reviewed the nature of prehistoric clothing from 3,500B.C.to 1000A.D., the relationship between the development of outer wear and the potential explanations for the evolution of underwear has also been considered and the key arguments summarised. Although inconclusive, it seems likely that underwear began being worn for utilitarian reasons but quite quickly evolved into other more ‘fashion’ related functions, particularly when farming replaced the hunter-gatherer lifestyle. In the next chapter, consideration will be given to the evolution of underwear from 1001A.D. to the early 1900’s, a period which provides the more modern context for the development of the brassiere over the last Century.

CHAPTER 3
THE EVOLUTION OF UNDERWEAR FROM 1001AD TO THE EARLY 1900S

3.1 Introduction: Outerwear Fashion and Underwear Development

The last chapter argued that the concept of underwear probably had humble beginnings as a layer underneath outerwear with hygienic or protective functionality, but gradually gained an identity of its own by supporting and complementing developments in outerwear fashion. Barbier and Boucher (2004) emphasise the fundamental role played by undergarments in creating a fashionable silhouette, and identify its crucial role in terms of changing perceived body shape. In particular, underwear undoubtedly assisted in changing the perceptual emphasis to the shoulders, waist, bust and hips. Therefore, it is crucial to recognise the impact fashion trends related to outerwear had on underwear development. Consequently, this chapter continues to explore and develop the historical context for the development of underwear and reviews some of the key developments in both outerwear and underwear from the medieval period to the early 1900s in Europe.

3.2 The Medieval Period /Middle Ages (1001AD -1484AD)

The Middle Ages in Europe are commonly dated from the 5th Century division of the Roman Empire and the barbarian invasions, until the 16th Century Protestant Reformation and European exploration. However, for the purposes of this chapter, the Medieval period is operationally defined as from around 1001 to 1484 largely because of the significant changes in outerwear fashion that occurred during this time. Historically highly significant events occurring during this period include the ‘Hundred Years War’ between England and France (which actually lasted 116 years from 1337 to 1453) and the ‘Wars of the Roses’, which were a series of civil wars between the House of Lancaster and the House of York in England and lasted for thirty years from 1455 to 1485. During this time outerwear for both men and women was simple and tightly fitted with lacing and gradually became ever more sophisticated and rich in materials and trims during the latter part of the Medieval Period (Figure 14).

Figure 14: Medieval attire in England. Source: Bruhn & Tilke, 1955

Underwear for both men and women was also simple throughout this period, not changing at all significantly over the four hundred or so years. Thursfield (2001) defines medieval underclothing as a layer of washable linen between the body and the outer clothing. Underwear was called ‘body linen’ or ‘linen’ as linen was by far the most common material for upscale comfortable underwear (Barbier and Boucher, 2004). The underwear from this Medieval Period was generally only designed to fulfil utilitarian functions such as protecting the body from the cold, and probably as an aid to keeping the body clean and hygienic. However, Cunnington and Cunnington (1992) question the effectiveness of the former function when comparing the underclothing of this period to modern thermal underwear. Underwear was always completely hidden underneath outerwear partly because underwear was associated with the idea that the body was sinful. In fact, some people of this time adopted a symbolic gesture of exposing their underwear to punish others for their sins or to express their humility in public. The notion that underwear might express the spirit of the changing times did not enter the Medieval mind (Cunnington and Cunnington, 1992) and the modern concept of ‘fashion’ in costume, mostly outerwear, really appeared in the late 14th Century, addressing the twin purposes of sexual attraction and class distinction.

3.2.1 Characteristics of the Medieval Female Attire

3.2.1.1 The Chemise

The female shirt was called a 'chemise' (Norman) or 'smock' (Saxon) and was similar in design to the female tunic from ancient civilisations. Chemises were loosely fitted with pleats and gathers and decorated with embroidery around the neck and hem. They were constructed using linen, cotton, long cloth, cambric, lawn and nainsook and Figure 15 shows the simple style of the female medieval chemise.

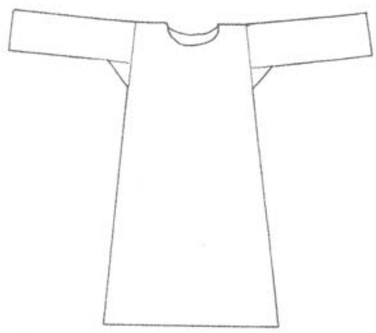


Figure 15: Medieval women's chemise. Source: Thursfield, 2001

There is a figure of a demon wearing a laced-up tight-fitting corset-like garment from 1170 but other than this, there is no substantial evidence to support the notion that medieval women wore stays or corsets during this period. However, primitive forms of the bustle were definitely in use by the more fashionable women by the mid 14^{th} Century.

3.2.2 Characteristics of the Medieval Male Attire

3.2.2.1 The Shirt and Braies

Men wore a shirt or undershirt which can be treated as roughly equivalent to the female chemise. Male undershirts were generally constructed using wool, linen, hemp and silk, and long hose were attached to the shirt. Shirts from the 11^{th} Century were effectively a loose fitted bodice with full sleeves, a front neck opening and tie. 'Drawers' were also known as 'braies' or 'breeches' (Saxon) and were used as a masculine garment to conceal the sexual region throughout the Middle Ages. Later, breeches became a name for the outer garment only. Braies, effectively an outer garment, only became a true undergarment in the mid-12th Century because until that time, they were effectively largely hidden by the long Norman tunic. The length of both shirt and drawers varied considerably with braies becoming shorter and tighter in the 14th Century and eventually evolving into a more modern style of brief from the 15th Century. Figure 16 shows braies and a shirt from the Medieval period. Ties and cross taps were used as fastening systems and braces were used to hold the drawers in place.

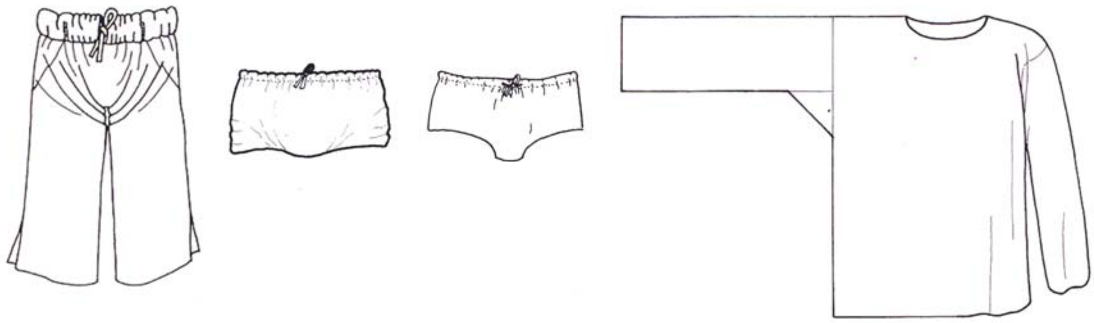


Figure 16: Medieval braies and shirt. Source: Thursfield, 2001

3.3 The Tudor Period (1485-1603)

The period between 1400 and 1600 were an era of crucial change for Europe. This period became known as the Renaissance and saw radical developments in philosophy, culture, and the spirit of scientific enquiry (Teeple, 2002). The Renaissance freed the European spirit from total submission to church authority in the sphere of politics, economics, science and art and not surprisingly, this change also had a considerable influence on fashion. The fashion centres of Europe gradually moved from Germany, to Italy and latterly to Spain (Gorsline, 1978). Figure 17 shows Spanish fashion in France from 1575 to 1590. During this time, there were significant changes to male outerwear with the exception of male hose and codpieces, the latter disappearing towards the end of this period. Long hose developed into stockings and breeches which were boned and padded at the hip and the knitted stocking was invented, with the consequence that the garter was in great demand. Later in this period, high heels appeared but generally, apart from court dress, people still wore plain clothing.

Figure 17: Spanish fashion in France from 1575 to 1590.
Source: Bruhn & Tilke, 1955

Female fashion tended to follow male fashion until the reign of Elizabeth I (1558-1603). Necklines were initially low-cut and square and eventually developed into high collars with a ruff which is often depicted as the signature fashion of this period and was starched and wired to hold its shape.

3.3.1 Characteristics of the Tudor Period Female Attire

Gradually male and female outerwear became more colourful and splendid and the richness of outerwear affected the characteristics of the underwear worn during the Tudor regime. For example, petticoats, hoops, farthingale and bum-rolls emerged to support the growing size and shape of the skirt and subsequently two new functions of underwear were added as underwear was used to show off the wearers' social status and draw attention from the opposite sex, firmly introducing modern notions of class distinction and sex appeal. The following items of female attire illustrate the characteristic styles of this period:

3.3.1.1 The Chemise

A variety of chemise necklines were available at this time, including a frilled high neckline and a square-cut low neckline. The chemise was embroidered around the neck and also often around the wrist where it was visible through outerwear, especially through the slashed sleeves. Figure 18 shows an Italian camicia or chemise from the late 16^{th} Century.

Figure 18: Late 16^{th} Century Italian shirt, camicia and drawers
Source: Cunnington and Cunnington, 1992

3.3.1.2 The Corset

Bodices became stiffer and compressed the bust from around 1500 and by the 1590s bodices with whalebones and centre busks were fashionable. Horn, whalebone or wood was the material of choice for the construction of the centre busks and the fashion was to compress the stomach area and thrust the bosoms upwards sometimes until they were clearly visible. The terms ‘stay’ or ‘a pair of bodice’ came into common use and generally replaced the term corset. Originally, the term ‘stay’ referred to the heavily boned lining to a bodice and ‘a pair of bodice’ came from the right and left sides to the bodice being made separately and fastened together with laces.

3.3.1.3 The Waistcoat

Women wore waistcoats from the 1560s and these were made using linen, silk or flannel and they were often lined, quilted and embroidered. Waistcoats were eventually adopted as outerwear to add warmth to the body during this period.

3.3.1.4 The Petticoat

In contrast to the waistcoat moving from an undergarment to an outer garment, the petticoat was first referred to as an outer garment during the 15th Century and later became an undergarment (Carter, 1992). By the 16th Century, the petticoat was well established in England with several petticoats being worn together, one over another, to support the outer shape and the outerwear styles of the time.

3.3.1.5 The Farthingale

The ‘farthingale' or ‘hooped’ petticoat was adopted in England from Spain around 1550 when the circumference of outer skirts became too large to be supported by many layers of petticoat. The farthingale was a cone shaped petticoat reinforced by a series of graduated hoops made of cane, whalebone and wire.

3.3.1.6 The Bum roll

The bum roll was introduced to give more support at the waist in the 1580s when outskirts were widened. Bum rolls were half-moon shaped cushion pads made of rolls of linen or cotton fustian, filled with cotton balls, and with ties at the each end. They would sit at the base of the lower back, resting on top of the buttocks and were secured around the waist with the ties.

3.3.1.7 The Drawers

Les caleçons (meaning pants in French) were worn by French women in the mid 16th Century and by Italian women from the late 16th Century. However, there are some conflicting records which suggest that caleçons or drawers were introduced into France from Italy by Catherine de Medici (Cunnington and Cunnington, 1992). Silk and linen were the construction materials of choice and Figure 18 shows Italian drawers from the late 16th Century. Interestingly, English women did not start wearing drawers until the very end of the 18th Century, this particular fashion taking a long time to make the journey across the English Channel.

3.3.2 Characteristics of the Tudor Period Male Attire

The following items of male attire are characteristic of this period, and like the female attire provide evidence of the developing sense of clothing and underwear to support more modern concepts of 'fashion', rather than purely utilitarian clothing:

3.3.2.1 The Shirt

This was similar to the female chemise except that a neckband and cuff were added and, in common with the chemise, the shirt was embellished with embroidery. Later in this period, ruffles were added at the edges of collars and cuffs. Figure 18 shows Italian shirts from the late 16th Century.

3.3.2.2 The Waistcoat

In common with the female chemise fashion of the time, the waistcoat or vest was originally worn under the doublet as underwear, only becoming outerwear towards the latter half of this period.

3.3.2.3 The Corset

According to the historical literature, men were also known to wear a corset during the Tudor regime although these were almost certainly not as restrictive as the female versions (Cunnington and Cunnington, 1992).

3.4 The Seventeenth Century

During this period, styles of dress changed considerably and men now began wearing a tight fitted doublet with basque or little skirts and padded breeches. Later in the 17th Century the male outfit comprised a straight, thigh-length coat, waist-length vest, and breeches. The female style was still under the Spanish influence but gradually became more feminine with the addition of lower necklines revealing the bosom. Later in the 17th Century women wore a long, waist-fitted bodice with loose sleeves, exposing a full underskirt under draped loose overskirts. During this period people became increasingly free to dress as they wished and by 1650 French fashion, which was extravagant and sumptuous, dominated Europe. This included menswear which was decorated with ribbons, bows, gold and silver embroidery and braids. Fashion dolls were used to spread the newest fashion trends until the advent of newspapers took up this role from 1672. Consequently, outerwear fashion changed significantly and many times during this period because there was greater, and more widespread, interest in personal appearance and etiquette, although this was still unmatched in terms of hygiene or cleanliness which remained largely ignored. Figure 19 shows some typical mid 17th Century costumes.

Figure 19: Mid 17th Century mode. Source: Gorsline, 1978

Cunnington and Cunnington (1992) point out that underwear also underwent significant change during the romantic period of the Stuarts. Whilst the expression of social status and sex appeal through underwear got generally stronger during this time, class distinction was demonstrated more in male underwear whereas sexual attraction was demonstrated more in female underwear. Silk and linen were preferred over wool because woollen clothing was easily infested with lice or fleas, and this dislike was reflected in an English Act of Parliament in 1678 to bury the dead only in woollen garments. This particular Act of Parliament took until 1814 to be repealed.

3.4.1 Characteristics of the 17th Century Female Attire

3.4.1.1 The Chemise

The female chemise of this time was simple and plain with a neckline which was low-cut with frills and adjusted by drawstrings. Puff sleeves were used and were below elbow length, being gathered at the cuff/band with ruffles. Figure 20 shows an example of a female linen chemise dated from 1700 or earlier.

Figure 20: Linen chemise from 1700 or earlier.
Source: Cunnington and Cunnington, 1992

3.4.1.2 The Corset

The first record of a corset type garment was a two piece bodice, a pair of bodice, from 1631 (Linthicum, 1972). Tabs which emphasised a miniscule waist were adapted to the corset from about 1630 and, later in the century, the number and length of tabs increased. The stays, which involved incorporating a boned lining to the bodice, became a separate undergarment around the 1670s. These corsets which were heavily boned with whalebones had lacing in the back and long pointed busks in the front. The outerwear fashion of the time which involved décolletage (low-cut necklines) influenced both the chemise and the corset, with the corset becoming a strapless garment. Achieving the desirable narrow waist by wearing a corset brought (as yet unrecognised) potential deadly results for women's health and even children began to wear corsets by the mid 17th Century.

3.4.1.3 The Farthingale

The Farthingale from Spain became obsolete in 1625 when the trained, flowing back of the outer skirts from this period required further support, and the colloquially named ‘bum-roll’ was often used as a substitute. There is indirect evidence to suggest that many layers of petticoats were worn underneath the outer skirt to add more volume.

3.4.1.4 The Bustle

The bustle was adopted in the late 17th Century in order to emphasise the hip and the back of the skirt. Later the bustle was replaced by the hoop in the late 17th Century and the hooped petticoat from the 18th Century. The bustle enjoyed a brief renaissance in the late 18th Century before being finally replaced by the cage crinoline in the 19th Century.

3.4.1.5 The Waistcoat

The waistcoat was still worn as an undergarment throughout this period and underwent very few significant changes at this time.

3.4.1.6 The Drawers

Whilst there is conclusive evidence that French women wore drawers during this period there is no direct evidence that English women adopted this item of clothing.

3.4.2 Characteristics of the 17th Century Male Attire

3.4.2.1 The Shirt

By this time shirt sleeves had become full and were gathered at the wrist. The shirt was displayed through the front and back slashes of the doublet and shirt cuffs were displayed from the doublet’s turn-back cuff. A neck band and cravat, was introduced and became longer and narrower around 1640. The ‘jabot’, a gathered frill, was added on to the side edge of the placket and, by the end of the century, an extensive area of shirt was visible. Wrist ruffles appeared around 1660 and a half-shirt, a short undershirt, was added to male underwear at this time.

3.4.2.2 The Drawers

There were two types of drawers. The first was in the shape of the modern trunk with a slit in the back which was tied at the rear with a ribbon at the waist, and the other was a pair of long drawers with stirrups around the insteps to hold them in place. Figure 21 shows shirts and drawers from the 17th Century.

Figure 21: Shirts and drawers from the 17th Century.
Source: Cunnington and Cunnington, 1992

3.5 The Eighteenth Century

Wars and political struggles dominated the first half of the 18th Century and the Industrial Revolution created a major shift in terms of technological, socioeconomic, and cultural conditions. Many workers from rural areas moved into growing urban areas and the textile industry shifted from the traditional cottage industry to mass production factories because of the increasing availability of labour and the development of new technologies. Also significant was the development of a social movement called 'Enlightenment' which tried to banish medieval obscurantism and live by the 'light of reason'. Christianity and the Papacy were favourite targets for criticism at this time. Perhaps influenced by this social movement, fashion during this time became much simpler and more practical.

The Spanish farthingale had already been replaced by bustles for moderate sized skirts, and by hoops for the larger size of skirts. In fact, according to Cunnington and Cunnington (1992) almost all female outerwear was dominated by the hoop during this period with metallic hoops used underneath the skirt. However, by the early 1780s, female dress became looser and more flowing in style. More conservative styles were increasingly adopted as a result in part of the influences of the French Revolution (1789-1799). Head-dresses and headgear in the 18th Century were often supported by frames or pads and elaborately decorated with feathers and beads. Generally, male fashion changed little although the loose fitted coats did develop into the swallow-tailed frock coat and breeches and culottes were bias cut and covered the top of the stockings, with tight pantaloons eventually replacing breeches.

Figure 22 shows the flowing dresses typical of France from the 18th Century, where the female body was moulded by structured hooped undergarments and boned stays. Carter (1992) claims that the underwear of the 18th Century carried out its traditional functions of warmth, modesty and hygiene.

Figure 22: The 18th Century outfits in France. Source: Bruhn & Tilke, 1955

3.5.1 Characteristics of the 18th Century Female Attire

3.5.1.1 The Chemise

Cunnington and Cunnington (1992) suggest that the centre of sexual attraction had now shifted from breasts to legs because of the fashion of hoop wearing. However, the neckline of the chemise remained low and square cut with rounded corners following the extreme décolletage popular in the previous century. Puff sleeves were largely overtaken by the bell sleeve by around 1740, but the chemise was still made with linen and remained quite plain and mostly white in colour. Decorations were generally also made in white.

3.5.1.2 The Habit-shirt

Habit-shirts first appeared in the 18th Century and the neck was constructed with a lapel, stand-up collar with frills, or a frilled jabot and wristbands, including a side slit which was also frilled. A long tape for tying around the waist was attached to the rear hem and the habit-shirt resembles the riding costume of the time. The habit shirt was considered to be underclothing because it was worn under a waistcoat. However, habit-shirts did not remain in fashion for very long (Figure 23).

Figure 23: Habit-shirt from the 18th Century.
Source: Cunnington and Cunnington, 1992

3.5.1.3 The Corset

By this time, the corset had commonly been worn from childhood and cane, whalebone, and metal busks were used to make the corset stiff and rigid so it could compress the young body to create a shaped waist. Reed or straw was used as a substitute for whalebone, and busks were made out of wood, ivory, whalebone or metal. The shoulder straps of the corset were designed to be flexible to accommodate different styles of outerwear (Carter, 1992; Tobin, 2000). For example, these shoulder straps were passed around the top of the arms when it was worn underneath outerwear with extreme décolletage, and this can be regarded as the first use of the concept of multi-way shoulder straps, later to be used on the contemporary brassiere. The 'open corset', a corset with front and back lacing, was also introduced at this time and the 'jump', a corset with no bones, was worn for informal occasions. Figure 24 shows a chemise and a corset from the 18th Century.

Figure 24: Chemise and corset from the 18th Century. Source: Ewing, 1971

3.5.1.4 The Petticoat

Petticoats were often quilted to add more warmth and additional stiffening, and were fully exposed under the formal 'mantua', a very formal gown worn at Court. The hooped petticoat was also popular, and expanding into the first dome-shape by 1720, with the front and back flattened and with extra width on the sides by 1740. By 1750 'panniers', or so called 'false-hips' made from a pair of hooped bustles, were also employed to enhance the desirable body shape of the time, along with a highly engineered hooped petticoat. This under-petticoat, known as a 'dicky', was narrow and tubular and didn't reach the lower part of the legs.

3.5.1.5 The Hoop

The hoop was first worn in the early 1700s and gradually became rounder, fuller and more oval in shape. It reached 3.3 meters in circumference by the 1720s and 7.3 meters by 1753 (Carter, 1992). Whalebone, cane or wood was used for the structure, and linen or cotton was used to cover the hoops. From the 1740s, the single hoop frame was divided into two for better movement and, later in the 19th Century, this framework became known as 'paniers' in French meaning 'baskets'. The enormous size of the hoops caused problems in confined spaces and this led to the development of separate boning, and the use of tape and metal hinges, to make hoops more flexible from 1760 and facilitate better movement.

3.5.1.6 The Bustle

The bustle, by now a large roll pad stuffed with cork or other cushion stuffing, was revived in the early 1770s.

3.5.1.7 The False bosom

The 'bolster', a quilted pad with ties, and 'bosom friends', a moulded wax breast, were available at the end of the 18th Century (Hawthorne, 1992) and were worn to achieve a more voluptuous figure. Figure 25 shows cartoons depicting the female practice of wearing false bosoms.

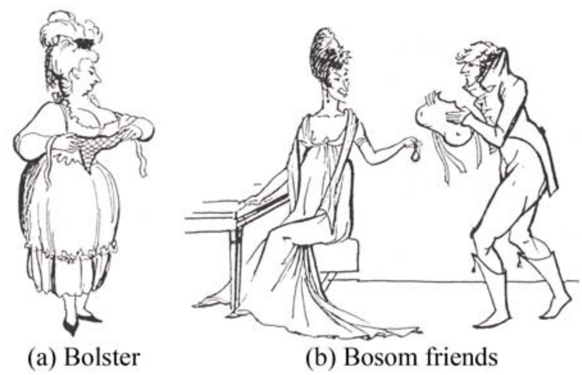


Figure 25: Cartoons of false bosoms from the Late 17th Century.
Source: Hawthorne, 1992

3.5.2 Characteristics of the 18th Century Male Attire

3.5.2.1 The Shirt

Once again male shirts did not change significantly during this period, with the exception of the neckband, which developed into a collar which reached a height of five or six inches by the end of the century. The cravat developed into a horizontal choker style neckpiece buckled at the back. The jabot remained popular and was also known as ‘chitterlons’ or ‘chitterlings’ and was attached to the placket whilst ruffles were usually detachable for washing purposes. Ruffles at the wrist disappeared at the end of the century. Figure 26 shows a typical men’s shirt from the 18th Century.

Figure 26: Men’s shirt from France, 1750.
Source: Cunnington and Cunnington, 1992

3.5.2.2 The Drawers

Drawers were short and tied in at the knees, and were sometimes used as a detachable and washable lining for breeches. Cunnington and Cunnington (1992) point out that 18th Century drawers, in common with male underclothing in general, had lost the attached connotation of sex appeal they once had.

3.5.2.3 The Corset

During this period, men also began commonly wearing stays to achieve a shapely waist, and it was at this time that the term 'smart' started to be used to refer to a well-dressed man.

3.6 The Nineteenth Century

Outerwear and underwear remained very simple during the French Revolution (1789 - 1799) and Napoleonic Wars (1800 -1815) but a sudden revival of Greek fashion dominated the Regency period in the early 19th Century. The Regency period actually stretched from 1811 to 1820, although for fashion purposes it can largely be regarded as stretching from 1800 to 1830, and was perceived as a time when the English were mimicking the fashions of the French Revolution. The era was distinctive for its architecture, literature, fashions and politics. Women wore a sheath dress with a low square neckline, short puffed sleeves and a girdle underneath the breasts, and materials were generally very flimsy, often revealing the body underneath. However, this fashion was short-lived and women's fashion soon returned to echoes of its previous style. The waistline was dropped below the natural waistline from 1840, and raised again around 1850, eventually returning to its natural level by the mid 1870s. Crinoline, named after the materials horsehair and linen, was introduced to support the full skirt from the mid 19th Century. Extreme circular skirts were abandoned in the 1860s and 1870s because of the growth in the popular pastimes of travelling and sports. Well developed breasts, a small shapely waist, and large hips were regarded as a good figure by 1873. The male style didn't change very much during this Century, with the Napoleonic style and the English hunting costume style remaining in fashion. A fitted short jacket called a 'spencer' was also in fashion for men at this time.

3.6.1 The Influence of Technological Developments

The invention of elastic in 1820 and the invention of the sewing machine in 1834 together with the spread of aniline dye colours in 1859, led to dramatic developments in underwear as well as outerwear. Hygiene and personal cleanliness became a social virtue, and affected the design and materials of underwear worn next the skin. Frequent changing of undergarments was regarded as a fashionable as well as a novel act at this time. Coloured fabrics and decoration for underwear began to appear widely in the late 19th Century and, as a result, the term 'lingerie' referred not only to white embroidered accessories to dress but also beautiful underwear (Tobin, 2000). Figure 27 shows outerwear fashion from the early 19th Century.

Figure 27: Early 19th Century mode in England. Source: Bruhn & Tilke, 1955

3.6.2 Characteristics of the 19th Century Female Attire

3.6.2.1 The Chemise

Greek inspired dresses with high waists were in fashion in the early part of this Century. Chemises were knee length, unshaped, with frilled square necklines and full sleeves until the 1870s. A breast seam or dart was used to shape the chemise into the contoured figure from about 1876, and 'empire' chemises with high waists and puff sleeves were introduced in the 1880s and 1890s. Figure 28 shows typical chemises from the 19th Century.

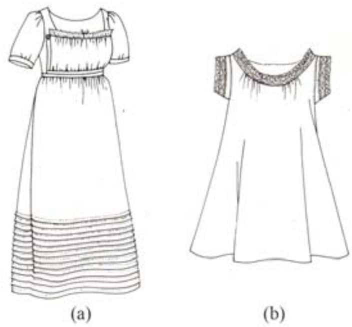


Figure 28: Chemise from 1800 (a) and 1866 (b). Source: Ewing, 1971

3.6.2.2 The Drawers

Drawers were finally introduced to England in 1800, although French women had been wearing drawers since the mid 16th Century. They quickly became popular and were used for riding and bathing from 1806 because they were practical and yet fashionable. Drawers were made of flannel, calico or cotton and the term 'knickerbockers' was used for winter-coloured flannel knickers. Figure 29 shows two types of drawers from the 19th Century.

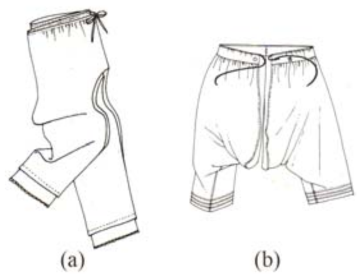


Figure 29: Drawers from 1825-1830 (a) and 1860 (b). Source: Ewing, 1971

3.6.2.3 The Pantaloons and Pantalettes

Pantaloons and pantalettes or calf-length drawers, were worn from the early 1800s, and became very popular amongst French women by 1824. However, they started to disappear in the 1820s, except for use by young girls (Ewing, 1971) and had completely disappeared by the 1830s (Cunnington and Cunnington, 1992). Pantaloons were longer than drawers, in the same way as male pants were distinguished from male drawers due to their longer length, and were designed to intentionally display the lower part of the legs below the petticoats.

3.6.2.4 The Petticoat

During this period the petticoat had a bodice with a front opening. The sides of petticoats were also left open to accommodate other garments. In the mid 1800s, four to six petticoats were often worn at once and were decorated with embroidery, lace and flounce. In 1820 the petticoat with a bodice 'slip' was introduced, and this later became known as a 'princess petticoat' (Figure 30). The princess petticoat was also called 'crinoline'. The word 'crinoline' from the Greek word for hair and the French word for 'horse-hair thread' was originally used for the horsehair petticoat in the 1840s but by the 1850s the word referred to 'artificial crinoline' or 'cage petticoat', or any kind of petticoat which was reinforced by metal or whalebone hoops. From 1857, a metal watch spring was used instead of whalebone as the supporting structure.

Figure 30: Princess petticoat from 1820.
Source: Cunnington and Cunningtion, 1992

3.6.2.5 The Crinoline

By 1867 horsehair petticoats with elastic waistbands replaced crinoline although the small sized crinoline persisted. In the early stages of this fashion, strong tones such as red, crimson, purple and peach were the preferred colours for petticoats and farthingales but by around 1867, less aggressive colours such as pale blue, pink and white were more frequently used. They were generally constructed of materials like cotton, cambric, linen, flannel, lace, taffeta, alpaca, rep, silk, lawn, batiste and moirette. During the Edwardian period (1897-1908), materials with flimsy, fluffy and frilly characteristics were used and petticoats took on a simpler form. Figure 31 shows different styles of crinoline from the 19th Century.

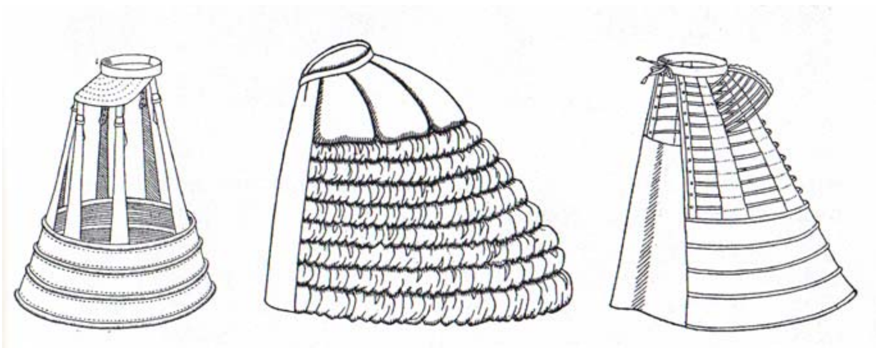


Figure 31: Crinolines from the 19th Century.
Source: Cunnington and Cunnington, 1992

3.6.2.6 The Bustle

The French style outside bustle, or ‘frisk’ was worn from around 1820, with down and horse hair used for the filling, and wire to obtain the shape. In 1849 the elegant name of ‘the dress-improvers’ was used to describe the bustle. During the 1880s, the bustle was at a right angle to the body, so much so that a tea-tray could be rested on it! However, the bustle had disappeared by 1890 (Gorsline, 1978) and Figure 32 shows the different shapes of the very last bustles from the 19th Century.

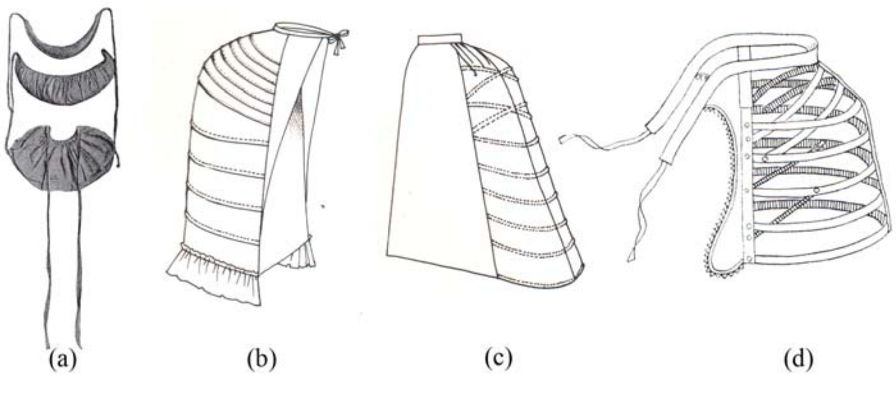


Figure 32: Bustles from the early 19th Century (a), from 1875(b), from 1885(c) and from 1888(d). Source: (a) & (d)-Cunnington and Cunnington, 1992 and (b) & (c)-Ewing, 1971

3.6.2.7 The Crinolette and Tournure

The 'crinolette' and 'tournure', meaning 'bustle' in French, were added to fashionable women's wardrobes in the 1870s (Figure 33). The crinolette is a combination of the bustle and the crinoline. According to Tobin (2000), it had dropped out of fashionable use by 1888.

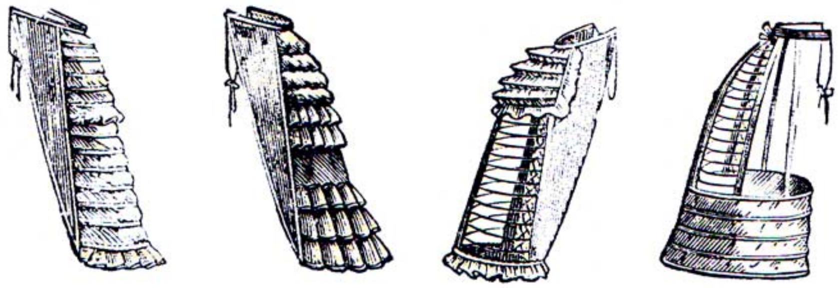


Figure 33: Crinolettes and tournures from an advertisement for Skinner's in 1885. Source: Carter, 1992

3.6.2.8 The Corset

The corset was discarded during the early 19th Century for a short period of time but soon re-appeared and continued to accentuate the fashionable small waist. The corset was now a part of a woman's everyday life, and became increasingly sophisticated and diverse in purpose. Elastic or stretchy stays, achieved as a result of the weave structure, were introduced in 1802, and steel boning was introduced in 1810. The 'pregnant' stay was introduced in 1818 and the 'divorce corset', named after the modern day bra effect of separating breasts, achieved by a padded triangle of iron or steel on the centre front, was introduced in 1819 in order to emulate Grecian fashion. The 'demi-corset' with flexible light whalebone was introduced around 1821 to facilitate movement during domestic work, and day-corsets with an elastic bodice, light whalebone, front lacing, shaped breast and a pair of shoulder straps, were also popular in the mid 19th Century. Metal eyelets were introduced in 1828 and a front opening was introduced in 1829. Short waist corsets appeared in the 1860's being replaced by long-waist corsets by the 1880s. A sanitary woollen corset was introduced in England by Mr. L.R.S. Tomalin who obtained exclusive rights from Dr. Jaeger who promoted the use of animal fibre, called a 'sanitary woollen system', for improving health in the 1880s. Figure 34 shows corsets from the 19th Century.

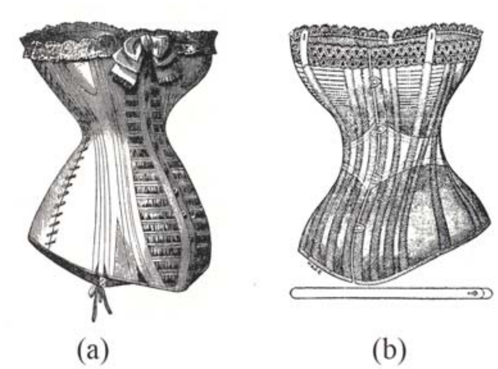


Figure 34: (a) Corset from 1879 and (b) Jaeger corset from 1886. Source: Cunnington and Cunnington, 1992

3.6.2.9 The Corset cover or Camisole

The camisole first appeared in the early 1840s. The camisole was originally called the ‘petticoat bodice’ or ‘corset cover’ (Figure 35). It is not clear whether the corset cover was protecting the corset from the dress, or the dress from the corset (Hawthorne, 1992), and it was frequently referred to as a ‘waistcoat’ as well as a camisole. The names of some items of underwear were quite vague throughout history and the corset cover is a good example of this. The camisole was derived from the French word for a bed-jacket or loose corset tied at the front with ribbon. It was shaped to the waist by goring and it covered the corset. It was a practical garment for the times, providing an easily laundered buffering layer between the dress and corset. A little front flap was used to conceal the corset.

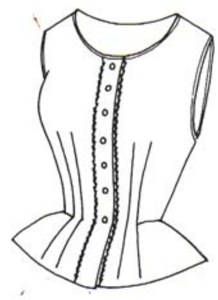


Figure 35: Corset cover from the 1880’s. Source: Ewing, 1971

3.6.2.10 The Bust Bodice

The bust bodice was introduced in 1886 in order to support the breasts because the corset of the 19th Century only covered the body from under the breasts to the lower parts of the hip and was worn over the corset. The bust bodice (Figure 36) is a camisole-like garment with elaborate structural supports of whalebone, or a series of wire springs, built into the underside of the front. This new garment started as a device to support the breasts in 1889 because the corset at that time lengthened under the hip and shortened above the waist, and consequently did not support the breast as it had previously done. Ewing (1971) claims that this was the second most influential item of underwear of all time, after the corset, in terms of how it impacted upon fashion. It was worn over the corset, usually with straps, and sometimes it was lightly boned at the sides and/or front for the fashionable 'mono-bosom' effect. Generally, it was laced at both the front and back.

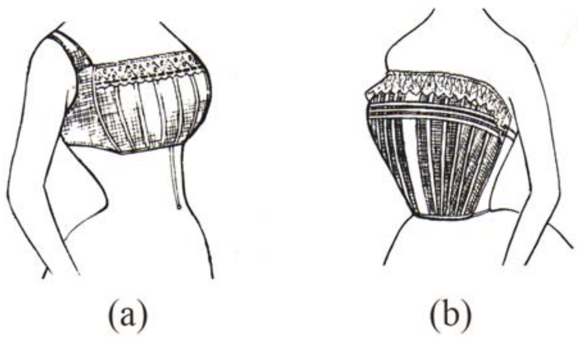


Figure 36: Bust bodices from 1890. Source: Ewing, 1971

3.6.2.11 The Combinations

A new garment, the combination, which combined a chemise and drawers, was introduced in 1877, some twenty years earlier than the combination for men. The attraction of this design was that it reduced the bulk of the underwear and, as a consequence helped with the outer fashion trend of a smooth connection between bodice and hip (Ewing, 1971). After that, there were many different versions of combinations, such as combinations of petticoats combined with stays, combinations of low bodice, petticoats and drawers, and combinations of camisole and knickers. Figure 37 shows one model of combinations from 1886.

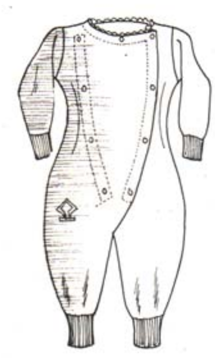


Figure 37: Jaeger combination from 1886. Source: Ewing, 1971

3.6.2.12 The False bosom

Advertisements from ‘The Lady’s Newspaper’ in 1847 showed the two false bosoms in fashion at the time. These were known as the ‘bust improver’ and ‘lemon bosoms’. Lemon bosoms were made of a light coiled spring stuffed with horsehair contained in each cup with whalebone support. Its resemblance with a lemon cut lengthwise gave it the nickname. Bust improvers were becoming more innovative in design and construction (Figure 38) and by 1887, they were made with wire and had shaped cups with pockets for the insert pads of different sizes. This concept of using different sizes of pad for different body builds is very similar to some more modern bra pads (Hawthorne, 1992).

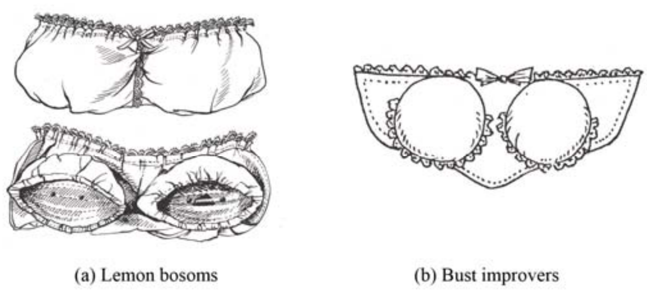


Figure 38: False bosom from the 1800’s. Source: Hawthorne, 1992

3.6.3 Characteristics of the 19th Century Male Attire

3.6.3.1 The Shirt

Shirts got more muscular and masculine when ruffles were abandoned as a fashion statement, collars became upright with a small v-shaped opening, and the wing collar was introduced. Sports fashion brought the polo collar to male shirts and this was known also known as the double collar (turn down collar). Cuffs without ruffles were preferred and jabot edging disappeared, being replaced with a pleated front for dress shirts. Although ruffles became popular again later, they were mainly used for evening shirt design. At this time a gusset was incorporated into the armpit design of men's shirts. A 'dickey', a separate or detachable shirtfront, was commonly used in the countryside when fine dressing was impossible. This was also called the 'tommy'. The curved bottom to shirts, still seen in many shirt designs today, was introduced only after 1850, and the stud-hole at the back of the neck band appeared around the 1860s.

3.6.3.2 The Drawers

Drawers came in two different lengths, with the short ones being worn under breeches, and the long ones worn underneath pantaloons or trousers. Braces were used to suspend both breeches and trousers.

3.6.3.3 The Corset

Men also wore corsets to create the new fashionable hourglass figure (Figure 39). Jean, duck, leather or webbing was used as the main construction materials. The male corset was worn between a shirt and a waistcoat and the majority of men preferred to wear combination vests with drawers during this era.

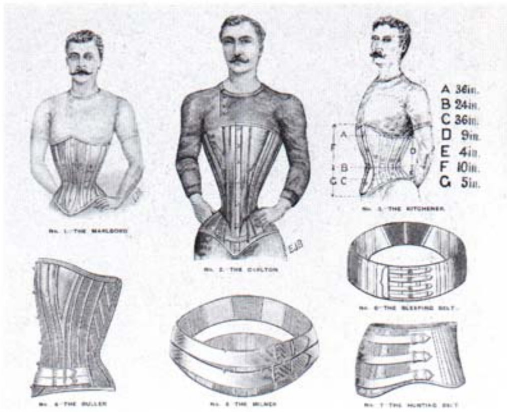


Figure 39: Men's corsets from the mid-19th Century. Source: Carter, 1992

3.7 The Early Twentieth Century/Turn of the Century

The female waist was constricted and the bosom and hip were accentuated to create an 'hourglass' shape. During this period country life and sports had a significant influence on fashion in England. The shirtwaist and the tailored separate skirt became very popular fashion items and, in contrast to utilitarian outerwear fashion (severe outer daytime clothes), dainty, feminine underwear began to be worn. Waists became higher and dresses longer, and the hobble skirt and the slit skirt came onto the fashion scene. High-buttoned shoes were also introduced in this Century. Prior to World War I, the female silhouette was fairly natural but this part of the century saw great changes take place for women. Skirts became shorter and American women obtained greater freedom from the rigid English style of fashion during World War I, and this inevitably crossed the Atlantic with other trends. Underwear became more practical and simpler in its form due to the shortage of labour. Figure 40 shows some examples of early 20th Century fashion.

Figure 40: The early 20th Century mode. Source: Gorsline, 1978

3.7.1 Characteristics of the Early 20th Century Female Attire

3.7.1.1 The Chemise

The 'empire' style chemise with a square neckline was still in fashion but was gradually being replaced by combinations.

3.7.1.2 The Corset

The corset was used to create the mono-bosomed straight front, and longer waist, for the new look of the so-called 'Gibson girl' style in 1905. The corset was getting longer below the waist and shorter above the waist, and eventually would no longer cover the breast at all. By the 1920s the corset was compressing and flattening the hips, thighs and breasts rather than enhancing the latter. A two way stretch corset appeared in 1932 and was known as the 'belts', and these were used as a substitute for the corset because they were easier to put on, being 'roll-ons' and 'step-ins', with a zip fastening. They were also popular because they allowed wearers to move freely without any 'riding up' of the garment. Materials such as jean, buckram, silk, satin, brocade and woven porous elastic were used for corset construction. Whalebone was used along with steel and leather for reinforcement. Rust-proof boning was introduced in 1912 using clock-rubber or celluloid coated spring steel. Figure 41 shows an example of the early 20th Century corset.

Figure 41: Corset from the early 20th Century. Source: Ewing, 1971

3.7.1.3 The Petticoat

Petticoats were still in fashion but becoming simpler in their design and forms.

3.7.1.4 The Drawers or Knickers

French knickers with an open leg, and ‘directoire’ knickers with a closed leg, were worn during this time. Directoire knickers were also known as ‘culottes’. ‘knickerbockers’, drawers with elastic around the knee for tight fit, were highly coloured and made out of flannel for warmth in winter. The legs of drawers were getting wider until World War I and French knickers and Directoire knickers persisted after the War. Knickers became shortened into ‘panties’ in 1924, then to ‘trunks’ in 1930, and finally to ‘panty briefs’ in 1939. Figure 42 shows two pairs of open knickers from the early 20th Century.

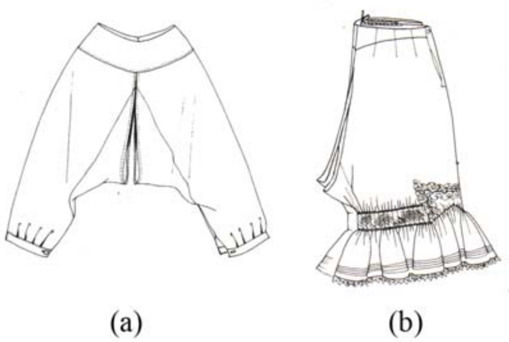


Figure 42: Flannel drawers from 1909 (a) and open knickers from 1912 (b). Source: Ewing, 1971

3.7.1.5 The Combination

In 1917, a combination of a chemise and knickers appropriately named 'chemi-knickers' appeared. Combinations gradually evolved into tight fitting garments and became almost 'tights' by the 1930s. These garments were generally constructed of linen, silk, wool and nainsook. Figure 43 shows four different designs of combination.

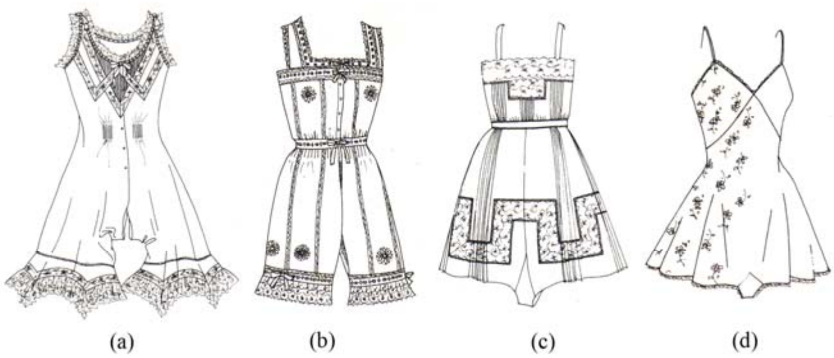


Figure 43: Silk combination from 1905 (a), cotton combination from 1916(b), close cami-knickers from 1920 (c) and silk cami-knickers from 1934 (d)
Source: Ewing, 1971

3.7.1.6 The Camisole

The camisole was worn over the bust bodice or brassiere by 1915 and Figure 44 shows a camisole from around this period (1918).

Figure 44: Camisole from 1918. Source: Cunnington and Cunnington, 1992

3.7.1.7 The Brassiere

The word 'brassiere' is used by Vogue magazine, published in America in 1907, and by the Oxford Dictionary in 1912 (Ewing, 1971). The English fashion magazine, The

Lady, advised English women to wear brassieres, because French and American women wore them, insisting that the brassiere would support the figure and give it a 'proper up-to-date shape'. In 1937, the word brassiere was shortened to 'bra' and by the 1920's the bra had been developed into a garment that was tight and compressed the breasts.

3.7.1.8 The Bust bodice

The bust bodice (Figure 45) was worn over the corset and Cunnington and Cunnington (1992) claim that Jaeger's 'bust girdle (1904)' was the forerunner of the brassiere.

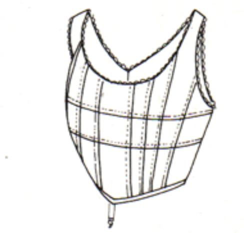


Figure 45: Bust bodice from the 20th Century. Source: Ewing, 1971

3.7.1.9 The False bosom

The bust improver, nicknamed 'amplifiers', was used in the early 1900s and consists of a chest piece with stiff starched ruffles which are designed to add volume secretly. A more drastic form of breast improver (the Neene bust improver) appeared in 1905 which looks similar to two tea strainers connected at the centre. Figure 46 shows amplifiers and the Neene bust improver.

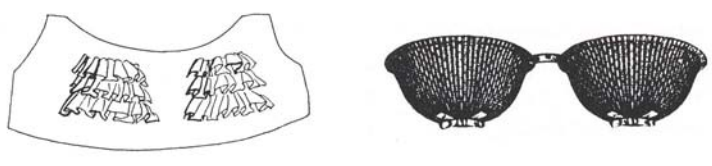


Figure 46: False bosom of the early 1900's. Source: Hawthorne, 1992

3.7.2 Characteristics of the Early 20th Century Male Attire

3.7.2.1 The Shirt

The notion of a coloured shirt for day time use was generally accepted by 1900, although the white colour shirt remained the dominant fashion of the day. However, a much wider range of designs of shirts became commercially available after World War I.

3.7.2.2 The Combination

Combinations, consisting of a vest and pants as combined garments, were popular in the Edwardian period (1897-1908) and remained popular throughout the early 20th Century. This trend was initially derived from America and used mainly in the summer months. The designs were quite conservative and did not change very much over the years, although those design variations that did occur, involved half sleeves, pant legs, short legs and 'knicker' legs, but eventually these resolved into a sleeveless version with a v-neck for year round use. Figure 47 shows the male combination produced by Jaeger between 1914 and 1937.

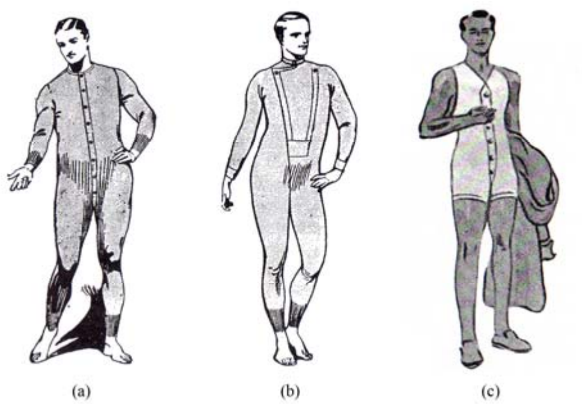


Figure 47: Male combinations/union suits by Jaeger: (a) & (b) from 1914-1915 and (c) from 1936-7. Source: Cunnington and Cunnington, 1992

3.8 Summary

This chapter has reviewed the development of underwear based on the development of outerwear in Europe, in particular England, from the medieval period to the early 20th Century. The review demonstrates that each era had its own fashionable silhouette and that the development of underwear helped men and women to create the appropriate fashionable silhouette of the time. The particular role played by underwear is often overlooked by many costume historians, and consequently there are not many books dealing with the history of underwear. In part, this is due to a lack of understanding of both the evolution, and the importance of underwear (Saint-Laurent, 1968) but also because of the difficulty finding surviving examples of historic underwear garments. Although the definitive history of underwear development remains rather elusive, there is a growing recognition of the important role underwear played in the development of fashion throughout recent history. For example, Christian Dior's comment that "without foundations there can be no fashion" demonstrates the important role underwear plays in the development of fashionable outerwear (Ewing, 1971 & Tobin, 2000).

This review clearly demonstrates the development of a crucial link between underwear and outerwear fashion, and shows that changes in shapes and styles of dress were strongly tied to developments in the design of underwear. Consequently, the total length of the underwear, the shape of neckline, the sleeve length and shape, and the style of decoration changed according to the fashion of the time. Carter (1992) suggests that the embellishment and distortion of the human form was an increasingly important function for underwear by this time, and it became a valuable tool for altering body shape and image throughout history. Although simple, medieval underwear did not contribute very much to altering or emphasising body shape, but rapid changes in outerwear fashion from the late 14th Century, when the modern concept of fashion started, brought significant changes in underwear fashion and it was probably then that the history of the more colourful and rich underwear fashion that we are now familiar with started.

In recent history, the enhancement of the body to increase sexual attraction was often gained through body embellishment, or sometimes painful body distortion, brought about by underwear design. Following the fashion of the day by creating a fashionable silhouette enhanced sexual attraction by emphasising particular body parts (Barbier and Boucher, 2004; Cunnington and Cunnington, 1992). Perhaps not surprisingly, the focus for enhancement in terms of body parts was restricted to a fairly predictable set which included the shoulders, waist, breasts, hips and legs. Which of these areas were enhanced or minimised depended upon the prevailing fashion, and included women exposing or compressing breasts, shaping their waists, exaggerating their hips, or revealing various portions of their legs underneath outerwear. A shaped waist or masculine legs for the male were also seen as potential ways of increasing sexual attraction. One interesting example of outerwear designed to enhance sexual attraction is the codpiece which was designed to accentuate manhood during Tudor times. Male drawers lost their sex appeal in the 18th Century and this was not regained until quite recently (Cunnington and Cunnington, 1992). The farthingale from the 16th Century, the bustle from the 17th Century, hoops and hooped petticoats from the 18th Century, crinoline from the 19th Century, and corsets from all these eras, provide further examples of body embellishment or distortion.

Before World War I, concealing the body created sexual attraction and the erotic purpose of female underwear was hidden in order to enhance desire (Chenoune, 2005). For example, the glimpse of an ankle beneath a petticoat was regarded as very sexy in the 19th Century (Cunnington and Cunnington, 1992) and concealing the body was strongly related to the reputation of women before the First World War (Cunnington and Cunnington, 1992; Saint-Laurent, 1968) with corsetry supporting the idea of female morality (Barbier and Boucher, 2004). In fact, the English expression "loose woman" comes from the connotations associated with un-corseted or loosely corseted women (Queen, 2002).

By the 19th Century, both male and female underwear had become quite diverse largely due to materials innovation and manufacturing technology improvements. Prior to World War I, women commonly wore several items of underwear at once, in contrast to their male counterparts, but after this time, significant changes were seen in female attitudes and their underwear because of the rapidly changing role and status of women in society. This was a turning point in terms of the history of underwear, and as Saint-Laurent (1986) points out, holidays and sports had already paved the way for a change in women's clothes, with the war doing the rest. Subsequently, the modern concept of sexual attraction normally involves either revealing, or hiding a particular body part, or revealing provocative underwear. Whilst it is only relatively recently that men have begun wearing provocative underclothing (Cunnington and Cunnington, 1992), they have nonetheless projected their sexuality onto female underwear. Possibly because of its contact with the skin, and subsequent closeness to the female form, lingerie has long been the object of male fantasy (Barbier and Boucher, 2004).

Underwear which started as a simple under layer from the medieval period, finally received attention for what it is from the end of 19th Century (Tobin, 2000). Underwear has developed into today's more sophisticated forms which not only provide support for the body and personal hygiene, but also enhance sexual attraction in similar ways to outerwear. However, underwear as a measure of class distinction is now quite difficult to identify because high quality fashionable products are available for every social level. Perhaps the most constant functions of underwear throughout history have been to provide warmth, and support for the costume, through to modern thermal underwear and foundation garments.

The next chapter progressively focuses upon the evolution and development of the modern brassiere from the late 19th Century through to the 1950s, a period which literally laid the foundations for the wide variety of female attire for the breasts available in today's marketplace.

CHAPTER 4
THE EVOLUTION OF THE BRASSIERE FROM THE EARLY 1900S TO THE LATE 1950S

4.1 The Origins of the Modern Brassiere

The modern brassiere, or bra as it is now more commonly known, is categorised as a foundation garment which can uplift, mould and support the female breasts. Modern brassieres are available in almost every possible type of wearable material, and in many forms of innovative design brought about by the development of modern, cutting-edge production technologies. Records, such as patent applications, indicate that the evolution of the modern bra took place from the late 19th Century. This marks a very long gap from the 4th Century when Greek and Roman women began to wear the first specific bra-like garments (the 'strophium' and the 'fascia pectoralis') and the 19th Century when the modern bra began to evolve. Although Hawthorne (1992) identified the strophium as the first bra-like garment recorded that resembled the modern brassiere, all early bra-like garments from the 4th Century lacked the modern functions of uplifting, moulding and supporting which are the required and expected functions of the modern bra. Abundant flexible and light support garments were invented during the late 19th Century in order to replace the notoriously hazardous 19th Century corsets, and these new inventions were largely responsible for bridging the gap between the 19th Century corset and the 20th Century modern bra. In this context, the 19th Century corset set a milestone in the development of modern underwear despite its deadly affect on women's health at that time. This significant impact of the 19th Century corset to the evolution of the modern bra is acknowledged amongst most costume historians and scholars (Saint-Laurent, 1968; Cunnington and Cunnington, 1992; Hawthorne, 1992).

Drawing from the context of the previous two chapters, chapter 4 progressively focuses on the development of the brassiere, and this chapter reviews the evolution and development of the modern bra from the late 19th Century to the early 20th Century. This particular evolution is marked by changes in society and the role of women, developments in marketing strategy, and the arrival of new technological developments and the impact of these on underwear design and production is considered.

4.2 The Mid-19th Century to 1910: The Era of the Corset and the Bust-Bodice

The corset and bust bodice are the two garments which can safely be regarded as the direct predecessors of the modern bra. Both garments can be said to share this credit, although the bust bodice was originally developed from the corset cover, a protective garment for the corset. Therefore, some scholars and historians identify only the corset as the sole and direct predecessor of the bra.

4.2.1 The Corset as the Predecessor of the Modern Bra

Farrell-Beck and Gau (2002) claimed Luman Chapman who invented the breast supporter in 1863 (Figure 48) should be regarded as the father of the prototypical brassiere in the 19th Century. The breast supporter was a corset with shaped breast cups which are capable of accommodating the volume of female breasts. In his patent application, Chapman (1863) stated that the purpose of his new invention was to help women to avoid injuries from the pressing and binding forces of contemporary corsets. Although Chapman's breast supporters bear little resemblance to the modern bra, except perhaps for the two accommodating cups, their development clearly shows that modern bra design and construction had commenced.

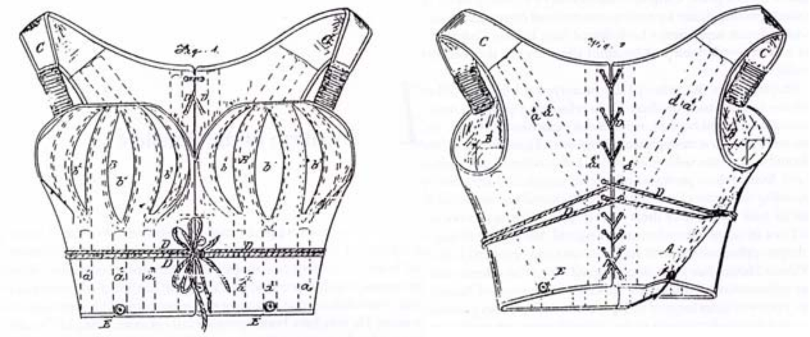


Figure 48: Breast supporter by Luman Chapman. Source: Chapman, 1863

Another example, which supports the notion of the corset as the forerunner to the modern bra, is 'Le Bien Être' (meaning 'well being' in French) designed by Hermine Cadolle in 1889. 'Le Bien Être' consists of a bra and a waist cincher. By 1905, Cadolle had renamed the bra or more specifically the upper part of 'Le Bien Etre', as a 'soutien-gorge' (meaning 'hanging under the throat' in French) and began selling this part separately. The term 'soutien-gorge' is still used in France as a synonym for the modern bra. As the name implies, the support for breasts was shifted from the bottom (waist) to the top (shoulder straps), which shows modern design elements were in progress, previewing the evolution of the modern bra.

4.2.2 The 'Bust Bodice' as the Predecessor of the Modern Bra

The bust bodice is a lightweight, soft undergarment, which was developed from the corset cover/camisole in the 1850s, and worn underneath a corset to protect the corset from body fluids and secretions. This new garment developed into a supporting device for the breasts in 1889 because the corset of that time didn't support the breasts as a result of the design changes outlined in the last chapter. Effectively the corset had been lengthened under the hip, and shortened above the waist. In fact, Cunnington and Cunnington (1992) claim that Jaeger's bust bodice in 1904 was the forerunner of the modern bra.

In 1904, De Bevoise invented a lightweight undergarment which looks similar to a modern camisole and named it the 'brassiere'. The word 'brassiere' first appeared in an edition of American Vogue in 1907, and was recorded in the Oxford English Dictionary in 1912 (Ewing, 1971). Figures 49a and 49b show a De Bevoise's 1915 bust bodice with the label 'brassiere', and this is taken by many scholars as evidence which supports the bust bodice, rather than the corset, as the direct predecessor of the modern bra. The importance of De Bevoise's invention is highlighted by Hawthorne (1992) who cites an editorial comment from the magazine 'The Lady' in 1915 which states that 'a pretty bust bodice or brassiere now counts for as much an essential as a corset'.

a) Bust bodice b) Bust bodice label

Figure 49: Bust bodice 1915
Source: Leicestershire County Council, 2006

4.2.3 Summary

Whilst it is difficult to precisely pinpoint which garment is the originator of the modern bra, both the corset and the bust bodice brought about significant changes in female underwear fashion (Ewing, 1971) due to their bridging roles in the history of intimate apparel. This viewpoint is supported by Hawthorne (1992) who points out that whilst the origin of the bra remains uncertain and difficult to pinpoint, it is nonetheless clear that the history of the modern bra started in the third quarter of the 19th century with the help of this new era of inventors and dress reformers. Women's right activists, Elizabeth Smith Miller and Amelia Bloomer, also tried to reform women's dress, so that is was less confining and restricting than existing Victorian Costume, by adopting Turkish pantaloons with a knee length skirt (Cunningham, 2003). Some dress reformers also tried to redesign women's underwear to be more morally acceptable to their own religious beliefs, which viewed women's underwear as fundamentally evil. At the same time, other dress reformers tried to redesign women's underwear to be more healthy and hygienic because they perceived that Victorian Costume, in particular the corset, posed great danger to women's health. Farrell-Beck and Gau (2002) takes the view that these dress reformers are the 'mothers' of a prototypical modern brassiere. Irrespective of political or religious stance, there is no doubt that the abundance of patented breast supporters during this period illustrates the above social phenomena.

4.3 The Late 19th Century and the First Modern Bra

Another breast supporter, invented by Marie Tucek in 1893, is generally regarded as the first modern bra largely as a result of its components and construction (Figure 50). It was composed of two separated cups, a plate which is similar to the cradle of modern bra, adjustable shoulder straps which crossed at the back to hold and support the breasts, and a number of hooks and eyes.

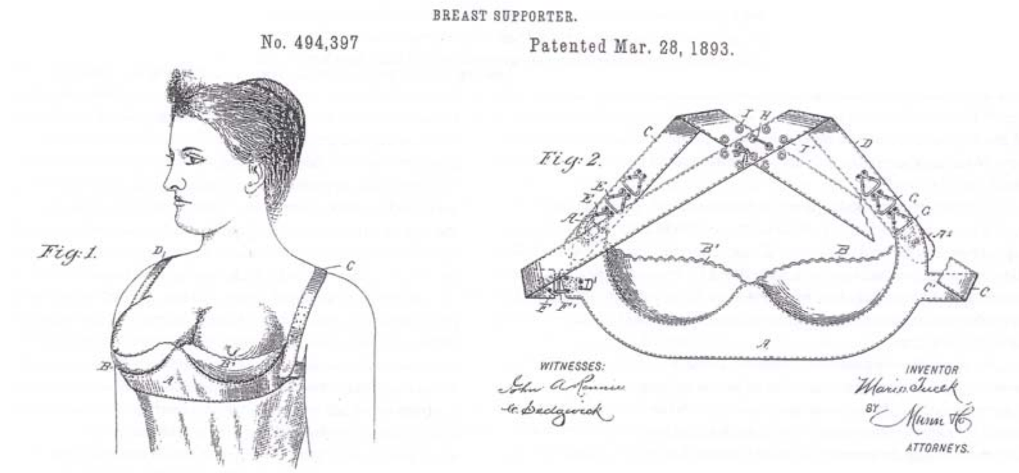


Figure 50: Breast supporter patented by Marie Tucek. Source: Tucek, 1893

The objectives of this invention were to provide a new and improved, yet simple and durable, breast supporter which could replace the corset and could be worn underneath the then popular ‘empire style’ dresses (Tucek, 1893). The empire style fashion had actually died out by 1897, but the breast supporters designed for the empire dresses, such as short stays and the bust girdle, bust corset or strophium, survived beyond the outerwear fashion. However, this particular modern bra with two separate cups, eventually became unpopular because of growing societal pressures which regarded a woman without a corset as promiscuous, or of dubious morality (Cunnington & Cunnington, 1992; Farrell-Beck & Gau, 2002). Therefore, whilst this new invention was initially and individually popular, it seems that society in general was not yet ready for this modern bra.

4.4 Developments from the 1910s

In 1914, Mary Phelps Jacob patented a bra which was constructed with two silk handkerchiefs sewn together with the addition of shoulder straps and ties. Whilst her brassiere cannot be regarded as the first modern bra, she nonetheless was credited with inventing and patenting a new undergarment using the name brassiere, and consequently sold her rights to Warner Brothers Corset Company. Figure 51 shows an illustration of the brassiere patented by Mary Phelps Jacob. In her patent application, Jacob identified the term 'brassieres' and stated that they were effectively 'corset covers' whose purpose was to cover the top of the corset. Two unique features of her invention are:

i. It can be worn underneath a low-cut back evening gown.
ii. It doesn't have any bones or laces which create undesirable marks or indentations underneath dresses.

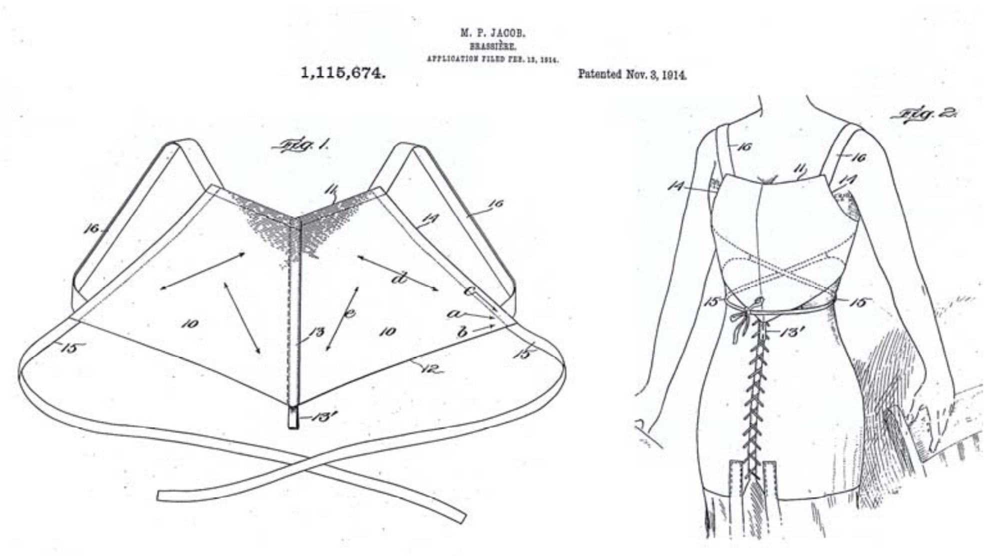


Figure 51: Brassiere by Mary Phelps Jacob. Source: Jacob, 1914

It is an interesting observation that the design and shape of Jacobs' brassiere is similar to the traditional Chinese underwear called the 'dudou'. The dudou is a triangle-shaped apron top with a shaped neck, which covers the breasts and stomach and is fitted with narrow tapes, and has been worn widely as underwear by Chinese children, girls and women since the 17th Century (Leung and Li, 2006).

The period of World War I, from 1914 to 1918, brought further significant changes to women's underwear. Significant social changes meant women were required to take over men's work, as many men joined the armed forces to fight in the war. These social revolutions had a substantial impact upon women's clothing and, in particular, their choice of underwear. For example, constricting corsets could no longer be regarded as consistent with the role of the new woman which involved working at the factory, repairing vehicles, and nursing injured soldiers at the frontline. As a consequence of these growing female roles, bras and girdles gradually replaced corsets, and the bra was adapted to fully support the breasts (Pedersen, 2004). Eventually, the corset gave way to the bra when the U.S. War Industries Board asked women to stop buying corsets in order to free up metals for war production in 1917 when America entered the war. War clearly expedited the democratisation of fashion, and the movement towards simplification of clothing which started before the war, and consequently made fashion a part of every woman's life, regardless of her wealth or social status (Gold, 1987).

4.5 Developments from the 1920s

After World War I, the further emancipation of young women led to a more frivolous, outrageous, and rebellious context for fashion development. Skirts were raised above the knees, breasts were concealed, and hip size was disguised by lowering the waistline. Gorsline (1978) described this phenomenon as women's best efforts to deny their essential femininity, and identified it as coming from the gain of equal suffrage and equal footing with men during and after the war. Unlike Gorsline, Gold (1987) describes this era as the most fantastic time for American fashion. American women led the way with their breast-minimising bras, loose chemises, and other promoters of the new fashion of the 'flat chest'. The slang term 'flapper' came into common use when referring to young women who wore short skirts, bobbed their hair, and listened to jazz. In terms of underwear, the bandeau-style brassiere, 'bandeaux', which were tight and compressing breasts became very popular.

In the middle of the 1920s, the popularity of the flat-chested boyish figure started to decline, and fashion slowly focused on a more womanly figure with curves and breasts. Bra manufacturers responded to this trend and produced a number uplifting and supporting bras incorporating their own fashion ideas to drive new trends. The patented 'uplift' brassiere by William and Ida Rosenthal, founders of Maiden Form was marketed on the basis of its uplifting ability which allowed breasts to expand and form a flattering silhouette for 1924. This was truly the time of 'breast lost and found' according to Farrell-Beck and Gau (2002). The shapeless bra from the 1910s was transformed into a voluminous bra with two separate cups, a cradle, elastic shoulder straps, and hook and eye tape. Largely due to the 1920s competitive inventions and marketing strategy, including the opening of a London office by the American giants Gossard (later to become a British Public Company in the 1930s), and the registration of major companies like Marks and Spencer in 1928, the bra became a part of middle class women's life.

In addition to driving changes to fashions and styles in body shape and silhouette, the industry also began to recognise new target groups of customers for their existing and newly designed products. For example, young consumers, aged from 12 to 18 years, began to be recognised by many corsetry and bra manufacturers and the term 'junior' was adapted as nomenclature for this new target customer group (Fields, 1999). Consequently, 'training bras' for teenagers became available in the 1920s (Farrell-Beck and Gau, 2002). One of the earliest mastectomy bras, the 'surgical breast substitute', was also patented around this time by Laura E. Mailleue in 1922 (US patent 1,417,930).

4.6 Developments from the 1930s

The 1930s brought a change of social and financial fortunes with the Great Depression starting to take hold in America in October 1929, and spreading quickly to Europe where it lasted through most of the 1930s. Ironically, bra sales rose during this time despite the widespread deprivation, business failures and financial restrictions of the 1930s. Furthermore, many bra manufacturers actually emerged in the 1930s, and a wide range of bra types, including specialty bras such as maternity bras, nursing bras, mastectomy bras and plus size bras, were developed and supplied by the major bra manufacturers. For example, Mothercare, Marks & Spencer and

Berlei began to manufacture comfortable nursing bras at this time. The diminutive word ‘bra’ came into common usage amongst the younger generation at this time, and this more trendy term was used by Warner for its advertisement for the ‘A’lure Bra’, in 1935 (Farrell-Beck and Gau, 2002), subsequently coming into widespread use and all but replacing brassiere as a name.

The womanly figure of late 1920s further developed during the 1930s into a figure with a tight waist and pointy breasts, which was called a ‘Belle Poitrine’. Cone-shaped breasts became popular by 1935. After the movie ‘They Won’t Forget’ made a big hit in America in 1937, a close-fit with the plump breasts of the ‘sweater girl’ look dominated fashion. In order to achieve the sweater girl look, some smaller busted women adopted ‘falsies’, which were effectively moulded rubber pads, so that they could add more volume to their breasts. However, falsies didn’t really get popular until the end of World War II. Bra manufacturers hired famous movie stars to front their advertisements and promoted their bras by associating them with the sex appeal of the movie star. Bra manufacturers emphasised not only the promotion of bras, but also the quality of customer service in order to retain consumer loyalty. Consequently, the role of sales personnel or bra fitters became important to the foundation business in the 1930s (Farrell-Beck and Gau, 2002).

4.6.1 Three Further Significant Developments

Amidst all the major changes taking place in society and the underwear business, there were three particularly distinct innovations which made a significant impact, and changed the course of bra history:

i. The advent of the bra sizing system.
ii. The establishment of a complete conventional bra design involving wire, hook and eye tapes with adjusters and stretch back panel.
iii. The development of new materials, in particular lastex and nylon.

4.6.1.1 The Advent of the Bra Sizing System

The need to accommodate the different sizes of breasts was identified early in the corsetry industry. For example, a corset patented by Chapman (1863) indicates the need for different cup sizes for the corset to accommodate the different sizes of the wearer. Whilst this demonstrates that the concept of sizing was in the air, a systematic approach to sizing took some time to be developed. In October 1932, the Formfit Company simply offered three different cup sizes, small, average, and full, for each band size but, by February 1933, S.H. Camp and Company emphasised the need for support for different breast profiles and different degrees of pendulousness by introducing a four letter, cup sizing system. Size A was small and flat to size D for larger and more pendulous breasts (Farrell-Beck and Gau, 2002). The Warner Brothers Corset Company introduced the Alphabet bra line in 1935, taking credit as the first to offer women a choice of cup sizes! The Alphabet bra line initially offered four different cup sizes A, B, C and D, and then DD (or double D) was added a little later, whilst UK manufacturers labelled cup sizes as Junior, Medium, Full and Full with Wide Waist. It took a further twenty years for UK manufacturers to adopt the Warner Brothers Corset Company bra sizing system when R & W. H. Symington, a leading UK manufacturer, introduced cup sizes for bras.

4.6.1.2 The Establishment of a Complete Conventional Bra Design

The adjustable design concept was first applied in the shoulder strap with an adjuster 'D-ring' in 1930s and hook and eye tapes, although around since the early 1500s for other items of clothing became available in the late 1930s for bras (Cunnington & Cunnington, 1992). The use of wire is also counted as one of the design innovations which completed modern bra composition. Helen Pons patented a brassiere with underwire in 1931 and commercially produced her underwired brassiere. With underwire, it was possible to support breasts without the use of a shoulder strap, and consequently strapless brassieres with wires were introduced from 1934. Although the underwired bra did not make the mainstream until World War II was over, it is important to recognise that the modern conventional bra design was essentially complete by the early 1930s.

4.6.1.3 The Development of New Materials, in Particular Lastex and Nylon

Another invention which revolutionised and helped push underwear into a new era of design possibilities was the development of Lastex. Lastex, which is a yarn in which a core of elastic rubber is wound with rayon, nylon, silk, or cotton threads, was invented in October 1931. Sewing on Lastex knitted or woven fabric was easier than sewing on rubber which is prone to rupture easily during the sewing process. Soon after the development of Lastex, the fabric began being used for girdles, bras and corselettes. Warner introduced a bra with a Lastex back panel to provide stretch capability similar to current bra composition. Lastex was certainly instrumental in increasing underwear sales despite the hardships brought by the Great Depression. This material innovation continued with invention of nylon in 1938 although this was mainly consumed for solely military use until war was over in 1945.

In summary, despite poor economic conditions, the 1930s was truly a time of innovation in design, materials, and production technology for the intimate apparel industry (including the introduction of the electronic washing machines in the late 1930s) and a time when retailers and wholesalers emphasised effective promotion as well as good customer service.

4.7 Developments from the 1940s

Bras in the 1940s were undoubtedly influenced by war once again, and this led to significant differences in design, shape, colour and available types between the pre-war and post-war periods spanned by the late 1930s and 1940s. Bras from the first half of the 1940s were associated with the image of healthy and firm breasts, as well as a women's readiness for action during war. During this time, all bra manufacturers simplified their lines, limited the quantity of production, and emphasised basic styles as the supply of rubber, metal and textiles became short due to armament production. Consequently, the UK government introduced the 'Utility' scheme, restriction on use of materials, from 1941 to 1952, and British women were forced to be resourceful and made undergarments out of anything and everything (Hawthorne, 1992). L-90 bras and girdles were part of government restricted design in the US.

The American movie industry continued to grow in both size and influence during the war, and Hollywood movie star's attire set the fashion trends of the time. Therefore, underwear manufacturers hired more and more movie stars to advertise their products because their market research had demonstrated that the majority of women followed fashion initiated by movie stars. One particularly iconic example of this is the American billionaire and movie producer Howard Hughes, who created a half-cup bra with no noticeable seams for the actress Jane Russell, whose bra size was a US 38DD, in order to emphasise her physique in his movie 'The Outlaw', and consequently gained credit as the inventor of the seamless underwired bra! This bra became known as the first 'cantilever bra' (Pedersen, 2004).

4.7.1 Post-war Developments

Bra manufacturers began to explore different colours for the underwear. Compared to pre-war underwear, which offered mainly pink and peach tones, post-war underwear offered a variety of pastel colours which reflected the liberated mood in the post-war post-rationing era. Bras from the second half of 1940s were clearly more associated with sex appeal than just utility and this was expressed through deep plunging necklines, embroidery, and the use of lace as well as the increasing range of colour available. Overall, the post-war bra cup shape was described as a 'torpedo', a term borrowed from the military. This change in post-war design concept from healthy, firm breast projection to sex appeal and a 'pointy' breast projection can be traced back to the early 1940s and one of the most famous bras of the twentieth century, the 'Wonder Bra'. The first Wonder Bra was patented in 1941 by Israel Pilot. Its design concept was to create a firm breast projection whilst maintaining comfort by using an inverted v-shaped slit under the shoulder strap which gives the required flexibility to accommodate different breast sizes. Pilot (1941) claimed that his invention remained comfortable but was supportive enough to create a naturally uplifted, firm breast shape. However, Pilot's Wonder Bra shows a different design concept than that of the Wonder Bra which appeared again in the 1990s, which was essentially a bosom booster or cleavage enhancer.

Women's role in society was significantly changed by the demand for labour for both civilian and military workforces, which was created by World War II. By 1945, a total of 19 million women or 36 percent of the American female population had a job (Farrell-Beck and Gau, 2002). Initially for utilitarian reasons, women started wearing pants or trousers, and pants became everyday attire for women for the first time in history, although (see previous chapters) this was not the first time in history that women wore pants. Pedersen (2004) claims that the adaptation of pants as everyday female attire was the final factor that contributed to rendering the corset obsolete, and it was the bra which had usurped its place by the 1940s. Despite this, 'New Look' in 1947 by Christian Dior staged a minor revival of the Victorian corseted small waist, with mid-calf length flared skirts. The 'New look' was achieved mainly by a new corset or corselette with a new uplifting bra, knickers and suspenders. The corselette, a short corset, was nicknamed a 'waspie' due to its wasp silhouette. 'New Look' was welcomed by women who were wearing unattractive wartime short shirts with big padded shoulders, and the attraction was strong as it was equipped not only with a shaped waist, but also perky breasts. The new uplifting bra lifted the breasts higher than the natural breast line in order to achieve the 'New Look'. The femininity of this fashion which included full skirts, curves, nipped waists, and drapery swept the world of fashion despite feminists' concerns over the possibility of the reincarnation of the deadly 19th Century corset. It was at this point that Christian Dior emphasised the importance of foundation garments for achieving a fashionable silhouette, and famously declared that there can be no fashion without foundation (Ewing, 1971; Saint-Laurent, 1986; Tobin, 2000).

4.7.2 The Push-up Bra

Bra manufacturers continued to market bras which created the fashionable pointy breasts, and consequently the world's first push-up bra, euphemistically called the 'Rising star' was introduced by the company Frederick's Hollywood in 1948 (Lingerie-uncovered, 2007). Frederick Mellinger, who was inspired by the sensuous nature of European underwear, started selling provocative lingerie lines in New York in 1946, moving to California and renaming his company as Frederick's of Hollywood in 1947. Frederick's Hollywood went on to dominate the US market until the early 1980s with its sensuous and intriguing style and a discrete catalogue marketing strategy.

Whilst Mellinger was building his sensuous lingerie business in Hollywood, California, Olga Erteszek, a refugee to California from Poland, was founding, in 1947, one of the leading underwear brands of the 21st Century known as simply

‘Olga’. These two brands emerged from the deprivation of the post-war era to become two of the world’s leading underwear brands.

4.7.3 The Advent of the Bikini and Nylon

Another important design invention from this era was the ‘bikini’. The bikini was invented by Louis Reard on 5th July 1946. Reard named his invention after the first atomic bomb test on Bikini Island, but the bikini did not become popular until the end of the 1950s in line with many other unique fashion items. The new material, nylon, with outstanding abrasion resistance, tenacity, light weight, formidability and its easy care characteristics was marketed as a high end fashion fibre by Du Pont, and soon became a major material in underwear and swimwear, as well as hosiery. Although it is not an ideal fibre for underwear because it absorbs less moisture than natural fibres, nylon clearly had advantages over natural fibres in terms of care, washing and drying and was suited to the easy care approach evidenced by the increasing number of households with an electronic washing machine. Also, a drip-dry fabric, known as Orlon acrylic, was introduced at this time with mixed commercial results. Nonetheless, the advent of nylon elastic net was significant and made a substantial contribution to the history of foundation garments, in particular as a component of the bra wing.

Also becoming popular, as a bra component at this time, was the wire which was used as a supporting and forming device. Many underwired and overwired bras were patented, and bras with the newly invented wires were first produced during the 1940s. The ‘Alene’ brand of Gluckin Corporation was the major producer of wired bras at this time and Figure 52 shows a typical underwire and an overwire for these bras.

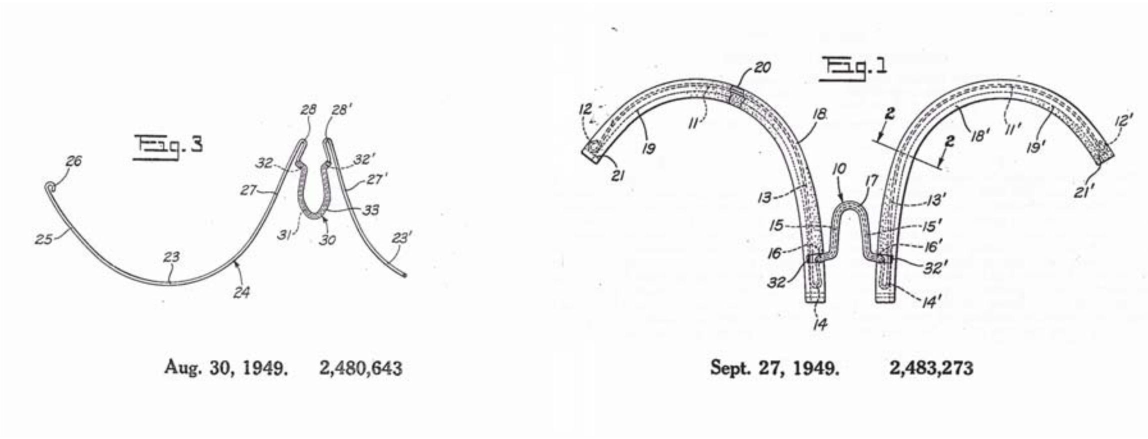


Figure 52: Underwire and overwire figures from the patent applications. Source: Glick, 1949b and Gluckin, 1949b

4.7.4 Post-war Market Diversification

The junior market share continued to grow after World War II, and bra and corset makers diversified their product assortment, and marketed their junior lines, through every mass media outlet they could use, including teen magazines, in order to attract teenage consumers and obtain their loyalty. ‘Bou-K-Bra’ by Kabo with a removable scent petal provides one example of attracting consumers by marketing a product with a difference. Also, the Australian underwear line ‘Berlei’ was imported as a high end line as the market began to segment. At this time, an early form of cross your heart bra styling was introduced by Mam’zelle but, in comparison to the growth in America, UK consumers were still suffering from the wartime utility scheme which encouraged women to sew up their own bras. ‘Bleumette’, a stick-on half bra was patented by Mrs. Lea Williams in 1955 and sold very well in the UK by mail order from 1949 for next 5 years (Farrell-Beck and Gau, 2002). The advent of rock and roll in the late 1940s and 1950s and its subsequent influenced on the 1960s’were to bring further changes in underwear fashion.

4.8 Developments from the 1950s: Details and More Details

By the late 1950s, bras and girdles were considered essential foundation garments by most women (Hawthorne, 1992) and the industry was refining and emphasising details by adopting novelty fabrics and trims for bra design, and innovation in materials and fastening systems continued at an unprecedented rate. The emphasis on the fastening system was partly due to the baby boom after World War II. This created great demand for maternity and nursing bras with easy opening for feeding babies. Consequently, front closures, drop-cups, absorbing pads, and zip cups were incorporated into the design of maternity and nursing bras in order to provide easy access for breastfeeding during 1950s. Bra designers adopted zippers and 'Velcro' for their bra fastening systems. Velcro, also known as hook and loop tape, was patented on 13th September 1955 by George De Mestral and soon became popular with clothing manufacturers, so much so that, for a time, it looked as if it might permanently replace zippers or buttons for outerwear. Also, awareness of breast cancer was now increasing, and mastectomy bras for breast cancer victims were introduced. Identical Form, Miriam Gates and Lov-é were the main producers of mastectomy bras at this time, and these came with prostheses which were balanced and weighed to closely approximate natural breasts.

4.8.1 Shape, Cup-padding and Wire

Cup padding made a comeback with strong features which were made possible by the increasing pace of material innovations. Foam-rubber and felts were employed in two different construction methods which can be effectively described as removable falsies, and built-in pads. Removable falsies give women the freedom to control the breast volume, whilst built-in pads offered greater convenience. Although foam-rubber falsies stitched permanently into bra cups scored highest points due to practicality, as well as being efficient as the bosom booster for this era (Pedersen, 2004), it did not stop bra manufacturers exploring other possible padding materials, including air. The innovative, but eventually short-lived, 'Inflatable bra', with blow-up air pockets built into the cup, was marketed by Frederick of Hollywood during the 1950s and early 1960s.

Creating a fashionable bust line was accomplished with not only padding, but also with wire. By then, wire had become an essential component in the design and construction of bras largely due to the support and shaping it provided for the breast. For example, the strapless bra, which was popular in early 1950s due to the popularity of strapless evening gown, was only made possible with the use of wire.

The 'Merry Widow', a corselette produced by Warner in 1952, was one of the most popular brands of strapless bra and supported the nipped waist, hourglass silhouette of the 1950s. The launch of this bra cleverly coincided with the highly successful movie 'Merry Widow', and the bra came complete with a long bodice for better support. Other names such as the long-line bra, corset bra, basque or corselette bra were also used to describe this type of garment. Wires were increasingly seen as essential in bra design because strapless bras required support for the breasts from under the bust. Subsequently, sharing technical information, and the functional attributes of a particular wire, with end consumers was a useful marketing tactic used by bra manufacturers to promote their products. The development of new wire technology remains an important part of research and development for many contemporary intimate brands.

4.8.2 Changing Shapes, Colours and Fibres

Not only pointy and full, but also separated breasts were preferred by women of fashion at this time, in order to create a better projection of the breasts which was believed to be better for the fitting of outerwear. The 'Action bra' by Lovable and 'X-Pert Separation' by Deala of Miami showed the similar X-shape design line of the 'Cross Your Heart' bra by Playtex. The increasing prosperity of the world economy in the 1950s was also reflected in terms of the available fashion colour choice in general, and skin-tones, white and black were added to the existing bright pastel colours commonly used for bra design. In addition, a variety of novelty fabrics was now added to the expanded colour palette and choice for bra design. These fabrics and innovations included eyelet, nylon, marquisette, power net, rayon satin, embroidery, plaids, gingham, dot prints, ruffles and flower patterns. Even fur was explored for fashionable bra manufacture, and lace was also used, with some restriction, due to the high cost. Two-way stretch warp knits and Lycra, a synthetic rubber, was invented in 1959 by DuPont and also became an important underwear material from the 1950s. Similar two-way stretch warp knitted materials were introduced in the mid-1950s, and these became extremely popular in the underwear sector due to the enhanced elasticity they provided. For example, Lycra is capable of stretching seven times its own length. The term 'spandex' and 'elastic' is used as well as trademark 'Lycra'. Barbier and Boucher (2004) point out that Lycra made second skin underwear possible as it is light in weight and does not compress the body, and alter its shape negatively.

4.8.3 Whirlpools, Circles and the Beginnings of the Moulded Bra

Details, such as stitching on the cup, or details on shoulder straps became more important and circular or whirlpool stitching was widely used on bra cups in order to achieve the pointy breast shape. The Hollywood Maxwell bra by Berlei in 1953 is believed to be the origin of the circular or whirlpool bra (Carter, 1992) which demonstrates the detail oriented design trend of the early 1950s. On the contrary, by the end of the 1950s, a smooth cup surface was emphasised and the 'Seam-free bra' for Lovable, patented by Garson in 1958 (US patent 2,857,916), shows the beginnings of early moulding technology. The seam lines of the thick inner cup were concealed by an outer cup of a thin knitted layer of stretchable nylon or other synthetic yarn, which was then moulded by heat setting prior to joining the two cups together. Synthetic fibres such as polyester and acrylic were introduced and widely used in this process by the 1960s.

4.9 Summary

The period covered in this chapter includes the two World Wars, and the impact of these events on the design of outer and underwear cannot be overestimated. The arguments related to the relative impact of fashion, status, and utilitarian needs, identified in chapters 2 and 3, once again come into play. There is no doubt that during the periods spanned by each war, utilitarian factors acted as major drivers for changes in female fashion, and this exerted a powerful influence on both outerwear and underwear design. However, it is also clear that each post-war period brought about a growing sense of liberation for society as a whole, and women in particular, and this is mirrored in the more elaborate and feminine designs of underwear associated with these periods. Rapid technological change, arguably also brought about in part as a result of two world wars, and the large-scale introduction of females into the workforce, where they stayed after the war, also brought about significant changes to the range of materials, colours, and techniques available to designers.

At the same time, companies were becoming more commercially competitive and expanding their target markets to include juniors who, with more buying power than ever before, urged bra companies to focus on their size, style, figure, and proportions, and some companies such as Peter Pan and Jantzen even tried to focus on the junior market with the hope of lifelong customer loyalty. This new lucrative teenage market is described by Carter (1992) as ‘a new body of opinion’. In addition specialist areas and niche markets for maternity bras and mastectomy bras were being exploited and expanded as new synthetic materials became available.

This expansion, and the general expansion in the underwear market, was facilitated by the enormous growth in the mass media during the twentieth century and this increasingly meant that films, radio, television, billboards and print media became major promotional tools for bra manufacturers, whilst retailers adopted a self-service system and focused more on packaging and display, instead of providing bra fitters in the store. Increased product development cost led to mergers or acquisitions between bra manufacturers, knitting mills, and other related businesses in order to survive, and consequently some of the large underwear brands we are familiar with today became established. All of these factors helped to establish the underwear market in general, and the bra in particular as globally accepted essentials and prepared the world for the rapid development in fashion and bra technology which would follow from the 1960s until today. This era of even greater change will be the focus of the next chapter.

CHAPTER 5
THE MODERN HISTORY OF THE BRA

5.1 Introduction

A recurring theme in the overview of the history and development of underwear, and in particular the bra, in previous chapters has been the relationship between developments in outerwear and underwear. This relationship has varied throughout history, and is linked to the role and functions of underwear in determining and supporting the fashionable body shape of the era, the extent to which underwear functions as an indicator of status, an expression of contemporary fashion, or merely the recognised utilitarian or health and hygiene requirements of the period. These themes are continued in this chapter with the notable and new addition of the rise in influence of more political factors in underwear fashion with particular regard to the bra.

5.2 The Fall and Rise of the Bra in the 1960s

The 1960s was a time of experimentation with newly discovered freedoms of expression, and the fashion of the era was all about vivid colours, bold shapes and easy care synthetic materials. Every conceivable colour was tried for underwear and outerwear in the 1960s and prints, especially floral patterns, were particularly popularly as a result of the rise of the hippie, flower-power trend. The floral prints were popular in underwear design but other designs also flourished, including a space-age style with metallic fabrics, a hippie style with cotton prints, and a more preppie style with conservatism, all of which somehow coexisted among the younger generation. In terms of outerwear, T-shirts and pants including the ubiquitous blue jeans became almost de-rigeur as women’s casual attire in the 1960s. Of significance for future decades, whalebone was replaced by nylon in bra construction during this time and cosmetic breast reconstruction began on a commercial basis.

Bras from the 1960s were often constructed using exotic and vibrant colours and prints and the advent of Lycra blended laces allowed bra manufacturers to produce luxurious lace bras at a much lower cost than previously with the added benefit of making the garment lighter. The availability of reliable contraceptives, in particular the contraceptive pill, made many women more liberated and adventurous sexually and brought with it a phenomenal increase in the sale of sexy bra designs and a decrease in maternity and nursing bra sales. Cleavage revealing, plunging necklines arrived on the fashion scene by late 1963. The iconic 'Wonderbra' with a plunging neckline and light padding at the cup was created by French designer Louise Poirier for the Canadian Lady Corset Company in Canada. However, everything was about to change for the fashion industry, and significantly for bra manufacturers.

The increasingly revealing cleavage trend, after the 30 year dominance of the conical bosom look was abruptly interrupted when sixties supermodel Twiggy made her debut in 1965, and firmly established the flat-chested figure as the new fashionable body shape. Suddenly, big breasts were out, and the focus of attention shifted to legs where outerwear fashion was celebrating youthful legs with the advent of the mini skirt and panty hose in 1966. Women of this part of the 1960s were depicted as waif-like 'child-women' (Hawthorne, 1992; Chenoune, 2005) and achieving the fashionable flat-chest-no-bra look became a big challenge for the foundation industry. Ironically, at about the same time, the hippie movement helped justify this braless trend via the radical feminist movement, and this pushed bra manufacturers to create comfortable bras with more natural silhouettes to attract those customers who followed the braless trend. Feminism had emerged again and championed equal rights and opportunity for women by the late 1950s, and had been busy in the early sixties promoting better status for women at work and home. Some radical activists expressed their opposition to what they saw as the image of women as sex objects, by announcing 'bans' on conventional feminine products, and rejecting the images of femininity from the 1950s. This culminated in mass political action on 7th September 1968, when Feminist protestors gathered in Atlantic City and tried to burn a bra in order to make a strong statement against the Miss America competition. They never actually burned anything because they did not possess a permit to have a fire. Instead they threw items which, in their opinion, symbolised women's oppression such as bras, brooms, and Playboy magazines into a rubbish bin which they named the

‘Freedom Trash Can’. Although this is the only major so-called bra burning incident, the mass media from this era exaggerated this happening and presented it as the staring point for the final demise of the bra (Johnson, 2005). However, some designers had already had other ideas and had been working on bras which made the wearer look as if they were braless. Rudi Gernreich, who was famous for his 1964 topless swimsuit, invented a bra which was called the no-bra bra, and was intended to present the breasts in nature’s own way (Gernreich, 1965). Transparent bras or flesh toned bras were suddenly in great demand for the trendy nude, see-through, or no-bra look. In line with this trend of increasing liberation and personal freedoms and equality, the colour preferences of different ethnicities were taken into the consideration in bra design and marketing practices for the first time. Warner introduced a see-through body stocking in 1965, and whilst the light and soft fibrefill padded contour conventional bras continued to sell during this decade, there had clearly been a considerable shift in the notion of the desirable female body image.

In order to cope with these rapidly changing and powerful forces in the fashion industry, business began to look for strategies which would help them to survive and prosper. Diversifying product assortments by offering swimwear or loungewear other than foundation garments was one of the more popular business strategies, along with a series consolidations, mergers and acquisitions amongst underwear producers. Computerisation was also beginning to be introduced in order to control stock inventory, and Bali implemented a computerised stock inventory control system which enabled complete oversight of the production process from factory floor to warehouse. One particularly important development, which was the forerunner of today’s globalised industrial practices, was that US produced bras were exported to countries all over the globe, whilst importing cheaply produced bras from their newly established overseas production lines. There is little doubt that the exportation of bras labelled ‘made in the USA’, but produced more cheaply overseas, helped bra manufacturers to withstand the costly new product development and braless trend of the late 1960s.

Not all consumers were satisfied with the braless movement and these potential customers wanted, or because of their breast size, needed something different which ran against the main fashion trend. Janet Reger, a British designer, proved this with her success. In 1967 she opened a lingerie shop in which she sold luxurious and sensuous underwear with lots of frills and laces which ran contrary to the ubiquitous braless trend. Her designs, which were partly a return to more traditional notions of femininity, and partly the beginnings of a new approach to feminism which gave women what they wanted, satisfied millions of customers with their strong statements of a new sensuous, but assertive femininity. However, by the end of the 1960s, the braless look prevailed, underwear became more natural again and continued to evoke nudity. In line with the advent of unisex T-shirts and jeans, underwear for women generally became more functional and utilitarian in line with, and supported by those feminists who were opposed to underwear which, in their view, depicted women as sex-objects (Saint-Laurent, 1986).

5.3 The Unisex, Multi-trend in the 1970s

This decade saw the rise of music and sport as major fashion influences and the introduction of computer aided design (CAD) into the underwear industry. Fashion from this era became much more liberal and self-defined than in the past because there appeared to be no single uniformed trend. For example, many different lengths of skirt, from micro to maxi, were mingled together throughout the 1970s, although a general trend towards the demise of the mini skirt was evident. Ethnic fashion sprang onto the fashion scene as a result of relatively easier and cheaper travel and the enduring, but weakening, influence of the 1960s' hippie movement. Blue jeans were worn by both women and men and the term 'unisex' mode was created. The 'unisex' trend became popular amongst teenagers, whilst the wearing of trousers with a matching top (the trouser suit) became extremely popular amongst the female adult population. As in the 1960s, this was in line with the developing political and social context with women in the 1970s now determined to be as or more successful than men in their chosen profession and therefore often 'playing-down' the feminine look.

Bras from the 1970s offered a more natural projection of the breast through the use of minimalist construction with spandex, whilst outerwear fashion had undergone an overall silhouette change, from body hugging styles to soft drape cuts which did not require the rigid emphasis on the breasts. Popular colours for bras were less striking and also more minimalist and were dominated by skin and neutral tones which were in fashion in the1950s, and pinks and pastels from the 1940s and 1950s made a big comeback. Silk was the material of choice for the higher priced market, whilst nylon was universally used for the lower-end mass market.

5.3.1 The Establishment of Music as an Influence on Fashion

Music also became a significant influence for the dominant fashion trends of the decade and the variety of music mirrored the self-defined nature of the various fashion movements. Disco set a hot and spicy mood with stretchy tops and glossy hot pants, but this was juxtaposed with the development in London of punk rock from the late 1970s which influenced the introduction of the harder-edged, seductive and provocative sex-object lingerie characterised by Vivienne Westwood who set the punk fashion style by dressing the punk group the ‘Sex Pistols’. At the same time, a new trend of elegant underwear with luxurious fabrics was evolving, aimed at women in their 30s, and three lingerie brands which hold a reputation for their exotic and sensuous designs were launched. Chantal Thomas started her store in 1976 in Paris with sexy yet cheap underwear and Victoria’s Secret by Roy Raymond started in 1977. Janet Reger’s flirtatious designs with frills and laces started in the 1960s had confirmed this new trend for glamorous and fancy lingerie, but more importantly the 1970s firmly established the diversity and segmentation of fashion trends.

5.3.2 The Growth of Underwear for the Health Conscious

Nonetheless, the younger set remained faithful to unisex and sterile fashion throughout the 1970s (Saint-Laurent, 1986) and comfort was once again established as an important factor for bra buying customers. An example was the introduction of Playtex’s ‘Eighteen-Hour Bra’ which claimed to offer comfort during long hours of bra wearing. One important design innovation which was firmly attached to the growing notion of health and comfort was the invention of the sports bra in 1977 by Hinda Miller and Lisa Lindahl. This bra was initially constructed using two men’s jock straps sewn together and was named the ‘jogbra’ as it was meant for the new health-conscious woman who regularly needed adequate breast support whilst jogging. Early sports bra’s compressed breasts against the chest to avoid bouncing and damage to supporting tendons, but the compressed mono-bosom was insufficiently attractive for the fashion conscious yet active woman, so design improvements in sports bras were required to stimulate the clear market demand for such a product.

5.3.3 Computer-aided Design and Outsourcing

The use of computer-aided design (CAD), which emerged in the fashion industry in the 1970s as a pattern drafting, grading and marker making tool improved many aspects of the mass-production procedure, rendering processes both faster and easier (Chase, 1997). This faster and easier pre-production coincided with the growth in cheap overseas production now practised by many bra manufacturers. The Philippines, Hong Kong, Jamaica, Honduras, Mexico and the Dominican Republic were now readily available and established sources of cheap labour for the industry, and increasingly underwear products and particularly bras were being produced in these countries.

5.4 The Rise of Power-dressing and New Romanticism in the 1980s

5.4.1 The Rise of Power-dressing

Anything ‘big’ was in fashion in the 1980s. Big square shoulder pads, big hair, and big breasts were making a come back. ‘Power dressing’ became popular amongst women pursuing promotion up the corporate ladder, or wishing to demonstrate their successes with both career and family. It became more acceptable to indicate social status by what one wore, and designer and brand names gained mass popularity. These trends in outerwear were mirrored in the underwear industry which also became associated with famous designers and global brands (Carter, 1992).

The focus on health which had its origins in the 1970s became widely established and the healthy body image found popularity alongside the rise in aerobics and other self-taught, often celebrity led exercise trends. With an established health conscious market, sports bras which prevented breasts from damage through bouncing grew still further in popularity as women participated in a variety of different exercise activities. By the mid 1980s, many bra manufacturers had created more fashionable but still functional sports bras, encapsulating designs which created more natural silhouettes yet maintained support and stability to the breasts. This movement was so significant that some researchers (Warren, 2001) claimed that underwear failed to retain its status as foundation garments because women were now opting to shape their figures through exercise and diet. Indeed, some women took drastic measures to enhance their body image by getting breast implants, reductions and enlargements, marking a new era of female body consciousness.

5.4.2 The Rise of New Romanticism

New romanticism was introduced into fashion in the early 1980s, so-called because of the glamorous look with frills and luxurious fabrics reminiscent of the Romantic era of the Regency period in the early 1800s. One of the early designers who set the romantic mood was Vivienne Westwood, who helped to set the punk trend in late 1970s, by dressing Pop star Adam and the Ants. Vivienne Westwood is still considered to be one of the most influential designers of the 20th Century due to her innovative ideas (Thomas, 2008a) and ability to read trends from the music and other industries. Music stars influenced both outerwear and underwear promotion and pop icons such as Madonna and Cyndi Lauper used provocative bras on stage, further helping to boost bra sales in the1980s onwards. Design elements drawn from the corset began to be used in evening gowns to create impact and style with underwear following this romantic trend by becoming more luxurious and glamorous. This was accomplished with the lavish use for underwear and bra design of various novelty materials such as velvet and satin together with polyester and Lycra blend materials. Ewing (1971) actually predicted the possibility of the cross-over of underwear to outerwear and also suggested correctly that an increase in casual wear would come from the use of stretch materials. Despite the experimentation with novelty materials, colours for bras did not change significantly during this decade, and white, black, pink and beige were still dominant. One interesting undergarment development in the 1980s was the thong, initially worn by erotic dancers, but which became a very popular undergarment in South America and, in particular, Brazil.

Materials technology also continued to develop and microfibre was introduced in 1986. Advances in manufacturing technology made it possible to extrude extremely fine filaments whilst maintaining the strength and uniformity of polyester and, consequently, this resilient yet extremely smooth microfibre became widely used for underwear in the next decade.

5.5 Achieving Individuality in the 1990s

The 1990s is the decade when a number of very different trends co-existed harmoniously on a global scale, in part due to advances in transportation, computer technology and the widening use of the internet. Waif, grunge, and the androgynous or unisex look were now a firm feature of the fashion scene in the 1990s. Companies began to offer 'Casual Friday' to allow executives to dress-down one day a week, and people started dressing for comfort. The whole notion of being fashionable by following a fashion trend was challenged and became less important than it was in the past. Achieving individuality was the main driving force behind the majority of fashion trends in this decade (Thomas, 2008b). One throw back to the sixties and seventies was the sense of minimalism which can be explained as making a look flattering look using a less fussy, or less is better approach (Marsh, 2006). Tight fitting T-shirts, without shoulder pads, set the scene for the fuller-busted and deep cleavage look.

5.5.1 Underwear Evolves into Outerwear

Madonna's influence as a fashion icon continued with her stage costumes, made up of two corsets for her world tour 'Blonds Ambition' in 1990, and marked an important turning point in bra history. These two corsets, which were reminiscent of the 1950s' bullet bra, brought women's attention back to retro saucy underwear and helped to boost sales of fashionable bras and corsets by 40 percent at Frederick's Hollywood (Pedersen, 2004). Alongside John Paul Gaultier, who designed the iconic corsets for Madonna, fashion designers like Helen Storey, Herbert Barrère, Vanina Vespirina, Vivienne Westwood, and John Galliano began to make their names by integrating underwear features into their outerwear designs (Barbier and Boucher, 2004).

5.5.2 The Further Development of the Bra

Whilst there remained a variety of bra types, Farrell-Beck and Gau (2002) usefully categorised bras from the 1990s into two extreme styles; push-up bras and sports bras. Coinciding with the increased media attention given to fashionable bras, and the new retro look, the ‘Wonderbra’ made its huge comeback in America in 1994. The name ‘Wonderbra’ was coined in 1941 but the real breast enhancing ‘Wonderbra’ was invented in 1964 by the French designer Louise Poirier for the Canadian Lady brand. This bra was introduced to Britain in 1992 by Gossard under licence and then, following a license takeover in 1994, Playtex introduced it to America. This new style Wonderbra sold at a rate of one every 15 seconds and became the best selling push-up bra in American history (Wonderbra, 2007). The Wonderbra phenomenon helped to increase push-up bra sales and largely due to Playtex’s failure to meet market demand, not only Wonderbra but also all kinds of push-up bras were introduced to the global market. These included household names like ‘Superboost’ by Gossard, ‘Miracle bra’ by Victoria’s Secret, ‘Rendezvous’ by Maidenform, ‘Push-Up bra’ by Wacoal and ‘Must Be Magic bra’ by Vanity Fair and all these producers shared the massive international demand for uplifting, push-up and neckline plunging bras. The phenomenon was such in the US, that padded and push-up bras accounted for more than 3 per cent of the United States bra market in 1994 (Kaufman, 2000). These push-up and plunge bras are deeply plunged at the centre and the use of padded cups push the breasts in, whilst the cleverly angled wings and back section lift the breast up. The fibre filled padding of early versions was later replaced with other materials which were supposed to give more natural look and feel. These materials included a water and oil mix, silicon gel, and even air. Barbier and Boucher (2004) claim that the advent of push-up bras, and the G-string or thong panties, provide perfect examples of sexy and comfortable contemporary underwear because they possess the utilitarian functions demanded of modern female underwear. In other words, they are comfortable, promote a sense of health and well-being, are physically supportive, and remain fashionably sexy. This final notion of being and feeling sexy or sensual was widely used for marketing underwear in the

1990s after the adage that ‘sex sells’. Some commentators claim that the Wonderbra phenomenon brought not only fashion changes but also increased personal and sexual empowerment of women (The Times, 2006).

5.5.3 The Rise and Rise of the Sports Bra

By the 1990s, sports bras have become normal everyday wear for the multi-activity lifestyle characteristic of the decade (Carter, 1992) and the development of sports bras gained further impetus from burgeoning sales demand. Bra manufacturers, in common with sports footwear manufacturers, began to take a very scientific approach to the research and development of sports bras. For example, Berlei commissioned the University of Wollongong in Australia to investigate breast movement when women are running, and the shock absorbing bra was launched in 1995 after research by Edinburgh University in the United Kingdom found that wearing a sports bra during exercise reduced breast movement by up to 74% and therefore delayed long term sagging. A collection of sport bras designed according to what are called specific ‘support levels’ based on activity levels, became the best selling sports bra in Europe at this time. In 2003, the ‘Shock Absorber’ was awarded the accolade of outright winner in the Sports Category at the UK Lingerie Awards for the fifth year running (Shock absorber, 2008).

Nike’s sports bra sales went up after Brandi Chastain, a U.S. women’s soccer player celebrated her wining penalty kick against China in the 1999 Women's World Cup final by doffing her shirt to reveal a black sports bra. Despite rumours that Nike instructed players to reveal their Nike sports bra, as they were sponsoring all the players’ outfits, Nike continued expanding its sports bra market share by launching a new sports bra line called ‘Inner Active’ in September 1999 after two years of research and development. The highlight of the ‘Inner Active’ line was the use of Nike Dri-FIT fabric which is lightweight and breathable, keeping wearers dry and comfortable during exercise by transporting or ‘wicking’ perspiration from the skin to the outside for rapid evaporation.

The sports bra market grew by 12.5 percent to $411.6 million in 1998, according to NPD, a market research firm in Port Washington, N.Y (Sandomir, 1999).

During this decade, displaying bra shoulder straps hanging from tank tops and racer tops also became very popular with many young women, alongside showing their underpants under low-waisted hip hop influenced baggy pants, or low-cut jeans. Young people had now changed their attitudes to underwear, and there was no longer any reason why branded and expensive, fashionable underwear should not be displayed.

5.5.4 Innovations in Moulding Technology

Innovations in technology continued to push forward developments in bra manufacturing production, materials, and computerisation for sales and marketing. In particular, advances in moulding technology and materials made the seamless bra possible. The fashionable slim fit T-shirt was popular in the1990s and required a smooth sleek appearance. Therefore, the seamless bra, also known as the t-shirt bra, became extremely popular for its natural look and the development of microfibre assisted in this because of its soft hand-feel and resilience. In addition, consumers were now able to shop online whilst in their own homes, and companies recognised that due to the development of internet and computer related technology, they could now sell their products to consumers with different demographics. Consequently, two major online underwear store websites were established in 1995, namely Bravissimo and Figleaves. Bravissimo founded by Tremellan started as a mail-order company offering a wide range of stylish bras in sizes up to a JJ cup and Figleaves, founded by Daniel Nabarro, offered a wide range of brands. This trend for online sales continues to grow well into the new Millennium. Other more avant-garde developments for this decade include the Techno Bra, which was invented by Kursty Groves, an industrial design engineering student at the Royal College of Art in London. This bra features a built-in heart-rate monitor, wireless telephone, and a global positioning system locator. The built-in heart-rate monitor will detect the wearer's sudden heart beat increment should she be unfortunate enough to come under attack, and will immediately notify police of the wearer's location via a phone call! Advances in new technologies such as these are significant in that they demonstrate that established distinctions and definitions of fashion and function are now being challenged to a previously unimaginable extent by the emergence of multi-function fashionable 'smart bras'.

5.6 The New Millennium

The new Millennium has brought a continuation and development of some existing fashion trends, and an increasing focus on the links between these developments, and the use of new technologies for what are now the global industries of underwear design and manufacture. Fashion icons from the world of music continue to influence the younger consumer in particular and the distinctions between outerwear and underwear continue to be blurred, whilst developments in science and engineering are increasingly impacting upon bra design, patternmaking, materials and production. The established youth and sports markets continue to grow and diversify and are increasingly joined by burgeoning niche markets for garments such as maternity and nursing bras. Wider availability of more nutritious food has led to significant size changes which are beginning to impact around the world and consequently, sales of larger size bras, with their accompanying, support challenges, are also on the increase.

5.6.1 Outerwear Trends

Body-consciousness continues into the new Millennium, and tight fitting T-shirts and body clinging asymmetrical dresses remained popular in the early 2000s. The influence of music icons on the fashion industry remains significant with popular stars such as Britney Spears, Christina Aguilera and Beyonce Knowles leading the ‘Girl power phenomenon’ which is replacing the more mature women’s image from the fashion scene, and modern life from politics to fashion, is becoming driven by an unashamed celebration of youth (Leach, 2004). Contrary to these trends, there are some signs of resurgence in interest in retro Victorian fashion.

The underwear-as-outerwear trend continues and the line between underwear and outerwear has now been all but broken down. For example, when Tom Ford presented the Spring/Summer 2003 collection for Gucci, the items were recognised as hybrids between daywear, swimwear and lingerie and Vivienne Westwood even put bras on some of the male models in her fall 2003 presentation. Dolce & Gabbana also incorporated the underwear as outerwear concept in their collection. Slowly however, a new trend, often termed as ‘New Sexy’ is emerging and is characterised by a demure, modest and ladylike style, with no obvious vulgar exposure of skin or underwear, and clearly influenced by Victorian style. Soft silks, muslin, cotton and voile are utilised in this style, and the basic garments are loose backless dresses, full skirts, camisole tops, sweaters, nipped jackets, cardigans, wrap dresses, baby doll dresses, and cocktail dresses with plunging necklines and décolletages. These clothes are versatile and can be worn from work directly to an evening dinner gathering. New developments in smart textiles are increasingly impacting upon the garment industry and influencing the underwear as well as the outerwear markets.

5.6.2 Underwear Trends

The girl power phenomenon brought a softer and prettier 'girlie' look, combined with a fresh sexiness to the underwear fashion trend in the early 2000s (Asome, 2002). The increased focus upon a celebration of youth brought back the sixties notion of the 'child-woman' although this time the notion, and the look, is more mature in everyway. Floral prints, laces, frills, organic patterns, polka dots, strips, saucy retro silhouettes and big knickers made a fashion come back, using muted tones, yellows, deep reds and violet. The thin sheer materials developed for the moulded cup bra became even more popular as skin tight T-shirts, body hugging dresses, and the sheer shirts of the early 2000s continued to require bras with smooth, seamless cups which project more naturally shaped breasts. Strapless bras continue to be in great demand due to the popularity of off-shoulder designs, although there are also visible underwear trends where women are happy to show off their bra straps, or other underwear. Gossard created a frothy line of underwear in the same style as the Salon Rose collections by Agent Provocateur for Marks & Spencer, and underwear purchasing became an intensely intimate experience for both men and women. Saint-Laurent's (1986) view that women's underwear has a sensual meaning, whilst men's underwear is very rational and without emotional connotations, is no longer seen as valid. Around the middle of the decade, the major global underwear manufacturers started paying attention to men's underwear partly because they saw a marketing opportunity with more male shoppers buying underwear for their female partners. In fact, Marks & Spencer introduced male lingerie advisers to help husbands and boyfriends to shop for underwear as Christmas presents in 2005.

5.6.2.1 Smart Bras

Many bra manufacturers and inventors have created unique bras or bra-like garments in order to satisfy health-conscious and body-conscious women in the 21st Century. The following are bras selected because they have achieved historical significance during the first decade of the new Millennium, and demonstrate the dominant demand trend at the end of the 1990s and early 2000s for a new comfortable, supportive, yet aesthetically pleasing bra.

5.6.2.1.1 The Bioform bra (2000) was created by Seymour Powell by using the latest 3D technology. A soft, moulded thermo-plastic wire offers more support and shape than the commonly used conventional metal wire. This bra is made only for bigger busted women from sizes D and E, sizes which account for nearly 50 percent of bras now sold in the United Kingdom. The uplifting effects of this smart bra have been praised by many women with larger breasts, and Thomas (2008c) claims that the Bioform bra was the first miracle of the new Millennium. Charnos commissioned and produced the Bioform bra.

5.6.2.1.2 The Brava bra (2001) was invented by Dr. Roger Khouri, a plastic surgeon in Miami, USA. It is claimed that women gained an average of 1 cup size by wearing this Brava bra and managed to retain this new size over at least 22 months. The bra is equipped with a small control box, and two suction cups and subjects must wear it overnight.

5.6.2.1.3 The NuMetrex heart sensing sports bra (2005) was created by Textronics, Inc. This bra consists of a built-in monitor which picks up the heartbeat and sends it to a compatible watch or cardio machine and was developed for the health conscious female (Numetrex, 2008).

5.6.2.1.4 The Ipex bra (2006) was created by a team from Victoria's Secret. It is called the world's most advanced bra. This patented bra features graduated pads for a balance between maximum nipple coverage and an almost weightless minimum padding (Victoria's Secret, 2008).

5.6.2.1.5 The ITEC bra (2006) was created by La Senza, and the retailer claims that it is "the world's most technologically advanced bra" because its one-piece design eliminates all tags and seams.

5.6.2.1.6 The Cleavacious bra (2006) was created by Karey Weyenberg. Two adjustable centre straps can change the distance between cups to fit women who are in between cup sizes (Cleavacious, 2008). It is claimed to let wearer's take control over cleavage for lopsided women, although, as will be discussed later in this thesis, a similar mechanism might be required to accommodate widely differing gore sizes for women of non-western origin.

5.6.2.1.7 A cancer screening bra (2007) was invented by a scientist from Bolton University's Centre for Research and Innovation and contains a built-in microwave antennae system to detect one of the first signs of breast cancer, a slight temperature change caused by cancer cells and tumours.

5.6.3 The Rise and Fall of the Push-up Bra

In 1994 padded and push-up bras accounted for less than 3 per cent of the United States bra market but by the first quarter of the year 2000, push-up bras accounted for 10 per cent of all bra sales at department stores in the USA, according to NPD. The demand for push-up bras fell from 8.9 million pounds sterling in 2003 to 8.8 million pounds in 2004, whilst sales of non push-up bras increased from 33 million to 35 million pounds during the same period. Elliot (2005) explained that the self-fulfilment trend influenced women to such an extent that they lost interest in the idea that attracting men would somehow fulfil their lives. Bra manufacturers also realised that the core marketing concept for push-up bras, pushing the breast out to interest the male of the species, started to lose its impact. Subsequently, Gossard launched a coordinate range which consisted of bras and matching panties as they believed this two-piece market had significant potential to grow, and they recognised that it was time to change the way lingerie was presented to customers (Dignam, 2002). Consequently, Wonderbra revamped its 'uplifting' brand image by marketing more natural and rounded cup bras in 2005. Despite falling sales in push up bras overall, 'Dream Bra' by Maidenform boosted its sales by 14.5 percent year on year in August

2006. If the market for push-up bras and the marketing concepts which supported it began to decline, the demand for different support levels of sports bras was increasing.

5.6.4 The Rise and Rise of the Sports Bra

Recognising an ever growing market, many bra manufacturers, as well as sports and fitness brands, focused on the research and development of the sports bra. Berlei, owned by Pacific brands, introduced a range of sports bras called ‘New Legend’ in 2005. The ‘New Legend’ came with two different cup construction methods (soft cup/wire free and underwire) with two different back designs (traditional back and cross/racer back). According to the Australian Institute of Sport (AIS) which Berlei commissioned to test their bra, the ‘New Legend’ range of bras, especially those with underwire and cross back construction reduced breast bounce movement by 53.2% (Berlei, 2005). The results lead the development of a system to assist customers to identify the right bra called the Berlei Support Factor. This unique referencing system allows consumers to find the right bra with right support for any specific sport. For example, one of its sports bras, ‘Ultrasport’, has a Support Factor of 3 for high impact sports such as running or horse riding. Nike introduced ‘Inner Support’ vests with built-in sports bras in 2004, marketing two styles, one for high impact and another for less vigorous exercise or activities.

Another sports bra innovation, the ENELL bra, was created by American Renelle Braaten in 2005 and quickly gained popularity in the US due to endorsement by the popular talk show host, Oprah Winfrey. This no-bounce bra was made of a material called Naturexx, a high-performance fabric that wicks moisture away while providing strength and long garment life, and also features a front closure and wide shoulder straps. It is rumoured to be so effective that some insurance companies will cover the cost of the bra when a physician prescribes it for patients recovering from breast surgery. Victoria’s Secret also introduced a new high-tech and high-performance line called ‘Sexy Sport’ in 2006 to claim its share of the lucrative 358 million USD sports bra market. A British sports bra maker ‘Shock Absorber’ was invited to be the manufacturer of the ‘Sexy Sport’ line which features trendy colours and sexy design elements such as a padded plunge neckline and a convertible racer back. High-tech performance materials such as ‘Coolmax’, ‘Supplex’ and ‘Meryl Actisystem’ were used for thermal control, soft hand feel, and quick drying. Sexy Sport introduced the notion of support levels for the intensity of activity from light, medium, firm to maximum and were colour-coded with size for consumer convenience. With this increasing interest from health-conscious consumers, many identified a need to research the support levels afforded by sports bras for the intensity of activity. Research conducted by the Department of Sport and Exercise Science at the University of Portsmouth found that breasts which were unsupported during rigorous physical activity could display permanent breast sag due to stretching of the Cooper's ligament which is partly responsible for holding the breast in position. This research, which was sponsored by Shock Absorber, showed that wearing an ordinary T-shirt bra during exercise reduced breast bounce by an average of 38 per cent whilst wearing a Shock Absorber sports bra reduced breast bounce by up to 74 per cent. Collaboration was also established between Marks & Spencer and the University of Wollongong, Australia, in 2001 and, by 2007 had resulted in the creation of a smart fabric bra which can tighten bra straps and stiffen cups to prevent breast pain and sag by responding to breast movement. The era of science and research in bra design and manufacture had clearly arrived, and the underwear industry continues to seek knowledge transfer collaboration with universities as it seeks new innovations in both materials and design knowledge.

5.6.5 The Big Size Bra

Better diet and other lifestyle improvements have led to significant breast size changes in many developed countries. For example, the Beijing Institute of Clothing Technology took measurements from 3,000 women over six years and reported that the average Chinese female chest had increased by nearly one centimetre, to 83.53 centimetres since the early 1990s (Shanghai Daily, 2006). The average bra size worn in UK had also grown from a size 34B to 36C since the 1960s probably due to an unhealthy diet, increased use of the contraceptive pill, and a lack of exercise. But Bravissimo speculates that the true average bra size worn in the UK is likely to be 34DD/E, because their research shows two thirds of women are wearing a bra with a big back and small cups (The Mirror, 2007). Consequently, the plus or big size bra became an important part of many bra manufacturers business, particularly those who import or export to or for the US and UK markets. As a result of persistent complaints from larger breasted women who wanted a feminine big size bra, some brands such as Bravissimo, Fantaiem and Goddess decided that they would respond to the market demand. According to Advertising Age, sales for larger-size bras are up 10.5 percent year on year since 2004, which is nearly double the growth of regular size bra sales. The total sales figure was US$1.9 billion in 2005 amongst a US$5.2 billion overall business. Flex-to-Fit technology bras by Maidenform and Olga's Christina by Warnaco now also offer more fashionable every day bras for big busted women. Consequently, a number of well-known manufacturers have followed suit and Goddess and Aviana even have sizes up to 56FF. Enell Inc. founded by Renelle Braaten offers sports bras for big busted women up to 52DD in white, nude and black. Magic Lift Active Sports bra by Junonia carries sizes up to 50F (Fallik, 2006).

5.6.6 The Nursing Bra

Comfortable and yet supporting nursing bras have always been in demand together with other breast-related nursing accessories. Tyco Healthcare introduced hydrogel nipple pain relief pads ‘Mother Mates’ to protect and soothe nipples sore from cracks, fissures or blisters caused by hungry babies. These non-toxic and reusable polyurethane nipple pads can be inserted inside a nursing bra. For additional cooling, they can also be stored in the refrigerator before application.‘Bravado!Designs’ is a specialist company which only produces nursing bras, tanks, and panties. The company was established in Toronto in 1992, and has been endorsed by celebrities such as Angelina Jolie, Britney Spears, Jennifer Garner and Sarah Jessica Parker. Bravado!Designs offers three different lines, the original nursing bras, supreme nursing bras, and lifestyle nursing bras, which offer sizes from 32B to 46H. The Essential Nursing Bra Tank, a top with a built-in full support bra, comes with sizes 34 B to 40 E (DD) with the real support needed for nursing mothers (Bravado!Designs, 2008).

5.6.7 Further Innovations: Stick-on Bras

The trends for transparent shirts, clingy sweaters, off-shoulder tops, plunge necklines and décolletages have driven women to seek healthy alternatives to going bra-less. In some ways, the no-bra trend of the 1960s was repeated during this decade, and ‘petal tops’, flower-shaped adhesive oversized disposable nipple covers with a centre pad of gauze for comfort and hygiene, were introduced in 2000 for a smooth look without a bra. In contrast, the natural braless look was also achieved using artificial nipples worn underneath a bra. These ‘Bodyperks’ or silicon nipple enhancers, have been praised for their creation of a naturally perky breast projection (Bodyperks, 2007).

In order to achieve the natural look of perky breasts under low cut necklines, California-based Bragel International created an adhesive silicon breast-enhancing bra with adjustable hooks in the front. The ‘NuBra’ comes in two colours, clear and nude, with A, B and C cup sizes. The NuBra was marketed as a strapless and backless bra with added desirable additional volume. However, this adhesive bra generally fails to support reasonably large or sagging breasts. In the light of this disadvantage, the rather colloquially termed ‘Liftits’, an oversized plaster-like adhesive tape, was marketed to lift sagging breasts and hold them in a position where perky breast projection can be obtained. The ‘Liftits’ lifts breasts up to 5 cm according to its website and is said to be perfect for slinky, backless, strapless or halter-neck styles (Usefulchickstuff, 2008).

5.6.8 Iconic and Newsworthy Bras from the New Millennium

Madonna’s beaded bra by Dolce and Gabbana for the ‘Girlie show’ tour in 1993 was sold for 16,640 pounds sterling at a Sotheby’s online auction in 2001, and made a world record as the most expensive bra in the world. A perfumed bra by Etam was introduced in 2001, and Reinlinde Trummer, an Australian designer, created the world’s first chocolate bra which is capable of withstanding body heat and which requires at least two kilos of chocolate with spice mix for each bra!

In August 2007, Playtex patented half-cup sizes ranging from Nearly A (NA), A, Nearly B (NB), B, and Nearly C (NC) and C from band size 34 to 38A under the label 'Half sizes too™' for women whose cup sizes lay between A, B and C. Triumph International Ltd in Japan also introduced very interesting bras throughout the 2000s. These bras were often featured by the mass media because they were associated with the latest contemporary social issues (Table 4).

Table 4: Themed Bras by Triumph International LTD, Japan

Year	Name	Specifications
May 2001	The structural reform bra	Black or grey colour with no strap and no hook and eye tape. This bra symbolises Prime Minister Koizumi's bold and revolutionary economic recovery.
	The total surprise bra/post box bra	This bra was designed to bring attention to previous Prime Minister Koizumi's post office privatisation plans.
Nov 2003	The non-smoking manifesto bra	This bra, made out of material containing titanium oxide, a chemical substance, degrades tobacco smells.
Jan 2007	The eco shopping bag bra	This bra's cup padding can be converted into a shopping bag. It is designed for environmental awareness and promotes the use of recycled shopping bags.
Nov 2007	The warm biz bra	This bra is equipped with removable pads that can be heated in a microwave or hot water, and a pair of furry straps which can be used as a scarf around the neck in order to prevent global warming.
Nov 2007	The my hashi (chopstick in Japanese) bra	This bra comes with collapsible chopsticks hidden inside the brassiere. It is meant to promote saving trees by recycling chopsticks.
	The birth rate decline bra	The bra emphasised one of Japan's social issues, an aging population and a declining birth rate, with patches of grandmother, grandfather, and babies on the cup.
	The world ecology bra	The bra cups are each one half of the globe and can be put together to make one globe which represents current environmental challenges.

(Source: Levenstein, 2007)

Other than social issues, Triumph International Ltd, Japan also created baseball and soccer theme bras. All of these offerings were cleverly engineered and highly effective marketing stunts (Levenstein, 2007). Unlike Japanese ‘social issue’ bras, at around the same time, there was also a bra which had become a social issue in the West, the bra for young girls.

5.6.9 The Bra for Young Girls

The provocative clothing, including bras for girls as young as ten years old sold in the children’s departments of major stores brought concerns to parents about protection of their children from commercial exploitation. Bra manufacturers and retailers were accused of `corporate pedophilia' in the US for selling these items, as well as putting children’s images on advertisements. Consequently, how far commercialisation in underwear sales should be allowed to go became a hot topic for discussion in the mass media (Conway, 2006; Overington, 2006). Barbie, Bratz, Disney and Target in Australia, Zeller in Canada, and the George brand by Walmart (UK) were some of the retailers accused of sexualising young girls by selling bras to ten-year-olds. However, despite the criticism, many underwear manufacturers and retailers argued that they now sold bras for young girls due to their earlier age of precocious puberty. According to the National Institute of Child Health and Human Development (2007), some girls experience precocious puberty from as early as 8 years old, and it is therefore difficult to attribute blame solely to the manufacturers and retailers.

5.6.10 A More Positive Note: Breast Cancer

October of each year became a national breast awareness month in the USA due to growing concerns about increases in breast cancer rates. The American Cancer Society (2007) estimated 180,510 new breast cancer cases for both males (2,030) and females (178,480) and 40,910 deaths for both males (450) and females (40,460) in 2007. Many charity events and promotions were held in the 2000s to fund the fight against breast cancer, or help breast cancer victims.

Nina Barough founded the charity ‘Walk the Walk’ in November 1996 which eventually led to the starting of the Moonwalk, a midnight power walking marathon which has raised, at the time of writing, in excess of £35 million for breast cancer research and cancer care. Playtex became a partner for this event and it is scheduled to launch a range of mastectomy bras with sizes from 34B to 42D in December 2008 (Walk the Walk, 2008). Another significant charity event took place in 2003 when 49 celebrities, including Bette Midler, Goldie Hawn and Sheryl Crow designed bras for auction by Sothebys.com to raise money for breast cancer research.

5.6.11 Business Development in the New Millennium

The intimate apparel business, generally characterised as a relatively risk-free, high-volume, and commodity-type business that typically yields profits even when the economy is in recession (Monget, 1999 & 2000), has witnessed unprecedented public interest, and growth in recent years (Dickerson, 2003). Since the1990s, with the growth of the fashion industry's 'sex-sells' marketing focus and the evolution of the internet, the intimate apparel business has become an important and thriving industry. There are more now than 620 lingerie labels in the world. French women alone bought 60 million bras and spent, on average, 102 Euros on lingerie whilst English women spent £114 on lingerie in 2003 (Barbier and Boucher, 2004). Women's intimate apparel grossed US$9.6 billion in the United States in 2005, according to market research firm NPD Group. However, exporters and importer in this lucrative business, whose production line is in China, struggled due to import/export restrictions on Chinese textile products in the summer of 2005. The European Commission imposed tariffs, with China and Vietnam limiting imports of cheap clothing such as trousers, sweaters, T-shirts and bras after a flood of imports followed the end of quotas, in order to protect textile producers in the European Union. Retailers' stocks were locked up in warehouses, threatening the survival of hundreds of smaller retailers. Therefore, innovation in production, material and design became an even more crucial activity for bra manufacturers due to the rapidly changing business environment. Partly, as a consequence of these and other developments, not only beauty lingerie, but also 'high-tech' engineered underwear is available these days. No longer are undergarments regarded as purely functional and necessary items of clothing. They are now clearly significant fashion items and the industry is responding by making use of fabrics, design, and production techniques which require greater skills and use of technology than ever before (Braverman, 2001). Major US and European companies such as Victoria's Secret, Marks and

Spencer, Triumph, Berlei, Calvin Klein and DKNY have established production lines in Hong Kong, China, Malaysia, Indonesia, Thailand and India, fuelled by the ready availability of inexpensive labour for garment production.

Many celebrities have joined this risk-free global underwear business by using their fame to promote their own lingerie lines. Elle Macpherson, a former model and actress, was first to start her line in 2002, followed by Kylie Minogue, Katie Price, Venus Williams, Collette Dinnigan, Caprice Bourret, Delta Goodrem, Elizabeth Hurley and Ian Thorpe. Designer brands such as Dolce & Gabbana, Roberto Cavalli, Prada, Christian Dior and Versace also use their successful brand image to promote lucrative underwear collections. Bra manufacturers hire celebrities to promote the image of their products, and Sarah O'Hare and Marina Dior have modelled for global brands such as Wonderbra. Even Anna Kournikova, a tennis player, modelled the Shock Absorber in 2004.

Whilst branding with celebrities was used as a marketing strategy, bra manufacturers also embraced the fact that research and development (R&D) were increasingly essential for survival in a fast-moving and competitive industry. Kathy Smith, intimate apparel marketing manager for DuPont, emphasised the importance of innovation rather than just sex appeal in the intimate apparel industry (Takahama, 2001). Innovation with new technologies should assist with the development of higher sales margins (Howard, 2002). As an example, Victoria's Secret created a line called 'VS Technology' which consists of new high-tech trademarks like Secret Embrace™, IPEX® and Infinity Edge™. In fact, IPEX® was launched in 2006 as the world's most advanced bra for its maximum nipple coverage, minimum padding, and light weight.

Bonding technology together with moulding technology and circular knitting technology made the one-piece seamless bra which is known as the 'one piece bra' or 'T-shirt bra' possible. Padding remains in fashion although the materials and construction methods are becoming ever more sophisticated. Water, air and whipped silicon are also becoming popular materials in modern bra construction. The 'Silicon Valley' by Elle Macpherson, 'Ultimate cleavage' by Lovable, and 'Ultimo bra' by Michelle Mone were new attempts at the push-up bra which employed silicon gel in order to create a more natural look. The push-up bras from 1990s reached their peak in the part of the 2000s and then slowly faded away from the fashion scene for the time being.

5.6.12 Material Technology and Innovation

During this decade there were innovations everywhere. A novel magnet fastener for the bra is just one example. These fasteners, which can be undone with a twist, began to be used in many bras boasting a front closure. The continued interest in a healthy lifestyle, and the growing emphasis on environmentally friendly materials, helped to drive the development and use of new materials in the textile industry. For example, a coating material called Chitosan started to be used for underwear construction due to its excellent absorbent and anti-bacterial properties (Natural-antibacterial, 2008). In 2002, a new silver yarn, X-STATIC® was introduced to the market. This consists of a normal yarn with a pure silver coating wrapped around it. The natural healing properties of silver, both anti-microbial and odour controlling enable inhibition of the growth of micro-organisms whilst remaining amenable to knitting or weaving in order to construct the end products. The material was particularly useful in the construction of mastectomy bras, nursing bras, mastitis and sports bras (Noble biomaterials, 2008). For example, the DriTec™ Mod Sport Bra by 'InSport', with a lining fabric made out of X-STATIC® silver fibre, was marketed for its anti odour performance. Sports bras produced by Goddess also used X-STATIC® silver yarn for its anti-static and odour-resistant properties. It was constructed with Coolmax for regulating body temperature and keeping wearers dry and comfortable.

In September 2007, Chantelle introduced an underwear collection made from breathable bamboo for warmer climates, and this product was featured in Vogue as one of the 30 latest 'eco chic' items which could help save the world (Fletcher and Hancox, 2007). Also, an underwired bamboo bra by Hanro and a bamboo nursing vest by Emma Jane were sold through the online retailer 'figleaves' website. Bamboo yarn possesses a natural anti-bacterial and bacteriostasis bio-agent called 'bamboo Kun' for anti-microbial functions and offers exceptional moisture absorbance and ventilation. Also, its biodegradable characteristics attract consumers who support green and eco-friendly textile manufacturing in line with current global warming and environmental concerns (Bambrotex, 2008). Other natural fibres such as organic cotton and hemp are also increasingly used for the eco-conscious consumer group.

5.7 Conclusion

The bra started as a layer to cover the breast probably for purely utilitarian purposes, and developed into a potent vehicle and symbol of a woman’s sexuality. During the decades covered by this chapter, the bra brought both sexual empowerment for women, but was also regarded by some as a symbol of male power over women as sexual objects (Njuguna, 2003). To some extent, these decades, in common with historical precedent, demonstrates that the bra has often evolved from social and political changes, some significant and some not so significant. For example, the two world wars changed the way women dressed and help to polish and complete the conventional bra design with outerwear once again dictating changes in underwear.

So many inventors and manufacturers have contributed to the lengthy and expensive process of bra evolution from prehistory until contemporary time. Rubin (2007) claims that twin social and individual pressures, of modesty and rebellion, have taken and will continue to take an active part in bra evolution. More controversially, she also considers that there is no reason to reinvent the bra since the evolution of the moulded, seamless ‘T-shirt’ bra. In this context, Saint-Laurent (1968) expressed a similar view point that any hope of discovering new undergarment is pointless as all possible solutions for holding the body tight with the additional ability to securely fasten have been developed and explored already. The author of this thesis does not share either viewpoint because there is still much to improve (some of which are the subject of the research presented later in this thesis) and there are so many inventors and manufacturers currently trying to create a new breast supporting device (not necessarily a bra) which can provide support yet project the naked body contour. Technology and fashion, if not social and political pressures, will continue to force the evolution of the bra, or a breast supporting device that evolves from it, throughout this millennium and probably beyond. In the next chapter, more detailed consideration is given to the enduring influence of new bra technology and materials on the evolution of this iconic item of underwear.

CHAPTER 6
TRENDS IN MODERN BRA TECHNOLOGY AND MATERIALS

6.1 Introduction

Evidence from chapter 5 demonstrates that early trends in bra technology were, to some extent driven by the fashionable and sought after 'sleek look' of the1990s when achieving a 'natural' cleavage was a primary consideration for fashionable and body conscious consumers. Creating this natural look around the bust area began with the removal of seams and stitches from the bra cups and culminated with the removal of all seams from the bra. The resulting seamless garments are generally comfortable, smooth, and durable, light in weight, and less bulky, whilst the technology which underpins them provides fast production and efficient material utilisation for manufacturers (Performance Apparel Markets, 2006). Cutting edge technologies such as moulding, laminating, welding and circular knitting were introduced into bra production in order to facilitate the creation of seamless bras, in particular the one piece bra or T-shirt bra. The further development of these seamless technologies was another driving force behind the trendy, healthy, yet sexy image of women in the 1990s and 2000s.

This chapter will look in detail at the history and development of moulding technology, bonding technology, ultrasonic technology and seamless knitting technology together with the development of the new eco-friendly textiles and smart materials used in the intimate apparel industry.

6.2 Moulding Technology

The process of 'moulding' can be defined as forming an object of a particular shape from a soft substance (Oxford English Dictionary, 2006). Fabric moulding technology refers to a thermo-forming process which involves high temperature with compression applied by a set of female and male mould heads. There are many factors to consider if a good moulding result is to be achieved. Physical factors include the particular yarn, weaving or knitting structures and chemical factors include the chemical composition of the fibre contents, and the dying and finishing treatments. Any changes in any one of these factors, requires different settings and combinations of moulding temperature, time, elongation, and compression. Therefore, a trial and error method is often used in the industry according to Ho (personal communication, 7th March 2008) who is a product development supervisor at Tavistock, one of the major bra cup and wire producers in Hong Kong.

6.2.1 A History of Fabric Moulding Technology

Whilst fabric moulding itself was regarded as a new industry in the early 1930s (Fuchs, 1939) the concept of moulding did not really constitute new technology. For example, Henry House patented a paper dish moulding machine as long ago as 1878 (House, 1878) which was later cited as a reference for many fabric moulding patents. The earliest record of actual fabric moulding is a patent by George Schneider from 1936. His patent entitled ‘wearing apparel and method of making the same’ revealed the early development of fabric moulding techniques and mouldable materials, and their potential applications. Schneider (1936) emphasised two advantages of this new method over conventional cut and sewn assembly methods:

i. Substantial permanent shape retention
ii. Reduced production time and effort

Schneider (1936) demonstrated that thermoplastic derivatives of cellulose need to be present for shape retention, and that the suggested temperature for moulding a fabric constructed of acetone-soluble cellulose acetate is between 125 º C and 180 º C without the aid of water or steam, or between 90 to 100 ºC with the aid of water or steam. He also compared the production time and effort to put a large number of small pieces of fabric together to form a three dimensional shape with his new fabric moulding process with positive results for the new technology. He argued that he had clearly demonstrated the potential of fabric moulding which, in his opinion would be substantially better than conventional cutting and sewing methods which were/are often technically challenging as well as time consuming. However, despite Schneider’s positive description, shape retention was a significant problem area for this new technology. Schneider (1940) patented a further construction method for bras, or other garments with moulded cups, in an attempt to rectify the problems with his previously suggested method whereby the moulded cups were losing their shape after repeated washing at high temperature. He recommended a trade-off solution which involved stitching or bonding the moulded cup edge in order to retain the moulded shape. Unfortunately, this modification removed some of the previous advantages of a seamless and quick to produce garment.

Another problem of moulded cellulose derivative fabrics in addition to failing to retain its moulded shape was a loss of original characteristics, in particular flexibility, due to the high plasticisation (Hardy, 1942). In order to solve this problem, Hardy (1942) suggested using fabrics made out of cold-drawn synthetic linear polyamide fibre instead of fabrics made of thermoplastic derivatives of cellulose fibres. Shape retention was the most critical issue in moulding technology according to Snowdon (1942) who suggested a final moulding temperature of 250 to 275 º C to overcome this problem, but he also cautioned that temperatures can vary depending on the presence of moisture and sometime plasticising of organic compounds in fabrics would be unavoidable. Since this time, moulding has become an active research area in the bra industry and these difficult to resolve chemical phenomena were recorded in many patents. Table 5 shows patents from the United States from 1933 to 2007 and their number clearly demonstrate the vigorous development efforts still being made in this area.

Table 5: United States Patents from 1933 to 2007

Patent #	Granted date	Title	Name of inventor
2,047,230	14 July 1936	Wearing apparel and method of making the same	George Schneider
2,179,692	14 Nov 1939	Machine for shaping forms for fabric materials	Harry Bricker Fuchs
2,190,807	20 Feb 1940	Method of making wearing apparel	Alfred J. Steinberger
2,191,545	27 Feb 1940	Wearing apparel	George Schneider
2,285,967	9 June 1942	Method for production of fabrics	Vernal R. Hardy
2,304,989	15 Dec 1942	Production of wearing apparel	Arthur Bruce Snowdon
2,391,417	25 Dec 1945	Brassiere	Iver F. Hill

2,402,554	25 June 1946	Moulded product and method of making	Fergus A. Irvine and Emile Frederick, Jr
2,460,674	1 Feb 1949	Shaped fabric article	Lajos Bihaly
2,460,715	1 Feb 1949	Brassiere	Henry Schoebel
2,580,566	1 Jan 1952	Bra forming device	Richard MacHenry and Charles A. Martin
2,616,084	4 Nov 1952	Seamless bust supporter	Howard E. Shearer
3,021,844	20 Feb 1962	Seamless moulded brassiere cups	John E. Flagg and Norman A. Cormier
3,058,154	16 Oct 1962	Apparatus and method for making breast fronts	Jack E. Howard and Lewis A. Kaplan
3,064,329	20 Nov 1962	Moulded nonwoven fabric articles	Walter M. Westberg
3,164,655	5 Jan 1965	Method of making breast pads, cups and fronts	Jack E. Howard and Lewis A. Kaplan
3,167,816	2 Feb 1965	Apparatus for making brassieres and other garments	Jack E. Howard and Lewis A. Kaplan
3,202,565	24 Aug 1965	Moulded brassieres	Billy Loftin
3,434,478	25 March 1969	Moulded garment	Benjamin Liebowitz, Lewisboro and Morris U. Cohel
3,461,504	19 Aug 1969	Fabric-forming apparatus	Marvin Becker
3,799,727	26 March 1974	Heat control for fabric moulding	Jack E. Howard
3,799,728	26 March 1974	Moulding closing device for fabric moulding	Jack E. Howard
3,880,561	29 April 1975	Brassiere moulding-forming machine	Richard A. Ferro
3, 981,310	21 Sept 1976	Moulded brassiere cups	James G. Donaghy
4,008,029	Feb 15 1977	Moulding apparatus	Richard J. Shokite
4,162,885	31 Jul 1979	Apparatus for hot moulding of material	John R. Asel
6,425,800 B1	30 July 2002	Seamless brassiere	Hui Lung Huang
2007/0066181 A1	22 Mar 2007	Brassiere	Bull Lau
7,192,332	20 Mar 2007	Brassiere	Zhen Qiang Liu

Despite the patent records shown in Table 5, it remains difficult to find samples of moulded bras created before the 1960s. However, the no-bra trend which was popular during that decade pushed bra manufacturers to produce and market the lightweight seamless moulded cup bra in order to achieve the fashionable braless look. The introduction of new materials such as Nylon made fabric moulding easier, and some researchers (Lehmann, 2001) claimed that moulding technology was first used in the production of commercial bras at the end of the 1960s when good quality polyester and elastane fibres with sufficient quantities became available. The availability of moulded products increased significantly in the mid 1990s due to the increasing interest in a healthy, natural body image, and an emphasis on exercise and a comfort-oriented lifestyle together with the introduction of microfibres, new bonding technology, and circular knitting. The fashion of tight fitted T-shirts which reveal what is underneath gave the moulded cup bra more commercial advantages amongst the affluent younger consumer than more traditional lace bras manufactured using the cut and sew method.

6.2.2 Modern Moulding Equipment

A conventional moulding machine consists of at least one set of moulding heads, a male mould head in an upper clamp, and a female mould head on a lower table, together with a digital timer and a thermo-regulator. Moulding has become easier than it was earlier because machines are equipped with a computerised controller which now allows operators to set the moulding temperature and compressing time according to each fabric's physical and chemical characteristics, and this user friendly feature means bra production is now more cost effective and efficient. A clamp holds materials in one place, whilst the application of heat and compression to the material by the two mould heads forms the desired shape. Figure 53 is an example of a moulding machine illustrated in a patent by Regina Miracle International Limited (Liu, 2007a).

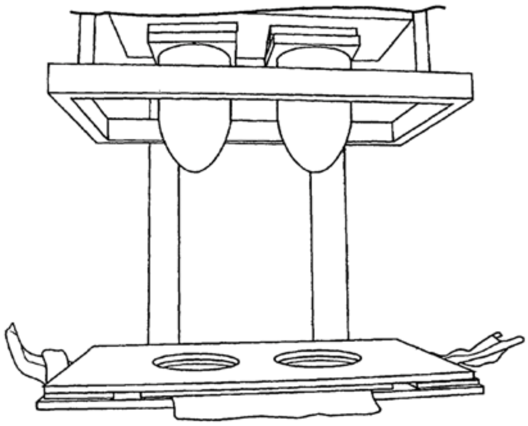


Figure 53: Moulding machine with double bullet mould. Source: Liu, 2007a

The moulding speed and cycles are affected by the machine set-up and the optimum cooling time for each material. Conventional moulding machines are able to exchange different sizes and shape of mould heads depending on the required bra cup size and the material being used.

6.2.2.1 Types of Mould Heads

Mould heads come in different sizes and shapes. Each mould head size is marked by the diameter at the mould head base and the depth and height of the head. The normal range for an elastic and bullet mould diameter ranges from 70 to 130mm. There are two shapes of moulding heads commonly used in the industry and their shapes and sizes are based on the elasticity of materials. Non-stretch materials require moulding into the exact shape of the breast, whilst stretch materials only require moulding into a reasonably stretched shape which can be further stretched and moulded to the breasts. Therefore, moulding heads come in two basic types called a rigid mould and an elastic mould. The rigid mould is also sometimes called a slope mould and the elastic mould is also referred to as a bullet or bubble mould due to their characteristic shapes. Unlike the elastic mould heads which can be created by any moulding machine supplier due to its relatively simple form, rigid mould heads are designed by bra manufacturers based on their own fit requirements after consultation with their designers and patternmakers.

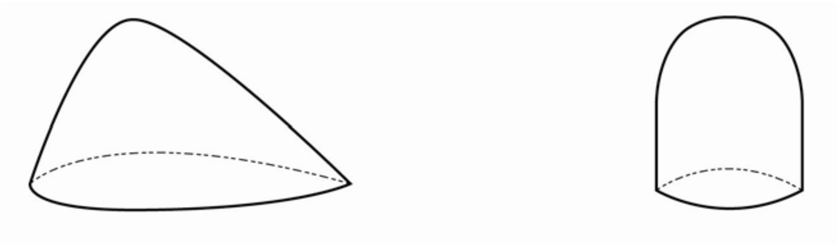


Figure 54: Rigid mould head vs. elastic mould head.

These two moulding head types (see Figure 54) are further categorised by the number of heads being used in one moulding operation. In other words, a single mould for one breast moulding at a time and a double mould, commonly used for one piece bras (see Figure 53). Compared to the double mould, the single mould is often preferred by operators for the easy control of materials during the moulding process and because it is more cost-effective due to its low material consumption.

In terms of production cost, the elastic mould has advantages over the rigid mould as it also consumes less material. The method of laying out fabrics to be cut for moulding is usually decided by moulding technicians based on material utilisation unless a designer or patternmaker specifically defines how the moulded pieces should be cut.

6.2.2.2 The Moulding Problem of Yellowing

One significant problem of the moulding process is a problem called yellowing. The rigid mould has a bigger fabric contact area and it is easy for a fabric to become overheated between two mould heads which leaves yellow marks. Also, the elastic mould can create yellow rings on the fabric around the base of the moulding heads because of the different temperatures between the base and tip of the moulding head. Therefore, a method of spraying water on to the material in order to prevent yellowing has been adopted by moulding machine operators in the industry. As a result of these and other potential moulding hazards, it is normal practice for manufacturers to test each material for effective and efficient production, whilst the moulding machine manufacturers continue to try to develop the machines to deal with these issues and fulfil industry requirements. Changes in moulding machines directly reflect changes in bra design and production techniques because these machines now play a critical part in the mass production of the bra.

6.2.2.3 The New Generation of Moulding Machines

In the early 2000s, Optotex form GmbH started to customise the moulding machine by developing a range of machines which only work for a particular material. Customisation of moulding machines was a new concept up to that point in time because previously one moulding machine could mould circular knit fabric, foam, and fabrics (Lehmann, 2001). Macpi, originally a fusing machine maker, developed an elastic moulding machine, the Macpi 365 (Figure 55) for Sara Lee. Sara Lee, an underwear brand, was looking for a moulding machine which did not leave the yellow marks described above so, in order to avoid applying different temperatures to the same piece of fabric, the Macpi 365 replaced aluminium female mould heads with extremely hot air circulating in the lower part of moulding machine. The principle is to apply evenly heated air to the materials and this rectified the yellowing problem of the conventional moulding machine but is only applicable to the elastic or bullet mould.

Figure 55: Macpi 365. Source: Macpi, 2008

6.3 Modern Moulding Materials

Lycra blend fabrics, in particular knitted blends, are commonly used as materials in moulding technology. In theory, any material can be used for moulding if it can withstand the required moulding temperatures, normally set from 190 to 200 degrees Celsius for about 40 seconds without melting or burning. However, shape retention and colour fastening after moulding determine whether a particular material is suitable for moulded bra design. Other fabrics widely used for moulding include nylon, polyester, or cotton blend with Lycra. Other materials involved in moulding include polyurethane foam and fibrefill. Polyurethane foam and fibrefill are used for forming the cup shape and adding more volume to the bra.

6.3.1 Polyurethane (PU) Foam

A German industrial chemist, Otto Bayer, discovered the basic di-isocyanate polyaddition process in 1937, which transforms polyurethane into coatings, adhesives, elastomers, and other forms with a wide range of firmness (American Chemistry Council, 2008). In the late 1950s, when PU material became commercially available, PU was explored at an industrial level, and bra manufacturers were one of the industry sectors which fully utilised this new flexible and comfortable foam material. PU has become ubiquitous and is now used in the building, transportation, bedding, furniture, appliances, packaging, textile and apparel, machinery, electronics, footwear, automotive interior, insulations, coatings, adhesives, sealants, elastomers, and flotation industries. However, despite its flexible characteristics and ability to conform, discolouration of PU foam remains one major disadvantage for bra manufacturers. The colour stability of PU foams is affected by UV light, oxidation and temperature and, once exposed to those elements; it becomes yellowish and some loss of its physical properties follow (Foamex, 2008). The extent of yellowing of PU foam as a major problem for bra manufacturers is illustrated by the fact that some bras with PU foam change colour even before reaching a retail store! Therefore, PU foam bra cups require multiple layers of fabric to conceal the foam cups.

6.3.2 Fibrefill

Fibrefill is a synthetic fibre used as a filling for pillows, quilted materials for bedding, and padding materials for bras and olefin and polyester are generally used for making fibrefill. Normally polyester fibrefill is used for bra padding due to its good resilience, high modulus, good recovery, and UV resistance. Fibrefill comes in the form of a sheet and can be laminated and moulded. However, despite its excellent stability and UV resistance, fibrefill lacks the softer hand feel, and look, of PU foam.

6.4 Moulding vs. Cutting & Sewing

The material consumption rate for a moulded cup bra is higher than that of a conventional cut and sewn garment because a moulded cup requires a substantial amount of extra fabric to allow for the moulding process as well as sewing, whereas a conventional cut and sewn cup produces a relatively smaller amount of material wastage. However, the overall cost of moulded cup bras is significantly cheaper than cut and sewn bras because of the reduced production time according to Ho, a product development supervisor from Tavistock (personal communication, 7th March 2008). Tavistock is a subsidiary of ACE Style, one of the biggest bra manufacturers in Asia which also produces bra accessories such as moulded bra pads and wires.

Moulding technology has changed the way bra patternmaking is done and the materials used in bra construction. The traditional method of bra patternmaking used in the industry is a direct drafting method which only requires a paper pattern (Shin, 2007). A rigid mould cup pattern is achieved by three-dimensional modelling (draping) and its pattern is recorded on a plastic cup duplicate of the moulding head's shape, whilst an elastic mould cup pattern is achieved by mixing both a two dimensional patternmaking method and a three dimensional draping method. Subsequently, an elastic mould cup pattern consists of a paper pattern and a plastic cup. In summary, moulding technology has clearly made bra production easier and faster than more conventional cut and sewn production methods (Huang, 2002; Hsu, 2006).

6.5 Bonding and Lamination Technology

Fabric bonding or lamination is a process of uniting layers of materials through the use of adhesives or other means. Fabric lamination technology started in the 1940s and fusible interfacing for tailoring, early fabric bonding, was first introduced in Germany after World War II due to a shortage of skilled tailors who were mostly Jewish and persecuted by the Nazis (Abboud and Stern, 2005). Since then, fabric lamination has been expanding its applications from apparel to accessories, upholstery, home furnishings, tarpaulins, covers, industrial blankets, and pressure sensitive applications (Fries, 1983). However, laminated fabrics only really gained commercial popularity from the mid 1960s (Koshetz, 1965). In response to this greater consumer demand, Howard and Kaplan (1965a) introduced a new technique that allowed moulding and lamination to be accomplished simultaneously making use of the fact that both lamination and the moulding process share the same medium, 'heat'.

6.5.1 Adhesives

The adhesives used in fabric lamination are required to have wash and dry cleaning resistance, a soft 'hand', and good elongation (Fries, 1983). Therefore, developments in adhesives and their application methods are one of main focuses of interest in fabric lamination for the textile and apparel industry (Yu et al, 2006). Adhesives can be classified by their physical form or their chemical specie (Fries, 1983) and Table 6 shows different types of adhesives under these two categories.

Table 6: Two Classifications of Adhesives

Adhesives by physical form	Adhesives by chemical specie
1. Solvent-borne adhesives 2. Water-borne adhesives 3. 100% solid, vehicle-free adhesives a. Hot melt adhesives b. Plastisols adhesives c. PUR (moisture cured polyurethane adhesives) 4. Film	1. Polyurethane 2. Polyester 3. Acrylics 4. EVA (ethylene-vinyl acetate copolymers) 5. PVC (polyvinyl chloride) 6. Rubber-based 7. Nylon (polyamide)

(Source: Fries, 1983)

The performance of adhesives largely depends on two factors or properties:

i. Adhesion: Adhesion is the bond formed between the adhesive and the substrates and is affected by viscosity and surface energy. The best combination for forming an intimate wetting between the adhesive and the substrate is low viscosity with high surface energy. The surface energy of an adhesive is fixed as it is intrinsic to its chemical properties.
ii. Cohesion: Cohesion is the internal strength of the adhesive and must be sufficient over the service temperature range of the lamination in order to avoid slippage or creep, and is usually obtained through molecular weight. Because high molecular weight equals high viscosity, different curing mechanisms are adopted to create low molecular weight for initial wetting and high molecular weight for completion.

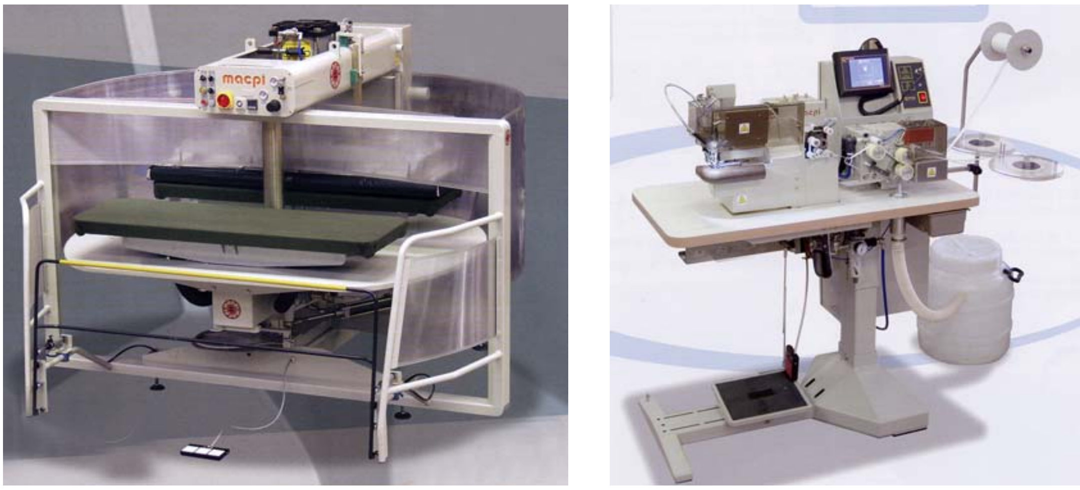
One of the most commonly used laminated fabrics in the bra industry is a thin polyurethane foam layer glued to one or two layers of cover fabrics. This flat sheet of laminated foam is conventionally used for both cut-and-sewn bra cup construction and moulded cup construction due to its shape retention and stability. Lamination not only reduces production time and cost, but also creates a smooth surface by eliminating sewing threads and seams in the same way as moulding. Freedom from sewing threads and seams has become a major focus of lamination technology and nowadays is often referred to as bonding rather than lamination.

6.5.2 Advanced Bonding Technology - Sewfree®

Thermoplastic film is another form of adhesives technology. Bemis, a pioneer and leading bonding technology company, introduced a state-of-the-art film adhesive ‘Sewfree®’ in 2002. Sewfree® is a soft, highly elastic, thermoplastic adhesive bonding tape which replaces the sewing thread and eliminates stitches from seams. Sewfree® can be used on everything from delicate and lightweight fabrics to heavyweight fabrics and on both innerwear and outerwear. Most importantly, it guarantees stretch and recovery, and bonding technology as a new construction technique makes garments look smooth and exceptionally light by omitting the need for bulky seams. Another advantage is that adhesive tapes do not need to match the colour of the fabric. Although this new technology was praised for its manufacturing efficiency (Walzer, 2003), it has the disadvantage of being rather costly due to a slower processing time, expensive adhesive tapes, and the fact that it requires highly skilled operators (Swantko, 2004). Bonding between a thermoplastic film and layers of fabric requires both heat and pressure to create a bond between the melted film and the fibre (Performance Apparel Markets, 2006) so using a well-designed and specialist machine makes a significant difference to the result.

6.5.3 Bonding Machines

Two major approaches to the design of laminating machines include the flat bed fusing machines, and continuous tape-feeding edge-bending machines. Figure 56 shows a flat bed fusing machine (a) and an edge bending machine (b) from Macpi, a leading fusing machine manufacture from Italy. Macpi offers flat bed fusing machines equipped with forming devices to bond pieces together and form a three dimensional shape, such as sleeve to armhole or crotch to crotch. The flat bed fusing machine has the advantage of being easy to control and operate.



(a) (b)

Figure 56: Flat bed fusing machine (a) and edge bending machine (b).
Source: Macpi, 2008

6.5.3.1 The Edge Bending Machine

Edge bending machines are equipped with a control panel, which can change operational parameters, and two independent wheels which feed materials with adhesive tape. These machines are also equipped with a control panel and two independent wheels. The computerised control panel changes operational parameters such as the temperature and the tape feeding speed. The two independent wheels feed materials together with adhesive tape. One disadvantage of the edge being machine is its slower processing speed because bonding can only happen when a film or tape melts and melting requires enough time to apply heat to the film or tape. Also, the speed of the feeding roller depends on not only melting point of the film or glue, but also the cooling speed of the film. The average melting temperature of bonding tapes is 130 degrees Celsius and, within this temperature, the edge bending machine can process 3 metres of adhesive tape per minute. This is significantly slower than conventional sewing where an industrial machine can sew over10 metres per minute. If there was an adhesive with a melting point as low as 95 degrees Celsius, production would be significantly faster and this is currently what the industry is working towards (Mosso, personal communication, 8th April 2008). Other significant potential disadvantages of garments produced by these machines are the often poor recovery and the poor shape retention results.

6.5.3.2 Lycra® Tape

Despite these disadvantages, adhesive tapes are environmentally safe and easy to use. Consequently, Invista, one of the largest US based integrated fibre and polymer producers, invented an adhesive tape with good recovery and shape retention, which was made from an aqueous polyurethane dispersion with a spandex fibre (Liu et al, 2006; Farmer, personal communication, 26th March 2008). This tape is scheduled to be launched in September 2008. Although the chemical composition of the tape is important for the quality of the finished garments, it is equally important to have a good releasing paper for quality production. The continuous feeding mechanism of the edge bending machine requires tape mounted on the releasing paper (see Figure 57) and for ease of operation, the releasing paper must be strong enough to endure the different speeds and tensions caused by two independent wheels (Mosso, personal communication, 8th April 2008).

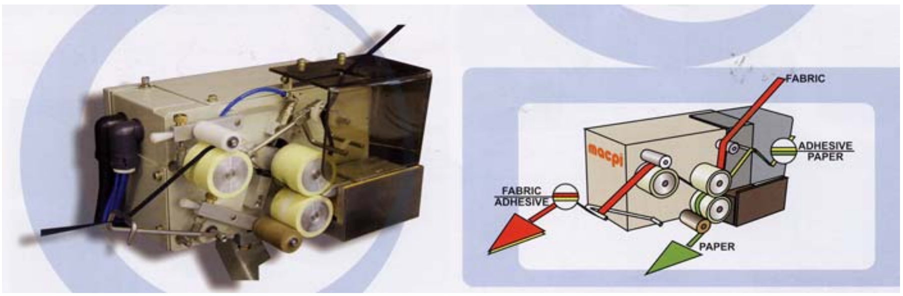


Figure 57: Adhesive tape and releasing tape on the edge bending machine. Source: Macpi, 2008

6.5.3.3 Applications of Bonding Technology

The applications of bonding technology include lingerie, active sportswear, military apparel and equipment, protective apparel, luggage, sporting equipment, and shoes. Recently, the underwear and lingerie industries are showing a decline in the use of bonding applications whilst the outerwear market is rapidly adopting bonding technologies into many applications (Mosso, personal communication, 8th April 2008).

6.6 Ultrasonic Sewing Technology

Ultrasonic technology or the use of ultrasound is the application of cyclic sound pressure with a frequency above the upper limit of human hearing which lies at approximately 20 kilohertz (Wikipedia, 2008). Its applications include medical diagnostic ultrasonography, industrial inspection, cleaning, sound navigation and ranging (sonar), and welding. A patent by Hayes in 1934 showed how ultrasound could be used as an impact tool for dental surgical procedures. Hayes (1934) described its mechanism as the transformation of electrical energy into vibratory mechanical energy. According to Vincourek (1987), the very first record of ultrasonic welding was introduced in a patent by a German firm, Siemens & Halske in 1936. Since then, progress in its development has been made in a number of different industry sectors. Carwile (1953), who is regarded as a pioneer of ultrasonic plastic welding, used ultrasound for food packaging which required minimum heat to avoid damaging the food products inside the package, and also to avoid melting the thin layers of plastic packaging sheets. Carwile claimed that it was particularly useful because ultrasound was able to weld ‘non-polar’ plastics which couldn’t be welded using electrical heating methods. Since then, inventors focused on developing methods and apparatus for ultrasonic welding in thermoplastics (Bodine, 1962; Soloff, 1968; Obeda, 1972).

6.6.1 Ultrasonic Welding for Textiles

The first implementation of ultrasonic welding techniques for textiles was shown in a patent by Minick (1978), ‘ultrasonic welding of thermoplastic fabrics’, which used ultrasonic welding to patch or seam thermoplastic mesh screens for papermaking equipment. Although this application was not designed for a fashion textile that would be worn on a 3-dimensional human body, it does demonstrate an early stage in the use of ultrasonic technology for the textile and apparel industry. Springs Industry Inc., a leading American textile company, introduced an ultrasonic trimming machine for cutting and sealing off undesirable salvage from each side of textile fabric in order to achieve an aesthetically pleasing and marketable appearance for bed sheets and apparel fabrics with reasonable durability which could withstand between 25 and 50 washing cycles (Lowery and Payet, 1985; Payet and Ballard, 1985 & 1987). However, the speed of adaptation of ultrasonic sewing technology to the garment industry appeared slow and was not fully explored. In fact, Vincourek (1987) criticised this slow progress in by referring to what he termed the general slowness of the clothing industry to take up new ideas. Table 7 shows the development of ultrasonic welding technology recorded in US patents.

Table 7: The Development of Ultrasonic Welding Technology in US Patents.

Patent #	Granted date	Title	Name of inventor
2,633,894	7 April 1953	Plastic welding	Preston B. Carwile
3,022,814	27 Feb 1962	Method and apparatus for sonic bonding	Albert G. Bodine Jr.
3,367,809	6 Feb 1968	Sonics	Robert S. Soloff
3,577,292	4 May 1971	Method for joining thermoplastic members by sonic or ultrasonic energy	Edward G. Obeda
3,666,602	30 May 1972	Apparatus for joining thermoplastic members by	Edward G. Obeda

		sonic or ultrasonic energy	
4,090,897	23 May 1978	Ultrasonic welding of thermoplastic fabrics	David G. Minick
4,496,407	29 Jan 1985	Apparatus and process for ultrasonically cutting off predetermined widths of selvages and sealing the cut edges of textile fabric	Sir. Jack R. Lowery and George L. Payet
4,534,819	13 Aug 1985	Woven textile fabric having an ultrasonically cut and sealed edge and apparatus and process for producing same	George L. Payet and Stephen C. Ballard
4,693,771	15 Sept 1987	Woven textile fabric having an ultrasonically cut and sealed edge and apparatus and process for producing same	George L. Payet and Stephen C. Ballard
6,547,904 B1	15 April 2003	Method and apparatus for welding polymer fabrics	Michael John Radley Young

The basic requirement for ultrasonic welding is that the fabric fibre content should contain at least 60 percent synthetic fibres and the range of ultrasonic frequencies for textile welding is from 20 to 40 kilohertz. Herrmann, Branson, Cera France, Rinco and Telsonic manufacture ultrasonic welding and cutting machines, and Figure 58 shows some of these. The machine consists of a horn and an anvil, and the anvil can be stationary or mobile with a wheel. Normally the wheels have patterns to imprint on the textiles. The fabrics placed between the horn and the anvil will be exposed to high frequency mechanical vibrations which will create frictional heat at an interface in order to melt thermoplastic and bond two fabrics. Ultrasonic welding is fast, clean, and economical as there is no sewing thread involved (Vincourek, 1987; Shi and Little, 2000; Branson, 2008).

Figure 58: Ultrasonic welding machine. Source: Rinco, 2008

Vincourek (1987) claim that ultrasonic welding for textiles started as an attempt to eliminate sewing thread from the textile assembly when the synthetic and thermoplastic materials and their blends became widely available in the industry.

6.6.2 Non-stitching Bonding Methods

There are two other joining methods, thermal bonding and laser enhanced bonding (LEB), which don’t involve sewing threads and can be considered similar to ultrasonic welding.
In thermal bonding, the thermoplastic surfaces of parts to be joined are melted individually through direct contact from the heat sources and then put together. The main disadvantage of this method is the risk of fibre degradation because of the excessive heat applied (Shi and Little, 2000). In LEB, THE bonding agent becomes part of the bonded materials by laser force and creates impermeable, flexible, environmentally friendly and long-lasting seams (Adhesives Age, 1995; Neff, 1994).

There are a number of shared advantages or characteristics of these three bonding methods. The thermal, LEB and ultrasonic methods are all free of sewing thread, permit a continuous joining area (no seam allowance hanging), and form an impermeable (sealed) seam compared to traditional sewing methods. The sealed edges and seams prevent the penetration of chemicals, liquids, blood-borne pathogens, and particulates, thus providing major benefits over conventional stitching methods, particularly for medical and similar applications. Consequently, these fast, clean and economic joining and sealing methods are frequently used to produce protective garments, disposable hospital gowns, shoe covers, face masks, infants' nursery garments, underwear, filters, bags, curtains, sails, and web splicing (Branson, 2008).

6.6.3 Parameters for Ultrasonic Welding

Since the weld ability of a thermoplastic textile is related to its structure, melt point, modulus and other additives, identifying and analysing the characteristics of the materials to be welded is essential. Shi and Little (2000) recommended two basic requirements for suitable materials for ultrasonic welding. Both materials to be welded should have similar melting points, or within 22 degrees Celsius of difference, and they should also have similar molecular structures which are chemically compatible. In addition, there are a number of governing factors affect the ultimate strength of ultrasonic sewing (see Figure 59). Ultrasonic sewing strength is correlated with thermal energy (temperature) at the interface. In order to achieve the strongest bond, the best combination of welding time, amplitude of vibration, and welding pressure need to be identified for each fabric before mass production.

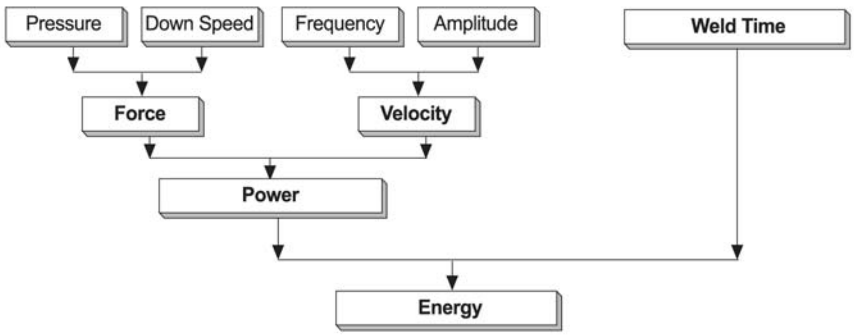


Figure 59: Governing factors of ultrasonic welding strength.
Source: Shi and Little, 2000

The thermal conductance of individual fabrics also affect welding strength by changing both the peak temperature and the rate at which it changes (Shi and Little, 2000; Walther, 2005). Modern bra manufacturers are gradually becoming more experienced about the effects of the physical and chemical properties of materials on ultrasonic boding strength. This is emphasised by Sia (personal communication, 14th March 2008) who showed how fabrics in different colours demonstrated different ultrasonic bonding results when some failed the garment pulling strength tests at the hook and eye joint points.

6.6.4 Ultrasonic Welding for Bra Construction

Today, the bra industry utilises ultrasonic welding technology in its production, not only for bonding, but also for sealing and edge finishing. Figure 60 shows some commonly used ultrasonic welding operations, such as a shoulder strap and slide assembly (a), shoulder strap attachment at the platform (b), ring attachment (c) and eye tape (d).

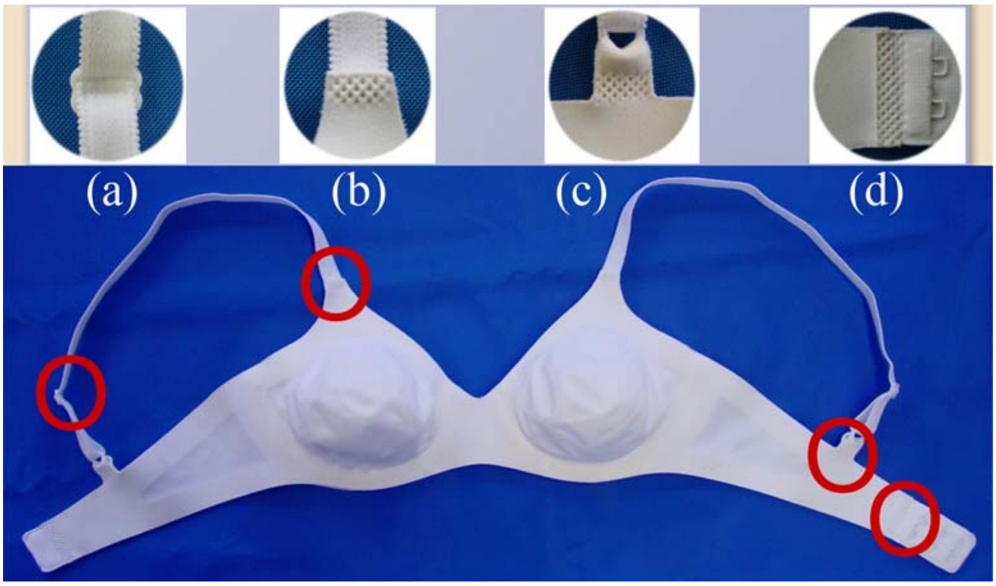


Figure 60: Shoulder strap slide (a), shoulder strap at platform (b), ring (c) and eye tape (d). Source: Walther, 2005

Walther (2005) pointed out that jointing points can become hardened due to plasticisation and suggested the embossing method shown in Figure 60 for a softer hand feel at the joint points. Table 8 summarises the major advantages and disadvantages of ultrasonic welding.

Table 8: Advantages and Disadvantages of Ultrasonic Sewing

Advantages	Disadvantages
1. No sewing thread cost 2. No needle overheating for synthetic fabric sewing 3. Option of having sealed seams 4. No trimming thread ends 5. Noise free operation 6. No seam puckering 7. No danger from needle puncture 8. No special training for operators 9. Boost energy efficiency	1. No natural fibre materials. Must use material blended with 60% synthetic /thermoplastic fibre 2. Configuration for every different materials required 3. Plasticisation at the joint points

6.7 Seamless knitting Technology

Knitting has a long history evidenced by the fact that, as early as 200 AD, a knitted fragment was found near the Euphrates River. As discussed in previous chapters, knitting techniques were introduced to Europe by the Arabs in the 5th Century. Since that time, knitting has progressed into a major textile industry. The first knitting machine was invented by William Lee, an English pastor, in 1589 and its basic principles remain unchanged in all modern knitting machines. A seamless circular knitting machine was invented in the mid 19th Century (Britannica, 2008) and companies such as Moses Mellor and G. Blackburn & Co, Peget & Co. Ltd, Scott & Williams and William Cotton & Co. Ltd. further developed circular knitting machines and fully fashioned knitting machines.

6.7.1 The Origins of Seamless Knitting Technology

The origins of seamless knitting technology can be traced back to Kenneth Macqueen (1962) who introduced a flat knitting machine which selected appropriate needles automatically using electronic impulses generated by a scanner. This flat machine produces complete fully fashioned knitted garments. Since then, seamless knitting technology has slowly progressed in Europe and Japan. For example, Shima Seiki introduced the first automated knitting machine for seamless gloves in 1965, Protti introduced individual electronic needle control in 1969 and Stoll introduced computerised knitting machines (ANV machines) with pattern versatility in 1975. Various V-bed flat knitting machines which were introduced in the 1970s are regarded as the direct forerunners of the current seamless knitting machine. The invention of the tension-free knitting presser foot in 1975 took seamless garment development to a new level and whole garment knitting became possible with simple designs by the early 1980s (Performance Apparel Markets, 2006).

6.7.2 Revolutions in Seamless Knitting Technology

Today, seamless knitting technology refers to a knitting technology which is capable of creating entire garments with minimal or no post operations of cutting and sewing (Choi and Powell, 2005). Santoni, a pioneer in seamless knitting machine production from Italy, started developing electronic circular knitting machines in the early 1990s, and has since been a leader in the whole seamless garment area. In fact, Santoni became a generic global brand name for the seamless knitting garment. Other seamless circular knitting machinery companies are Sangiacomo from Italy, and Okuma from Japan. Consequently, seamless knitting technology has grown significantly from the areas of socks and hosiery to the areas of sportswear, swimwear and underwear. The market share of seamless garments increased by seven percent in 2002 from a mere one percent of knitted production in 1997 (Robert, 2002). Many brands such as Adidas, Banana Republic, Calvin Klein, DKNY, Nike, Patagonia, Speedo, The Gap and Victoria's secret have incorporated seamless technology into their product development and the current top six seamless apparel producers are Tefron Ltd (Israel), Sara Lee (America), Scalina (Brazil), Delta Galil (Israel), Illuna (Italy) and Pompea (Italy). Currently, sportswear and active wear are rapidly growing areas for seamless knitting technology, but intimate apparel still accounts for a 65 percent share of the total seamless market. Amongst intimate apparel garments, the bra remains a major area of focus for seamless knitting technology even though, knitted bras, or bra-like garments, are not a new concept and have a long history of development.

6.7.3 Knitted Bras

A patent by Pike (1892) first suggested a knitted construction for creating the bust cup for female underwear and both knitted fabrics, and knitting techniques, were commonly used for underwear in the 19th Century. Rutledge (1932), an assignor to the Vassar Company, patented a knitted bra made of elastic yarns in order to eradicate undue constriction or compression. His bra consisted of two seamless pieces, a front and a back, which were sewn together at the side. William Rosenthal (1935a-c), the founder of the Maidenform bra, patented two improved bra making methods and a bra with two seamless cups using a circular knitting machine with a new stretch frame although bras with fully fashioned seamless cups were first introduced by the Vassar Company (Rutledge and Davidson, 1938; Davidson, 1946). By the early 1960s, fully fashioned knitted bras and swimwear had gained widespread popularity (Gordon, 1961a & 1961b; Goff et al; 1961; Levine, 1963; Rinehart, 1963; Braxton et al, 1970; Epley, 1970;) and Knohl (1969) incorporated a tubular, jersey knit with elastomeric yarns for stockings, girdles, bras and bandages. Although it was possible to knit complete garments on a V-bed flat knitting machine, the industry initially combined this with the cut and sew method for production, having not yet fully refined or explored the technology. For example, a tubular knitted fabric also known as ‘blank’ was cut and sewn to create a seamless bra in a tubular shape (Richards, 1985: Osborne, 1996).

After the introduction of the Santoni circular seamless knitting machine, intimate apparel manufacturers adopted this advanced technology for bra production because it can eliminate between 30 and 50 percent of the makeup procedures in bra production by avoiding cutting and sewing (Lam, 2005; Performance Apparel Markets, 2006). However, seamless knitted briefs have become more popular than seamless knitted bras in the industry (Yu et al, 2006) because bras require reasonable support levels for heavier breasts and a single double layered knitted bra, without additional supporting devices such as wires, do not work well. Table 9 shows progress in the development of seamless knitted bras as recorded in US patents.

Table 9: Seamless Knitted Bras Patents

Patent #	Granted date	Title	Name of inventor
482,097	6 Sept 1892	Knit undergarment	Joseph H. Pike
1,863,697	21 June 1932	Brassiere	George E. Rutledge
1,988,516	22 Jan 1935	Means for making brassieres	William Rosenthal
1,988,517	22 Jan 1935	Method and mean for making brassieres	William Rosenthal
2,013,110	3 Sept 1935	Brassiere	William Rosenthal
2,121,489	21 June 1938	Knit breast pocket for garments and method of producing same	George E. Rutledge and Roy H. Davidson
2,397,247	26 March 1946	Breast pocket for brassieres	Roy H. Davidson
2,608,078	26 Aug 1952	Foundation garment and elements	Carroll R. Anderson
2,969,622	31 Jan 1961	Knitted garment with breast cups and method of making	Barnett D. Gordon
2,976,708	28 March 1961	Knitted garment with breast cups	Barnett D. Gordon
2,966,785	3 Jan 1961	Full-fashioned knitted brassiere	Clarence David Goff, Elkins Park and Walter S. Detwiler
3,092,987	11 June 1963	Element of apparel and method of making the same	Alex Levine
3,103,111	10 Sept 1963	Body bulge receiving cup and method of	Arthur H. Rinehart

		making same	
3,226,957	4 Jan 1966	Elastic knitted form-fitting undergarments	Barnett D. Gordon
3,425,246	4 Feb 1969	Protuberance covering tubular elastic garments	Herbert Knohl
3,500,665	17 March 1970	Full-fashioned brassiere and blank	Ralph C. Braxton, Glenn R. Schoffner, Alex Levine & Ida Levine
3,537,279	3 Nov 1970	Knit seamless brassiere and method of forming same	Preston C. Epley
3,772,899	20 Nov 1973	Seamless brassieres and brassiere blank	Giuesppe Novi
4,531,525	30 Jul 1985	Methods of knitting brassiere blank, manufacturing brassiere, and products	Mark S. Richards
5,479,791	2 Jan 1996	Brassiere blank, brassiere and methods of making same	Harold G. Osborne

6.7.4 A Summary of the Advantages of Seamless Garment Production

The growing popularity of seamless whole garment technology is inevitable because it offers a reduction in production costs, lower yarn consumption, flexible production, improved 'just-in-time' deliveries, higher quality, and added value (African Textiles, 2000), whilst the consumer enjoys generally greater comfort and a better fit with natural drapes and silhouettes. Kopell (2005) identified well-being and comfort as two long-term winning benefits of seamless apparel. Choi and Powell (2005) claim that seamless knitting will be one of the largest next generation knitting technologies largely as a result of the following potential benefits:

i. Minimising or eliminating the labour intensive cutting and sewing process
ii. Savings in production times and cost
iii. Minimal yarn consumption
iv. Higher productivity
v. Multi-gauge knitting
vi. Lightness and softness
vii. No bulky and irritating stitches or seams
viii. More constant product quality
ix. Better trim-ability for finished edge lines
x. Better look, better fit and more comfortable

xi. More creative possibilities for knitwear designers
xii. Quick-responses production for size and pattern changes
xiii. Just-in-time production
xiv. Mass customisation

6.7.5 Yarns for Seamless Knitting

Nylon is the mostly widely used yarn for seamless knitting and is estimated to account for a 63 percent share of this still growing market (see Table 10). Polypropylene is a newly emerging yarn in the seamless market and the consumption of polyester yarns is expected to grow continuously in the near future because of the growth in the sportswear sector. However, polyester yarn suppliers need to improve the elasticity of polyester which remains prone to damage from the dyeing process.

Table 10: Yarn Consumption in Seamless Market (tons)

Year	1977	2004	2005	2010
Nylon	1,444	23,870	25,666	27,300
Spandex	289	5,651	6,254	7,340
PES	39	3,768	4,650	5,780
Cotton	50	2,637	2,918	3,200
PP	19	377	417	520
Others	10	150	650	1,010
Total	1,850	36,453	40,555	45,150

(Source: Kopell, 2005)

In summary, the use of new and improved innovative yarns will expand the market share of seamless products in the apparel industry, and close collaboration with innovative brands or designers will lead to further success in this area of rapid market expansion.

6.8 Material Trends

It is not only the use of new technologies for production that has helped fuel success but also the use of increasingly innovative smart materials has helped companies compete against fierce competition and business trends that have turned towards the ethical trade, involving eco-friendly production with sustainable materials. As a result, the intimate apparel sector has begun adopting eco-friendly and so-called smart materials along with the new and advanced technologies discussed in the previous sections.

6. 8.1 Eco Friendly Materials

Eco friendly materials are defined as recycled, renewable or sustainable materials which are free from both harmful chemicals and compounds. Furthermore, these materials should be produced through a manufacturing process which limits the negative impact on the environment (Specialty Living, 2008) Eco friendly, or environmental friendly, materials, and ethical clothing manufacturing became an issue among consumers and clothing manufacturers in recent years as a result of the growing awareness and popularity of the global warming and climate change phenomena. Therefore, materials such as organic cottons or eco-friendly initiative textiles have been used by producers to add more value to the end product. Common eco-friendly alternative fibres used in underwear include bamboo, Ingeo™, Lyocell/Tencel®, Modal, organic cotton, Seacell® and soy. The following are the key characteristics of each material:

6.8.1.1 Bamboo: Bamboo is a grass fibre harvested from the wild. Bamboo grows easily without the use of pesticides and fertilisers. Bamboo fibre is thermal regulating, anti-fungal, anti-static and UV resilient. It is a natural anti-microbial fibre due to its agent ‘bamboo kun’ which prevents bacteria from growing. Bamboo fibre is soft and silky and keeps a wearer dry and comfortable in a hot and humid climate due to its excellent absorbent qualities which are 3 to 4 times better than cotton. However, the growing popularity of bamboo fibres has created other environmental issues such as preserving or protecting wild habitat, as well as air and water pollution related to the chemical processing of bamboo. Consequently, Broudy (2005) recommends further investigation into how green bamboo really is in terms of environmental protection. Although it is a relatively new material for clothing, many clothing companies have produced bamboo underwear for some time. C-IN² introduced bamboo briefs for men. 2(X)ist, an American men's underwear brand, introduced underwear out of carbon fabric made from burnt bamboo charcoal powder infused into polyester yarn. Claiborne, North Face, Cosabella, Perry Ellis and DKNY have also introduced underwear made out of bamboo fabric. Chantelle, Elita, Fantasie, Hanro, Green T and Lucy introduced bras made out of bamboo fabric whereas Bamboosa produces clothing only made from bamboo fabric.

6.8.1.2 Ingeo™: Ingeo™, a trademark of Cargill Dow, is the world's first man-made fibre derived from 100% annually renewable resources such as corn nut oil. Ingeo fibre is based on a proprietary polymer derived from fermented plant sugars. It possesses UV resilience, flame retardant properties, anti-pilling, low odour retention, stain resistance and excellent wicking capabilities. Strength and resilience are balanced with comfort, softness and drape in these textiles due to its similarities with both natural and synthetic fibres (Natureworks, 2008). Its insulating properties and dryness make it suitable for bedding, mattresses, pillows and duvets and it blends well with natural fibres such as wool and hemp, adding a silky appearance and strength to the fabrics. Its weaknesses are a low breaking point and low melting point (Childers, 2004). Ingeo has also been used for underwear. Verdissima, an Italian underwear and beachwear brand, produced a nightgown made of 100 percent Ingeo fibre and Docare, a Chinese underwear brand, produced Ingeo and cotton blend briefs for both men and women, whereas Wicker, a US performance underwear brand, produced camisoles, tank tops for women, and T-shirts and briefs for both men and women.

6.8.1.3 Lyocell/Tencel®: Lyocell is a cellulose fibre made from wood pulp by an organic solvent spinning process. Its production is a closed loop solvent spinning process and all solvents remaining after processing are continuously reused, which minimises pollution to the environment. Lyocell is 100 percent biodegradable and Tencel® is a trademark of Lenzing Inc for Lyocell. It offers desirable properties such as soft touch, anti-microbial functions, durability, natural cooling and moisture management. Tencel® absorbs 50 percent more moisture than cotton and guarantees optimum conditions for the skin (Lenzing, 2008). Tencel® is widely used in underwear due to its soft hand-feel, outstanding moisture control and anti bacterial properties.

6.8.1.4 Modal: Modal is a bio-based cellulose fibre derived from beech trees, which actually falls under a sub-category of rayon. Modal textiles do not fibrillate or pill, and are resistant to shrinkage and fading. The hand or feel is soft and smooth and, as a result, many intimate apparel manufacturers use Modal fabrics. Modal is also the main textile used in the 'Supersoft' style of panties in the 'Angels by Victoria's Secret' collection, the Flaunt series in 'aussieBum' underwear, sleepwear by 'Gap Body', the 'Micro Modal' line for men by 'Calvin Klein', dresses by 'Kiyonna' and items in 'Lululemon Athletica's' casual line. 'La Senza' uses Modal in a variety of panty styles. Old Navy also uses Modal in their sleep wear and clothing lines.

6.8.1.5 Organic Cotton: Organic cotton refers to cotton that is not genetically modified, and is grown without using pesticides and chemical fertilisers which impose a threat to the environment. The artificial fertilisers, pesticides and chemicals used in cultivating and processing cotton are a major source of pollution to soil, air and water. Organic cotton makes up only 0.03 percent of the world's cotton supply but is rapidly growing as sales of US and Canadian organic fibre products increased 40 percent year on year in 2005, amounting to an annual total of US$160 million (Organic Trade Association, 2008). According to Pepper (2007), organic cotton was grown in 22 countries in 2004 and 2005, led by Turkey (40 percent), India (25 percent), the United States (7.7 percent, grown in Texas, California, New Mexico and Missouri), and China (7.3 percent). Although organic cotton is environmentally friendly and demand for it is growing, it remains relatively expensive to produce and is extremely water intensive. Brands which use the most organic cotton globally in 2005 include Nike, Coop Switzerland, Patagonia, Otto, and Sam's Club/Wal-mart (Pepper, 2007). Companies adopting a particular philosophy of green living and an ethical lifestyle and offering organic cotton bras and briefs include online retailers such as Janice's (www.janices.com), Blue canoe (www.bluecanoe.com), Gaiam (www.gaiam.com), and By Nature (www.bynature.co.uk).

6.8.1.6 SeaCell®: SeaCell® is a cellulose-based fibre which is based on the Lyocell structure using seaweed substances manufactured through the Lyocell process. The structure of SeaCell facilitates the active exchange of substances between the fibre and the skin, including nutrients such as calcium, magnesium, and vitamin E. Therefore, it is designed to create a complete sense of well-being. Other smart fibres offered by Smartfiber AG are smartcel™ clima, smartcel™bioactive, smartcel™energy, smartcel™ filaments, and smartcel™ ceramic. Smartcel™ clima can help regulate body temperature by absorbing and disposing of excessive body heat, whereas Smartcel™ bioactive kills bacteria and viruses in a natural way by using ions released from silver. Smartcel™ energy achieves consistent infrared warmth in textiles at relatively low energy consumption and Smartcel™ filaments and smartcel™ ceramic clearly have a wide variety of possible applications in the apparel industries (Smartfiber AG, 2008).

6.8.1.7 Soy: Soybean protein fibre is chemically processed like bamboo and has the lustre of silk with excellent draping qualities. Processed soy has a soft, light, and smooth feel similar to a silk and cashmere blend and possesses a higher breaking point than wool, cotton and silk together with good moisture absorbance, and excellent moisture transmission/ventilation, better than that of cotton, with excellent colour fastness. 2(X)ist, an American men's underwear brand, introduced the first line of soy underwear in 2006.

6.8.2 Smart Materials

Smart materials have one or more properties that can be dramatically changed in terms of viscosity, volume, or conductivity following certain condition changes in magnetic stress, moisture, temperature, and pH and include piezoelectric materials, electrostrictive, and magnetostrictive materials, rheological materials, thermoresponsive materials, pH-sensitive materials, electrochromic materials, fullerences, and smart gels. Intelligent gels, ceramics, alloys, and polymers are emerging smart materials with potential applications in the underwear market. Amongst these smart materials, shape memory polymers and shape memory alloys are already being used for the intimate apparel industry and are effectively thermoresponsive materials because the deformation and recovery of their shapes occur through temperature changes.

6.8.2.1 Shape Memory Foam: Memory foam is made from polyurethane with additional chemical additives. The extra substance is added to increase viscosity level and, as a result, the density of the resulting foam is increased. It is sometimes also known as visco-elastic polyurethane foam and the difference between 'normal' foam and memory foam is that the latter not only compresses, but also moulds to the shape of the wearer (Memory foam reviews, 2008). Memory foam with a higher density responds to body heat and moulds itself to the shape of a warm body within a few minutes whereas memory foam with a lower density responds to pressure and moulds itself to the shape of body. It is firm in cool temperatures and soft in warm temperatures. The 'Natural Accents Memory Foam bra' was introduced by Playtex early in the new millennium and this bra reacts to the wearer's body shape and temperature creating tailor made fit and comfort.

6.8.2.2 Shape Memory Wire: A mix of roughly 50 percent nickel and 50 percent titanium, (NiTi) is the most commonly used shape memory alloy. Shape memory alloys are now used for many applications including medical devices, orthodontics, eyeglass frames, mobile phone antennas and, more specifically for our purposes, the underwire component of the bra. It possesses extraordinary characteristics such as shape memory and super-elasticity. Super elasticity refers to the ability to recover from large amounts of strain and a NiTi bra can fully recover from strain values up to 8%. Shape memory is a design function of the material's temperature characteristics which occurs because nickel titanium undergoes a phased transformation when the material is heated or cooled through its temperature transition range. When it is cooled, it becomes pliable and can be formed into almost any required shape and then when it is warmed, it remembers the programmed shape and returns to it (UltimateNiTitechnologies, 2008).

6.9 Conclusion

This chapter has reviewed the development and applications in the underwear industry of four major technologies (moulding, bonding/lamination, ultrasonic welding and seamless knitting technologies) and two materials (eco friendly and smart materials) which have contributed significantly to modern bra production. These technologies are capable of being used separately or in combination. The advent of seamless and stitch-less technologies is rapidly changing the face of the industry because they involve either no sewing at all or a significantly limited sewing process. Seamless technology began as a result of attempts to get rid of cutting and sewing procedures, but, as a result of developments from these technologies, the clothing manufacturing process is becoming faster, more efficient, and more economical for manufacturers, and facilitating the production of textiles that are both more aesthetically pleasing and functionally capable.

The concept of seamless technology with minimal, or no sewing at all, attracted the underwear sector which has been quick to adopt these advanced technologies into their production lines to help them meet consumer demand for a comfortable second skin effect without the use of, what are increasingly being regarded as, unsightly seams. Despite the excitement surrounding these developments, there have been a number of challenges to overcome for bra manufacturers in particular. For example, the balance of achieving appropriate levels of tension amongst the supporting devices, and the integration of each component of the garment, were initially inferior to those of a conventional cut and sewn bra. Even today some of these challenges remain, and, for example, it is known that the wires sandwiched in a one-piece moulded bra are incapable of supporting large breasts in the same way as wires firmly held inside a cut and sewn bra using channelling tapes. However, the one piece bra remains in great demand and can now be regarded as an historical turning point in bra history. With growing concerns over global warming, the demand for eco-friendly or environmentally friendly ‘green’ fibres as well as smart materials has also been growing considerably over the last decade. These materials achieve physical and psychological comfort for consumers whilst using manufacturing processes which do not pollute the environment.

All these technologies and materials have been integrated and incorporated into underwear industry practices in to create new bras for a new generation of technology and ecology-conscious consumers. Given the current frenetic pace of development and change, it is becoming more difficult to predict what will be the next hot technology or material for bra production because technology is now making many more innovations possible, and those in the bra industry are constantly pushing hard to be the first to market a new technology, material or design.

In the next chapter, the development of patternmaking for the bra, and similar garments is considered because this is the one very technical area which remains crucial despite the developments discussed in this chapter.

CHAPTER 7
THE HISTORY OF BRA PATTERNMAKING

7.1 Introduction

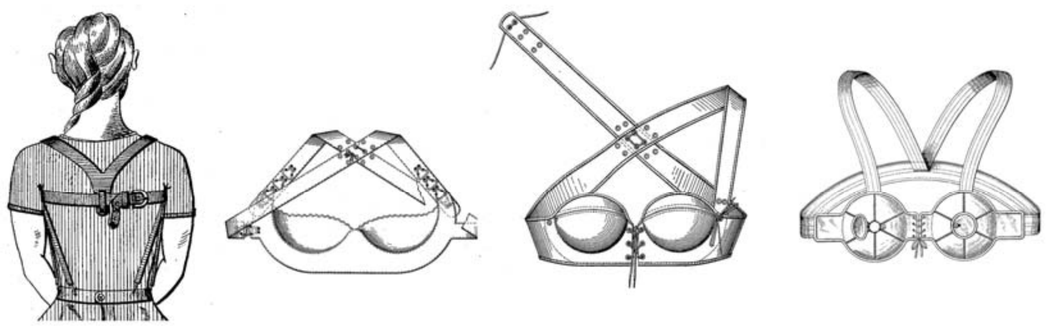
The art of brassiere or bra patternmaking is not generally well known except amongst skilled practitioners from the underwear industry. The specialised machines, attachments and raw materials required to make a bra largely prevent interested parties, including researchers, educators and home sewers, from studying more about the detailed process of bra patternmaking. Technological developments, and industry security relating to new patterns and designs, has led to a distinct sense of secrecy currently surrounding bra patternmaking to the extent that Shin (2007) referred to patternmaking in this area as a 'dark art'.

In this chapter, the developmental history of the bra will be further examined by way of a review of bra patent records from the late 19th Century to the early part of the new Millennium. A total of 1,671 United States patents are reviewed primarily because of the major contribution made by United States inventors in bra development. Significant changes in design, materials, production methods, fasteners and accessories are considered together with the impact these had on the bra patternmaking process.

7.2 The Mid 19th Century to 1899-Early Foundations for the Bra

This period can be considered the time when the first modern bra evolved, and the 'breast supporter' and 'bust supporter' with shoulder straps became particularly popular in this era with the available patent information demonstrating a growing demand for functional and aesthetically pleasing breast supporters together with an unprecedented growth in efforts from inventors and entrepreneurs. Consequently, developments in patternmaking achieved during this period laid the foundations for modern bra construction designs and techniques. Indeed, some designs for early breast supporters bear significant similarities to the modern bra. For example, the ‘mammiform and protector’ by Marshall (1864) and the ‘bosom pad’ by Libbey (1868) already show a distinct resemblance to the shape of the modern bra. However, garment construction methods of the time remained rather primitive and consisted of a simple pair of metal wires or rings covered with rubber or other non-textile materials which required very little sewing. Despite these differences, the foundations for the shape, and some aspects of the construction of the modern bra were laid.

Figure 61 shows examples of four late 19th Century breast supporters. Marie Tucek got credit for inventing the first modern bra in 1893 (Farrell-Beck and Gau, 2002) but it is interesting to note that Mortimer Clarke also patented a modern bra-like garment called the ‘combined breast and skirt supporter and shoulder brace’ (Figure 61a), nine years earlier than Tucek’s invention in 1884. It can be seen from Figure 61 that the designs from this era are characterised by shoulder straps in the shape of the letter X, and the use of fastening devices like buckles, buttons, laces and eyelets. The terminology for modern bra construction also began to evolve at this time as well as some of the forerunners of modern cup and seam construction methods. These developments are now considered in more detail.



a) Clarke (1884) b) Tucek (1893) c) Tucek (1894) d) Murray (1899)

Figure 61: X-shape of shoulder straps on the back from the US patent application.

7.2.1 The Cross Back or ‘X’-shape Design

In this design, the shoulder straps are both positioned and attached very closely together on the back panel, or the straps are crossing to form a distinctive X-shape at the back of the garment as shown in Figure 61. This design was adopted in order to assist with securing the garment in one place because all of the garment components were then made of fairly rigid materials with less ‘give’ or stretch than is currently the case. In addition, the fastening systems used during this period for breast supporters and similar garments were usually fairly rudimentary buckles, buttons and buttonholes, eyelets and lacing, because the use of modern fasteners such as hooks and eyes had not yet been adopted by the underwear industry.

7.2.2 Bra Terminology and Construction Methods

The terminology for the pattern components which make up the bra, trims and accessories, became increasingly sophisticated during this time largely due to the increased pace of development in both designs and materials. For example, bra cups began to be referred to as either ‘enlargements’ (Stout, 1886), ‘breast covers’ (Murray, 1899) or ‘pockets’ (Clarke, 1884; Stout, 1886; Lendry, 1893; Tucek, 1893 & 1894; Busby, 1909). The modern term ‘cup’ was first used for a detachable breast portion in a United States patent entitled ‘Corset’ by Mary Lyons in 1898. This detachable cup design concept marked revolutionary thinking for that time, and demonstrated the industry’s recognition of the need for a bra design which could be made to fit a variety of different size breasts. Since patent applications from this era were generally rather vague in their descriptive content, this allowed inventors not only to protect, but also to stretch their legal rights to develop a broad range of designs, and this makes it difficult to extract the exact patternmaking methods used. However, some figures provided in the patent applications give a more detailed insight into the development of construction methods, particularly in relation to how they designed to accommodate breast volume through innovations in bra cup construction. In practice, two major patternmaking methods were employed to facilitate the formation of a three dimensional cup shape during this period. These were the use of ‘slashing’ and the addition of extra or intermediate gusset style pieces, and using style lines for joining the seam lines. These are now described in more detail.

The processes of slashing and adding extra pieces can best be described by reference to the construction of the breast supporter or ‘the prototypical modern brassiere (Farrell-Beck and Gau, 2002)’ by Luman Chapman in 1863 who used the slashing and adding extra pieces method to construct the bra cup. This breast supporter was equipped with the major necessary elements of a modern bra, including a pair of elastic shoulder straps, and a pair of soft three dimensional cups which were intended to free the breast from all the other fit restrictions imposed by the bra design. Essentially the cup was formed from a two dimensional pattern and pieces were cut and fitted together to form a three-dimensional shape with the use of slashes or darts to achieve a rounder shape.

The use of style lines is best described by reference to Marie Tucek's breast supporter where a style line is formed when two seams are joined. She was the first to employ a style line (joining cup line) to create a full cup bra with a front opening in her design of the 'breast supporter' in 1894. This involved the recommendation to incorporate a topstitching line on both sides of the cup joining seam in order to make the cup shape rounder and avoid a 'pointed' shape and appearance. She also recognised the importance of making the cradle shape a good fit along the breast roots, a method which is currently still used in the underwear industry. A bra cup constructed using many two-dimensional pieces to form a three-dimensional shape, comparable to the design of a stitched football, was also used in Tucek's technique. One example of this is the 'breast shield' by Murray (1899) which features a cup constructed with six segments with a cap for the area of the nipple. One of the purposes of this bra was to allow easy access for nursing a child, particularly important in a cold climate because it allowed access to the nipple without the necessity of removing the whole bra.

In summary, the breast supporters produced during this era were designed to give support to the breast, unlike the late 19th Century corset, which was unable to provide adequate support because of its inherent design characteristics which included a lower corset height. This is another reason why the length of the breast supporters from this time was necessarily short because they needed to cover only the breasts themselves and the top of the corset which was remained in common use. The other significant design feature of a 'full round cup shape' reflected what was commonly regarded as the ideal breast shape during this era. Whilst detailed information about bra design during this period is generally in short supply, it is nonetheless clear that both bra design and pattern development were already set to accommodate differences in breast volume whilst also providing support for the weight of breasts. This marked a significant change in emphasis which set the scene for design and technological developments which would lead to the design and construction methods we currently still see in the modern bra.

7.3 The 1900s

Overall, bra designs from this period remained relatively short and simple in their form and shape, whilst retaining a reasonable level of functional support. Despite earlier developments, only four patents, including three breast supporters and one dress shield, are available for review from this period of time (Figure 62). Other bra-like garments with different functions, including breast pads and the advent of artificial breasts, have been omitted from this review because their production did not involve what might be regarded as true patternmaking and sewing construction consistent with, and preceding modern bra design and construction methods.

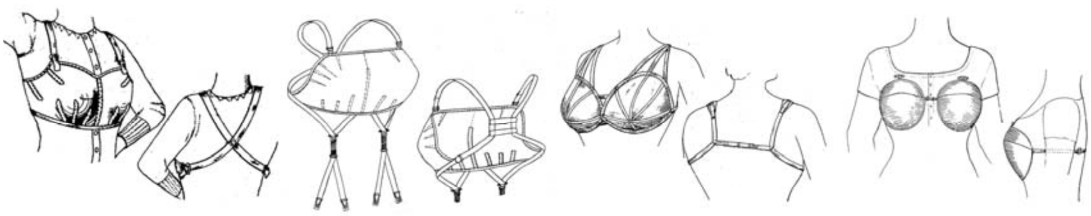


Figure 62: Breast supporters in the 1900s.

7.3.1 Cup Construction Methods

Darts were now commonly employed to form the 3-dimensional concave breast shape during this era, but the methods of slashing and adding extra pieces common in designs until this time, are no longer found in patents from the 1900s. The increased use of darts can be described by reference to Beeman (1903) who introduced a breast supporter with cross shoulder straps on the back forming an X-shape (Figure 62a). Buckles were used in order to fasten the shoulder straps to the bust section and a total of five darts, two at the armhole and three under-bust darts, to construct each bust section. Another bust supporter patented by Kellogg in 1907 is similar to Beeman's but attaches suspenders at the front (Figure 62b), and features a cross back which is more akin to the racer back of the modern bra. The word 'dart' is used in this patent indicating that the term was now probably being widely used in the industry before being recorded in a written form.

The use of style lines is illustrated in a bust supporter designed by Busby in 1909 which features a design which predicts much of the shape of a modern bra consisting of two cups, shoulder straps, a straight back strap with a front opening, and a back strap with snap buttons (Figure 62c). The back fastening system was specifically designed to adjust the back length for different wearers and provide appropriate support directly from the shoulder. Each cup was constructed from eight sections and, although it resembles the modern bra with some very practical design features, it has a rather peculiar cup shape which gives the breasts the appearance of drooping due to the relatively shorter lower cup height incorporated into the design. A breast shield for nursing mothers designed by Kleinert (1909) offers a very simple alternative design concept because its only function is to protect the corsets, gowns, and other apparel from staining due to the dripping breast milk of nursing mothers (Figure 62d).

7.3.2 Terminology

The fastening systems used for breast supporters still included the use of buckles, buttons or studs and button holes, eyelets and lacing, but now also incorporated the use of clasps and snaps. The terms 'spring socket' (female) and 'knob' (male) now came into use for the snap button fasteners and the so-called 'take-up buckle' appeared in a patent 'breast shield' by Kleinert in 1909 roughly equivalent to a contemporary adjuster 'slide'. This fastener allows wearers to adjust both front centre distance and the whole body circumference by easily sliding the 'take-up buckles' at the centre front and the centre back respectively. This demonstrated that differences in centre distance between breasts, a theme taken up in the major quantitative study in this thesis in relation to differences between Asian and Western body types, had finally registered with the bra inventors and entrepreneurs of the 1900s (Thompson, 1906; Kleinert, 1909). This particular aspect of bra fit remains largely ignored today, except in relation to cup size, and underscores the importance of understanding the history and development of underwear and of recognising the fact that every female body is different, especially the size weight, shape and consistency of the breasts, making fitting requirements for the bra in the contemporary global environment a challenging area.

In Summary, despite a distinct lack of patent records, it remains clear that, during the 1900s, the design of the bra and the associated growing underwear industry continued to move forward at a relatively steady pace. This is evidenced by the new emerging terminologies for the pattern, including the increased use of darts akin to the modern equivalent, and progress in the development and use of a wider range of fasteners and adjusters indicating a recognition of the importance of fit to the bra design and patternmaking industries.

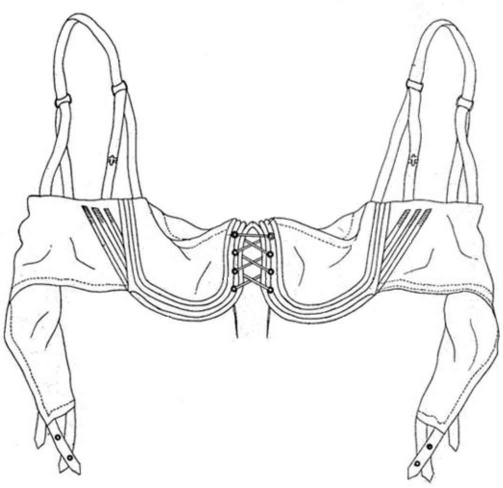
7.4 The 1910s

A review of patents from this period makes it clear that some terminology such as ‘breast supporter’, ‘breast waist’, ‘brassieres’, ‘bust supporter’, ‘corset cover’, ‘stay’ and ‘waist’ tended to be used interchangeably and without distinction (Lowman, 1919) and also that a greater variety of shapes and designs became available. The length of the brassiere in this period generally became longer in order to achieve the fashion of a smoother silhouette by overlapping the edge of this garment with the upper part of the still fashionable low-waist corset. This means that the majority of breast supporters and brassieres from this decade look like a composite of a corset and a camisole, and therefore only a small number of breast supporters and brassieres can be properly regarded as forerunners to the modern bra. This decade also saw the use of vertical panels with supporting bones inserted along joining seams, similar to corset construction, introduced for the first time into bra construction. Despite these challenges, and the lack of clear distinctions between styles, there were nonetheless some important developments during this decade worthy of more detailed consideration. One of these was the invention of an early form of the underwired bra.

7.4.1 An Early Form of the Underwired Bra

Whilst the wire had been used in breast supporters since the 19th Century to support and protect the breasts (Marshall, 1864), an underwire which follows a similar design and performs the same function of the modern underwire was patented by Gabeau in 1911. This underwire was described as an outlining metal band with an inverted V shape in the centre which would mould and separate the breasts into a more natural shape (Figure 63).

This particular breast supporter also employed other metal devices, such as three busks on each band to provide adjustable support from the shoulder straps. This development marked one of the first truly ergonomically well designed underwired brassieres but unfortunately, the inventor failed to adequately describe the cup construction method, giving only a vague description that it consisted of a "formed textile covering".



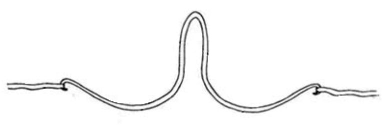


Figure 63: Breast supporter, an early form of the underwire bra. Source: Gabeau, 1911

The term 'wire' was used for the first time in a patent application for a bust supporter invented by Martell and Payne in 1912. The shape resembles the modern wire including the innovation of a rounded tip at the end and the size of cup could be adjusted by simply bending the wire to accommodate breasts of different sizes. The whole concept of providing support for the breasts began expanding in this decade, and the direction or source of support was normally from underneath the breasts in order to control and support the weight of each breast. Hain (1914) introduced another way of support by applying a curved metal plate over the bust in his patent breast supporter and this metal 'over bust plate' is the earliest form of the overwire approach to bra design which became much more popular in the 1940s. However, the key difference between the design of this over-bust plate and the 1940s overwire is that the former was designed to prevent the straight pull caused by shoulder straps whilst the latter was designed in order to form a cup shape at the neckline for strapless bras. At this time, most breast supporters still have the look of a composite of a corset and camisole, and to date there was little progress in forming a truly 3-dimensional cup shape.

7.4.2 The Adjustable Centre Piece

One of the features which inventors and entrepreneurs strongly emphasised from their breast supporter patent applications was adjustability. They clearly understood that it is important to fit a multitude of body shapes and sizes, in particular a wide variety of breast sizes. Consequently, fasteners such as hooks and eyes, buckles, clasps, snaps, slides and buttons began to be employed to function as adjusters, as well as fasteners, at the shoulder straps and centre back. Although many breast supporters feature a front opening by employing a fastening system on the centre piece (gore) at the sternum, this particular fastener did not serve as an adjuster until Oliver Dennis (1912) introduced an adjustable buckle on the front straps which made it possible to adjust the position of the cups to provide a better fit for the wide variety of breast sizes and shapes. Once again, this was an important innovation in modern bra history because, as will seen later in this thesis, the distance at the sternum between breasts can vary considerably from woman to woman and can impact significantly on the final bra fitting result. A front opening brassiere patented by Lowman in 1919 can also be categorised as an adjustable centre piece design but the main purpose of this particular invention was purely easy application and removal using safety pins as a fastening system.

7.4.3 Crossover Design: The X-factor

Another bust supporter designed by Hacker (1918) consists of a continuous elastic string encircling the body, with a hook and eye fastening system. The elastic string passed under the breasts and crossed at the sternum, forming an X-shape on both the front and back. Hacker (1918) claimed that this was useful in gymnasium work because it holds breasts firmly against ballistic movement whilst simultaneously providing sensations of cooling, comfort and support. Although this design required an underlay garment, it effectively demonstrates the starting point for the crossover design which is capable of shifting and distributing the weight of breasts without undue compression.

In summary, whilst the key developments of this decade include the use of a wider range of fasteners and adjusters and the use of a bra 'wire' enabled progress to be made in terms of bra shape and support, it remains difficult to identify what additional design developments took place in this era because construction methods, particularly of the bra cup, were not generally shared. Therefore, despite the innovations identified in this section, this decade can be regarded as a dark period for bra pattern development which continued until the end of the 1920s whilst the long waist length breast supporter managed to maintain its popularity.

7.5 The 1920s

The so-called flat chest 'flappers' and the music of jazz dominated the 1920s fashion scene. Consequently it became fashionable to achieve a flat chested look in keeping with the outerwear fashion trends of the decade. Therefore, the majority of popular brassieres were designed to compress the breasts rather than support them, and to achieve the flat-chested appearance so in vogue during this decade (Rothstein, 1924). All the terms commonly used for the breast supporter, including 'breast supporter', 'breast waist', 'bust supporter', 'corset cover', 'stay' and 'waist' became all but obsolete in the late 1920s and were replaced by the term 'brassiere' which was dominantly used by the end of this decade to describe underwear for the upper torso.

7.5.1 Silhouette and Construction Methods

The length of brassieres continued to increase toward the level of the waist and a strip with a hook or other fastening system was introduced to secure the brassiere to a corset or other foundation garments (Figure 64) and give a more fashionable smooth and sleek looking silhouette. Therefore, not surprisingly given this quest for sleekness, this was the decade that saw the hook and eye supersede other fastening methods to become the most popularly used fastening system for the bra, something which has persisted to the modern day. Methods of shaping also became more diverse and sophisticated despite the previously slow progress in terms of silhouette and style with inventors and entrepreneurs proactively seeking methods to construct bras primarily to support the breast.

Fashion demands from this decade meant that the use of darts, style lines, tucks and gathers became a common part of the design lexicon in order to achieve the fashionable and highly sought after silhouette of the era. The use of darts and style lines meant it was possible to create a smooth and sleek surface around the bust, whilst the use of tucks and gathers created a bulkier appearance with fullness around the bust.

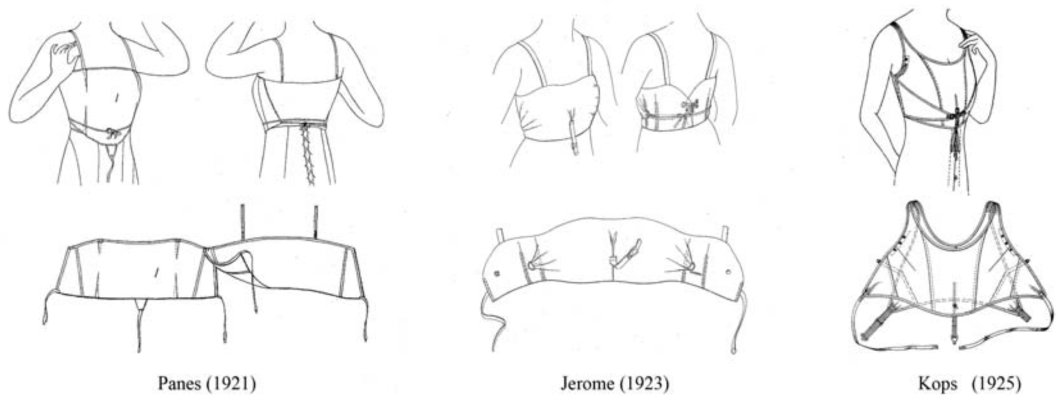


Figure 64: The brassieres for flappers in the 1920s.

Darts were by this time popularly used to accommodate the fullness of the breasts and both mid-shoulder and waist darts were commonly employed in bra construction. Whilst the position and number of darts was carefully considered, there were no rules found for the length, the position of the dart pivotal point, or the folding direction. In the midst of these developments, it was at this time that the centre dart was adopted for the first time for bra construction. Oppenheimer (1920) patented a 'bandeau bra and chemise combination' which was shaped with three underarm darts on each side. These three underarm darts could be sewn by a customer after the sale of the garment to ensure a close fit. The centre dart was first employed by Roth (1922) who was soon followed in this innovation by Monrose (1924) and McKeefrey (1925) (see Figure 65). The use of a centre dart became a novel way to hide a seam in places where it is important that any bulkiness in the bra is not detected under the outer garment.

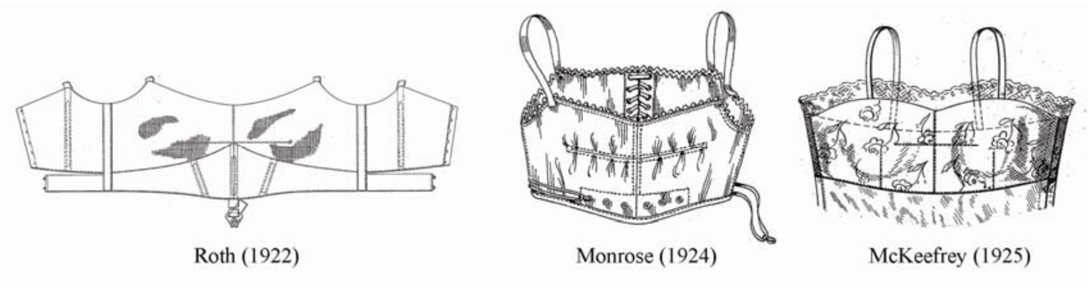


Figure 65: Dart manipulations, the advent of the centre dart.

The use of gathers was a design technique also popularly used at this time to accommodate the fullness of the breasts. The most common place where gathers were used was at the centre front of the bra where potentially bulky fabrics could be hidden without bulging (Gladstone, 1924; Haven, 1926; McKeefrey, 1926; Rosenthal, 1927b; Hirsch, 1928; Standish, 1928; Yerkes, 1929; Cunningham, 1929). Rosenthal (1927a) identified gathering as a commonly employed method for cup construction during this period and suggested replacing this gathering, also known as shirring, with style lines and darts to create the more fashionable sleek look. As previously described, the style line is a joint of two seams and the most commonly used style line in the 1920s was called the shoulder princess line which was used to create a smooth surface.

Around this time, few inventors and entrepreneurs started the trend of adding the pattern pieces to their patent applications, and the first patent application featuring pattern pieces was 'brassiere' by Roth (1922). This application displayed a figure of a partly sewn bra which depicted the shape of the pattern pieces. The complete garment is shown in figure 65. Other patents featuring pattern pieces are ‘bust support’ by Negri (1924), ‘bust former and supporter’ by Espinosa (1926), and ‘brassiere’ by Rosenthal (1927a). Negri’s ‘bust support’ was composed of a pair of upper cups, a pair of lower cups and a pair of back pieces (Figure 66). These patterns were carefully designed so that when they were laid on the fabric, the over bust seam would be placed at a bias to give an elasticity and some adjustability for the cup, whilst the under band was cut straight on the grain line to give support without the need for additional supporting devices such as whale bones or stays. This bra designs and patterns of the late 1920s now clearly begin to demonstrate a close resemblance to those of the modern soft bra.

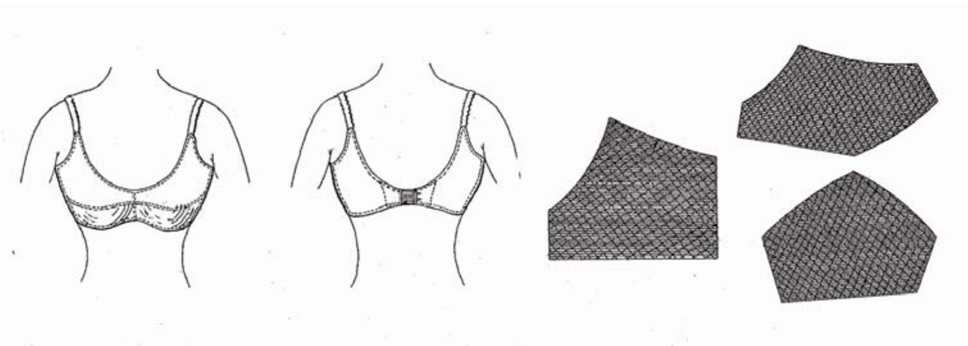
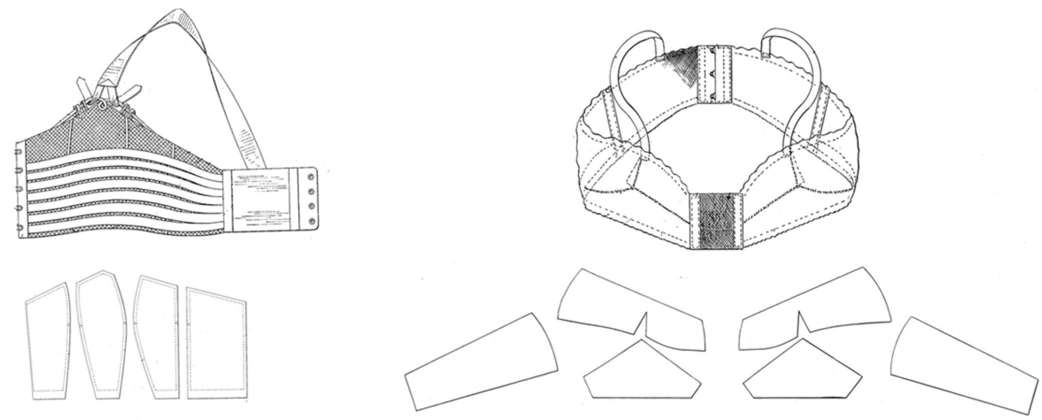


Figure 66: Early soft bra with pattern pieces. Source: Negri, 1924

The Espinosa (1926) patented ‘bust former and supporter’ was composed of eight panels for the front and side and two back panels, adjusted with eyelets and a lace. The purpose of this invention was to retain the natural shape of breasts. It fastened at the centre front with a hook and eye binding and could be adjusted with the lacing at the back. Two vertically curved style lines were employed to form a contoured cup shape, and the seam allowances and hem allowances were marked with a dotted line. The matching notches were labelled on the seam allowance along the cut lines and the more detailed nature of this patent information shed some light on pattern making practice for 1920s brassiere manufacturing. Rosenthal’s (1927a) patent for a new bra construction method also yields valuable cup construction detail. Figure 67 shows one half of the bust former and supporter by Espinosa, and a complete set of pieces for the brassiere by Rosenthal.



Espinosa (1926) Rosenthal (1927a)

Figure 67: Two influential 1920s brassiere patterns.

7.5.2 Breast Separation and the Centre Piece or Gore

One particularly important and relevant innovation was discovered as a result of attempts to achieve a more fashionable silhouette by separating the breasts through the use of the bra. Separation of the breasts also proved to be an effective method to hold breasts against the body. Schloss (1920) applied a rigid shield with an inverted V-shape at the top centre of his brassiere, which can be regarded as an early form of the centre piece or gore. Although Schloss identified the importance of keeping a good shape by compressing protruding flesh, he failed to relate this idea to breast separation despite the fact that both the shape and function of his innovation are similar to those of the centre piece for the modern bra. Freeman (1926) also emphasised the separation of the breasts in order to achieve better support even though her invention did not share similarities in shape to that of Schloss. McKeefrey (1926) introduced a bandeau style bra sewn with an inner cradle (a centre piece and side panel combined) and Cunningham (1927) applied a rigid centre piece to add more compression to the brassiere. Ulman (1928) applied a cradle shape in her invention ‘combination corset and brassiere’ and Rose (1929) invented a ‘lady’s undergarment’ with a shaped lower torso which depicts the shape of a cradle. The importance of this innovation should not be underestimated in terms of its impact upon modern bra design and construction. The role of the gore or cradle for the modern bra is critical because it holds the breasts close to the body and provides support together with the shoulder straps. Therefore, this development can be regarded as a highly significant step forward towards modern bra design and construction.

Despite the increasing attention on the centre piece and its development, bra designs from the 1920s clearly indicate that understanding of the female body was not yet fully developed and remained rather speculative. For instance, a 'brassiere' by Wood (1926), a 'bust supporter' by Farkas (1927), a 'brassiere bust supporter' by Imershein and Ginsburg (1928), and a 'brassiere' by Leuchtag (1928) were constructed with a wide centre piece between cups whilst a 'brassieres' by Morrison (1928) and Whippy (1929) were constructed with a relatively narrow centre piece between the cups. Despite the vagaries and speculative nature of some of these designs, it is nonetheless important to recognise that the industry was now really beginning to move forward in a more scientific way, albeit involving trial and error.

Separation of the breasts was also accomplished with the use of built-in pouches or 'slings' on the inside of the brassiere. Both the purposes and shapes of this kind of separation varied considerably (see Figure 68).

Figure 68: Slings in the 1920s.

Bosky (1921) was the first to introduce two square shaped patch pockets to a wide bandeau style brassiere in order to confine potentially pendulant breasts, whilst achieving a fashionable flattened appearance by giving the appearance of reducing breast size. Gladstone's (1924) innovation added two half circle cups to the inside of the brassiere in order to avoid possible irritation and chaffing to the wearer's skin, whereas Whippy (1929) created a pair of quarter moon shaped pouches by the novel invention of utilising the top of the elastic under band at the cup joining seam, which also served to prevent 'creeping' or movement of the brassiere.

7.5.3 Crossover Design: The X-factor

Voliva (1924) patented a bra which consists of a top with two wide bands crossing at the centre front and continuing under the bust and over the shoulder, then crossing at the centre back. In a patent application for a 'brassiere', Voliva (1924) explained the main purpose of the invention was to relieve the strain on the muscles by holding the bust in a more natural position without pressing, binding, or flattening. Although this bra does not resemble the modern bra design, the innovative concept of supporting breasts' through the distribution of their weight to the opposite shoulder has persisted.

In summary, despite a rather slow start because of a preoccupation with long camisole-like brassieres, the 1920s brought exciting developments which further set a solid foundation for modern bra design and patternmaking. The most significant bra pattern developments from this decade were generally achieved as a by-product of efforts to create the fashionable silhouette of the era by separating the breasts. This led to the realisation that this process also provided benefits in terms of breast support and, together with the persistent development of the crossover design, bra designers and pattern makers began to pay attention to providing both a desirable shape and comfortable support, in line with the demands of today's consumer.

7.6 The 1930s

Despite many earlier versions of the bra being designed to accommodate the fullness of the breasts, the 1920s bra has often been roundly criticised for the compression imposed upon the breasts by a flat outer cup surface (Lowenfeld 1930; Klopfer 1931; Gifford 1932). Of course, this development was mainly due to the desire to achieve the fashionable boyish figure of that decade (Rasch 1938). Finally, natural and youthful curves returned to the outer wear fashion scene in the 1930s and consequently, bra inventors and entrepreneurs turned their attention to seeking ways to create a natural and youthful bust profile which nonetheless retained the interest in achieving the look of breast separation popularised in the 1920s. The simple patch pocket form of sling of the earlier decade progressed into a more stylish and complex form and the bra with sling were used to separate the breasts, whilst a pair of shoulder straps was used to provide uplift and support. The sling was particularly recommended for pendulous or sagging breasts and came with the promise of a fashionable contour with no compression. Despite a range of diverse designs and construction techniques, the slings from this decade can generally be categorised into four major groups:

1. A separate moon shaped pocket attached only at the bottom of each cup (Figure 69a).
2. A crescent shaped band attached at the front centre, front hem and sides (Figure 69b).
3. A body encircling band (Figure 69c).
4. A hybrid style incorporated with shoulder straps (Figure 69d).

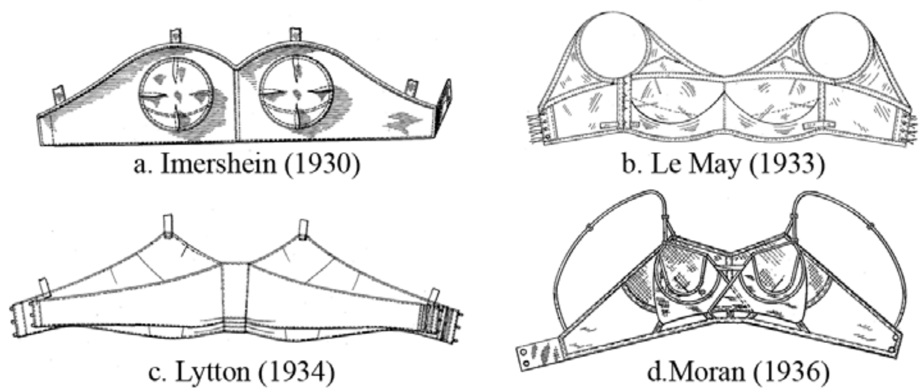


Figure 69: Four different types of slings from the 1930s.

Table 11 shows the number of 1930s patents with slings, categorised into the four different groups identified above. Other types of garment such as the bathing suit are also included in Table 11 because of their relevance to modern bra design and pattern making.

Table 11: Types of Sling Patents from the 1930s

Type of sling	Name of invention	Name of inventor	Patented date	Patent number
Moon shape pocket	Bust supporter	Imershein, M.	25 Feb 1930	1,748,715
	Brassiere	Frieland, H.	28 April 1931	1,802,464
	Bathing suit	Maier, W. G.	27 Oct 1931	1,829,100
	Brassiere	Haimoff, D.	1 Sept 1936	2,052,707

Crescent shaped band	Bust uplift	Le May, A. M.	18 April 1933	1,904,644
	Corrective brassiere	Clancy, P.	28 Nov 1933	1,937,008
	Brassiere	Spare, L.	12 Jan 1937	2,067,354
	Brassiere	Witkower, M.	30 Nov 1937	2,100,890
Body encircling under band	Brassiere	Lytton, R. K.	12 June 1934	1,962,314
	Garment	Julius, E.	28 Aug 1934	1,972,045
	Brassiere	Greenbaum, B.	12 March 1935	1,994,359
	Brassiere	Kunstadter, S. W.	7 Dec 1937	2,101,716
	Brassiere	Freedman, R.	22 March 1938	2,112,151
	Adjustable brassiere	Freedman, R.	25 April 1939	2,155,935
Hybrid style incorporated with shoulder strap	Brassiere	Alexander, M. R.	15 Sept 1931	1,822,872
	Brassiere	Rose, H. D.	8 Nov 1932	1,886,742
	Bust supporter	Gifford, J. C.	13 Dec 1932	1,890,507
	Brassiere	Moore, C.	10 March 1936	2,033,847
	Woman's garment	Moran, P. J.	16 June 1936	2,044,623
	Brassiere	McKeefrey, E. C.	21 July 1936	2,048,638
	Brassiere	Rosenthal, W. & Sachs, C. M.	26 April 1938	2,115,397
	Brassiere	Rosenthal, W.	26 April 1938	2,115,398
	Brassiere	Rubinstein, A.	7 March 1939	2,149,819
	Brassiere	Walters, A.	10 Oct 1939	2,175,676

Whilst the sling was a popular design feature providing both separation and support, achieving separation through use of the gore appears to have been superseded by the 1930s crossover design to the extent that some bra cups from this era were actually joined to each other directly at the centre without the use of either gore or cradle. The crossover design also became popular for its diagonal support function of supporting and uplifting the breasts by transmitting the strains caused by their weight without compression.

7.6.1 Crossover Design: Diagonal Support

The provision of diagonal support, also known as 'yielding support' (Lowenfeld, 1930; Kemp, 1938; Yerkes 1938; Gluckin, 1939), was heavily utilised at this time for creating maximum support whilst maintaining a feminine contour, more precisely the cone-shaped breasts which were so popular in the 1930s. In total, 18 crossover designs can be found from the 1930s United States patent information. 15 of these are straightforward and fall into the diagonal support design category described earlier, whilst some are modified in order to fulfil a range of different purposes including creating a low back (Kennedy, 1933), changing into many styles and adapting different cup sizes (Park & Martin, 1935), and prevention of shoulder strap slipping (Kemp, 1939). Figure 70 shows some typical 1930s crossover bra designs with yielding support built into the design concept.

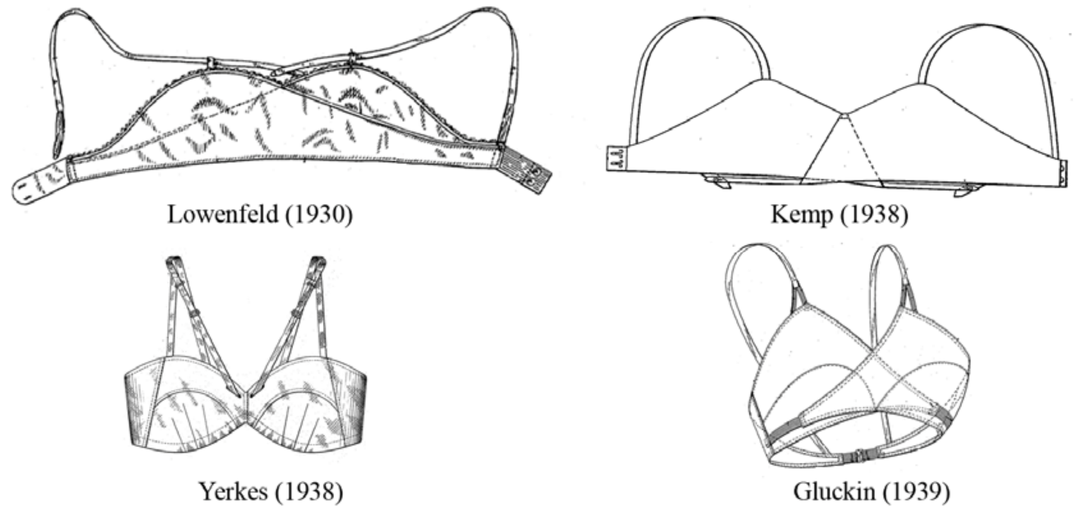


Figure70: Examples of the 1930s crossover bras.

Pattern design development in the 1930s made significant progress with the advent of many new and innovative designs. In addition to breast separation and crossover design, adjustability became another area of focus which inventors began to address. A method of using flexible stitch formation as a connector between components was introduced in this decade in order to facilitate the fitting of different breast sizes, as well as allowing ease of movement (Weiner, 1934; Amyot, 1937). Of particular relevance is the addition of elastic tape material at the gore to provide further flexibility. The use of supplementary supporting techniques, such as wires around the breasts (Alberts, 1935), and stays at the bottom cup, together with multilayer fabrics reinforced by stitching also became increasingly popular at this time.

7.7 The 1940s

Key design concepts from the 1930s were repeated in the 1940s but with the advantage of better materials and production technology. During this decade, both moulding and lamination technology were fast becoming growing areas of interest to underwear designers and manufacturers as a result of the growing materials revolution. The fashion trend of a womanly figure continued to be emphasised throughout this decade, and the bra industry responded to this trend. Consequently, the term ‘uplift’ came into popular usage and this is reflected in descriptions of patents from a number of inventors and entrepreneurs. Other terms such as ‘contour’, ‘youthful’ and ‘natural’ were also frequently used in patent applications and publicity materials to describe the pointed but separated breast profile of the 1940s. Adjustability also remained a key design feature and most bras produced during this period came equipped with adjustable components which included shoulder straps, cups, and bands.

Further innovations in wire design were also influencing bra design and patternmaking practices as designers made efforts to incorporate this new supporting component into their bra designs. For example, the strapless bra was made possible largely through the use of wires which made it possible to support the breasts without the need for shoulder straps, and overwires set in along the neckline also became very popular for use with the ubiquitous low cut evening gowns which arrived on the outerwear fashion scene (Bowen, 1948; Schaumer, 1949).

7.7.1 The Birth of the Long-line Brassiere

The term ‘long line brassiere’ was introduced in the 1940s (Berdach, 1943) when changes in the length of this garment was motivated by the fashion for creating a wasp-like narrow waist (Clermont, 1941), the need to perfect the fitting process (Kaupp, 1941), create breast uplift (Panes, 1946), and demonstrate the youthful and natural breast position all of which was precisely expressed in the trend-setting ‘New Look’ by Christian Dior in 1947. Amongst a wide range of long-line bras introduced at this time, some illustrate a rather unique design concept which is worthy of particular attention. For example, a patent ‘brassiere’ by Berdach (1943) is constructed with two separate symmetrical half bras connected at the side of the waist with an adjustable hook and eye tape. This allowed the fitting of different body shapes whilst maintaining a constant breast size. Berdach (1943) claimed that the ‘perfect fit’ could be achieved when other body measurements are accommodated, in particular waist measurement. Becker and Becker (1943) patented a long line bra with diaphragm and abdomen control adjusting straps which was designed to ease the tension around the mid-section when wearers are seated. Gerace (1946) patented a long line brassiere with a pair of slings with which wearers could modify the contour of the breast by adjusting the size of both slings and the height of outer cups at the platform. Becker and Becker (1949) patented an improved version of their 1943 brassiere which allowed automatic waist circumference adjustment by adopting the use of an elasticised band instead of straps with adjusters.

Harvey (1949) patented a bra which had a pocket where the wearer could hide valuable belongings, and the term ‘uplift brassiere’ was used for the first time by Edelston (1947) in a patent ‘brassiere’, which consisted of a long-line bra with a V-shape opening at the upper portion of the cup. Each V-shape opening was laced with a drawstring which was connected to a shoulder strap. When the drawstring was pulled by the shoulder strap, the opening of the cup automatically adjusted to naturally and evenly fit the wearer’s breasts.

7.7.2 The Material Revolution and its Impact on Bra Design

Body moisture, or more specifically sweating around the breast area, had long been recognised as a problem by bra designers and inventors and many attempts had already been made to change the micro-environment within and around the bra which was responsible for both discomfort and unpleasant odours. Williams (1940) patented a ‘lady’s health brassiere and health protector’ which was designed to destroy the odours caused by perspiration through the use of a chemical pad and Bullinger (1941) introduced a brassiere with bottom cups made from a flannel laminated with a water insoluble rubber to withstand and mask perspiration. Blum (1941) introduced the innovation of perforations on the lower cup lining in order to facilitate the free flow of air and improve ventilation. Later, Amyot (1946) followed up this idea by patenting a bra with a centre joining seam formation which also helped facilitate the ventilation of the brassiere. Later still, Florsheim (1949) patented a bra with a plastic-coated fabric which contained perforations to help vent the moisture, and coincidentally this plastic coating also helped to rectify some of the issues related to cup design up until this point, namely that bra cups tended to be either too soft or too stiff.

7.7.3 Breast Separation

The emphasis on the separation of the breasts continued in this decade and three methods were commonly used to achieve this effect:

1. The employment of a rectangular centre gore. McKeefrey (1941), Schoebel (1949), Wittenberg (1949) and Kriz (1949) employed a pair of reinforcing cut-out pieces which outlined the breasts and a centre gore in order to facilitate breast separation.
2. The employment of a pair of slings. The sling, which became popular in the 1930s, has by this time been modified and blended into the crossover design (Table 12). However, there still remain a small number of designs featuring the sling alone as a means of support and separation.
3. The employment of the crossover design. The concept of yielding support was continued in 1940s bra pattern design and the terms ‘adjustable support (Rasch, 1947)’ or ‘independent support (Gluckin, 1947)’ were interchangeably used with ‘yielding support’ (Lo Cascio, 1948).

Table 12 shows those patents which focused on the adjustable, yet yieldable support approach to design. These designs appear similar to the 1930s crossover designs with some slight improvements because the concept and basic bra shape did not change significantly despite the developments in materials and technology.

Table 12: Crossover Design Patents in the 1940s

Name of invention	Name of inventor	Date	Patent number
Brassiere or similar garment	Glick, J.	28 Dec 1943	2,337,810
Brassier	Cohen, D. I.	21 Nov 1944	2,362,974
Brassiere	Gluckin, E. W.	17 April 1945	2,374,093

Brassiere & similar garments	Gluckin, E. W.	16 Sept 1947	2,427,402
Brassiere	Redares, R. J.	2 Dec 1947	2,431,829
Brassiere	Gluckin, E. W.	23 March 1948	2,438,210
Brassiere	Glasser, A. A.	13 April 1948	2,439,567
Brassiere	Moon, A. M.	20 July 1948	2,445,449
Brassiere	Glick, J.	21 Sept 1948	2,449,808
Brassiere	Glick, J.	16 Nov 1948	2,454,151
Brassiere	Glick, J.	16 Nov. 1948	2,454,153
Brassiere & similar garment	Gluckin, E. W.	21 Dec 1948	2,456,695
Brassiere	Glick, J.	26 April 1949	2,468,621
Brassiere or similar garment	Gluckin, H.	26 April 1949	2,468,623
Brassiere & similar garment	Gluckin, E. W.	24 May 1949	2,470,847
Brassiere	Witkower, M.	11 Oct 1949	2,484,440

7.7.4 Wire Development and its Effect on Bra Patternmaking

This is the time when the two different types of bras, the soft bra and wired bra, became firmly established, and many variations of these bras were patented. The wire shapes in the 1940s were very diverse and there were, at this time, no set rules for wire placement, although inventors did pursue the creation of a wire which was easy to use and cheap to produce (Ax, 1946). This wire was placed either under the bust, over the bust, and/or at the inner bust circle. Wire designs were more imaginative in this decade because wires generally served as a cup shaping and forming device rather than as a supporting device in the way they are used in modern bra design. The 1940s innovations in the use of wire nonetheless made significant contributions to bra pattern development, in particular in relation to gore construction.

7.8 The 1950s

The clear new trend for the 1950s was ‘moulding’ of the breasts. The style of bras from this era were similar to designs from the 1940s, and it is largely because the main players and inventors from the previous decade continued their developments in the 1950s that bra design became more stable in style and continued to repeat some design elements over a longer period time.

7.8.1 The Conical Cup with Spiral Stitching and the Advent of an Intermediate Layer

One interesting feature from this era was the design of the conical cup which was constructed with reinforcing stitches in a range of different patterns and formations including concentric, spiral, helical, radiant, horizontal, vertical and criss-cross patterns, with single, zigzag, or chain stitch formation. Normally, this conical cup was made of four sections. Gluckin (1950 & 1951) argued that the direction of the stitches was an important design factor because the reinforcing stitching was used to provide the rigidity and stability which gave additional support. Gluckin (1950) recommended vertical stitching for extreme uplift effects and horizontal stitching for firm yet comfortable support. This pointed cup shape with its component reinforcing stitches increased the sales of bras (Froehlich, 1953), and this became the most fashionable bra during the 1950s. Figure 71 shows examples of such a bra with spiral stitching on the conical cup.

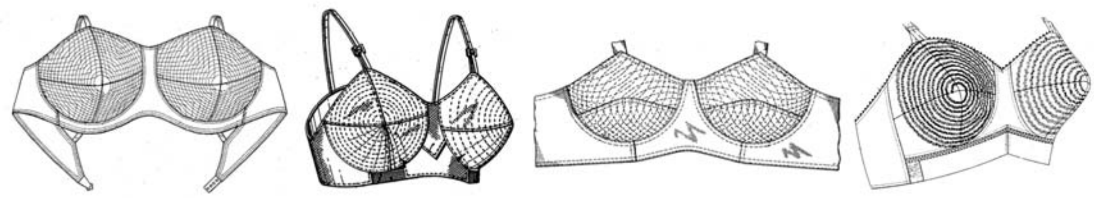


Figure 71: Examples of the 1950s bras with spiral stitching on a conical cup.

The beginnings of this four sectioned cup can be found in a patent called ‘brassiere and method of making same’ by Plehn in 1946. He recorded that the trend of a four sectioned cup with reinforcing stitches, normally spiral stitching, was adopted in order to produce better form-fitting, breast moulding, and breast supporting cups because more conventional bra cup materials remained rather flimsy and flexible. Schaumer (1952) explained that spiral stitching enabled his invention to achieve a firm moulding of the breasts whilst maintaining comfort when compared to the conventional bra, even under conditions of vigorous movement.

Up to this point in history, bra cups were constructed using a single layer of material and the concept of using an intermediate layer in order to strengthen the cup only started in the 1950s. Whilst there had been many attempts to create breast pads, which were generally used as an insert with the aim of creating a natural breast projection, the search for better cup construction materials became an increasingly hot issue among inventors at this time. In fact, the use of an intermediate cup layer for moulding, supporting, and retaining breasts barely existed before the 1950s and a patent 'brassiere' by Gluckin (1955) which featured an intermediate cup layer constructed with four sections of porous sponge rubber intended to assist with cup shape retention. During this decade, Witkower (1955) also applied a soft yieldable rubber-like material as an intermediate or reinforcing sheet at the lower half of each cup, together with reinforcing stitches, which added more stiffness to the cup component. However, the rather thick characteristics of the intermediate layer materials such as foam rubber, latex and sponge rubber led to a puckering or quilting effect when the reinforcing stitches were applied onto the multiple layers of intermediate materials. Furthermore, these materials effectively shrank the cup dimensions so, in order to rectify these problems, Verreault (1956) introduced a triple line of an 'r' shaped looping stitch formation in order to improve the circumferential flexibility of the bra cup material. Then, one year later, Verreault (1957) suggested the zigzag stitch formation for the helical, parallel rows of stitching for the bra cup with intermediate materials, in order to eliminate the quilting effect in the circumferential direction, as well as shrinkage of the bra cup.

In summary, the introduction of spiral stitches enabled the effective use of intermediate materials which can be regarded as equivalent to the padding used in modern bra design. Before the advent of spiral stitches, bras were normally composed of a single layer of material, unless the design incorporated slings or flaps which were not exactly built-in or integrated as a cup layer. The problems associated with the thickness of the intermediate layer materials, forced bra manufacturers to diversify into the different kinds of stitch formations such as loop stitches and zigzag stitches.

7.9 The 1960s

The uplifting conical spiral stitched bras of the1950s were criticised for their lack of comfort and adjustability (Kahn, 1962) and consequently many inventors and entrepreneurs tired to find ways to support the breasts whilst allowing reasonable free movement without any strain around the breast tissue in order to achieve a comfortable fitting. As a result of this movement, the Y-shape of an integrated neckline and gore frame (Figure 72) became a distinct feature of bra in the 1960s.

7.9.1 The Frame Concept or Neckline and Gore Integration

The idea underpinning this particular design concept was to bring the bra cups closer to the body around the cup itself by using a connected neckline and gore piece. The word 'frame' was introduced by Guberman (1965) to refer to this integrated neckline, gore and side assembly. It acts to anchor the bra cups and sides closer to the body and creates a tighter fitting around the neckline whilst also transferring the weight of the breasts to the shoulder strap.

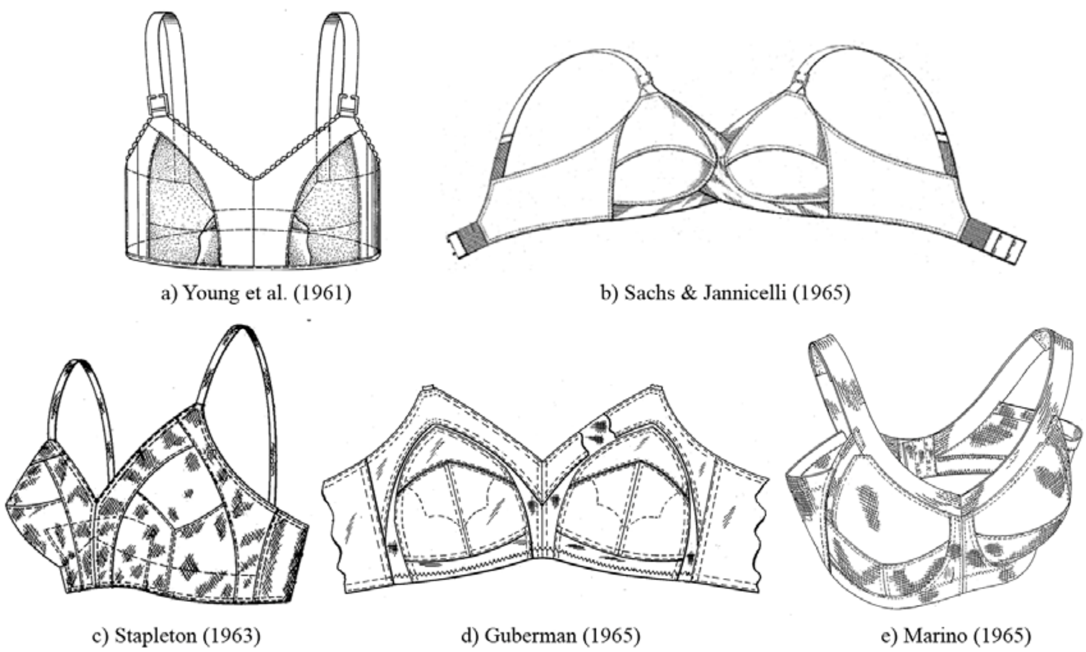


Figure 72: Examples of the 1960s 'framed' bras.

In common with many other designs, the other components and the shape of the framed bra varied greatly but the variety of styles can generally be categorised into five major groups:

1. A frame consisting of neckline and gore (Figure 72a).
2. A frame consisting of neckline, gore and front underband (Figure 72b).
3. A frame consisting of neckline, gore and side (Figure 72c).
4. A frame consisting of neckline, gore, front underband and side (Figure 72d).
5. A frame consisting of neckline, gore, front underband, side and shoulder strap (Figure 72e).

These five design and other variations tended to dominate cutting-edge 1960s underwear trends and this domination is illustrated in Table 13 which shows the bra patents from the decade and the prominence of the new frame structure.

Table 13: Examples of Bras with Frame Structure Patents in the 1960s

Name of invention	**Name of inventor**	**Date**	**Patent number**
Brassiere	Gingras, M.	5 Jan 1960	2,919,698
Brassieres	Smith, F. M.	24 Jan 1961	2,969,067
Brassiere	Young, E., Nuys, V., Jacobs, B., & Young, D.	28 Nov 1961	3,010,456
Brassiere	Kahn, M.	6 Feb 1962	3,019,792
Brassiere	Amyot, P.	13 March 1962	3,024,789
Brassiere	Stein, M.	6 Nov 1962	3,062,216
Brassiere	Sachs, C. M.	26 Feb 1963	3,078,851
Brassiere	Stapleton, A. M.	26 Feb 1963	3,078,852
Brassiere	Freedman, M.	9 June 1964	3,136,317
Brassiere with elastic support straps	Gingras, M.	25 May 1965	3,185,157
Brassiere with elastic support tapes	Kurland, W.	1 June 1965	3,186,412
Brassiere	Guberman, S.	6 July 1965	3,192,929
Brassiere	Sachs, C. M. &Jannicelli, E.	24 Aug 1965	3,202,153
Adjustable elastic strap brassiere	Schustack, R.	2 Nov 1965	3,215,144

Brassiere	Marino, N. A.	30 Nov 1965	3,220,415
Brassiere	Lo Cascio, J. J.	4 Jan 1966	3,227,185
Brassiere	Bernfeld, I. M.	2 Aug 1966	3,263,685
Brassiere	Sachs, C. M.	16 Aug 1966	3,266,495
Self-positioning brassiere	Puliafico, F. V.	13 Dec 1966	3,291,132
Brassiere	Hölscher, H.	21 Feb 1967	3,304,940
Anti-creep brassiere	Sachs, C. M.	30 May 1967	3,322,127
Brassiere	Hölscher, H.	16 July 1968	3,392,732
Anti-crease brassiere	Sachs, C. M.	19 Nov 1968	3,411,509

7.10 The 1970s

The sling, initially introduced in the 1920s, in a form of a simple inner patch pocket to separate the breasts, was elaborated into a hammock-like structure composed of suspending straps with additional back bands, in the late 1960s. This hammock-like structure takes the shape of the classical 1960s framed bra with no centre cup portion but is now normally paired with an outer shell bra. Although this design structure coexisted with the framed bra in the 1960s, it failed to make a strong impact on the fashion scene with only seven patents applied for during that decade. However, this inner bra with associated hammock-like structure eventually became popular in the 1970s because of the support it provided for the breasts whilst avoiding undue constriction.

7.10.1 The Breast Supporting Band of the 1970s

This hammock or sling-like structure was also called a ‘breast supporting part’ (Simonsen, 1965), ‘bust supporting band’ (Simonsen, 1970), ‘sling member’ (Stephensen, 1968), ‘insert liner’ (Werth, 1971), ‘inner support band’ (Defru, 1969), ‘inner breast supporting band’ (Nobbs, 1975), and ‘inner suspension section’ (Huttle, 1976). Inventors believed that it not only separated the breasts but also provided stronger levels of support. The unique thing about this supporting band was that it could be completely separated from the outer shell bra unlike many previous breast supporting bands which were permanently fixed to the cover layer. Catanese and Catanese (1970) identified some of the common design problems in some prior patents from the 1960s. These included folding and breaking-down of the shelf area and rolling over of the band at the front bottom. Both of these were clearly major factors which contributed to a lack of earlier appreciation for this design. These critical points were largely addressed in the patents for many breast supporting band designs of the 1970s.

Some key examples of breast supporting bands patented in the 1970s are shown in Figure 73.

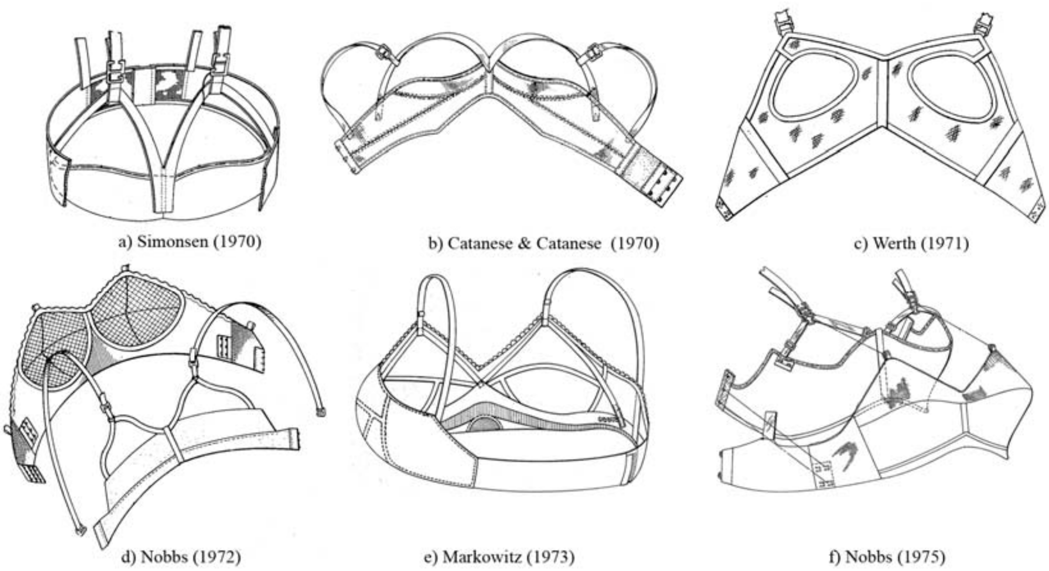


Figure 73: Examples of breast supporting bands from the 1970s.

7.10.2 Adaptability, Flexibility, and Adjustability

Werth (1971) emphasised that the detachable breast supporting band could be used for any type of bra, nightgown, swimming suit or other garments. This adaptability can be understood as similar to the truly modern design concept of 'mix and match' applied to underwear design for the first time. Furthermore, the supporting band's general design was incorporated into mastectomy bra designs because it provided better and more resilient support (Balow, 1972; Penrock, 1977), as well as facilitating the easy application of different types and sizes of prostheses (Hankin & Hankin, 1975) and, as such, truly demonstrated the flexibility of the applications of this design.

Adjustability, or the ability to fit many breast sizes, was still a major issue for bra designers and patternmakers. Markowitz (1973) employed Velcro to adjust the length of the suspender straps so that individual adjustment at the cups could be achieved (Figure 73e), whilst hook and eye tapes were now popularly used as adjusters at the bust girth. In line with the rise of feminism in the previous decade, Lavergne (1970) pointed out the importance of understanding the female body and criticised the male dominant fashion industry for a lack of understanding about the female breast. In so doing she put forward the idea of an arch shaped breast supporting band which would readily conform to the shape of breasts.

7.11 The 1980s

People became very conscious about health, fitness and exercise in the 1980s and demand for fashionable and appropriate exercise attire, including a bra suitable for sports wear and engaging in vigorous physical activity, amongst health conscious young female consumers began to rise. In fact these consumers began taking an interest in the so-called 'jogbra' by the late 1970s. The very first 'jogbra' prototype was composed of two 'jockstraps' sewn together. The patent for this jogbra was granted on the 20th of November 1979 under the title 'athletic brassiere' and it was referred to as the first-ever sports bra (Vermont women's history project, 2008). From then on, sports bras continued to gain popularity among sports conscious females and athletes throughout the 1980s.

7.11.1 Sports Bras from the 1980s

There were a total of 19 sports bras patented during this decade and these are shown in Table 14 below.

Table 14: Sports Bra Patents from the 1980s

Name of invention	Name of inventor	Date	Patent number
Athletic brassiere	McDavid, R. F.	4 Mar 1980	4,191,192
Jogger's brassiere	Ichelson, D. L.	13 May 1980	4,202,343
Athletic brassiere	Atwater, M. V. & Atwater, W. D.	19 Aug 1980	4,217,905

Counter weighted brassiere for athletic use.	Clark, H. E. & Clarl, P. T.	2 Sept 1980	4,220,157
Brassiere for strenuous physical activity	Johnston, E. D.	10 Mar 1981	4,254,777
Sports brassiere	Dell, D. G. & Clifford, C. H.	15 Sept 1981	4,289,137
Brassiere	Champion, C., Wolcott, J., Hart, B., & Garcia, Z. C.	6 Oct 1981	4,292,975
Halter top for sports suit	Rennhofer, L.	13 Oct 1981	4,294,257
Athletic brassiere	Schreiber, H. S. & Lindahl, E. Z.	19 Jan 1982	4,311,150
Bra for athletic activities	Speno, J. E.	9 Feb 1982	4,314,569
Sports garment	Wilkinson, M.	20 April 1982	4,325,378
Support Brassiere	Kuznetz, H.	27 July 1982	4,341,219
Brassiere	Martini, J. M.	21 Feb 1984	4,432,364
Athletic garment	Henderson, E.	3 Sept 1985	4,538,614
Sports bra	Flanagan, C. & Gilbert, A. I.	22 April 1986	4,583,544
Athletic/industrial brassiere with protective inserts	McCusker, L. H.	26 Aug 1986	4,607,640
Garment with breast supports	Wirth, C.	3 May 1988	4,741,791
Athletic support brassiere	Ekins, C. L.	1 Nov 1988	4,781,651
Sports bra	Braaten, R.	28 Mar 1989	4,816,005

The basic design requirements for the sports bra during this decade were:

1. Restriction of the bouncing (vertical and lateral) movement of the breasts.
2. Reduction of skin irritations through rubbing and bodily secretions.
3. Comfort and appearance.

7.11.2 Compression Bras vs. Encapsulation Bras

Sports bras can be categorised by the methods employed to minimise breast movement. One preferred method was compression (see Figure 74a), and another was encapsulation (see Figure 74b).

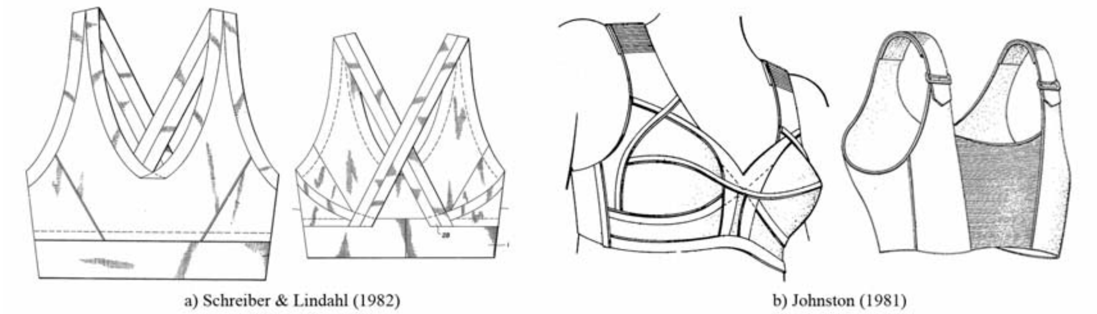


Figure 74: Two types of sports bra.

The compression bra works by holding the breasts tightly through the use of the binding force of design and/or materials and the first example of a compression bra was an ‘athletic brassiere’ by McDavid in 1980. This bra looks as if a conventional bra is positioned upside down, and is composed of an elastic chest encircling band with two leg encircling elastic bands. The breast compression was achieved by a pulling force generated by leg movements. This concept of using downward force to restrict breast movement can be found in a patent ‘joggers’ brassiere’ by Ichelson in 1980 that used a midriff strip (similar to a suspender) at each cup. These midriff strips were to be attached to the wearer’s waistband to exert pressure directly to the cups and compress the breasts. Another compression bra (a revised jogbra) by Scheiber and Lindahl in 1982 was made out of elastic material so it would snugly fit around the breast with no cups. The encapsulation bras were composed of three dimensional cups which restricted the bouncing movement of the breasts without the need for any binding force. In order to achieve the three dimensional shape, the cut and sewn method was applied in most sports bra from the 1980s. The joining seams and stitches became a source of great discomfort because skin irritation was caused by chaffing and rubbing of the breasts against the bra during vigorous exercise. Therefore, some inventors employed a range of different methods to reduce the skin irritation problem. In order to address this problem, Speno (1982) lowered the cup joining seam to a point below the bust point and nipple so there rubbing would be minimised. Amongst joggers, the term ‘jogger’s nipple’ referring to the sore nipple which resulted from chaffing and rubbing became a talking point (Wilkinson, 1982). Schreiber and Lindahl (1982) took a different approach to this problem, constructing a jogbra with all seams facing to the outside in order to avoid skin irritation whereas Flanagan and Gilbert (1986) preferred a circular knit blank where there was no joining seam.

7.11.3 Wide and Crossed Shoulder Straps

The construction of the shoulder strap became one of the most important design elements of the sports bra design during this decade in order to meet both comfort and support requirements. The width, shape and structure of the shoulder strap were critical factors which could significantly impact upon the performance of the sports bra. For instance, the narrow shoulder straps, common in the conventional everyday bra style tend to dig into the shoulder and easily slip off. In order to prevent these problems, many inventors employed wide shoulder straps (Atwater & Atwater, 1980; Flanagan and Gilbert, 1986; Ekins, 1988: Braaten, 1989), wide shoulder straps that crossed at the back (Johnston, 1981; Champion et al., 1981; Schreiber & Lindahl, 1982; McCusker, 1986), and even wider shoulder straps forming a T-shape at the back (Dell & Clifford, 1981). Also, Flanagan and Gilbert (1986) emphasised rules which suggested that the height of the back of the bra should reach at least 60 percent of the height of the front in order to give additional support around the bust, which can also be interpreted as designing a shorter length of shoulder strap due to the increment in the back panel height in order to hold the bra firmly.

7.12 The 1990s

The health conscious developed society of the 1980s became elaborated into the concept of body consciousness in the 1990s with women returning to a desire to have both a healthy life and figure and a fuller breast profile which paved the way for the advent of the push-up bra.

7.12.1 Push-up Bras and Breast Enhancing Bras

The 1990s can be regarded as the era of the push-up bra largely due to the historical success of he branded 'Wonderbra' initially in the UK but closely followed by a similar trend in the United States. Other names commonly used for the push-up bra include breast enhancing, cleavage enhancing, and plunge bra. Despite its popularity during this decade, a total of only six breast enhancing bra patents were granted in the 1990s (see Table 15). In Table 15, a further two push-up bras from 1963 and

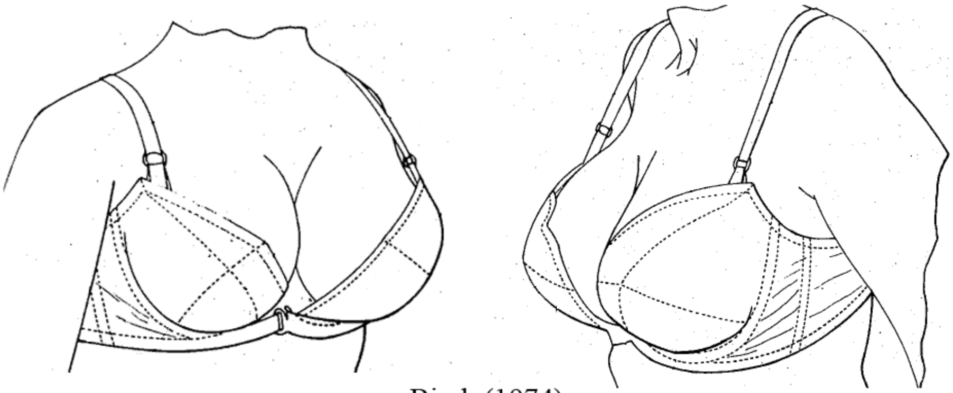
1974 have been included in order to demonstrate that the history of the push-up bra extends beyond this decade. An example of this history is the original ‘Wonderbra’ which was actually invented in 1960s.

Table 15: Push-up Bras

Name of invention	Name of inventor	Date	Patent number
Brassiere	Smith, R. K.	29 Jan 1963	3,075,530
Brassiere construction	Birch, B. A.	10 Sept 1974	3,834,397
Breast enhancement brassiere	Greenberg, B.	24 Mar 1992	5,098,330
Brassiere	Vass-Betts, R.	3 Sept 1996	D373,236
Brassiere	Vass-Betts, R.	24 Nov 1996	D373,237
Brassiere	Modena, G.	26 Aug 1997	5,660,577
Cleavage creating and/or enhancing brassiere	Kelemencky, M. R.	9 Feb 1999	5,868,601
Cleavage enhancement brassiere	Abadi, J.	18 May 1999	5,904,607

In fact, there have been numerous attempts to create what is often termed a ‘perky’ profile for the breasts. However, it was the material innovations of the 1990s which helped inventors to be more creative in making the breast look natural whilst enclosed in a comfortable and healthy bra. This had significant spin-offs for mastectomy patients. Commonly used padding materials in the early 1990s included polyester fibre fill, latex foam, and polyurethane foam. Polyester fibre fill was criticised for its lack of resilience whilst latex and polyurethane foam were criticised for the relatively short lifespan before disintegration began and the early yellowing effect of the material (Greenberg, 1992).

However, these shortcomings were compensated for by the fashionable designs of push-up bras which included the distinct features of a deep V- shape neckline, small gore, and substantial padding at the cup in order to achieve the desired effects of enhancing breast profile and cleavage (see Figure 75).



Birch (1974)

Figure 75: A diagrammatic example of a push-up bra.

This evolution in bra technology enables the breasts to be lifted and gently pushed together by exerting force generated by the judicial use of wire, padding at the cup, and innovatively engineered wing angles. Modena (1997) also emphasised the importance of the mixed use of materials with different levels of elasticity in constructing the push-up bra. He claimed that supporting components such as the shoulder straps and band should be constructed of less stretchy material than that used in the cup in order to appropriately distribute and transfer the strain applied on the cup. Kelemencky (1999) suggested an alternative means of achieving the push-up effect which involved the use of a pair of reinforcing straps with hook-and-loop fasteners made of Velcro which helps pull the breasts together and avoid the need for a padding insert. In summary, the development of moulding technology and material innovations helped fuel the development of the push-up bra which managed to maintain popularity well into the early years of the new millennium. At the beginning, a T-shaped style line was employed for bra cup patternmaking but this was soon replaced with the use of a seamless moulded cup, the patternmaking for which is achieved using a three dimensional plastic moulding cup.

7.13 The New Millennium

Due to innovations in bra production technology, the one piece bra, also know as the seamless bra, arrived on the underwear fashion scene and, although there were other exciting new products introduced at this time, the seamless bra can rightfully be regarded as the most innovative due to the use of entirely new production and material technologies.

7.13.1 The Seamless or One Piece Bra

Two main technologies are employed for constructing seamless bras; moulding and lamination or bonding, both of which were reviewed in chapter 6. The term 'seamless' indicates there is little or no sewing involved in the whole production procedure and most importantly, the patternmaking is accomplished in three dimensions via the use of plastic moulds. Despite the popularity of the seamless bra, only eight patents have so far been registered (see Table 16 for details). One of the most interesting of these was a seamless brassiere introduced by Huang in 2002 which is composed of an outer shield, a support pad, an inner lining, a pair of shoulder straps, and hook and eye tape (see Figure 76).

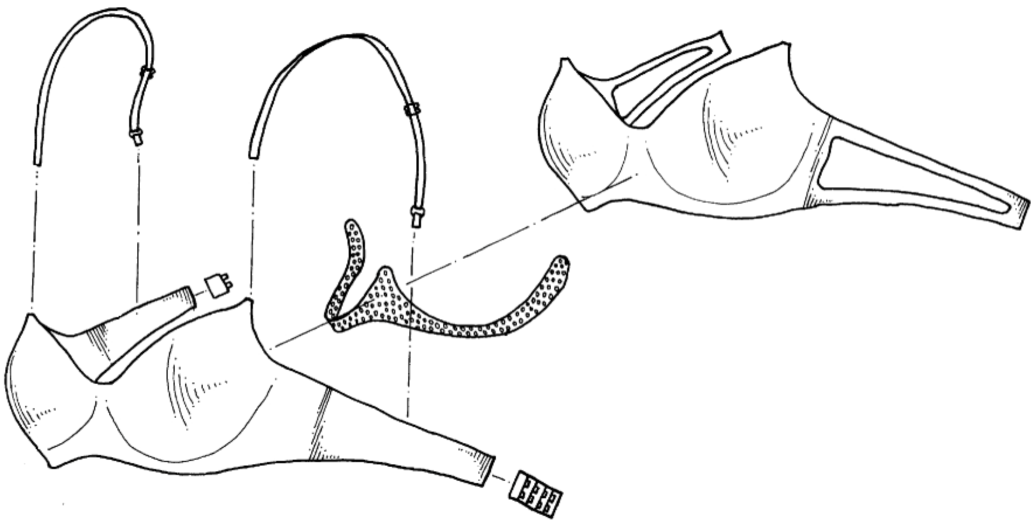


Figure 76: A seamless brassiere.
Source: Huang, 2002

The support pad can be replaced with a pair of steel wires and the bra pads can be used or discarded based on the desired effect. Huang (2002) claimed that the bonded one piece bra possessed excellent shape retention ability, was easy to care for, and would not cause skin irritation.

The sequence of assembly for a seamless bra is important and production is arranged so that all components follow a strict order of preparation prior to assembly.

Although the complete bra looks simple and seamless from the outside, there are nonetheless many layers of fabric together with supporting components such as wires and stabilisers, either sewn or glued inside. As an example of the complexity of the production and assembly processes a patent 'brassiere' by Liu (2007a) had a total of 21 steps making up its assembly procedure.

Table 16: Patent Information for the Seamless Bra of the Early 2000s

Name of invention	Name of inventor	Date	Patent number
Seamless brassiere	Huang, H. L.	30 July 2002	6,425,800B1
Two-ply support garment and method of making same	Rabinowicz, S. & Azulay, M.	11 Nov 2003	6,645,040 B2
Undergarments made from multilayered fabric laminate material	Falla, G.	4 Jan 2005	6,837,771
Bra cups without sewing seams	Hsu, C.	2 Nov 2006	7,131,888 B2
Brassiere	Liu, Z.	20 Mar 2007	7,192,332 B2
Brassiere	Lau, B.	22 Mar 2007	2007/0066181
Brassiere with under breast support	Liu, Z.	27 Dec 2007	2007/0298681 A1
Brassiere and injection moulded components therefore	Liu, Z.	27 Mar 2008	2008/076324 A1

The advent of the seamless bra marks a significant turning point in bra history because of the highly technical processes involved in its production in comparison to earlier eras and this changed both the design and patternmaking processes. Despite the growing popularity of the seamless bra, cut and sewn bras remain in demand, but now with three dimensional patternmaking complementing traditional two-dimensional, or flat patternmaking.

7.14 Summary

Bra patternmaking has continued to make substantial technological progress evidenced by comparing the primitive mid 19th century bra to the seamless bras of the early 2000s. However, one of the most significant breakthroughs for bra patternmaking was undoubtedly the development of the ability to form a three-dimensional bra cup from a two-dimensional or flat pattern. However, as can be seen from this review of patents, this is not restricted to, nor simply a result of innovations in bra moulding and bonding technology. In fact, cup and bra shaping methods involving the use of darts, style lines, pleats and gathers have been employed over one hundred years in order to perfect the cup fit and achieve a fashionable bust and silhouette, and conventional bra patternmaking still makes up the majority of world bra production. Furthermore, the patternmaking skills involved in two-dimensional or flat patternmaking remain at the core of professional courses offered at university or within the industry. Despite this enduring flat-patternmaking trend, the development of conventional bra patternmaking was largely complete by the end of the 1980s, well before the introduction of moulded three -dimensional patternmaking which was not introduced until the 1990s when the appropriate innovations in moulding and bonding technology became available. Both methods have their drawbacks and it is interesting to that the difficulties involved in fitting the bra remain despite the long developmental history of bra patternmaking. This is partly because lack of structured training and partly because of the shroud of secrecy which still surrounds the patternmaking process within the bra industry. This is an area which has not been studied at this level before, perhaps because it is only industry 'insiders', in other words those very few people who are both designers and patternmakers, who have access to the knowledge and skills necessary to understand what even the industry regards as a very technical process. The author is an industry designer and patternmaker who has designed, made patterns and produced commercial underwear for some of the industry's leading brands and which have been sold all over the globe. Therefore, armed with that experience and the knowledge gained from a thorough review of underwear design development through the ages, it is to the sometimes 'dark art' of two-dimensional or flat patternmaking that we now turn. In the next chapter, a review of the textbooks which have begun to introduce bra patternmaking to public and professionals alike will be undertaken and a totally new and innovative method of creating patterns for the ever popular underwired bra, created by the author, will be introduced.

CHAPTER 8
PATTERNMAKING FOR THE UNDERWIRED BRA: NEW DIRECTIONS

8.1 Introduction

The previous chapter considered the history of patternmaking, the evolution of flat patternmaking, and brassiere patternmaking. In this chapter the literature related to patternmaking for the bra, and the underwired bra is briefly revisited and the secrecy currently surrounding the practice of patternmaking is also considered, and the extent to which this has restricted the growth of innovative practice in this area. The effect this has had on the development, learning and teaching of patternmaking practice is considered and new research into bra patternmaking conducted by the author, which marks a move away from traditional 'copy' methods to a single innovative approach which is practical, and provides for further development of patternmaking practice in this area, is presented and evaluated.

8.2 Context

The intimate apparel industry and the educational field have traditionally neglected the need for innovation in pattern development and the value of sharing existing patternmaking techniques. This is partly because the industry itself is very secretive about knowledge sharing in this area and, as a consequence, lengthy and expensive pre-production schedules have become the norm in the intimate apparel business. According to research conducted by Hardaker and Fozzard (1997), the average time spent on bra pattern development can be anything from two to six months and the average training time expected for becoming a professional bra patternmaker capable of producing a good fit bra is 10 years. This is both inefficient and expensive and there is a clear industry need for more efficient methods of patternmaking which guarantee a good fit. Most recent developments in patternmaking for the brassiere have occurred in the area of the moulded bra cup and the new technologies surrounding the moulded brassiere. However, moulded brassieres currently represent a much smaller proportion of the world market than their traditionally constructed counterparts so this study will concentrate on the latter.

Garment fit depends on five elements: (1) Grain (2) Set (3) Line (4) Balance and (5) Ease (Brown and Rice, 2000). These five elements are normally used as the evaluation tool for outerwear fit where the laws of gravity impact upon the whole garment. As the bra is resisting gravity which pulls the breast downwards it creates an undesirable shape as well as potential muscle and posture problems, particularly as the breast size increases. Since the bra is a foundation garment, it is required to support the weight of the breast. Therefore, bra making means not only producing an aesthetically pleasing appearance, but also making a functionally supportive garment. The bra doesn't have 'ease' to assist with evaluating proper fit. This is replaced by 'tension' because the bra wing is largely made up of stretch materials which require taking the 'ease' of a total of 10cm -15cm from the actual ribcage circumference. Consequently, in order to accomplish the goal of a good fit and an aesthetically pleasing bra, consideration needs to be given to the type and properties of the construction materials. As a result, a perfect fit is unlikely at the first attempt because various bra materials and the direction of cut make it difficult to achieve an immediate perfect fit even for very experienced patternmakers. As a result of some of these difficulties, and in particular the time taken to learn the 'dark art' of bra patternmaking, the author has developed and tested an innovative flat patternmaking method which will enable faster bra patternmaking and substantially faster industry training.

8.3 The History of Pattern Cutting and Evolution of the Basic Block

Despite a booming printing business, few pattern cutting books were published until the 19th Century. The earliest surviving pattern and cutting book was Alcega's *Libro de Geometría, Practica, y Traça* (Spanish, translated as 'Tailor's pattern book') which was published in Spain in 1589. The book contains 163 patterns for 23 categories of men's and women's wear. Whilst it doesn't show how to make patterns, it does show scaled patterns and cutting layouts on folded fabrics. Alcega's intention was to share knowledge with other tailors and reveal the 'mysteries' concerning the art of tailoring (Bean, 1979). In total, there were just 18 pattern cutting books (including Alcega's) published from the 16th Century to the 18th Century in Europe (Seligman, 1996). This is largely due to high levels of illiteracy and innumeracy amongst tailors and dressmakers at the time. At this time in the history of pattermaking, tailors traditionally passed on their skills to apprentices through demonstration accompanied by verbal instruction (Kidwell, 1979). This method of teaching the next generation of patternmakers is still in practice in the fashion industry today, particularly in the practice of intimate apparel and bra patternmaking.

The earliest known English pattern book was 'Instructions for Cutting Out Apparel for the Poor' written for the Industrial School and Sunday School Children of Hertingfordbury in 1789. This book was produced with the intention of helping poor parents clothe their children and contains 13 plates of patterns. However, 'The Tailor's Complete Guide', published in 1796, is generally considered to be the first English publication on pattern drafting. It differs from the earlier book in that it contains instructions for measuring the body, as well as instructions for the actual pattern drafting of various styles of breeches, waistcoats and coats. However, it was not until 1818 that the first pattern cutting book was published by Hearn 'Rudiments of Cutting – The Coat System' introduces what is described as the 'real' system of cutting for the first time.

Kidwell (1979) categorised drafting systems used between the 18th and 19th Centuries into three different categories:

- The Proportional system.
- The Direct –measure system.
- The Hybrid system.

Proportional systems were cutting methods based on the assumption that all human bodices are formed according to common geometric or proportional rules and that most tailors used full breast circumference as a guide measurement which is related to the other body measurements in different ratios. The direct-measure system uses individual dimensions as the basis for drafting. The hybrid system is a combination of the proportional system and direct measurement system.

Hearn was a pioneer in pattern cutting because he combined the proportional system with direct measurements (Giles, 1887). Interestingly, he was also a pioneer in adopting the inch tape measure in pattern cutting. The inch tape measure was invented along with the tailors square in 1799 by George Atkinson. In 1820, Edward Minister introduced the breast measure system (along with the use of a tailor's square) in his book 'System of the Art of Cutting' and by 1850, the publication of drafting systems had developed into a marketable field (Seligman, 1996).

The development of the pattern drafting system is considered one of the key elements of the development of ready-to-wear clothing in the 19^{th} Century. Godley (1997) emphasises that the original force behind the development of ready-to-wear clothing is not the invention of the sewing machine, but the development of standard sizes. In elaborating on Godley's point Aldrich (2000) identifies three important factors in this development:

- The standardisation of measurements.
- The improvement in pattern drafting.
- The adoption of a grading system.

Dickerson (2003) supplements these factors with the invention of the sewing machine and a cheap immigrant labour force which together expedited the development of ready-to-wear clothing in the 19^{th} Century.

Alongside these technical changes, there were also social changes which helped accelerate the development of patternmaking systems. These include:

- The evolution of the women's magazine and mail order.
- Developments in the postal system: Mail order started in 1892.
- The growth of a middle class.
- The growth of urban populations.

- Improving literacy and numeracy.
- The evolution of a commercial paper pattern industry.

As a consequence, the development of a basic block for faster production among tailors was inevitable in order to survive in a fast developing area of commerce. Flat patternmaking using basic block patterns started in the mid-19th Century. Figure 77 gives an example of the early stages of the flat patternmaking method for a corset using a basic block, patented by Tentler in 1841. He describes the pattern drafting practice of that era in his specification of letters for patent:

"Hitherto, corsets have been cut from patterns, without any fixed rule, I being the first to apply the dress measure as a guide in this particular."

(Tentler, 1841. p2)

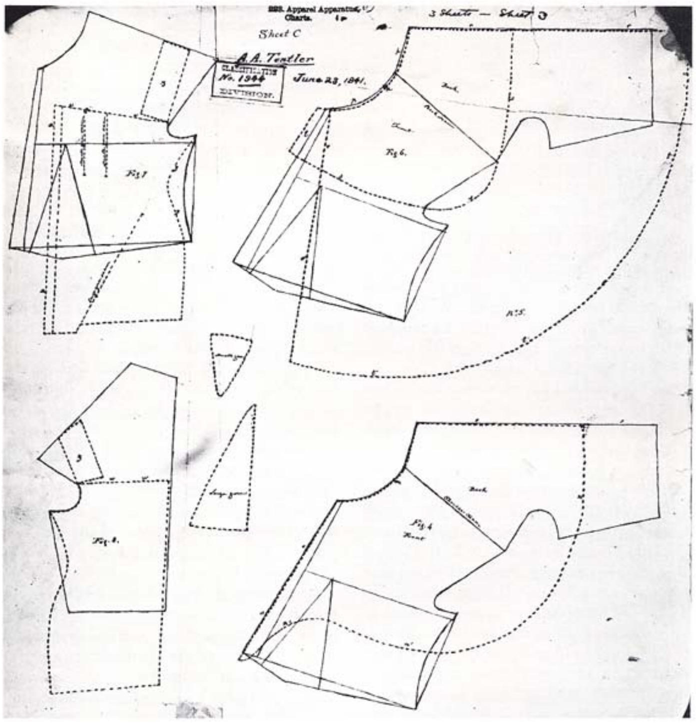


Figure 77: Use of basic bodice block in US patent no. 1,944 (Tentler, 1841). Source: Kidwell, 1979

Since the 19th Century, patternmaking has continued to develop into more organised formats, and now there are basically three different patternmaking systems available.

8.4 The Four Different Patternmaking Methods

The four different patternmaking methods commonly used by fashion designers and patternmakers in the industry, and educators in the education field, are:

1. Draping.
2. Pattern drafting.
3. Flat patternmaking.
4. Knock-off.

Depending on the material used and the style to be achieved, the above four methods can be used separately or blended. Patternmaking systems are sometimes mixed or blended because patternmakers must be able to interpret the design idea and create the first pattern using methods suitable for the proposed design (Hollen and Kundel, 1999).

8.4.1 Draping

This is the oldest patternmaking method and is generally regarded as a creative approach. The draping method involves creating the pattern pieces by applying fabric directly onto the three dimensional dress form. The advantage of using the draping method for patternmaking is that designers or patternmakers can transfer their two dimensional sketch to a three dimensional sample directly onto the dress form, which gives a reasonable view of the finished look of the design without having to cut and sew sample garments. The disadvantage of this method is that finding fabrics with an equivalent hand feeling/drape to a fashion fabric for a finished garment can be difficult and costly. Unfinished plain weaved cotton, or muslin, is normally used in the fashion industry and educational institutes for draping methods in order to lower cost, but often designers prefer to use fashion fabrics for better results. The expense in terms of material and time is why this ‘ideal’ method of developing design ideas is usually reserved for higher price fashion such as designer brands or ‘Haute Couture’. It is common practice in the fashion industry to combine the draping method and the flat patternmaking method for faster production.

For example, Jaffe and Relis (2000) recommend using the draping method to develop the basic block, and then use the basic block for flat patternmaking.

8.4.2 Pattern Drafting

Direct pattern drafting or pattern drafting is a system of patternmaking that uses a combination of ease allowance and body measurements taken from a dress form or fit model to create patterns including basic, foundation, and fashion patterns (Joseph-Armstrong, 2005). This method started as early as the 15th Century (MacDonald, 2002) and according to Aldrich (2000), there are records from the 18th Century showing that creating the shape directly from the body was mainly reserved for the upper classes of society, and consequently a tailor who drafted directly onto the cloth was afforded higher status among other dressmakers. This shows that direct drafting is a highly valued skill that comes from experience, and obtaining accurate body measurements ensures the accuracy of the pattern. The measuring techniques used for this method were also highly regarded as an important skill which required considerable experience.

8.4.3 Flat Patternmaking

Flat patternmaking is a system of creating patterns by manipulating a basic block. This basic block, known as a basic pattern or 'sloper', is created by using either the direct drafting method or draping and has already undergone the fitting and alteration process for good fit. The basic block contains a movement ease allowance which allows the body to move without tearing the garment. Each basic block tends to be different from one company to another. Creating a fashion pattern by using the flat patternmaking method is reasonably logical and easy to understand. Joseph-Armstrong (2005) emphasises that the flat patternmaking method brings consistency of both size and fit of mass-produced garments and is also the fastest and most efficient pattern design method. This leads to less frustration for students or industry trainees learning patternmaking skills. Therefore, this is generally the method favoured by the majority of U.S. apparel companies for production (MacDonald, 2002), and the majority of fashion schools for training the next generation of designers and patternmakers.

8.4.4. Knock-off

The aptly termed ‘knock-off’ is a frequently used method of creating patterns by copying ready-made garments. It is commonly used when a manufacturer wants to take advantage of a well publicised hot fashion item, sometimes from a famous designer label, without the need for lengthy preproduction time before the season ends or sales cool down (Joseph-Armstrong, 2005).

There is a significant difference between the outerwear and underwear industries in the ways and frequencies they use the knock-off method. Outerwear designers and patternmakers knock off ‘the designer labels’ which can then benefit from the media exposures of the designer labels. However, underwear designers and patternmakers from the well established bra manufacturing retailers and brands seldom knock off ‘designer bras’. Instead, they are often encouraged to copy, recycle, or slightly alter existing patterns, or knock off their direct competitors’ bras. This is because: 1) designer labels cater only for a specific target consumer group which is a very small part of the multi-million dollar bra industry, 2) the main purpose of the bra is for support not for fashion (although there have been changes in recent years), and most importantly 3) the copy/recycle/alteration/knock-off does not require professional training or experience in bra patternmaking. Therefore, this has been a quick and easy solution for the bra industry where well trained and experienced patternmakers are difficult to find. Whilst there are some innovative designers who create innovative products by adopting an out-of-box approach, the industry continues to predominantly use the ‘copy/recycle/alteration/knock-off’ method(s). Consequently, this has stifled some creativity and innovation in bra patternmaking which requires a solid understanding of the relationship between body measurements and pattern.

8.5 The Development of the Intermediate Block

The need for further development of the basic block led to the development of the concept of the intermediate block. The intermediate block, or foundation, is a developed from the basic block to enable easier and faster pattern manipulation. Use of the intermediate block maximises the utilisation of flat patternmaking because it enables patternmakers to produce patterns for a variety of styles within a short period of time. As shown in Table 17, many instructions are in existence for developing intermediate blocks. For example, the basic kimono foundation can be used for producing various styles of kimono dress (sleeve is attached to the bodice) with deep-cut armhole, drop shoulder or raglan sleeve (Joseph-Armstrong, 2005). Use of the intermediate block is now commonplace in the outerwear industry. Normally larger companies, which produce garments with lower fashion change frequency, prefer the use of intermediate blocks. However, with increasing fierce competition and consumer demand, fashion frequency now has a significant impact on most fashion companies, irrespective of their size (Staples, 1993). Therefore, a broader range of true patternmaking skills is normally required for contemporary patternmakers. As Abrahams (1998) points out, a patternmaker should possess not only the ability to make a good block, but also the knowledge of how to change simple pattern shapes into something more stylish.

Table 17 shows different intermediate blocks developed from the basic block as described by Kopp et al (1984), Aldrich, (2004) and Joseph-Armstrong, (2005).

Table 17: Various Intermediate Blocks used in Patternmaking Books

Kopp et al (1984)	Aldrich (2004)	Joseph-Armstrong (2005)
1. Fitted sleeve sloper	1. Closed fitting bodice block	1. Basic dress foundation (front and back bodice with sleeve)
2. Straight sleeve sloper	2. Easy fitting bodice block	2. Basic Kimono
3. Bodice sloper with shoulder and waistline dart	3. Tailored jacket block	3. Kimono torso foundation
4. Bodice sloper with waistline darts	4. Classic Coat block	4. Torso foundation
5. Fitted torso sloper with darts	5. One-piece sleeve block	5. Princess-line foundation
6. Dartless torso sloper	6. Two-pieces sleeve block	6. Panel dress foundation
7. Skirt slopers with one dart	7. Dress block: one piece and two pieces	7. Empire foundation
8. Skirt slopers with two darts	8. Shaped Kimono block	8. Tent foundation
9. Pants sloper	9. Tailored skirts block	9. Strapless princess bodice foundations
10. Fitted dress sloper	10. Classic tailored trouser block	10. Bra-top torso foundation
11. Shift sloper	11. Very close fitting trouser/jean block	11. Princess torso foundation
12. Tent sloper	12. Easy fitting trouser block	12. Shirt and blouse foundation
	13. Simple trouser block	13. Casual shirt and sleeve foundation
	14. Simple skirt block	14. Jacket and coat foundation
	15. Basic shirt block	15. Mannish jacket foundation
	16. Basic ‘flat’ overgarment blocks	16. Shawl foundation
	17. ‘Flat’ Kimono block	17. Cape foundations
	18. Tee shirt and track suit blocks	18. Pant foundation
	19. Knitwear blocks	19. Jumpsuit foundation
	20. Body shape blocks	20. Knit top foundation
		21. Bodysuit foundation
		22. Leotard foundation
		23. Maillot foundation
		24. Bikini foundation
		25. Little-boy legline foundation
		26. Full-figure foundation

8.6 Review of the Bra Patternmaking Approach

We have established that the use of a basic block pattern is common, and has a long history in the outerwear industry, where it is often the preferred training method for the next generation of patternmakers. This method is preferred largely because it expedites production time considerably, with consequent savings in terms of cost, both important advantages given the highly competitive nature of the intimate apparel industry. Abundant information on patternmaking for outerwear is available from various sources including the internet. In comparison, there remains a dearth of information available about underwear patternmaking, in particular the brassiere.

Many attempts have been made to draft a bra pattern from the basic bodice block. Since 1968, literature from both the UK and USA introduced bra patternmaking through the use of a basic bodice block. Table 18 shows a list of the publications in which bra patternmaking using the flat patternmaking method via a basic block are presented.

Table 18: Books Presenting Bra Patternmaking from the Basic Block

Year	Title of book	Author
1968	Pattern drafting and grading	Mayer Rohr
1968	Pattern cutting	Margaret Melliar
1986	More dress pattern designing	Natalie Bray
1989	Designing patterns: a fresh approach to pattern cutting	Hilary Campbell
1991	Flat pattern cutting and modelling for fashion	Helen Stanley
2004	Pattern Cutting for Lingerie, Beachwear and Leisurewear	Ann Hagger
2005	Patternmaking for fashion design	Helen Joseph-Amstrong

The hypothesis that underpins the methods described in all of these books is that once movement ease is omitted from the basic block, bra patternmaking is easily accomplished. Figure 78 shows the development of a bra block from the basic bodice block.

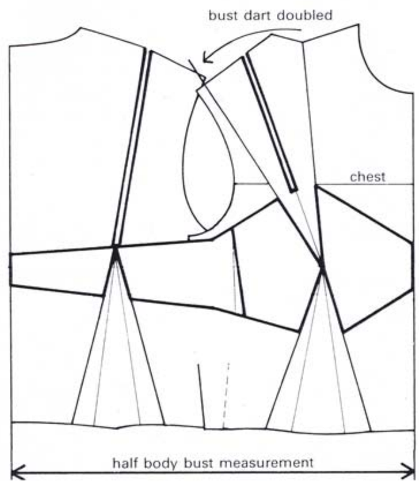


Figure 78: Bra block development from basic bodice block.
Source: Hagger, 2004

Hagger (2004) emphasised the importance of creating a bra block from the bodice block. However, in reality experienced bra patternmakers and fashion designers in industry rarely use a basic bodice block to create a bra block. In fact, they often draft the bra pattern directly onto paper from breast measurements. Typically, these direct bra drafting methods haven't been published, presumably because the bra industry remains very secretive about sharing information. Running contrary to this secrecy, demand for making one's own bra is growing amongst well-endowed home sewers because they are often unable to find a large cup bra that provides sufficient support. Generally, their pattern making skills are restricted to simply cutting up an old bra and then tracing the cut out pieces and adding up the seam allowance. Consequently, there are resources available for those who wish to 'knock off' bra patterns from existing commercial bras, but these normally reflect a low level of understanding of bra pattern drafting. One of the purposes of this paper is to rectify this situation. Whilst bras containing no wire, such as sports bras, can be developed from a basic bodice, using a basic bodice for underwired bra drafting remains a highly technical task.

8.7 The Underwired Bra Patternmaking Process

The underwire itself can be categorised by three different centre heights; lower centre, medium, and full cup wire, and various wire gauges are available as well as a multitude of wire shapes. Typically, underwired bra pattern pieces consist of a bra cup, front centre, side panel, and wing. The front centre and side panels together are called a 'cradle'. Normally the front part of the bra is rigid and the back section (wing) is constructed of stretch material. When a wire is selected for bra design, there are three things which should be considered; curve, tension and the length of wire. Bra band patternmaking starts with the shape of wire, and bra cup patternmaking depends on the wire centre height along with the breast measurements.

8.7.1 'Ideal' Body Measurements for 75B and Direct Drafting of Full Cup Bra Body Measurements

The basic bra sizing system currently used consists of two measurements; the circumference of the ribcage, and cup size. Normally, production samples are made for size 34B/75B. In this paper, the metric system is used for pattern drafting since 75 cm is a more exact ribcage measurement whilst a formula should be used for the imperial sizing system (34B). The difference between the ribcage and full bust circumference determines cup size (Table 19). To some extent, 34B seems too small to be a standard size for patternmaking when commercial sizes range from 28-AA to 56-FF, but 34B "ideal" is not an entirely arbitrary designation because it represents the bust line considered most pleasing to the 'artistic' eye of most dress/outerwear designers-although there is clearly room here for disagreement!

Table 19: The Relationship between Body Circumference and Cup Sizes

Difference between ribcage and full bust circumference	Cup size (US sizing system)
10cm	AA
12.5cm	A
15cm	B
17.5cm	C
20cm	D
22.5cm	E
25cm	F

Breast measurements are important because a bra cup pattern should project/ accommodate the exact volume of a breast. Table 20 and Figure 79 show the ideal breast measurements for 75B. In addition to the breast measurements, the breast root shape should also be considered. The 'breast root' can be defined as the crease line where the breast forms on the chest. Every woman's breast and its breast root are unique and it is essential that the wire curve is matched with the breast root otherwise the wire will create discomfort. However, matching the right shape for individual customers is largely impossible in mass production practice. A good fit bra which is comfortable, uplifting and supporting simultaneously depends on finding a wire which closely matches the shape of the breast root of the wearer.

Table 20: Ideal Breast Measurements for 75B

Where to measure	Measurements
Breast inner curve length	9cm
Breast outer curve length	10cm
Breast depth	8.5cm
Distance between bust points	18cm

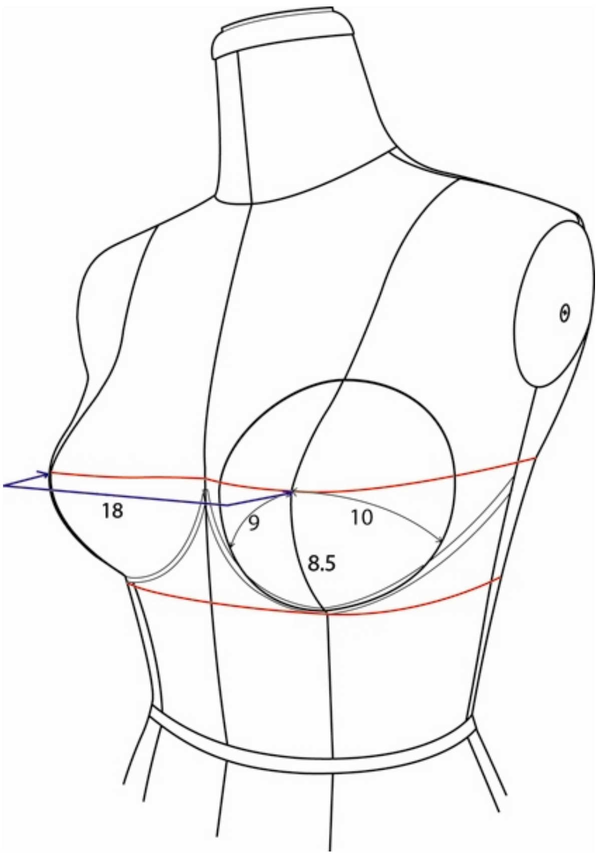


Figure 79: Ideal breast measurements for 75B.

Patternmaking for an underwired bra consists of two basic patternmaking procedures: These are band drafting (Figure 80) and cup drafting (Figure 81). The band pattern shape depends on a wire curve and the cup pattern shape depends on breast measurements (breast inner curve length, outer curve length and breast depth). The following method is for a full cup underwire bra (a 215mm length full cup wire was used for the sample patternmaking illustrated here).

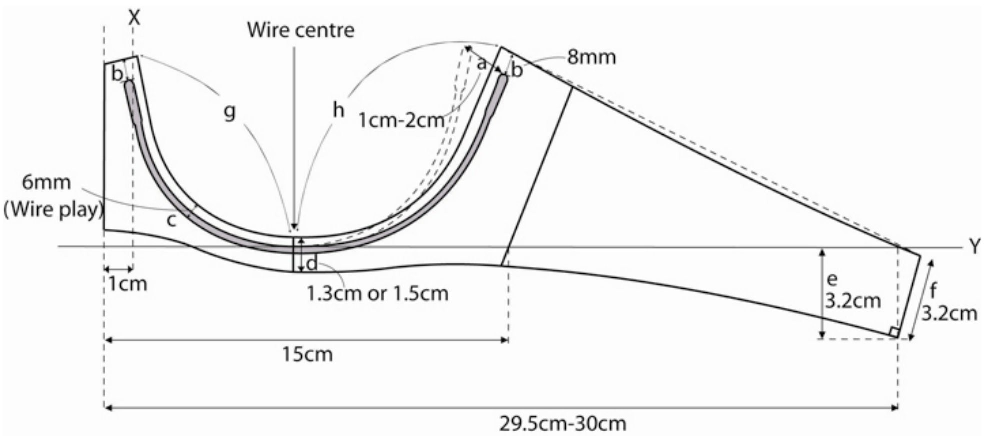


Figure 80: Underwired bra band drafting.

8.7.2 Band Drafting

8.7.2.1 Finding the Centre of Wire

First of all, it is essential to identify the centre of the wire, which works as a fulcrum. Each end of the underwire tip should point directly towards an appropriate body point. The inner wire end should be directed towards the centre of the pit at the base of the neck and the outer wire end should point directly to the point of the shoulder. After defining the centre of wire, draw a horizontal line and a vertical line on a piece of paper. Place a wire by matching the inside curve of the centre point of the wire with the X-axis at the same time matching the inside of the inner wire end point with the Y-axis. Marking the centre of the wire can be done simultaneously or after marking the guideline.

8.7.2.2 Marking the Guide Lines

The total circumference of the bra band for 75B (excluding hook and eye tape) is around 60cm. For this paper, 29.5cm was used for the half of bra band width. The cradle width is nearly half of the bra band width. 15cm was used for this paper. The width of the gore indicates the closest distance between the breasts or cups. It is important to note that there can be differences in this measurement between ethnic groups as well as individuals. 1 cm is used for the purposes of this paper.

8.7.2.3 Tracing Wire and Opening the Wire

Place a wire by matching the centre of wire to the horizontal guide line and trace the whole wire. After tracing, open the half of wire on the armhole side and trace the open shape of wire as shown in Figure 80. Opening amount (a) between the original tip and open tip is between 1 cm and 2 cm. The amount depends on the shape and tension of the wire used. The purpose of this procedure is to mimic the open and bent shape of the wire when the bra is worn on a three-dimensional human body. 1.7 cm was used for the purposes of this paper.

8.7.2.4 Allowance for Wire and Wire Play

An 8mm allowance (b) for both movement ease and sewing (bar tacking) is added on both wire tips and 6mm wire play (c) is added. Wire play is literally where wire resides.

8.7.2.5 Mid-point of Cradle Height

The mid-point of the cradle height (d) depends on the underband elastic tape width. In order to prevent flipping or a ‘folding’ effect on the mid-point of the cradle when a bra is worn, wire casing and underband elastic tape should be overlapped and sewn together. Therefore, when a 1cm width of elastic tape is used, the mid-point height of the cradle should be 1.3cm and when a 1.2cm width of elastic tape is used, the mid-point height of the cradle should be 1.5cm.

8.7.2.6 Wing Drafting

The starting point for wing drafting is finding the amount of wing drop. As the opening amount (a) gets bigger, so the wing drop (e) gets bigger. Some patternmakers suggest using a set amount for both opening of the wire and dropping of the wing.

The back of the wing height (f) is same as the hook and eye tape width since it is attached to a hook and eye tape. A 3.2cm hook and eye tape was used for this sample. Coincidently, a 3.2cm drop of the back wing was also used for this paper.

8.7.2.7 Finishing the Band Drafting

The other lines are style lines and can be changed according to the design sketches. This is of course a matter for the patternmakers own judgement.

8.7.2.8 Measuring Joining Seam/Preparation for Cup Drafting

After finishing the bra band drafting, the length of the seam line where the cup will be sewn together should be measured. Each half of the curve is labelled as (g) and (h) for explanatory purposes.

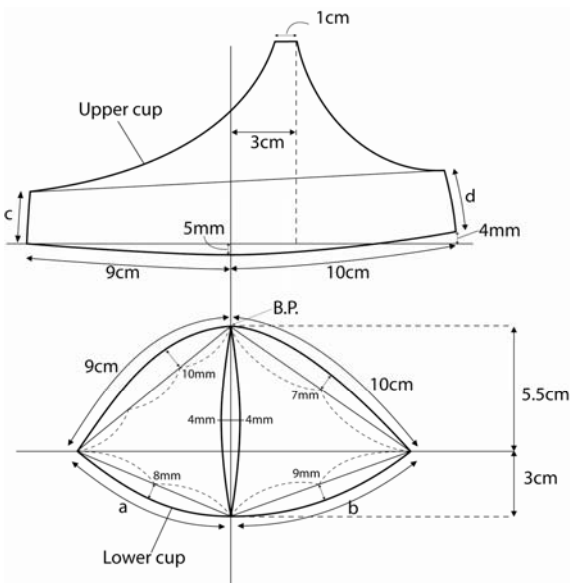


Figure 81: Cup drafting.

8.8 Cup Drafting

8.8.1 Lower Cup

8.8.1.1 Guide Lines

Draw a vertical line for the breast depth of 75B (8.5cm) and divide into two different lengths (5.5cm and 3 cm) with a horizontal line.

8.8.1.2 Upper Curve Lines of Lower Cup

In order to achieve the breast inner curve length (9cm) and breast outer curve length (10cm) draw straight lines of 8.8cm and 9.8cm from B.P to each side of the horizontal guide line. Complete the curve lines by following the guide measurements (10mm for centre side curve and 7mm for the armhole side curve). Measure the curve lines in order to make sure the finished line lengths are correct.

8.8.1.3 Lower Curve Lines of Lower Cup

Once the upper half of the lower cup is finished, drawing the lower half of the lower cup is relatively easy. Draw two straight guide lines by connecting the two end points of the upper line with the 3cm point on the centre guide line of the cup. Draw curve lines by following the guide measurements (8mm for centre side curve and 9mm for the armhole side curve). Measure the length of lower curve lines ('a' and 'b' as shown in Figure 81) and write their lengths alongside both curve lines for future reference.

8.8.1.4 Splitting the Lower Cup

The lower cup can then be split in half and 4mm of fullness can be added on the centre of the line.

When two layers are used for bra construction, the inner layer can have a split for fullness and the outer cup, normally cut with a stretch material, can be used as one piece.

8.8.2 Upper Cup

8.8.2.1 Joining Seam Length

Drafting the upper cup starts by dropping the centre point by 5mm. The bigger the amount is, the 'pointier' the bra cup projection is. Draw a smooth curve which is close to the straight line to each side. Each side length from the bust point (B.P.) should be the same as the lower cup length (9cm and 10cm) because they will be sewn together. The armhole side of the upper cup is lifted 4mm from the guide line in order to make the smaller cup edge/neck line length.

8.8.2.2 Upper Cup Height

Each side of the upper cup height (c and d) is calculated by subtracting lower curve lengths from the cradle joining seam. The following is a simple formula for each side of upper cup height length.

c = g (bra band) – a (bottom cup)

d = h (bra band) – b (bottom cup)

8.8.2.3 Shoulder Strap

A 1 cm width of shoulder strap was used for this sample. Other measurements are considered as design lines.

After completion of the pattern drafting process, matching and reshaping of the pattern pieces is required. The seam allowance and notches are added afterwards. Figure 82 shows the finished pattern pieces.

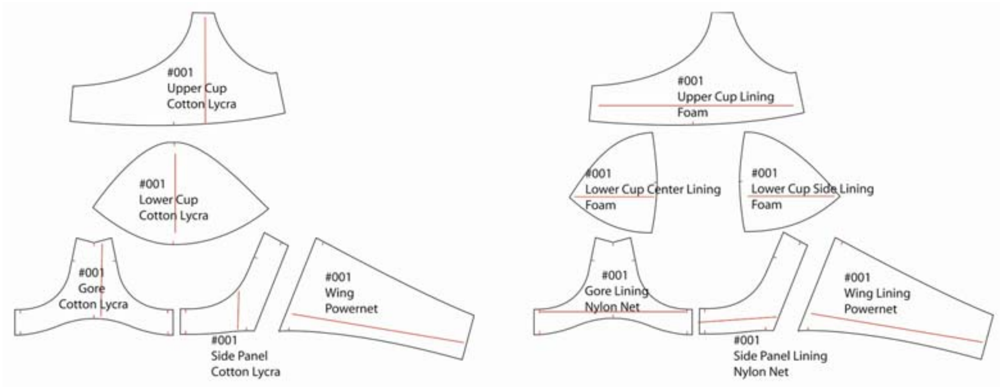


Figure 82: Complete pattern pieces with seam allowance, matching notches and pattern information.

8.9 The Impact of the Underwire on the Patternmaking Process

Using measurements of the breast (the breast inner curve length, outer curve length and breast depth) for a full cup wire is not only logical, but also easier to understand and use than previous methods. When a lower centre wire is used, cup drafting becomes rather like free-hand drawing which is difficult to rationalise, learn, and teach. Figure 83 shows the most popular/common cut and sew design variations for lower centre wires.

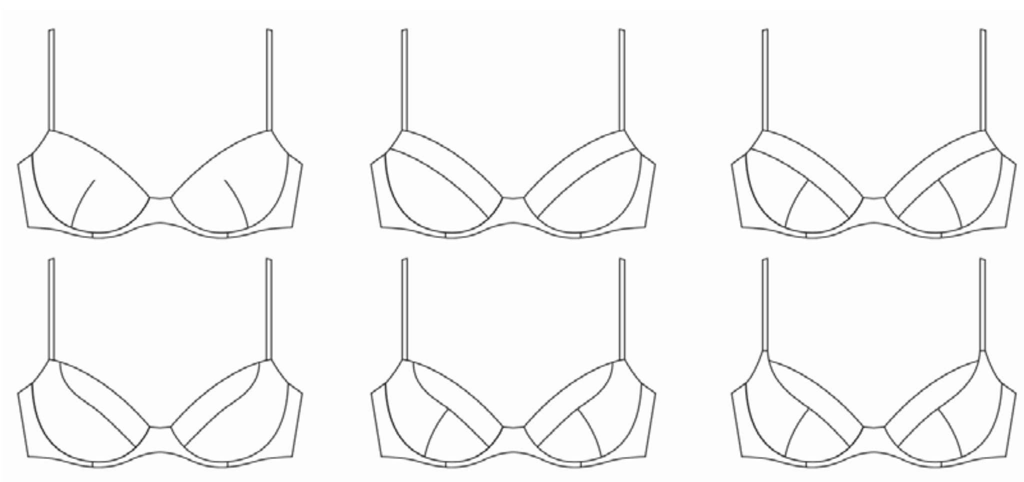


Figure 83: Design variation of lower centre wire bra.

The cup draft method introduced earlier in this paper, and commonly used in the industry, cannot be used because the upper cup shape is out of proportion. Figures 84a and 8b show examples of off-proportion upper cup pattern designs.

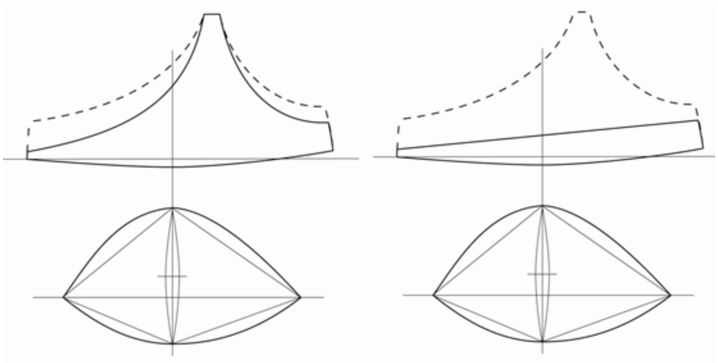


Figure 84: Example of off-proportioned upper cup pattern (a) and (b).

8.10 A New Method: Shin’s Bra Pattern

So, the use of a lower centre wire means that cup drafting becomes rather like free-hand drawing (Figure 91) and consequently difficult to achieve. However, the author’s method is much simpler in both concept and practice and therefore has considerable advantages for the home producer as well as the intimate apparel industry and educators.

8.10.1 Basic Block: Lower Cup Pattern

The lower cup pattern from the full cup bra drafting is used as a basic block. Figure 85 shows a cup guide pattern with a U-shape back bra band drafting.
The cup guide pattern for the lower centre wire is completed by extending each side of the bottom curve line and matching the length of the joining seam (see Figure 85). The curved line length [A–B] on the lower cup is the same as line [a-b] on the cradle and line length [B-C] matches line [b-c]. For this sample a 178mm lower centre wire was used.

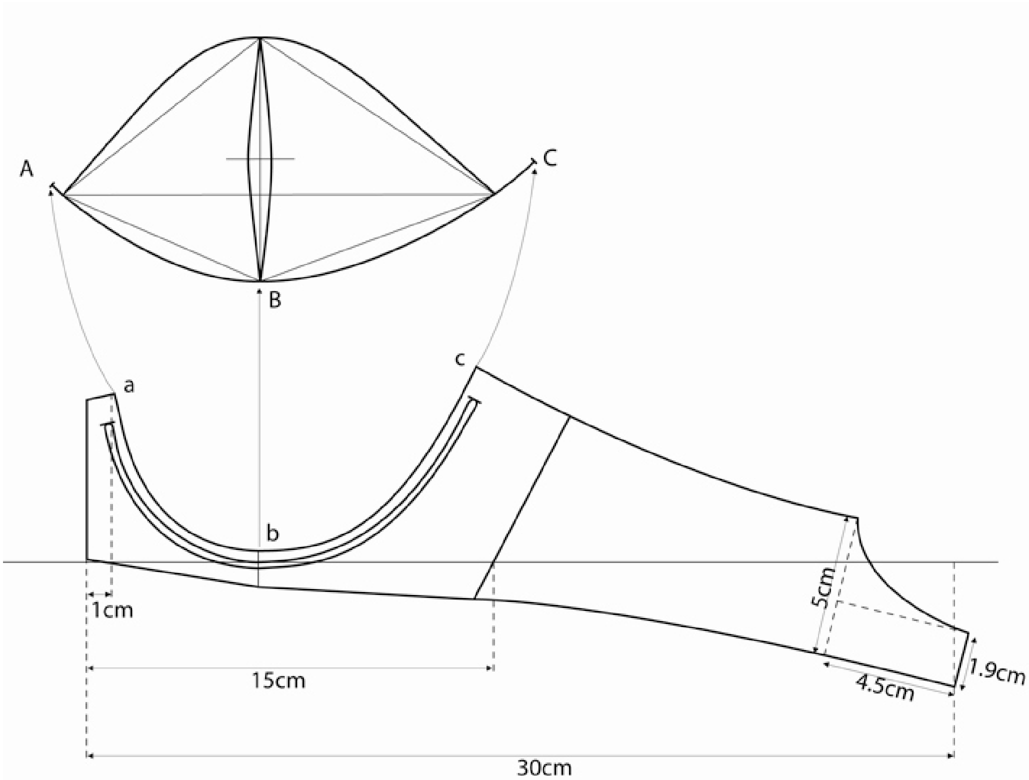


Figure 85: U-shape back band pattern with a cup guide pattern.

In Shin’s method, the lower cup works as a basic block and contains the body measurements to ensure fit and that the finished pattern shown in Figure 89 works as an intermediate block. This can then be further developed into various designs as shown in Figure 83. Finding the correct centre of the wire makes for different results when fitting, therefore it is important to train patternmakers to find the correct centre of the wire. Once the wire length growth is defined from the centre of the wire, development of a new intermediate block, or manipulation of an existing intermediate block, is relatively easy to accomplish. With this method, junior patternmakers and students with basic patternmaking knowledge can easily create various styles of bras from standard breast measurements.

8.10.2 Development of the Intermediate Block

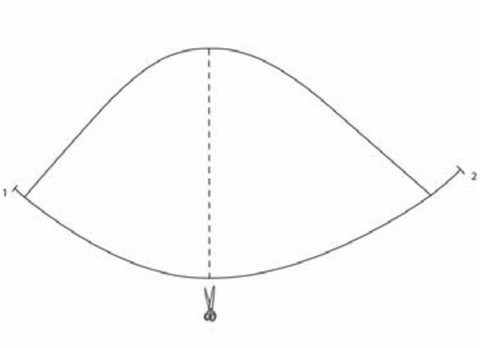


Figure 86: Development of intermediate block (step 1).

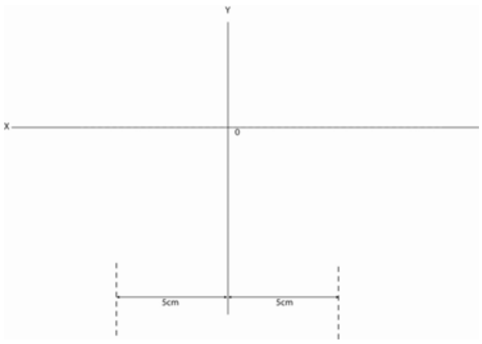


Figure 87: Development of intermediate block (step 2).

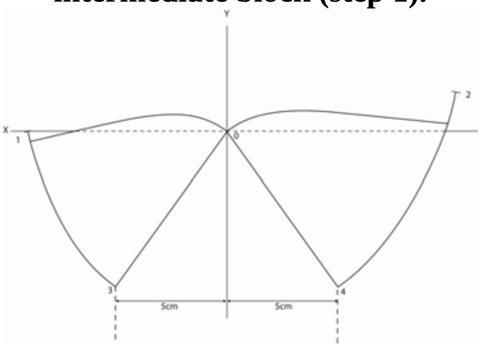


Figure 88: Development of intermediate block (step 3).

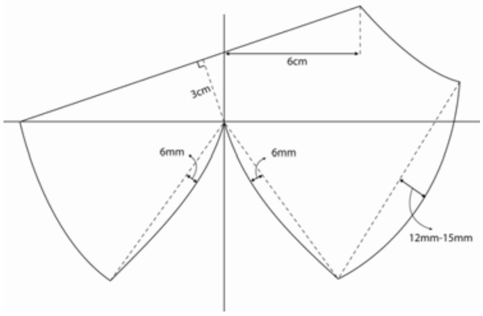


Figure 89: Completion of intermediate block (step 4).

Development of the intermediate block starts with cutting up the cup guide pattern at the centre (Figure 86). Then draw guide lines, X, Y and 5cm dotted parallel lines to Y for the underbust dart draft (Figure 87). The optimum underbust dart value for 34B is 10 cm which is calculated from the full cup bra pattern. Match the bust point to the point 0 and each centre of split guide patterns (point 3 and point 4) to 5 cm guide line (Figure 88). Reshape the dart legs and draw the neckline by following the guide measurements. The guide measurements can be different depending upon the construction materials used (Figure 89).

8.11 Pattern Manipulation: Industry Drafting Method vs. Shin's Method

Figure 90 shows an example of working drawings/ technical sketches for a patternmaker with measurements. The other measurements concerning the cradle and wing are omitted since this article is about bra cup drafting based on wire length/height change. Normally, designers provide as much information as they can give to patternmakers in order to achieve a more precise result.

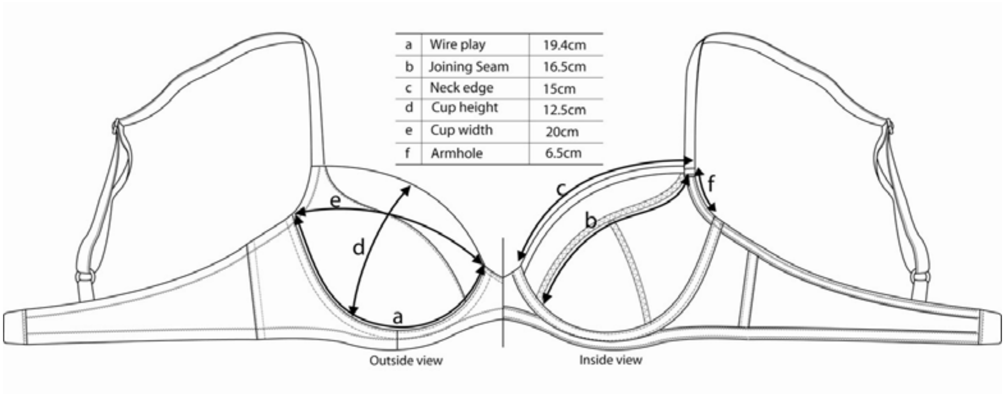


Figure 90: Sample work drawing with measurements.

It might be helpful here to provide some explanation of the industry practice in relation to how designers create a work drawing/technical sketch in order to instruct patternmakers. Generally, the designer measures an existing bra which is similar to what she wants to create and fills out the measurements along with a flat sketch so patternmakers can make patterns which will project the same fit. This practice is called preparing a 'knock off' and is one of the most popular methods used by industry fashion designers for both outerwear and under wear.

Figure 91 shows the direct drafting method for the technical sketch commonly used in the industry. Each individual patternmaker tends to have their particular unique way of drafting. Since measurements given by designers do not generally guarantee whether the final bra will cover the breast dimensions, this free drafting method is normally expected to have revisions of revisions.

This is one of the reasons why experienced patternmakers/designers are highly respected in the intimate apparel industry because this free direct drafting cannot be as easily or rationally explained as the flat patternmaking method, and junior patternmakers or junior designers spend much time working under the chief patternmakers' supervision in order to gain the necessary experience.

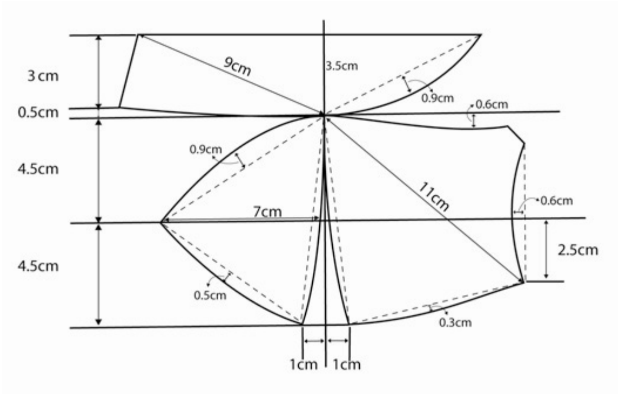


Figure 91: Direct drafting method used in industry.
Source: Anonymous, 2006

8.11.1 Pattern Manipulation Using the Intermediate Block

In comparison to the industry direct drafting method, Shin's method is easy to understand and use. Most importantly, it keeps the required breast measurements to ensure fit of the bra.

The following figures (Figure 92 – 96) show the steps of pattern manipulation using the intermediate block for design shown in Figure 90.

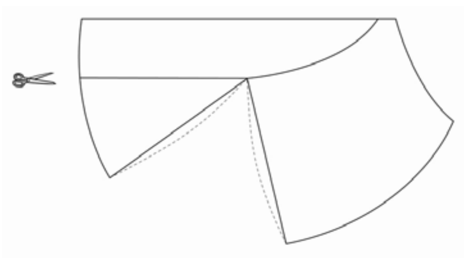


Figure 92: Pattern manipulation Step 1.

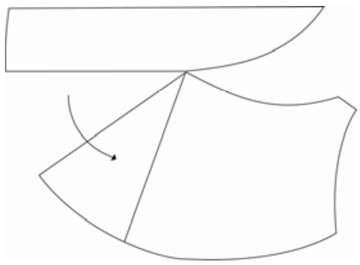


Figure 93: Pattern manipulation Step2.

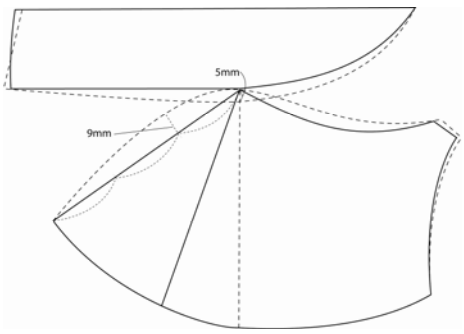


Figure 94: Pattern manipulation Step 3.

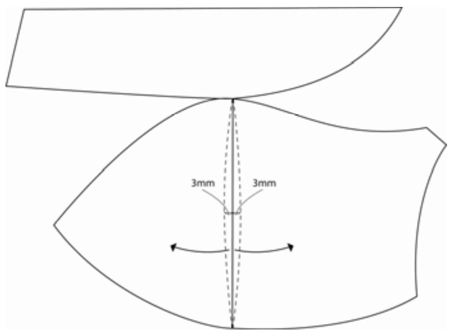


Figure 95: Pattern manipulation Step 4.

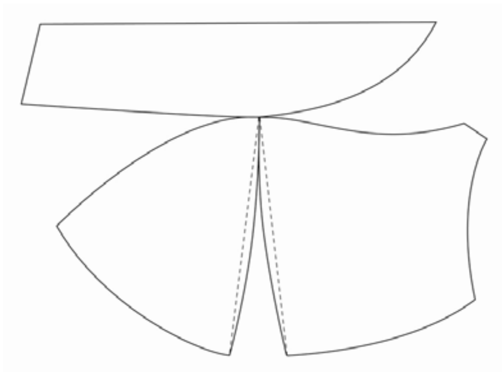


Figure 96: Finished pattern.

In order to pilot a comparison of the two alternative methods in practice a small study was set up using an experienced patternmaker and sewer working in an industry setting. In the sample preparation completed for this study, the finished pattern pieces using Shin's method (Figure 96) were virtually identical to the pattern pieces produced using the common industry method (Figure 91) with a minor difference in centre curve length (2mm).

8.12 Method

For ease of reference the study is described according to the chronological sequence used in production at the factory rather than the usual research report format.

8.12.1 Patternmaking

For this study a patternmaker with 5 years of experience in the intimate apparel industry was used for both methods of underwired bra patternmaking in order to minimise the effects of using two different patternmakers with their own styles. The specification sheet was presented (Figure 90) before the patternmaking commenced and the patternmaker used the industry method (one she is very familiar with) in the first instance. The pattern was complete in 4 hours and 25 minutes using this method. The patternmaker was then given instruction by the author on how to create and manipulate the intermediate block (Shin's method). The pattern was complete in 3 hours 28 minutes demonstrating a significant time saving over the original method.

The patternmaker also commented that, with a little more practice she could reduce still further the time taken using Shin's method.

8.12.2 Cutting

Cutting was done by a professional cutter with over ten years industry experience. Cutting and assembling trims such as rings, slides, hook & eye tapes and shoulder straps took 1 hour per bra. In other words, this time is the same irrespective of method. Table 21 shows pattern pieces and matching materials used.

Table 21: Pattern Pieces and Matching Materials

Pattern pieces	Material
Outer cup	Cotton lycra
Inner cup	Laminated foam
Outer centre piece/gore & outer side panel	Cotton lycra
Inner centre piece/gore & outer side panel	Nylon net
Wing double layers	Powernet

8.12.3 Sewing

Sewing was completed by a professional sewer from the same intimate apparel company with 8 years of experience. The same professional sewer produced each bra (one from each patternmaking method). Each bra took a fraction over 3 hours for complete sewing in industry conditions and the sewer noted no particular differences or difficulties with either of the two methods.

8.12.4 Sewing Machines Used

Table 22 shows the sewing operation and sewing machines used.

Table 22: Sewing Operation and Machines

Sewing operation	Sewing machine
Joining cotton upper cup and lower cup	Single machine (stitch type 300)
Joining foam upper and lower cups	Cover stitch machine (stitch type 600)

Joining wing and side panel	Single machine with 2 needle single machine
Joining cup to cradle	Single machine (stitch type 300)
Attaching elastic tape	1 zigzag machine (stitch type 300)
Attaching wire casing tape	2 needle single machine (stitch type 300)
Closing wire casing	Bar tack machine
Attaching shoulder strap	Bar tack machine

8.12.5 Fitting Result: Industry Direct Drafting vs. Shin's Method

Two bras were fitted on a 34B size dress form and a 23 year old Asian female model whose bra size is 34B. A comparison of the fitting, using the industry method versus Shin's method, showed no difference in terms of fitting result or time taken. Foam laminated with polyester warp knit fabric was used for the inner cup layer. Cotton with Lycra jersey was used for the outer cup and cradle, nylon net was used for the cradle lining, and two layers of 'powernet' were used for each wing. A 1cm elastic shoulder strap with metal rings and sliders, and a 1 cm width elastic underband together with a pair of 3.2cm width hook and eye tapes were used for the samples. Figure 97 shows the finished sewn bra using the pattern developed with Shin's method on the stand as well as on the 23 year old model. Both bras were compared and the fitting results of both bras were good making it difficult to distinguish which bra was made from which patternmaking method in a subsequent double-blind test using two more experienced patternmakers. In perfect conditions fitting should be undertaken using a variety of live models in order to achieve an optimum fitting result. This is because in practice the so called 'ideal' category 34B is made up of a number of different somatotypes!

Figure 97: Picture of finished garment on the stand and live model.

8.13 Conclusion

This study has considered the development of patternmaking methods in the intimate apparel industry and compared the ‘traditional’ industry method of patternmaking for the brassiere with the proposed new method. Results, and feedback from the industry professionals involved in this trial, indicate that Shin’s method is:

- More logical and easy to learn and use than the traditional method.
- Accurate in terms of maintaining the consistency of size and fit (Joseph-Armstrong, 2005).
- Considerably faster in the industry setting than the traditional method and therefore capable of expediting both the preproduction process, and job training for patternmakers.
- Suitable for use for both custom made and mass production patterns.

The potential benefits of adopting this new method for both the industry and in the field of education for training purposes are evident from this study and sharing this information amongst the industry and educators should help rekindle debate on patternmaking for the brassiere, something that clearly needs to happen given the long-term lack of patternmaking innovation in this area. The method is currently being tested using larger samples of a range of designs and materials and early indications are that it is performing in line with the results presented in this study. The continuing development of this method will rely upon the maintenance of close collaboration between educators and teachers of patternmaking and the intimate apparel industry. The rewards to both are significant, not least of which is casting light on the ‘dark art’ of patternmaking for the bra and encouraging further innovation in this ever growing area of intimate apparel design and production.

As a direct result of the study described in this chapter, the author identified several major technical issues related to patternmaking and fit in what is now the global industry of patternmaking and bra production. In recent years, Asian consumers have begun to recognise that bras designed, produced and fitted using a western patternmaking template have sometimes failed to provide a good enough fit, particularly in relation to the distance between the cups. Consequently, the next chapter presents a study which uses scanning data, another recent revolution in the underwear industry, to investigate the extent to which gore (the component material that goes between the cups on the contemporary bra) design and construction is truly global, and identifies other body type differences that the industry needs to address as it continues to become an ever more global provider.

CHAPTER 9
THE FAILURE OF BRA SIZING SYSTEMS AND THE POTENTIAL FOR 3D BODY SCANNING TECHNOLOGY: A QUANTITATIVE STUDY IN ETHNIC DIVERSITY

9.1 Introduction

It is not an overstatement to say that the contemporary bra industry is firmly focused on the goal of creating the 'ideal' breast shape through the utilisation of the now rapidly developing new design and production technologies. Recent developments in materials and production technology are being driven by the desire to accomplish this outcome. However, despite these developments and the increasing use of cutting edge technology to create a sleek, sexy, yet supportive bra, the traditional bra sizing system remains a problem for consumers and the industry. For example, it is estimated that more than 70 percent of women are currently wearing the wrong size bra (Boyes, 1996; Lipton, 1996; Young et al, 1994; Wacoal, 2008), and to some extent, this has resulted from the fact that the art of making a bra, including acquiring body measurements, patternmaking, and production technology, has not been as transparent a process as has been the case for outerwear. Given this context, it is perhaps not surprising that the profile and needs of the relatively new and growing body of Asian consumers has not been identified or fully understood by the industry (Lam, 2006). This is partly because, over many centuries, the bra has become largely a product of more developed western societies, and as this study will demonstrate is consequently still largely designed to fit the western body.

Therefore, the research question for this study is to investigate whether there is any significant difference in body measurements between Asian and Caucasian women, controlling the bra size at the industry norms of 34A-C. A particular measurement of interest in this regard is the sternum width (or distance between the breasts) which is currently a neglected area of bra design and patternmaking. In order to provide further background, the literature concerning breast measurement protocols, anthropometry, anthropometric tools and ideal breast shape are reviewed, and the results of a quantitative research study utilising three-dimensional body scanning data conducted by the author are reported and discussed.

9.2 Bra Sizing Systems and Breast Measurement Protocols

Although the size of the bra cup is said to represent breast volume, the traditional bra sizing system is calculated using only two measurements; the full bust girth and the underbust girth, both of which provide only inadequate approximations of breast volume (Zheng et al., 2007: Nethero, 2008) and no real allowance for the degree of firmness or consistency of the breast tissue (Nethero, 2008). This often leads to an inaccurate estimation of breast volume (the wrong cup size) which is further compounded by a lack of consumer knowledge about bra sizing protocols making it even harder for consumers to find the correct size of bra for their body type. In attempts to correct this situation, researchers from diverse fields, including the field of plastic and reconstructive surgery, have tried to establish a more precise breast sizing or measuring system, and this has led to the use of new technologies which involve three-dimensional body scanning techniques. In order to understand the potential importance of these developments, it is first essential to understand the characteristics of current industry practice in relation to bra sizing before the other suggested breast measurement protocols can be introduced. The next section will therefore review and describe the current system of bra sizing.

9.2.1 Bra Sizing and Labelling: Current Industry Practice

The bra sizing system currently used by many in the industry was introduced in the 1930s in the United States (Farrell-Beck and Gau, 2002). It is basically composed of two parameters; band size and cup size, which are calculated using only two body measurements; full bust and underbust girth. This method is very simple, although often inaccurate, but further problems arise from the different sizing and labelling practices adopted by the industry in different countries. Whilst this does not unduly affect the band size, which is a true underbust girth measurement, the same size of cup is often labelled differently between countries, and sometimes even between manufacturers in the same country (Westreich, 1997). For instance, 34B size bras sold in the United States tend to be, although this is not consistent, one cup size bigger than the 34B size bras sold in the United Kingdom. Furthermore, bras sold in Asian countries are generally one cup size smaller than bras sold in Western countries, so although the size label says 34B, the product is what would be regarded as a 34A in Europe. This is generally done to please smaller breasted Asian consumers who can say they are a size 34B whereas they are probably a size 34A. This adds considerable confusion and leads to consumers experiencing bra fitting problems in a world where the industry is increasingly global, and consumers increasingly travel cheaply. The situation gets even more complicated when the cup size is above size D because of the practice adopted by manufacturers to please big size customers by using a smaller size labelling system. For instance, DD which is equivalent to E is used or DDD is used instead of F. Consequently, big busted women find bra buying even more difficult (www.85B.org, 2008). As a consequence of these vagaries in sizing and labelling, the traditional bra sizing system is often criticised for its lack of clarity (Pechter, 1998; Zheng et al., 2007). The confusion, and sometimes discomfort, created by inconsistent industry practice in terms of bra sizing is clearly a very important consideration when those sizes are used in mamaplasty breast augmentation surgery.

9.2.2 Bra Sizing for Plastic Surgery

Plastic surgeons often use the bra as a guide to conduct an augmentation mamaplasty (Young et al., 1994; Bates, 1995), but because these surgeons are also focusing on actual breast volume differences (measured in cubic centimetres), they have increasingly tended to create and use their own breast measurement protocols in order to ensure the correct size change in volume, rather than using the two gross linear measurements of underbust and full bust girth. Subsequently, many breast volume assessment studies have been done including thermoplastic cast (Edsander-Nord et al., 1996), mammography (Katariya et al. 1974), MRI (Fowler et al., 1990; Mineyev et al., 1995), stereo-photogrammetry (Loughry et al., 1987) and three dimensional (3D) laser scanning (Kovacs et al., 2006). Some of these studies have emphasised the need to standardise the female breast measurement protocol and, consequently we will now turn to a consideration of these new breast measurement protocols, using anthropometric data which is both 2 and 3-dimensional.

9.2.3 Breast Measurement Protocols in the Western Context

Interest in this area of body measurement increased in the 1950's with the development and use of surgical techniques for breast enhancement and reduction. After analysing 20 females whose breasts were evaluated as 'aesthetically' perfect, Penn (1955) suggested normal body measurement values for the so-called aesthetically perfect breast (see Figure 98) which can be used for breast reduction surgery calculations.

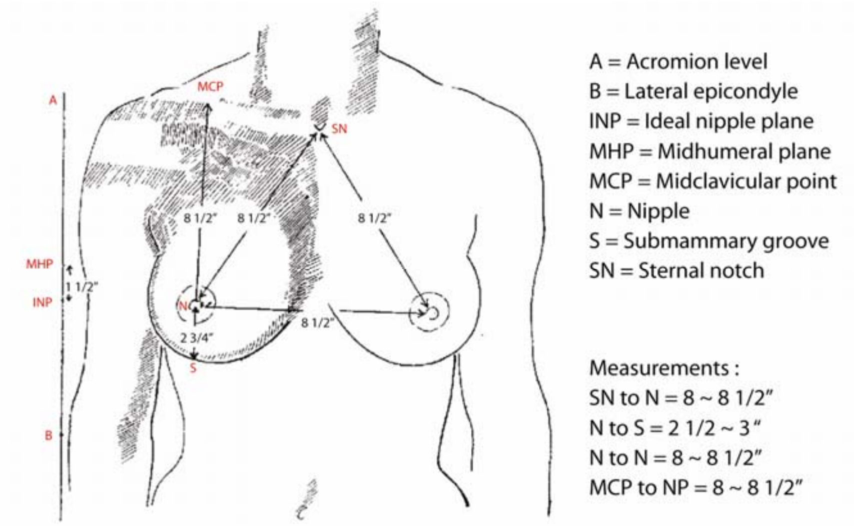


Figure 98: 'Aesthetically perfect' breast measurements. Source: Penn, 1955

One of the most startling findings from these studies (for the bra industry) was the fact that there was little or no correlation between breast dimensions and the participant's height and weight. Based on his data analysis, Penn identified an aesthetic triangle which connects the sternal notch, right nipple and left nipple which is defined with each line at a length of 8 ½" (21.6cm). Initially Penn's measurement values were widely used for breast reduction surgery, but it was later found that this 'universal aesthetic triangle' could not be applied to many body shapes (Westreich, 1997). Smith et al. (1986) conducted a similar study using a randomly selected sample of 55 women and suggested a normal value for breast volume and anthropomorphic measurements based on their result. The linear measurement points for their method are shown in Figure 99.

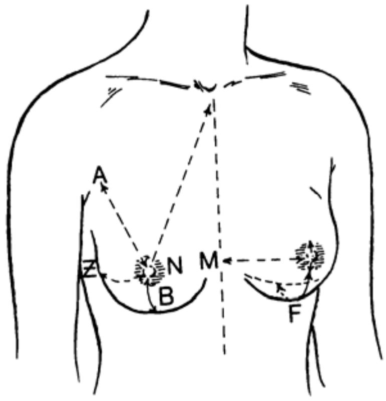


Figure 99: Linear measurement points. Source: Smith et al., 1986

However, the validity of this study was also criticised as many of the participants' demonstrated significant volumetric asymmetry, and moderate degrees of ptosis. In 1997, Westreich studied 50 women with the 'aesthetically perfect breast' in order to find a simple measurement protocol for clinical practice. He found a significant correlation between breast volume and four variables including measures of sternal notch-to-nipple, nipple-to-nipple, clavicle-to-nipple, and sternal notch-to-inframammary fold distance. Subsequently, he created a normal breast volume calculation formula (see Figure 100 for details) for clinical application which makes use of only two of these measurements; 1) sternal notch-to-nipple distance (M-Ni) and 2) nipple-to-nipple distance (N-Ni).

$$\text{Volume} = (\text{M–Ni})^{1.103} \times (\text{N–Ni})^{0.811}$$

or

$$\log(\text{volume}) = [1.103 \times \log(\text{M–Ni})] + [0.811 \times \log(\text{N–Ni})]$$

Figure 100: Equation for breast volume. Source: Westeich, 1997

Pechter (1998) also developed a new breast measurement protocol after examining the body measurements of 100 women. Participant bra size was used as a measure of validity for this new method and Pechter suggested using a mammary hemi-circumference as a key parameter in order to determine the cup size of his participants. With this method, a mammary hemi-circumference of six inches corresponds to the AA cup size, seven inches to A cup, eight inches to B cup, and so on (see Figure 101). A breast implant of 300cc for each breast is required to achieve an increase of one cup size, or a one inch increment on the mammary hemi-circumference.

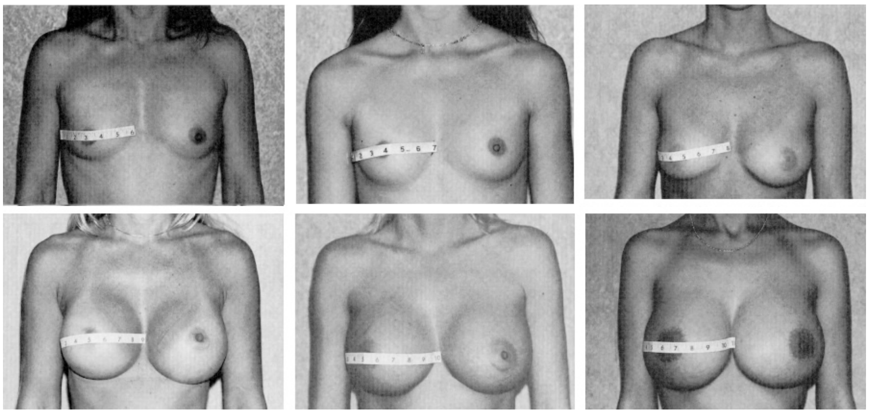


Figure 101: Pechter's breast cup sizing method. Source: Pechter, 1998

Also, the result showed that 77 percent of the participants were wearing the wrong size of bra when the traditional bra sizing calculation method was used, whilst this percentage dropped to 16 percent when his new method was used. Subsequently, he concluded that previous reports which suggested that over 70 percent of women were wearing the wrong size bra (Boyes, 1996; Lipton, 1996; Young et al., 1994) demonstrated how inaccurate and inappropriate the industry bra sizing system is. However, Pechter's new bra sizing method failed to define the bra band size (Kanhai and Hage, 1999), although he later identified a workable band size range as 34 to 38 (Pechter, 1999). Unfortunately, although this method is simple and easy to use, it requires drastic changes in industry practice which would not necessarily result in higher sales.

9.2.4 Breast Measurement Protocols in an Asian Context

Lee et al. (2004) proposed another protocol for 3 dimensional (3D) anthropometric breast parameters in order to achieve a reliable breast boundary and breast volume. This study involved measurements gathered from the naked 3D scanned body data of 37 middle-aged Korean women, whose bra size is 36A (80A), and they suggested a breast boundary defining method by pushing the breast up and inward (see Figure 102a).

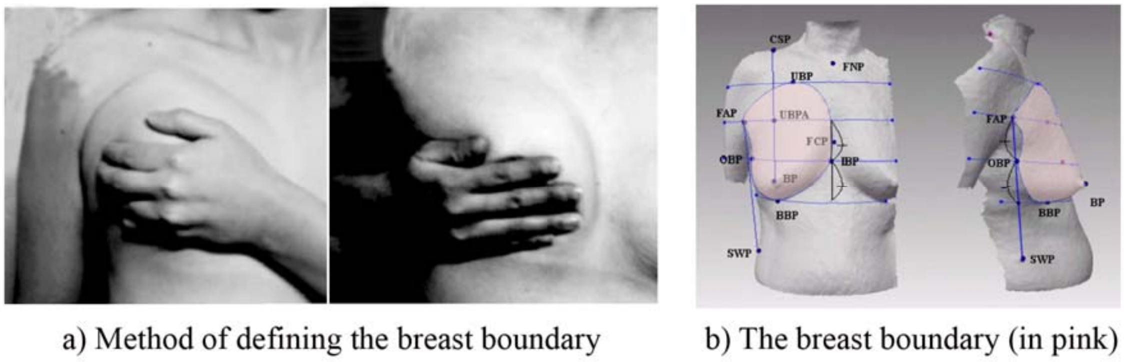


Figure 102: Breast boundary defining method (a) and defined breast boundary(b). Source: Lee et al., 2004

Using this protocol, having defined the breast boundary, an accurate measure of breast volume is determined by using the 3D images of the breast separated from the chest wall. In addition, the bottom breast volume and the bottom breast curve can be used to design a more comfortable and form-fitting bra. Wang and Zhang (2006 & 2007) took this idea one step further and developed a breast model library based on 3D body scan data by using free form deformation technology (see Figure 103).

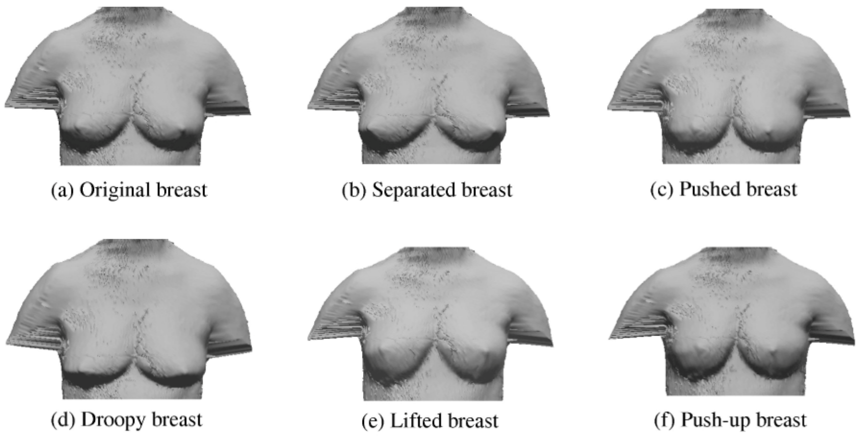


Figure 103: Virtual breast shapes. Source: Wang and Zhang, 2006 & 2007

One particular advantage of these approaches is that the suggested body model parameters (see Table 23) can be compared with the bra fitting result. However, a broader range of sizes are required as this particular body model can only fit certain bra sizes; namely US 36AA, UK 36A or 80A, which only represents a small proportion of the global female population.

Table 23: Parameters of Body Model

Body dimensions (cm)	Bust	Underbust	Bust point distance	Bust point height	Underbust point height
(a) Original	92.1	78.6	23.5	108.5	102.7
(b) Separate	92.1	78.6	28.8	108.5	102.7
(c) Pushed	92.1	78.6	17.0	108.5	102.7
(d) Droopy	92.1	78.6	23.2	105.6	102.7
(e) Lifted	92.1	78.6	23.2	113.3	102.7
(f) Push-up	92.1	78.6	17.0	113.3	102.7

(Source: Wang and Zhang, 2006 & 2007)

Zheng et al. (2007) suggested a new bra sizing protocol particularly for the Chinese female after analysing a sample of 456 females scanned 3D body data. The key parameters used for this new sizing system are 'underbust girth' and 'breast depth width ratio'. Figure 104 shows the breast depth and breast width used in the calculation.

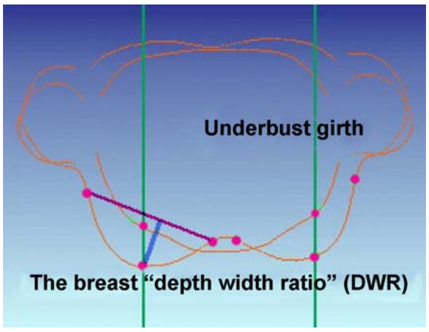


Figure 104: Two key control measurements for the new bra sizing system. Source: Zheng et al., 2007

Table 24 shows the breast depth to width ratio which Zheng et al. (2007) claim can help determine bra cup size for Chinese women.

Table 24: New Bra Sizing System for Chinese Women

Cup size	AA	A	B	C	D	E	F	G
Breast depth/width ratio	0.25	0.30	0.34	0.38	0.42	0.46	0.50	0.55

(Source: Zheng et al., 2007)

Zheng et al. (2007) found that the bra size accommodation rate, or the degree of perfect fit, increased to 98.72 percent for this sample using their new sizing system, whilst traditional bra sizing accommodation rate was 96.99 percent. In addition to the new bra sizing system, Zheng et al. (2007) also identified 103 body measurements which they suspected were relevant to achieving measurements which would accurately delineate the breast shape. They concluded that overall body build (factor 1) was positively correlated to underbust girth, which, in turn was positively correlated with the participant's weight. However, this contradicts some previous studies (Katch et al., 1980; Penn, 1955) which identified no correlation between height, weight and breast volume. Zheng et al.'s method complements the traditional bra sizing system despite the core idea being to move away from this approach. In practice, there is so far no evidence of any significant implementation of any of these new approaches led by the bra industry. Despite this, the fact that 3D body scanning technology was adopted for these three recent studies (Lee et al., 2004; Wang and Zhang, 2006 & 2007; Zheng et al., 2007) sends a clear signal that this technology is highly likely to eventually influence the bra design and manufacturing industry. Consequently, the next section will introduce this technology and its role as a cutting-edge anthropometric data collection tool.

9.3 Anthropometry and its Tools

9.3.1 Anthropometry for Clothing Design

Anthropometry is the study of human body measurement for use in anthropological classification and comparison (American Heritage Dictionary, 2006), and the use of anthropometric data for clothing design has a long history. The US military conducted 40 anthropometric surveys of U.S. military personnel from 1945 to 1988 in order to provide clothing that was a good fit, and ensure ergonomically designed equipment and workplaces for their personnel. Also, the first survey and statistical analysis of women's body measurements in the UK was conducted as long ago as 1951 with around 5,000 participants aged between 18 and 70 years (Beazley, 1997). Anthropometric data is currently mainly used for the development of a sizing system which can benefit both manufacturers and consumers by accurately identifying the correct body measurements which then dictate the fitting result because pattern construction will be based on these body measurements. Therefore, the choice of body measurement collection tools holds the key to the integrity of the body measurements and subsequent success in terms of fit.

9.3.2 Anthropometric Data Collection Tools

9.3.2.1 Manual Measuring Tools

There are currently two available types of anthropometric data collection tools. The first of these are, of course, the manual measuring tools but more recently the industry has taken more of an interest in three-dimensional (3D) body scanning. Commonly used manual tools include tape measures, calipers, and anthropometers which are specially designed for obtaining human body measurements. The price of manual tools is considerably cheaper than 3D body scanners but they overcome many of the difficulties associated with manual tools. Firstly, manual anthropometric data collection relies heavily on the experience, judgement and skills of the person doing the measuring. Furthermore, the integrity and accuracy of manually collected body measurements can be easily affected by the industry standard landmark method, which involves the identification of certain crucial points on the human body such as bust, centre and neck points, as well as the way the measurers use the tools at their disposal. In addition, manual anthropometric data collection is time consuming. For example, it took four hours to landmark, measure and record one subject during the 1988 U.S. Military anthropometric survey (Paquette, 1996). In order to minimise the time and error in anthropometric data collection, it has been suggested that using a computer for data input and editing on site (Churchill et al., 1988; Healy, 1989) as well as setting up the measurement protocol (Gordon & Bradtmiller, 1992) would be helpful. However, the problem of different individual judgements by those doing the measuring in terms of, for example, landmark location, instrument application, and subject positioning remains a potential source of error (Bennett and Osborne, 1986). Therefore, the advent of the 3D body scanner was exciting news for the field of anthropometry because it has the potential to reduce collection time considerably. One particular example of this is provided by the Uniform Systems for Improved Tariffs (USFIT) programme being conducted by the U.S. Army Solider Centre, which is utilising 3D whole-body scanning technology to update the anthropometric data collected in 1988, in order to ensure the accuracy and integrity of current anthropometric data (U.S. Army Soldier Systems Center, 2007).

9.3.2.2 The Introduction of the 3D Body Scanner

Simple, fast, and sufficiently accurate 3D body scanning technology for partial-body scanning was introduced in the 1970's (Lovesey, 1974) but did not develop into whole-body scanning until the mid-1990's (Paquette, 1996). In the 1970's, 3D body scanning technology was not yet sufficiently well-developed for use in clothing patternmaking, and this remained the position throughout most of the 1990's (Beazley, 1997). However by early 2000, with improvements in technology and the emergence of different types of scanning technology, these 3D systems became sufficiently well-developed to have practical use in terms of patternmaking for underwear (Mckinnon and Istook, 2002). Various technologies including CMM (Coordinate Measuring Machine), laser, long range, portable CMM, structured laser light projection, and white light projection are now used in order to capture an accurate 3D image of the human torso (see Table 25 for a review of available scanners and technologies).

Table 25: Currently Available 3D Scanning Technology.

Technology	Company	Product
CMM	Polhemus	FastSCANTM
Laser	3D Alliance GmbH	n-Sigma Sensor DXS, Digi Scope, Hexman, n-Sigma Sensor PHT1, n-Sigma Sensor PH2/1, n-Sigma Sensor XXS, Digimill.
	3D Digital Corp.	Optix 400M, Optix 400H, Optix 400S, Optix 400L, EScan
	Creaform	Handyscan 3D
	Cyberware	Whole Body Color 3D Scanner Bundle, Model Shop Color 3D Scanner Bundle, Mini Model Shop Color 3D Scanner Bundle, Desktop 3D scanner Bundle, Head & Face Color 3D Scanner, Whole Body X Scanner, Whole Body 4 Scanner
	Digibotics	Digibot
	Faro Technologies	Faro Laser ScanArm Platinum
	Frontier Advanced Technology Ltd.	Scan 3D

	Hamano Engineering	HEW-50HS, HEW-250HS, HEW-300DS, LPW-1100FW, LPW-2000FW, HEW-1800HSW
	Immersion	MicroScribe 3D
	INTECU	Callidus CT 180, Callidus CT 900, Callidus CP 3200.
	Konica Minolta sensing, Inc.	VIVID 910, VIVID 9i
	Kréon Technologies	KLS171, KLS51, KREON ZEPHYR
	Leica HDS	HDS 3000, HDS 4500
	Metricvision	MV-200-24
	Nextec technologies 2001 Ltd.	Hawk, Wizprobe
	NextEngine	NextEngine Desktop 3D scanner
	Perceptron	ScanWorks V3, ScanWorks V4i, ScanWorks V5.
	Renishaw	Renscan5, Revo
	Riegl	LMS-Z420i, LMS-Z390, LPM-i800HA, LMS-Z210ii, LPM-2K
	RSI (Roland Seifert Imaging GmbH)	DigiScan 2000
	Scantech	Scantech
	ShapeGrabber	LM600, LM1250, LM1750, AI300, AI600, AI810 Inspection System , PLM300, PLM330, PLM600
	Surphaser	Surphaser 25H S Hemisherical
	Tecnodrill	Digiform, Digimill
	Vitana Corp.	PixeLINK
	Wolf & Beck	Sensorik
	Z Corporation	ZScanner 700
Long range	Trimble	GX, GS200,
Portable CMM (Coordinate Measuring Machine)	Cimcore	Infinite Portable CMM, Infinite Scanning Arm, STINGER II, GridLOK, SpaceLOK
	Immersion	Microscribe G2LX, Microscribe G2L, Microscribe G2X, Microscribe G2.
	Metronor	SOLO
Structured Laser Light Projection	DEIOS S.A.	IFP 1
White-light	Breuckmann GmbH	Stereo SCAN 3D, smartSCAN 3D Mono, smartSCAN 3D Stereo, triTOS-HE, mikro TOP, derma TOP, opto TOP-HE600, opto TOP-HE400, opto TOP-HE200, opto TOP-HE100, opto TOP-SE, Bodyscan, face SCAN II, face

		SCAN III
	Genex	Rainbow 250
	GOM mbH	ATOS
	Inition, Ltd	Mephisto
	NEC Engineering	Danae100SP
	Opton	Cloudforma, Surftizer
	Steinbichler	COMET T-scan, COMET IV
	[TC]²	NX-16 3D full body non-contact body scanner
Others	CGI	CSS-3000, CSS-1000, CSS-300
	Optimet	Mini-Conoscan 3000
	Roland Digital Group	MDX-15, MDX-20, LPX-600
	Romer, Inc.	G-Scan RX2
	Surphaser	25HS, 25SP

(Source: www.rapidform.com, 2008)

Despite the seemingly vast range of scanners and scanning technologies available today, the methods they employ can be explained very simply. Data points corresponding to the shape of the subject are collected (this is called a '3D point cloud'), then a body model is produced from this 3D point cloud, and the required anthropometric data is then extracted from this body model ([TC] ², 2007; Mckinnon and Istook, 2002; Istook and Hwang, 2001; Paquette, 1996; Staples et al., 1994). Although these machines use relatively simple methods, it is still crucial to check not only the operation of the 3D scanner but also the particular body measurement extraction software. From the designer and patternmaker viewpoints, after measurement extraction, statistical data analysis is required in order to understand the population from which the sample is drawn, and to develop a sizing system from the collected anthropometric data (Beazley, 1997). 3D body scanning technology has many advantages over manual methods which include the fact that accurate sets of complex data can be produced and reproduced in seconds, and then mapped onto other body data to check for generalisability (Mckinnon and Istook, 2002; Istook and Hwang, 2001; Paquette, 1996; Staples et al., 1994). Furthermore, with the traditional body measuring method, if any measurement points are missing, a subject needs to come back to be measured, whereas, with 3D body scanning technology, it is possible to collect additional body measurement data without recalling a subject as the exact copy of the subject's body is already scanned, stored and ready to be reused.

9.4 Method

9.4.1 Design

This study involved a lengthy and arduous process of filtering out potential participants whose bra size measurements did not fall within the required range from a convenience sample obtained through public advertisement and industry contacts. Having thus identified and obtained consent from the remaining 90 Asian and 90 Caucasian participants, individual naked body scans for each participant were then conducted using the most up-to-date 3D scanner currently available for industry use. The detailed body measurements (over 200 are actually produced) were then given to each participant as a thank you, and for their personal use when purchasing both underwear and outerwear. All participants were provided with a written undertaking that their individual identities, other than their ethnic origin, would not be divulged either as part of this study or any other subsequent study. The author (female) conducted all scans personally and in the total privacy and comfort of the studio laboratory space at Polytechnic University of Hong Kong.

9.4.2 Participants

The sample for this study consists of 180 women (90 Asian and 90 Caucasian) with bra sizes within the range of US 34AA-C (equivalent to UK34A-C) who volunteered to take part in this study in return for obtaining their own scanned body data. In order to ensure that participants actually were within the size range of US34AA-C (and not just reporting inaccurate bra sizes) the breast volume (commonly known as cup size) of each individual subject was calculated by using the breast depth and width ratio (DWR) method suggested by Zheng et al. (2007). This particular range of bra sizes was selected in order to align with industry bra band patternmaking practice which uses 34B as the core size from which other bra sizes (34AA, 34A, and 34C) are graded. Therefore, potential participants with a bra size falling outside this range (e.g.

US 34D) were excluded from the sample because the industry creates a new set of bra patterns for these sizes. This is done because the grading from 34B method fails to produce sufficiently accurate garments. Tables 26 and 27 show the distribution and number of participants grouped by the US and UK bra sizing system respectively, after application of the DWR method of manual measurement.

Table 26: Bra Size of Participants by US Sizing System

US sizing system	34 AA	34A	34B	34C
Asian (n=90)	13	32	29	16
Caucasian (n=90)	0	15	75	0

Table 27: Bra Size of Participants by UK Sizing System

UK sizing system	34A	34B	34C
Asian (n=90)	26	36	28
Caucasian (n=90)	0	90	0

Perhaps surprisingly to those not familiar with the industry, age is not a significant factor for fit-models (unlike catwalk models) with breast size (34B) and projection being more important factors. The age range of participants in this study was between 19 and 63years, and the mean age of the Asian and Caucasian groups was 30.5 and 33.45 respectively. Therefore, this sample represents characteristics (e.g. body measurements and age) which are consistent with the requirements for bra industry fit-models. All participants were residents of Hong Kong at the time they were scanned.

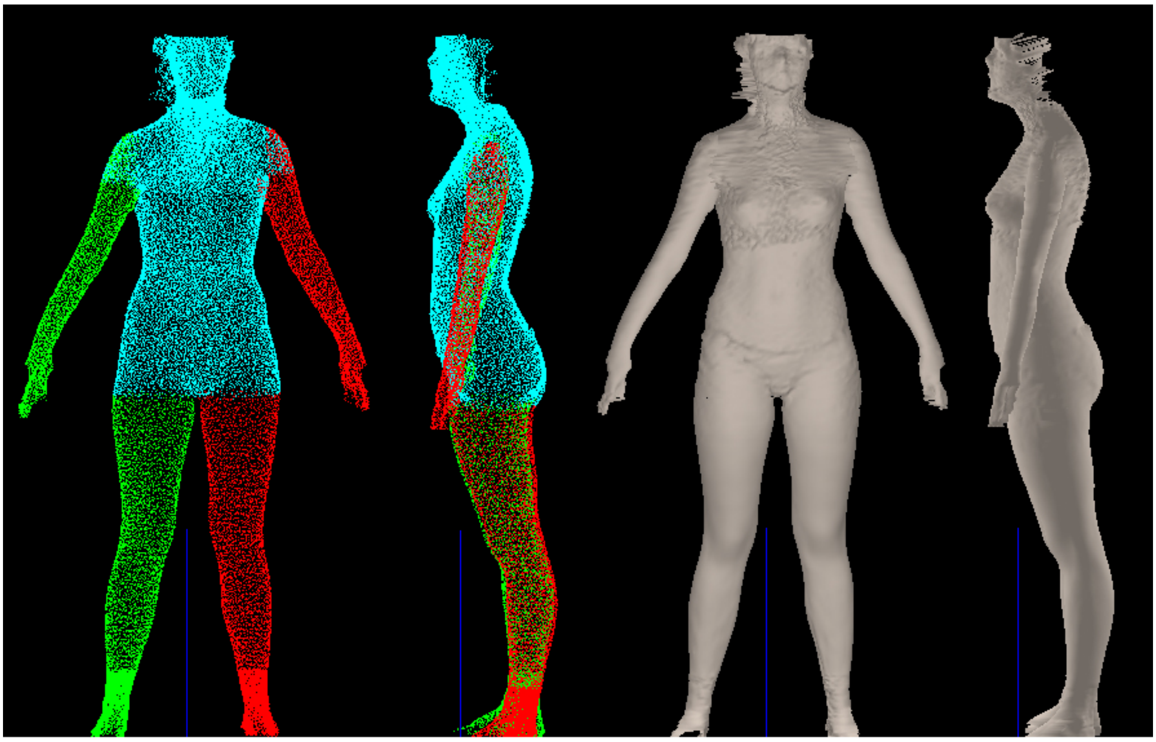
9.4.3 Apparatus

The cutting edge 3D body scanner by [TC] ² was used for obtaining the body scan and subsequent measurement data, and the statistical software package SPSS (SPSS Inc.) was used for data analysis. Textiles Clothing Technology Corporation [TC] ² is a pioneer in 3D whole body scanning technology. The [TC] ² NX-16 3D full body non-contact body scanner and its software was employed for the collection of body measurements from the naked bodies of the participants. The [TC] ² NX-16 is designed to provide accurate and consistent measurements of the human body to enable the clothing industry to produce better fitting garments ([TC] ², 2007). The system has relatively low running costs and a short processing time because it utilises white light projection technology (Mckinnon and Istook, 2002; [TC] ², 2007).

9.4.4 Procedure

Participants came to be scanned in small groups of two or three at a time during weekday evenings and Saturdays between September and December 2008. They each met with the researcher who obtained a signed consent form in accordance with the undertaking to protect their identity. They were then allowed to undress and given a gown to wear which was only removed when they were in the scanner and passed to the researcher, who returned it to the participant at the completion of the scanning process. A study by Mckinnon and Istook (2002) showed that respiration and foot positioning or span could easily affect the accuracy of body scan data and recommended a measurement protocol, specifically for the [TC]² 3D body scanner, to increase data integrity and reproducibility.

Consequently, the participants for this study were advised to breathe normally and put their foot on a foot pattern which was pre-manufactured on the [TC] ² 3D body scanner. Figure 105 shows two sets of scanned body surface images; (a) 3D points and (b) surface image. Each scan takes less than one minute to complete. On completion, participants were given coffee and biscuits, and a copy of their scan data, which they could then ask the researcher to explain in more detail.



a) 3D points surface data b) Surface data

Figure 105: Scanned body surface data by [TC]² body scanner

9.4.5 Variables

Whilst the scanner produces over 200 parameters or measurements, this study concerns itself with a total of 29 parameters including linear body measurements, volume, and bra sizes, which are relevant to bra sizing protocols and these were either extracted or calculated and used as variables for data analysis (see Table 28 for a list of these). The independent variables for this study were the ethnicities (Asian and Caucasian) and the dependant variables are the scanned body measurement data and subsequent bra size information. A total of 22 body measurements were selected from an initial set of 198 body measurements. The discarded measurements generally related to body parts not implicated in bra sizing (e.g. head circumference and foot length). Amongst these 22 body measurements, 10 involve measurements of both the right and left sides of the body which demonstrates another advantage of using a 3D body scanner. In contrast, the manual anthropometric protocol recommends collecting the only the right side measurement for certain body parts (Beazley, 1997). For the sake of clarity and brevity, only those parameters which returned consistently significant and sizeable results in terms of ethnic differences are presented in the results section of this chapter.

Table 28: Linear Body Measurements and Other Parameters

Linear body measurements	Other parameters
1. Prominence (right and left) 2. Bust girth 3. Underbust girth 4. Bust point to bust point 5. Sternum 6. Full bust width 7. Full bust depth 8. Underbust width 9. Underbust depth 10. Breast arc 11. Breast inner arc (LBIA) 12. Breast outer arc (LBOA) 13. Back neck to bust point (right and left) 14. Front neck to bust point (right and left) 15. Front neck to bust point to waist (right and left) 16. Front neck to bust level on the centre line 17. Side neck to underbust (right and left) 18. Side neck to underbust to waist (right and left) 19. Bust to waist (right and left) 20. Bust height (right and left) 21. Underbust height (right and left) 22. Height	23. DWR (depth and width ratio) (right and left) 24. Weight 25. US bra size 26. UK bra size 27. Asian bra size 28. Age 29. Ethnicity (Asian and Caucasian)

Figure 106 shows the measurement positions on the body. Each number corresponds with the numbers in the list in Table 28.

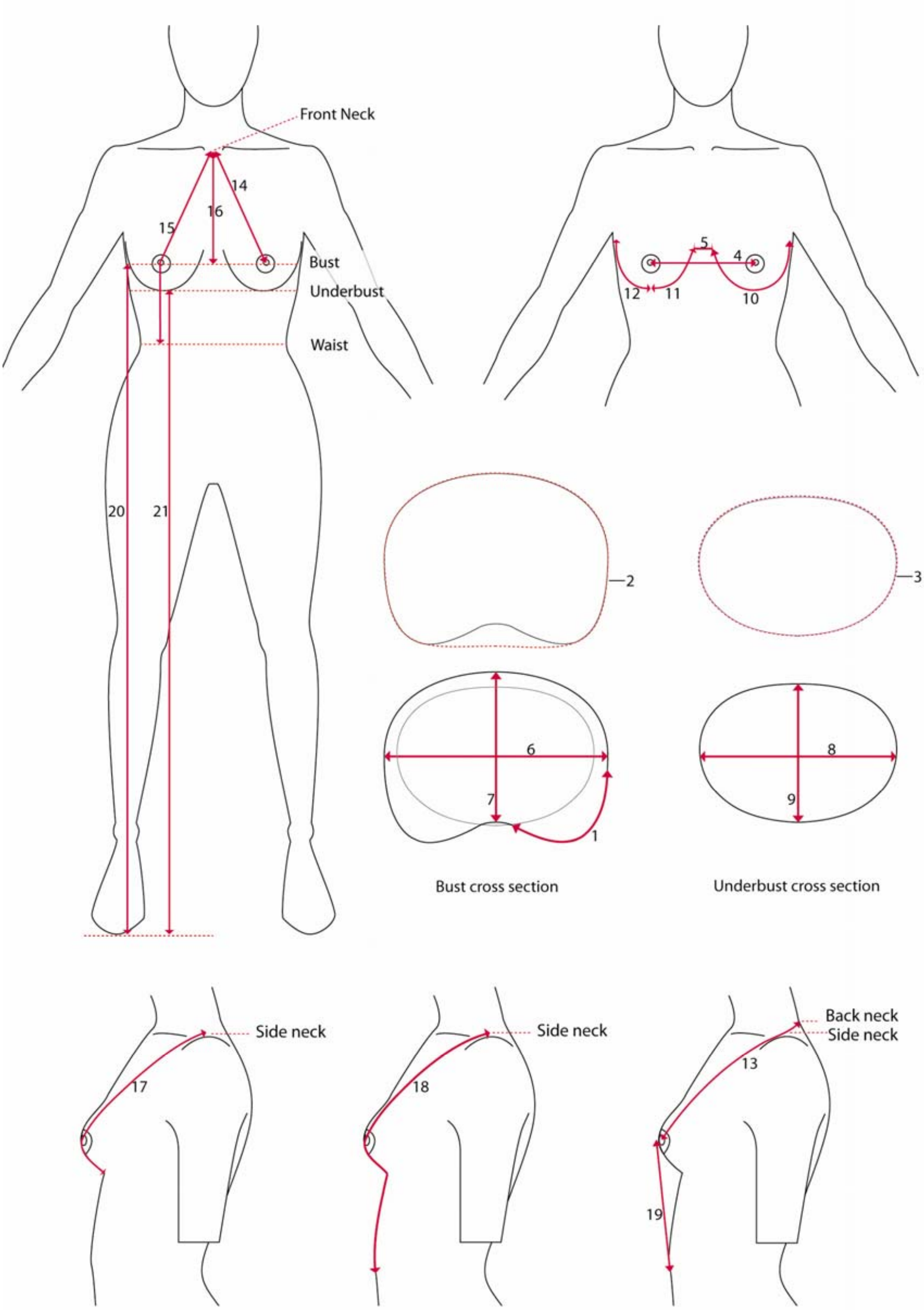


Figure 106: Body measurement points used in the study.

9.5 Results

The data set was grouped and analysed using three separate approaches in order to capture any significant differences between the Asian and Caucasian groups whilst controlling and investigating other potential variables such as height, weight, somatotype, and bra size using the DWR method of manual measurement. The data was therefore grouped and analysed in sequence as follows:

i. **Analysis of all data:** Table 29 shows the results of the analysis of all data relevant to bra size (N=180) both with (adjusted) and without controlling for height and weight. For the purposes of adjusted data treatment, the height cut-off point was set at less than or equal to 5 feet or 60 inches and the weight cut-off point was set at less than or equal to120lb (54.43Kg).

ii. **Analysis of all data by four somatotypes:** Figure 107 and Tables 30 to 33 show the results of the analysis of all the data (N=180) when participants were grouped into the four accepted somatotypes (Sheldon, 1940) based on both height and weight. In other words participants are divided into four groups or body types using the same height and weight cut-off points as in i above.

iii. **Analysis of all data for bra sizes US 34A and 34B:** Tables 34 and 35 show the results of the analysis of the data for US bra sizes 34A (n=47) and 34B (n=104) for both Asian and Caucasian participants. This analysis was accomplished by selecting only the data for those participants with US bra sizes 34A and 34B which correspond to the most popular bra sizes by sales, and the industry core sizes for grading purposes.

The results were analysed using *t*-tests for unrelated and related samples as appropriate and an a priori significance level of $p<.05$ was set.

9.5.1 Analysis of All Data

Table 29 shows the results of the statistical analysis for the whole sample (N=180) where the actual measurement points form the content of column 1, ethnicity in column 2. Columns 5 and 6 represent the significance levels before and after height and weight adjustment respectively, with significant results highlighted and in bold typeface.

Table 29: Analysis of All Data Relevant to Bra Size (adjusted)

Measurement (inches)	Group	N=180			Adjusted *p*-value
		Mean	SD	*p*-value	
Bust girth	Asian	35.56	0.82	0.051	**0.035**
	Caucasian	35.73	0.25		
Bust point to bust point	Asian	7.31	0.47	**0.002**	**0.003**
	Caucasian	7.52	0.43		
Sternum width	Asian	1.47	0.57	0.070	**0.032**
	Caucasian	1.33	0.47		
Underbust width	Asian	10.38	0.30	**0.021**	0.360
	Caucasian	10.49	0.37		
Bust height	Asian	44.36	2.01	**0.000**	0.729
	Caucasian	46.03	2.07		
Underbust height	Asian	41.65	1.94	**0.000**	0.171
	Caucasian	43.38	2.04		

In summary, these results demonstrate non-adjusted significant differences between Asian and Caucasian participants for the following measurements; bust point to bust point, underbust width, bust and underbust height. When the data is adjusted to control for height and weight, statistically highly significant results are obtained for the following measurements:

- Bust girth
- Bust point to bust point
- Sternum width

In terms of description, this means that the Asian participants in this study showed marked differences from their Caucasian counterparts (in terms of height and weight) in three major areas of measurement. Asian participants display a significantly smaller bust girth, a shorter bust to bust point, and a wider sternum width (distance between the breasts) than their Caucasian counterparts. The average difference in each case is approaching two-tenths of an inch, enough to make a substantial difference in bra sizing and in terms of design, comfort, and support. The non-adjusted findings also suggest ethnic differences with Asian women displaying a slightly longer torso and smaller underbust width (rounder ribcage profile) than their Caucasian counterparts.

9.5.2 Analysis of All Data by Four Somatotypes

Sheldon's (1940) concept of somatotype was applied and operationalised as below to identify the distribution of differences in body shape between the two ethnic groups and to analyse the impact of somatotype on the key bra sizing measurements. The protocol for group allocation is as follows:

Group 1: (Small Mesomorphs) Height <= 60 inches, Weight <= 120lbs.
Group 2: (Endomorphs) Height <= 60 inches, Weight > 120lbs.
Group 3: (Ectomorphs) Height > 60 inches, Weight <= 120lbs.
Group 4: (Large Mesomorphs) Height > 60 inches, Weight > 120lbs.

Figure 107 shows a diagrammatic representation of these general body types. In terms of distribution, Asian participants are in the majority in terms of small mesomorphs (group 1 with n=40) whilst Caucasian participants are dominant in terms of large Mesomorphs (group 4 with n=48). The representation of ectomorphs (skinny) and endomorphs (chubby) is fairly evenly divided between the two ethnic groups. Each of the four group's data was analysed to ascertain if there were any significant differences in the six key measurements identified in Table 29. Table 30 shows the results for group 1 where a highly statistically significant difference for the bust point to bust point measurement ($p=.016$) was evident between the two ethnic groups of small mesomorphic body types. Once again, the Asian participants demonstrated a shorter distance from bust point to bust point than their Caucasian counterparts. Table 31 shows the results for the endomorphic body types and the Asian participants show significantly larger bust girth ($p=.044$) and full bust depth ($p=.017$) measurements than their Caucasian counterparts. Conversely, they also demonstrate significantly smaller measurements in terms of bust height ($p=.001$) and underbust height ($p=.000$) than the Caucasian group.

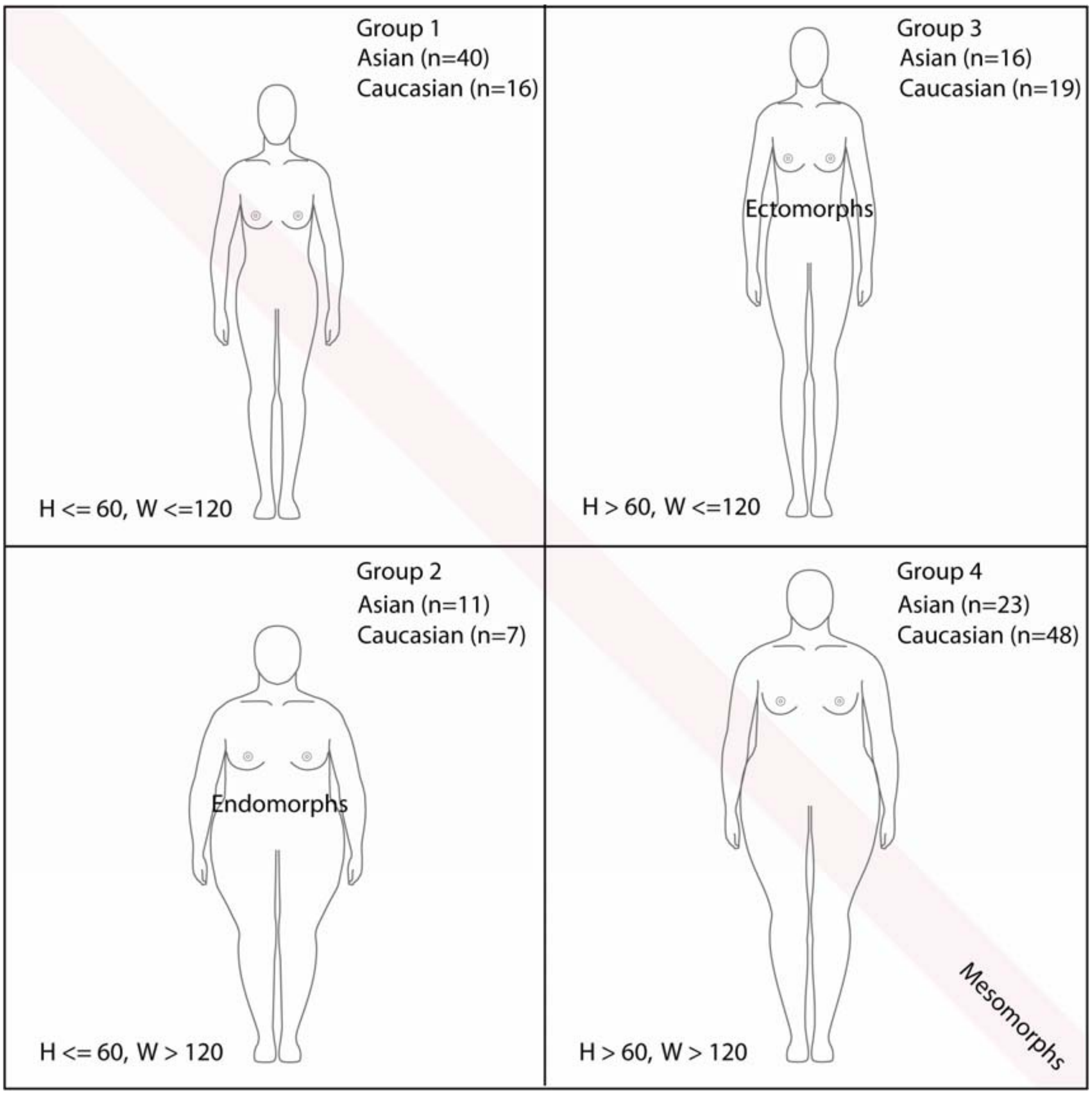


Figure 107: Four somatotype sub-groups categorised by height and weight

Table 30: Group 1 (Small Mesomorphs) H <= 60, W < = 120

Measurement (inches)	Group	N=56		
		Mean	SD	*p*-value
Bust point to bust point	Asian (n=40)	7.20	0.45	**0.016**
	Caucasian (n=16)	7.53	0.43	

Table 31: Group 2 (Endomorphs) H <= 60, W > 120

Measurement (inches)	Group	N=18		
		Mean	SD	*p*-value
Bust girth	Asian (n=11)	36.21	0.52	**0.044**
	Caucasian (n=7)	35.73	0.25	
Full bust depth	Asian (n=11)	8.71	0.38	**0.017**

	Caucasian (n=7)	8.34	0.21	
Bust height	Asian (n=11)	42.64	0.86	**0.001**
	Caucasian (n=7)	43.91	0.34	
Underbust height	Asian (n=11)	39.99	0.74	**0.000**
	Caucasian (n=7)	41.29	0.35	

Table 32 shows the results for the ectomorphic body type and here once again there are significant differences in bust girth (*p=.010*) and full bust depth (*p=.006*), although this time it is the Asian participants who return the smaller measurements. The same pattern holds firm for the underbust depth measurement (*p=.031*) for this somatotype group. For the final group of large mesomorphs (shown in Table 33) only one of the six measurements show a statistically significant difference between the ethnic groups and this suggests that Caucasians tend to have a larger underbust height measurement (*p=.029*) than their Asian counterparts.

Table 32: Group 3 (Ectomorphs) H>60, W< = 120

Measurement (inches)	**Group**	**N=35**		
		Mean	**SD**	***p*-value**
Bust girth	Asian (n=16)	35.10	0.85	**0.010**
	Caucasian (n=19)	35.74	0.22	
Full bust depth	Asian (n=16)	8.00	0.45	**0.006**
	Caucasian (n=19)	8.34	0.21	
Underbust depth	Asian (n=16)	7.48	0.53	**0.031**
	Caucasian (n=19)	7.84	0.39	

Table 33: Group 4 (Large Mesomorphs) H > 60, W > 120

Measurement (inches)	**Group**	**N=71**		
		Mean	**SD**	***p*-value**
Underbust height	Asian (n=23)	43.33	1.66	**0.029**
	Caucasian (n=48)	44.30	1.75	

In summary, the direction of the statistically significant findings for each group is as follows:

- Group 1: (small mesomorphs) The Asian participants have a shorter distance between bust points than Caucasians.

- Group 2: (endomorphs) The Asian participants have a larger bust girth with larger full bust depth measurements (rounder ribcage) than Caucasians. Asian participants also demonstrate shorter height on both bust and underbust height.
- Group 3: (ectomorphs) The Asian participants have a smaller bust girth with larger depth in both full bust and underbust depth measurements than Caucasians.
- Group 4: (large mesomorphs) The Asian participants have a shorter underbust height than Caucasians.

9.5.3 Analysis of All Data for Bra Sizes US 34A and 34B

A sub sample of participants with US bra sizes 34A and 34B (industry core sizes) was selected (n=151) to analyse the extent to which Asian and Caucasian measurement differences held for the industry bra sizing practice. This sub-sample was further sub-divided into two groups based on US bra size protocols. Group 1 (n=47) are US bra size 34A and group 2 (n=104) are US bra size 34B, as determined by the DWR method described earlier. The total sub-sample includes a distribution of 61 Asian and 90 Caucasian participants, with the Asian participants in the majority in the 34A size category and the Caucasian participants in the majority for the 34B size category. Tables 34 and 35 show the results of this analysis. A total of five relevant target measurements demonstrate statistical significance for both bra size groups. Once again column 1 shows the target measurement area, and columns 6 and 7 show the non-adjusted and adjusted levels of significance highlighted and in bold typeface.

Table 34: *t*-test Result based on Bra Sizes US 34A

Measurement (inches)	**US Bra size**	**Group**	**N=47**			**Adjusted *p*-value**
			Mean	**SD**	***p*-value**	
Bust girth	34A	Asian (n=32)	35.09	0.27	**0.001**	0.216
		Caucasian (n=15)	35.29	0.13		
Underbust girth	34A	Asian (n=32)	29.46	0.47	**0.000**	**0.000**
		Caucasian	30.15	0.16		

		(n=15)				
Underbust width	34A	Asian (n=32)	10.36	0.31	**0.001**	0.070
		Caucasian (n=15)	10.79	0.36		
Bust height	34A	Asian (n=32)	44.26	1.67	**0.000**	**0.049**
		Caucasian (n=15)	46.98	1.70		
Underbust height	34A	Asian (n=32)	41.57	1.68	**0.000**	**0.003**
		Caucasian (n=15)	44.49	1.71		

Table 35: *t*-test Result based on Bra Sizes 34B

Measurement (inches)	**US Bra size**	**Group**	**N=104**			**Adjusted *p*-value**
			Mean	**SD**	***p*-value**	
Bust girth	34B	Asian (n=29)	36.00	0.27	**0.002**	**0.000**
		Caucasian (n=75)	35.82	0.15		
Full bust depth	34B	Asian (n=29)	8.60	0.41	**0.019**	**0.016**
		Caucasian (n=75)	8.39	0.39		
Underbust depth	34B	Asian (n=29)	8.09	0.39	**0.007**	0.113
		Caucasian (n=75)	7.85	0.38		
Bust height	34B	Asian (n=29)	44.01	1.91	**0.000**	0.697
		Caucasian (n=75)	45.84	2.10		
Underbust height	34B	Asian (n=29)	41.38	1.74	**0.000**	0.991
		Caucasian (n=75)	43.16	2.04		

In summary the most significant findings for each of the two groups are:

- Group 1: (US34A) The Asian participants have smaller bust and underbust girth and width measurements than their Caucasian counterparts and they also demonstrate a shorter bust and underbust height. When height and weight are controlled (adjusted condition), the Asian participants have a significantly smaller underbust girth (*p = .000*), a shorter bust height (*p = 0.049*) and a significantly shorter underbust height (*p = 0.003*) than the Caucasian participants.

- Group 2: (US34B) The Asian participants in this group return larger measurements for bust girth, full bust and underbust depth than the Caucasian sample. The Asian participants also have shorter bust and underbust heights. When height and weight are controlled, the Asian participants demonstrate a significantly larger bust girth (*p = .000*) and full bust depth (*p = 0.016*) than their Caucasian counterparts.

9.6 Discussion

This study set out to investigate whether there are any significant differences in key body measurements between Asian and Caucasian women in terms of the parameters commonly used in bra design, patternmaking, and manufacture. In order to answer this question, it has utilised the latest developments in cutting-edge three-dimensional body scanning technology. This research question is an important one because the bra industry has become increasingly globalised over the past decade, with mass production being moved to many parts of the world where skilled labour is cheaper and readily available. Furthermore, in the past decade, interest in the latest fashionable designs of bra has grown exponentially in parts of the world where it was previously regarded as a largely functional garment. Despite this growth, the industry has failed to come to terms with the problems associated with bra sizing in general, and the potential difficulties in fitting both Asian and Caucasian women (Zheng et al., 2007; Nethero, 2008).

9.6.1 Bust Point to Bust Point and Sternum Width

The picture that emerges from the data is of significant differences in terms of bust point to bust point, and sternum width measurements, with Asian women displaying a wider sternum area (a key measurement relevant to gore sizing), and breasts which are closer together in terms of bust point to bust point (nipple to nipple) measurement (see Figure 108 for a diagrammatic representation).

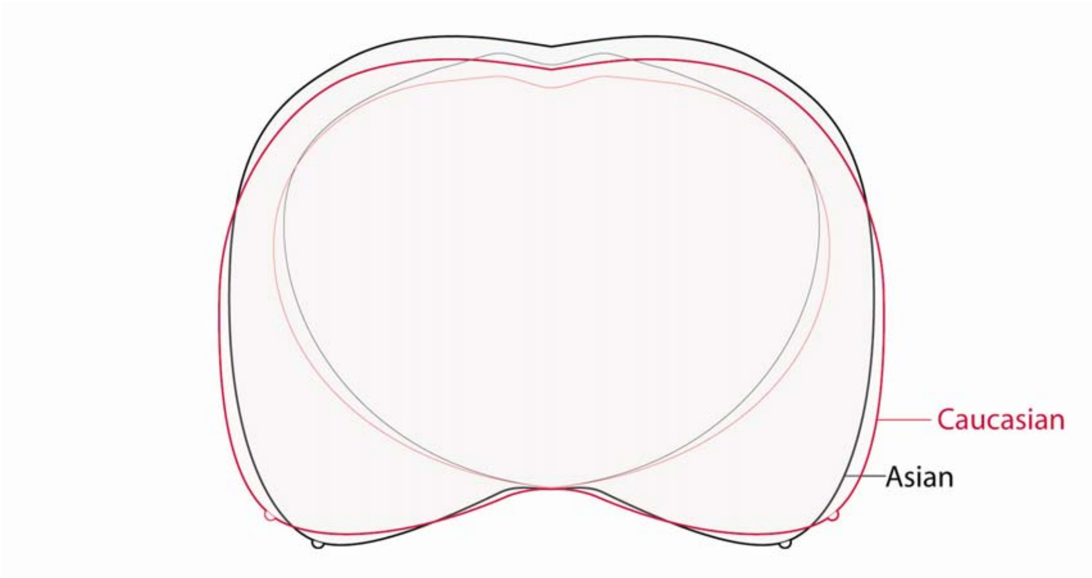


Figure 108: Simulated cross sections of Asian and Caucasian.

The implications for bra sizing are that, without the ability to adjust gore size (available earlier in the last century-see chapter 7, Thompson, 1906 and Kleinert, 1909) to accommodate the differing sternum widths, Asian women will find their bra does not fit well in the crucial central area (i.e. between the cups or gore) and consequently the breast will be forced against the upper inner side of the cup, leading to potential discomfort. The bust point to bust point differences (which are generally in the magnitude of more than two tenths of an inch) will mean that Asian women are likely to experience less support at the outer sides of each cup than their Caucasian counterparts because their breast configuration is such that the bulk of each breast is more centrally located with the nipples pointing in a more parallel plane. The summary bra fitting picture which emerges for Asian women is of a garment which is too loose at the lower outer edges and too tight at the upper inner edges. For Caucasian women, some of the most popular bra designs of recent decades (see chapter 7) have been of the push-up variety, which provide significant support for the outer edges of the breast, pushing them together and inwards to achieve the fashionable cleavage of the era. The wider bust point to bust point measurements for the Caucasian participants perhaps partly explains the popularity of this type of bra amongst Caucasian consumers. All of these measurement and fitting issues can be addressed by making slight changes to the bra design using either the flat patternmaking method discussed in chapter 8, or the new moulding technology. For the flat pattern and cut and sewn type of bra, this involves changes to the angles and line lengths for the cup components, whereas for the moulded bra, it involves changing the size and, more particularly the shape of the moulds used to construct the bra cup. In terms of mass production, the use of three-dimensional scanning technology lends itself more to the moulded, rather than the cut and sewn method of production and it is possible to foresee a scenario where computer generated logarithms, based on a similar but much larger survey of Asian, Caucasian and other ethnicities, can effect these design changes automatically in adjustable moulds, and consequently produce a very well-fitted garment. However, with recognition of these ethnic differences, flat patterns for cut and sewn bras could also be adjusted to allow for different world markets, or alternatively a consistent system of sizing and design for the Asian market could be developed based on a more complete set of measurements than those currently used. Unfortunately, this latter option is unlikely to be developed in the short to medium term because it is difficult to see a significant enough return for the time and resources required, and it is unlikely that current levels of ignorance about bra sizing differences will change significantly. Nonetheless, one of the most interesting and exciting possibilities in the medium term future, is the development of 'scanning at home' technology, through the webcam or similar device, which would facilitate highly accurate ordering of bespoke bras via the internet.

9.6.2 Bust Girth, Height, and Underbust Height

Overall, Asian women have a smaller bust girth than their Caucasian counterparts by a magnitude of just under two tenths of an inch but this difference is reversed for the endomorphic body type (round and chubby), and the participants with a B cup size. This suggests that larger Asian participants in this study actually had a proportionally larger bust girth than their Caucasian counterparts. In other words, the general trend in terms of bust girth is for Asians to be smaller, but as they get larger more is likely to be represented in terms of breast tissue deposits than for the Caucasian group. Without further studies involving medical and anatomical information it is hard to triangulate this effect. However, as a general rule this has face validity and has implications for band size which might not be fully accommodated by the adjustment possible with the current hook and eye system.

The picture in relation to bust and underbust height is somewhat easier to interpret; with the Asian participants displaying significantly smaller measurements across all data treatments (see Figure 109 for a diagrammatic representation).

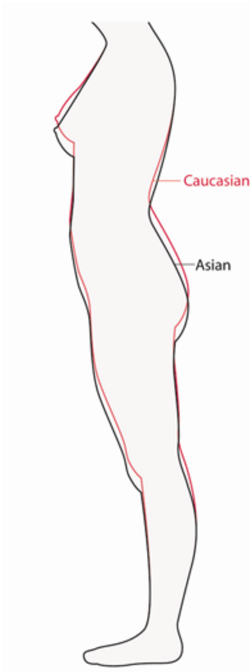


Figure 109: Profile of Asian and Caucasian.

Bust height is the measure taken from the centre of the nipple to the floor when the participant is standing upright in the scanner, and underbust height is the same measurement but taken from the lowest point of the breast. The difference between the two measurements gives an indication of the participant's lower cup size, and to some extent, how firm the breast tissue might be. The Asian participants were generally around 1.5 inches shorter in both measurements, and perusal of the full scanning data set suggests this is largely attributable to a slightly shorter leg length and a proportionately longer looking torso than the Caucasian participants. This has significant implications for bra design dependent upon the fashionable silhouette of the particular era. For example, a bra design which gives more lift from the bottom of the cup will make the body look longer and, without the use of heels, might lead (for the Asian participants) to further visual shortening of the leg area in proportion to the torso, whereas this effect is likely to be less marked for Caucasians. Consequently, designers need to be aware of these potential effects when designing for both Asian and Caucasian markets.

9.6.3 Full Bust Depth

The data for full bust depth provides a measure of the depth of the ribcage measured from the sternum to the spine, around the level of the nipple, and significant results were obtained which suggest that endomorphic Asian body types have a significantly rounder ribcage than their Caucasian counterparts but that this is reversed for the thinner ectomorphic Asian participants. This might also provide a partial explanation for the complex picture in relation to the differences in bust girth explained in the previous section, but a larger scale study is required to investigate this fully. The implications of these differences on bra design are likely to be minimal because the band size is already well taken care of in terms of bra sizing and adjustability, with most modern bras having at least two, and (for the larger sizes) sometimes three or four, sets of hook and eye fastenings for adjustment.

9.7 Conclusion

The demands of bra mass production in a labour intensive industry has meant that many women, particularly in Asia (Lam, 2006), are increasingly wearing garments that do not fit well, either because they do not understand the various sizing protocols, or the protocols themselves are inadequate for the new global marketplace (Boyes, 1996; Liption, 1996; Wacoal, 2008). The earlier chapters on the history of the bra provide evidence that the modern bra is largely a product of companies based in Western countries and is still basically designed to fit the Western body type. If there were no significant differences in ethnic body types, the problem could be resolved fairly simply, although probably this would involve more expense from a design, patternmaking and production viewpoint. This resolution would involve reviewing sizing protocols, and including other parameters (e.g. gore size) in the flat patternmaking and moulding processes. However, evidence from this study strongly suggests that the picture is far more complex than has hitherto been established. The most consistent findings from all three treatments of the data from the body scans suggests what all experienced bra patternmakers already know, that there are significant differences between Asian and Caucasian women in terms of some key parameters for bra sizing. A clear picture emerges that the differences in body shape for these two ethnic groups are far more complex than is served by the current sizing protocols of band size (e.g. 34) and cup size (e.g. A, B etc.). Whilst problems in relation to bra size have been previously investigated using scanning technology in the field of cosmetic and reconstructive surgery (e.g. Pechter, 1998), and in an Asian context for manual measurement methods (Lee et al., 2004), this study constitutes the first comparative investigation of bra sizing using body scan data from two broad ethnic types which also relates findings to the underwear industry.

The implications of these findings for the small made-to-measure bra market (almost exclusively based in the West) are probably modest. Basically, more care needs to be taken in terms of the parameters used to obtain measurements when fitting a bespoke bra, and the ideal solution is to utilise three-dimensional scanning technology to obtain these measures. However, the cost of this technology for relatively small companies, which are already highly labour intensive, probably means this approach is not commercially viable. Consequently, following on from future larger scale investigations of this kind, new manual measurement protocols can be developed which include the significant measurements related to bra sizing for different ethnic groups.

However, for larger companies, particularly those producing bras using moulded technology, the three-dimensional body scanner has a potentially exciting future which could eventually bring about significant change to bra sizing systems and allow a greater range of measurements to be included when producing each moulded cup. Whilst it is also possible to utilise the measurements obtained from scanning in flat patternmaking for the cut and sewn bra, the labour intensive nature of this approach, and the lack of skilled patternmaking practitioners, probably means that these developments will not occur in the foreseeable future. Nonetheless, there is clearly potential to develop new manual measurement protocols which take account of significant parameters such as those identified in this study, and for the industry to pay more attention to its global consumer profile. This might at first glance seem desirable but commercially unlikely, but there are many precedents, including the cosmetic industry which has responded to public demand to produce cosmetic products for different skin colours and tones. Could the bra industry also follow this path, producing bras and a bra sizing system which actually works for their ethnically diverse consumers? The extent to which this future happens will of course be largely a result of consumer demand, fashion trends, and the economic pressures associated with operating in a truly global and increasingly technologically advanced industry.

CHAPTER 10
CONCLUSION

10.1 Introduction

This thesis has taken its reader on a unique journey through time from the perspective of a professional underwear designer and patternmaker. The journey has taken us across continents and cultures, and through significant breakthroughs in human technological innovation and discovery. In so doing it has reviewed secondary source data to chart the major changes in underwear design from debates about the nature and dates of its earliest origins in chapters 2 and 3, to the subsequent evolution and development of the modern brassiere or (as it is now more commonly known) the bra, in chapters 4 and 5. As the journey through time continued, the bra became a more technically challenging garment and the thesis progressively focused on the salient trends in modern bra technology and materials in chapter 6, before turning to a patent history of the 'dark art' of flat patternmaking and the importance of this skill in producing important innovations in both style and comfort in chapter 7. Having reached contemporary times, bra design and manufacture stand at an exciting point where future development is distinctly bifocal. On the one hand, flat patternmaking for the cut and sewn bra has evolved into a highly prized skill which is in short supply amongst bra designers and manufacturers, with the industry complaining that few underwear fashion graduates leave university with the necessary flat patternmaking skills to function as bra designers in a commercial environment. On the other hand, the industry faces the challenge of a wave of possibilities brought about by the advent of new machine and textile technologies, and changes in fashion trends. These include the development of textiles, bonding methods, and machinery for producing moulded bras which do not involve flat two-dimensional patternmaking, and recent developments in three-dimensional scanning technology which are challenging long-held views about bra sizing and fitting. These two areas of development now provide a distinctly dual context for the future evolution of the bra, and consequently they form the subject of the two major primary source data studies reported in chapters 8 and 9. The study in chapter 8 begins to answer some of the questions raised by the secrecy surrounding the skill of patternmaking, and culminates in the development of an entirely novel way of producing, learning, and teaching the flat patternmaker's art for the cut and sewn variety of bra production, so that underwear fashion graduates leave university with the skills they need to survive in a fast moving global industry. The study in chapter 9 is the first of its kind in the field of underwear design and uses cutting-edge full body scanning technology to investigate problems with current bra sizing systems and measurement protocols which have not yet kept pace with globalisation or technology. As such, this study also stands at the very beginning of the future evolution of perhaps the most technically complex garment in human history, the not so humble bra.

10.2 Origins of the Species

Chapter 2 considers the academic debates that still persist about the origins of underwear, and the reasons it came into existence, with some commentators (e.g. Ewing, 1971) taking the view that underwear began as outerwear which gradually migrated to being worn as underclothing for largely functional reasons sometime in the Middle Ages. The timing of the birth of underwear is disputed by Tobin (2000) who suggests that the concept of underwear became significant only from the end of the 19th Century, whilst Saint-Laurent (1968) provides yet another viewpoint, suggesting that the concept and existence of underwear began in ancient civilisation around 3000B.C. from a sense of status, and not for hygienic purposes or protection from extreme weather. According to Cunnington and Cunnington (1992), the only likely function of underclothes before the Middle Ages was utilitarian even though these early garments were almost certainly not as effective as today. Underwear can be considered as having five core functions; protection of the body from cold weather, hygiene, sex appeal, outer costume shape support, and class distinction. The first two of these functions, protection from cold weather and hygiene, are largely utilitarian and are probably the major influences which first drove early humans to add layers under their clothing. However, it is clear from the evidence presented in chapter 2 that the latter three functions were added to underwear design soon after human beings began to settle in one place for the purpose of establishing agriculture and trade, and by the Renaissance were firmly established as design issues.

The development of the first underwear technology also probably has its origins with early hominids who are thought to have survived the long, harsh era of Würm glaciation by developing and improving both shelters and clothing. Clark (1969) suggests that their survival is evidence that they possessed the rudimentary tools, probably made of bone, and stitching made of leather or fibre strips, required for joining animal furs together to make garments which were then probably layered for added warmth. In other words the foundations for the origins of underwear in terms of, utilitarian need, natural materials, and a rudimentary flat patternmaking 'technology' in terms of cutting and joining pieces of fur or animal hide, were already in place during prehistory. It is fascinating that these fundamental drivers of the evolution and development of underwear design and patternmaking practice can be traced back to the earliest times. In summary, although inconclusive, the available evidence from chapter 2 suggests that underwear probably began being worn for utilitarian reasons in prehistoric times but quite quickly evolved into other more 'fashion' related functions, particularly when farming replaced the hunter-gatherer lifestyle. Although similar garments were probably already in existence, the earliest evidence of anything resembling a bra was probably the 'fascia pectoralis' from 4th Century BC Rome which was essentially a single piece of cloth bound around the breasts and formed the upper part of a gymnastics bikini.

10.3 The Evolution of Underwear and the Birth of the Bra

Whilst chapter 2 considered evidence that the concept of underwear probably had humble beginnings as a layer underneath outerwear, with a hygienic or protective functionality, it also demonstrates that the underwear itself gradually gained an identity of its own by supporting and complementing developments in outerwear fashion. This theme is continued in chapter 3 which deals with the period from 1001AD to the early 1900s and demonstrates the substantial impact that fashion trends in outerwear had upon underwear development during this time (Barbier and Boucher, 2004). This is another fundamental driver in terms of underwear design and production which remains highly relevant today and can still be seen in the development of moulded technology (discussed in chapter 6), initially for sleek, seamless bras to be worn under the modern T-shirt.

Developments in technology during the Middle Ages included the use of linen, cotton, cambric lawn and nainsook, providing materials that were more conducive and comfortable to wear as undergarments. The advent of international trade accelerated the availability of a wide range of materials, dyes, stiffening and fastening devices, which gradually became more accessible to the general populace, particularly during the industrial revolution. Furthermore, because of the importance of maintaining the shape of the outer garments, and therefore a fashionable silhouette, materials such as whalebone, wood, horn, and latterly wire, started to be used for corsets and other garments for the first time and consequently provide the earliest technological forerunners of the now ubiquitous underwired bra. Forerunners of both the cut and sewn and moulded bra are also evident from the end of the 18th Century with the use of the 'bolster', a quilted pad with ties, and the first truly moulded product for the breast was the aptly named 'bosom friends', a moulded wax breast (Hawthorne, 1992). Each of these products was worn to achieve the fashionable voluptuous female shape popular during that time. By the 1900s bust improvers, bust bodices, lemon bosoms, and amplifiers had laid the foundations for the development of the modern garment we know as the moulded bra. From the Middle Ages to the end of the 19th Century underwear started receiving serious attention for the functions of sex appeal, and outer costume shape support (Tobin, 2000). By the end of the period covered by chapter 3, underwear has developed into today's more sophisticated forms which not only serve the utilitarian functions of support for the body and personal hygiene, but also enhance sexual attraction in similar ways to outerwear.

Chapter 4 progressively focuses upon the evolution and development of the modern brassiere from the late 19th Century through to the 1950s, a period which saw the beginnings of the evolution of the wide variety of female attire for the breasts available in today's marketplace. This era marked a period which saw rapid increases in the pace of development and change following the industrial revolution and the availability of mass produced undergarments. The upheaval caused by two World Wars, and the technological advances in materials technology, together with developments in the mass media industries, also brought about significant changes in the design of underwear in general, and the bra in particular. The era began with renewed interest in the corset, but on this occasion it was a corset with comfort and health in mind. Farrell-Beck and Gau (2002) suggest that Chapman who invented the breast supporter in 1863, should be rightfully regarded as the father of the prototypical brassiere. His breast supporter was in fact a corset with shaped breast cups which were capable of accommodating the volume of female breasts. In his patent application, Chapman (1863) stated that the purpose of his new invention was to help women to avoid injuries from the pressing and binding forces of contemporary corsets. Although Chapman's breast supporters bear little resemblance to the modern bra, except perhaps for the two accommodating cups, their development clearly set the stage for modern bra design and construction. The 'bust bodice' is also identified by some (e.g. Cunnington and Cunnington, 1992) as the direct predecessor of the modern bra. The bust bodice was a lightweight, soft undergarment, which was developed from the corset cover/camisole in the 1850s, and worn underneath a corset to protect the corset from body fluids and secretions. This new garment developed into a supporting device in 1889 because the corset of that time did not support the breasts. In 1904, De Bevoise invented a lightweight undergarment which looks similar to a modern camisole and named it the 'brassiere'. The word 'brassiere' first appeared in an edition of American Vogue in 1907, and was recorded in the Oxford English Dictionary in 1912 (Ewing, 1971). In practice, it remains difficult to precisely pinpoint which garment is the originator of the modern bra, but both the corset and the bust bodice brought about significant changes in female underwear fashion (Ewing, 1971) due to their bridging roles in the history of intimate apparel.

All five functions of the bra were now driving change to varying degrees and the arguments related to the relative impact of fashion, status, and utilitarian needs, identified in chapters 2 and 3, once again came into play. There is no doubt that during the periods spanned by each war, utilitarian factors acted as major drivers for changes in female fashion, and it is also clear that each post-war period brought about a growing sense of liberation for society as a whole, and women in particular. This is mirrored in the more elaborate and feminine designs of underwear associated with the two post-war periods. Again rapid technological change, arguably brought about in part as a result of two World Wars, and the large-scale introduction of females into the workforce, also brought about significant changes to the range of materials, colours, and techniques available to designers. At the same time, companies were becoming more commercially competitive and ideas were patented to protect them from unscrupulous exploitation by others. In addition specialist areas and niche markets for junior bras, maternity bras and mastectomy bras were being exploited and expanded as new synthetic materials became available. This expansion, and the general expansion in the underwear market, was facilitated by enormous growth in the mass media industry during the twentieth century, and this increasingly meant that films, television, billboards and print media became major promotional tools for bra manufacturers. Increased product development cost, and a highly labour intensive industry base, led to mergers between bra manufacturers, knitting mills, and other related businesses in order to survive, and consequently some of the large underwear brands we are familiar with today became established. All of these factors helped to establish the underwear market in general, and the bra in particular as globally accepted essentials, and prepared the world for the rapid development in fashion and bra technology which would follow from the 1960s and continues today.

10.4 The Modern History of the Bra from the 1960s

A recurring theme in the overview of the history and development of underwear, and in particular the bra, in previous chapters was the relationship between developments in outerwear and underwear. This relationship has varied throughout history, and is linked to the role and functions of underwear in determining and supporting the fashionable body shape of the era, the extent to which underwear functions as an indicator of status, an expression of contemporary fashion, or merely the recognised utilitarian or health and hygiene requirements of the period. All of these themes were continued during this period with the notable new addition of the rise in influence of political factors in underwear fashion with particular regard to the bra. During the decades covered by chapter 5, the bra brought sexual empowerment for women, whilst also being regarded by some as a symbol of male power over women as sexual objects (Njuguna, 2003). To some extent, these decades, in common with historical precedent, demonstrate that the bra has also often evolved from social and political changes as well as technological developments. The continued interest in a healthy lifestyle, and the growing emphasis on environmentally friendly materials, also helped drive the development and use of new materials in the textile industry.

The advent of mass production in the earlier part of the 20th Century and later technological advances in the media, laid the foundations for mass marketing on an unprecedented scale. This led to a broader consumer base and the introduction of trends related to the popular film, music, and athletic icons of the time. Health issues became particularly important and attention was once again focused on the support and comfort (utilitarian) elements of bra design, although on this occasion with 'form' being as important as 'function'. The bra as a garment also become iconic in its own right with the immense popularity of push-up and sports bras and, more recently the advent of the so-called smart-bras. Technological advances in moulding, textile, and bonding technology meant that it was now possible to produce a truly seamless and sleek breast supporting bra which could be worn under light figure-hugging T-shirts. Advances in materials technology saw developments in bra strap design with some now being produced in a clear soft plastic polymer that was almost invisible when worn with an evening dress. Women with larger breasts were now demanding greater support from their bra than had previously been the case and this led to an enduring increase in demand for lighter and more feminine designs of underwired bra, and a search for better materials for underwire manufacture. Technology still acted as a major driver of bra design but not all innovations were accepted by the consumer. For example, one idea involved the use of a novel magnet fastener which could be undone with a twist and this began to be used in many bras boasting a front closure. Not surprisingly, this idea has now been generally abandoned, at least for the time being.

In summary, from the perspective of a designer and patternmaker, the bra had now entered an era where two distinct lines of development began to emerge. The first has a history as old as clothing, and relates to the two-dimensional flat pattern and the cut and sewn variety of modern bra. From the earliest times when human beings began to join materials to fit a particular body size or part, some sort of mental representation or drawn pattern was necessary for success. This remains the case, and the popularity of the cut and sewn bra, particularly amongst those with larger breasts, and those uncomfortable with the largely synthetic materials employed in constructing the moulded bra, remains paramount. However, alongside this line of development, advances in moulding, bonding, and computer technology continued and, together with the evolving designs of modern outerwear, led to the second distinct developmental line, the development of the seamless moulded bra.

10.5 Technological and Product Bifurcation

Chapter 6 gave more detailed consideration to the growing influence of new bra technology and materials on the evolution of this iconic item of underwear, and considered the development and applications of four major technologies (moulding, bonding/lamination, ultrasonic welding, and seamless knitting technologies), and two materials (eco friendly and smart materials), which now contribute significantly to modern bra production. Evidence from chapter 5 demonstrated that early trends in bra technology were driven by the fashionable and sought after ‘sleek look’ of the 1990s, and creating this natural look around the bust area began with the removal of seams and stitches from bra cups, and culminated with the removal of all seams from the bra. The resulting moulded bras are generally comfortable, smooth, and durable, light in weight, and less bulky, whilst the technology which underpins them provides fast production and efficient material utilisation for manufacturers (Performance Apparel Markets, 2006). Consequently, seamless and stitch-less technologies are rapidly changing the face of the industry but, despite the excitement surrounding these developments, there remain a number of challenges for bra manufacturers to overcome. For example, the underwires sandwiched in a one-piece moulded bra remain incapable of supporting larger, heavier breasts in the same way as the wires in a cut and sewn garment, which are firmly held within the lower cup using channelling tapes. This limitation, together with a general aversion to some synthetic textiles, has contributed to the enduring popularity of the underwired cut and sewn bra. Nonetheless, the one piece bra remains in great demand and can now be regarded as a turning point in bra history. Many new technologies and materials are currently being integrated and incorporated into underwear industry practices to create new bras for a new generation of technology and ecology-conscious consumers. Given this frenetic pace of technological development and change, it is becoming increasingly difficult to predict what will be the next hot technology or material for bra production, because those in the bra industry are constantly pushing hard to be the first to market a new technology, material or design.

As a result of some of the remaining technological challenges in relation to moulded bra construction, and continuing consumer demand for natural fibres and feminine, lacy, bra products, the cut and sewn bra, constructed from a flat patternmaking process, still retains the largest proportion of the bra market. Consequently, chapter 7 turns its attention to this crucial strand of bra development and reviews a total of 1, 671 U.S. bra patent records from the late 19th Century to the early part of the new Millennium. Significant changes in design, materials, production methods, fasteners and accessories are considered together with the impact these had on the bra patternmaking process. Perhaps the most significant breakthrough for bra design and development came from the flat patternmaking process, and involved the ability to form a three-dimensional bra cup from a two-dimensional or flat pattern. The review of patents in this chapter demonstrates that cup and bra shaping methods involving the use of darts, style lines, pleats and gathers which have now been employed for over one hundred years, and that the patternmaking skills involved in flat patternmaking remain at the core of professional courses offered at university or within the industry. However, despite this enduring flat-patternmaking trend, this chapter demonstrates that the development of conventional bra patternmaking was largely complete by the end of the 1980s.

Both flat pattern making for the cut and sewn bra, and moulded bra technology, have their drawbacks, and it is interesting that difficulties involved in fitting the bra remain despite the long developmental history of bra flat patternmaking. This is partly because of a lack of structured training, and partly because of the shroud of secrecy which still surrounds the patternmaking process within the bra industry. This area has never been studied at this level before, probably because it is only industry ‘insiders’, (the few people who are both designers and patternmakers), who have access to the knowledge and skills necessary to understand what even the industry now regards as a very technical process.

10.6 Flat Patterns and Moulded Technology

Chapters 8 and 9 considered the two major developmental strands now existing in the bra industry. In chapter 8, the literature related to flat patternmaking for the bra, and the underwired bra, was reviewed from a designer and patternmaker's perspective including the considerable secrecy currently surrounding the practice of patternmaking, and the extent to which this has restricted the growth of innovative practice in this area. For example, many patternmakers in the industry today simply copy and adjust earlier patterns in order to effect changes in design, largely because most bra designers are not trained patternmakers, and many bra patternmakers are incapable of producing highly technical accurate flat patterns for this complex garment. This has impacted on the development, learning and teaching of flat patternmaking practice, because few people are capable of teaching the process or fully understand the technical issues related to this area. This has become one of the most pressing issues facing the industry today, and is undoubtedly restricting innovation in flat patternmaking and the development of the cut and sewn bra product. Consequently, new research into bra patternmaking conducted by the author, which marks a move away from traditional 'copy' methods to a single innovative approach which is practical, and provides for further development of patternmaking practice in this area, is presented and evaluated. The potential benefits of adopting this new method for both the industry, and in the field of education for training purposes are discussed, and it is argued that this new approach will help rekindle debate on flat patternmaking for the brassiere, something that clearly needs to happen given the long-term lack of patternmaking innovation in this area. As a direct result of this study several major technical issues related to patternmaking and fit are identified. In particular, the growing disquiet amongst Asian consumers who have begun to recognise that bras designed, produced and fitted using a western patternmaking template have sometimes failed to provide them with a good enough fit, particularly in relation to the distance between the cups.

In considering the second of the two major developmental strands now existing in the bra industry, that of moulded technology, chapter 9 follows up the ethnic 'fit' issue, highlighting the global nature of the industry, and problems with existing sizing protocols. In so doing, it introduces one of the most significant technological breakthroughs currently arousing interest amongst industry insiders (three-dimensional whole body scanning technology), and uses this as a broader counterpoint to illustrate the current state of the industry, and the increasingly diverging nature of modern bra development. The final study uses primary source three-dimensional body scanning data to investigate the extent to which gore (the component material that goes between the cups on the contemporary bra) design and construction is truly global, and identifies other body type differences that the industry needs to address as it continues to become an ever more global provider. In considering the demands of bra mass production in a labour intensive industry it highlights the fact that many women, particularly in Asia (Lam, 2006), are increasingly wearing bras that do not fit well, either because they do not understand the various sizing protocols, or the protocols themselves are inadequate for the new global marketplace (Boyes, 1996; Liption, 1996; Wacoal, 2008). This research is linked to earlier chapters on the evolution of the bra, and provide evidence that the modern bra remains largely a product of companies based in Western countries and is consequently still basically designed to fit the Western body type. It argues that, if there were no significant differences in ethnic body types, the problem could be resolved simply by reviewing global sizing protocols, and including other measurement parameters (e.g. gore size) in both the flat patternmaking and moulding processes. However, evidence from this study strongly suggests that the picture is far more complex than has hitherto been established. As such, this study constitutes the first comparative investigation of bra sizing using body scan data from two broad ethnic types which also relates findings to the underwear industry.

In summary the two studies presented in chapters 8 and 9 respectively not only complete the biography of the bra up to the current date, and add significant new knowledge to the field, but also serve to illustrate the extent to which the socio-cultural, commercial and technological threads identified in the opening chapter and throughout the thesis, will continue to be enduring influences on this highly evolved everyday product.

10.7 Summary

In the opening chapter this thesis was identified as a biography, not of a person, but of the bra, a garment which is woven into the threads of human development. Whilst both human beings, and the humble bra, have significantly evolved over the past 600,000 years, many of the factors which influenced the development of underwear from its origins continue to impact upon its design and production today. These include socio-cultural and political factors such as the differing levels of mobility of human populations through the ages, and the desire to dress in ways which demonstrate power or wealth. In addition, developments in technology from the use of the earliest leather or animal hide stitching materials, and needles made of bone, to modern flat patternmaking, materials and moulding technology, laminating, and bonding methods have exerted their considerable influence on the current design of the bra. Finally, the five core functions of underwear identified by Cunnington and Cunnington (1992) as the utilitarian functions of protection from cold weather and hygiene, and the non-utilitarian functions of supporting the outer costume, class distinction, and sex appeal have also continued to exert influence on the design of the bra from its earliest beginnings to the modern day.

10.7.1 Culture, Politics, and Power

Socio-cultural and political factors have undoubtedly influenced the development of underwear in particular, and clothing in general from its very beginnings. As human beings moved into farming communities, abandoning the hunter gatherer lifestyle, the utilitarian functions of underwear were complemented by functions related to status, power and wealth. An example of this enduring influence is available when a comparison is made between the terracotta Sumerian statue of a woman, wearing a loincloth, and what appears to be a relatively modern form of brief, dating from 3000BC (see chapter 2) and the political debate surrounding the wearing of the bra in the early 1960’s (see chapter 5). The status of the woman depicted in the Sumerian terracotta is believed to be a slave because higher quality garments have since been discovered for higher status people (Ewing, 1971; Saint-Laurent, 1968). Njuguna (2003), in identifying the arguments which surrounded the ‘burn the bra’ feminist movements of the 1960s, highlights the fact that some feminists from that era regarded the bra as a symbol of male power over women. This single comparative example illustrates that the design and production of underwear has enduring associations with the non-utilitarian functions of both status and power.

Socio-cultural and commercial factors related to human mobility, wars, trade, and travel across continents has also continued to exert powerful influences over the development of the materials and textiles used in underwear and bra manufacture. This is illustrated by comparing the fashion changes brought about by the Nordic invasions which swept over Central Europe from the 3rd Century AD to the 6th Century AD (see chapter 2) and the 1920s (see chapter 4) when American underwear fashion invaded Europe following the First World War. Gold (1987) describes this latter era as the most fantastic time for American fashion when American women led the way with their breast-minimising bras, loose chemises, and the new fashion of the ‘flat chest’. Another example is the influence of religion and religious beliefs on the development of the bra. In Roman times the ‘fascia pectoralis’ was worn to be seen as well as provide support for the breast, whereas by the Middle Ages all underwear was always completely hidden because it was associated with the idea that the body was sinful (Barbier and Boucher, 2004), and consequently worn only to fulfil utilitarian functions such as protecting the body from the cold, and probably as an aid to keeping the body clean and hygienic.

Today, the body scanning study presented in chapter 9 serves as a reminder that issues relating to power, politics and history continue to exert an enduring influence on the design and development of the bra. This study demonstrates the ethno-centric nature of the modern bra industry where inadequate Western measurement protocols continue to be used for marketing bras in a growing Asian marketplace. As the balance of commercial power shifts perceptibly from West to East with the economic growth of China and South East Asia, the demand for knowledge about everyday products like the bra from new consumers will help drive the changes suggested by the body scanning study. Asian consumers have moved from purchasing and wearing bras for purely utilitarian functions, to highly sophisticated consumers looking for cutting-edge design and fit and a wide range of choice.

10.7.2 Technological Developments and Challenges

The bra is a now a highly evolved and complex garment which can be designed and produced using two distinct approaches, both of which have actually been around for longer than might at first seem likely. The first of these approaches involves the use of a flat two-dimensional pattern to produce an elaborate cut and sewn three-dimensional product. Earlier chapters demonstrate that the production of three-dimensional underwear from two-dimensional flat patterns has a long history. Whilst the 'fascia pectoralis' from 4th Century BC Rome involved only a single piece of cloth wrapped around the breasts (see chapter 2), developments in outerwear design from the highly conservative and utilitarian designs of the Middle Ages, to the flamboyant and innovative designs of the Renaissance, have proved to be a powerful driver in terms of flat pattern development. Many underwear products from the Renaissance onwards were undoubtedly designed to give three-dimensional support to the popular outerwear fashions of the era. This meant that flat patterns of some sort, perhaps initially in the patternmakers head, had to be used in order to produce three dimensional garments like the corset and bust bodice, and new materials (e.g. whalebone, wood, horn, wire, and later, plastic) had to be incorporated into designs to give them the required stiffness to adequately support the often heavy outerwear. Consequently, forerunners of both the cut and sewn and moulded bra are clearly evident from the end of the 18th Century with the use of the 'bolster', a quilted pad with ties, and the first truly moulded product for the breast (the so-called 'bosom friends'), which was essentially a moulded wax breast, (Hawthorne, 1992). The advent of amplifiers in the 1900s (see chapter 3) probably illustrates the first serious commercial attempt at applying moulding technology to the bra but this development was quickly followed by bust improvers, bust bodices, lemon bosoms, and amplifiers which laid the foundations for the development of the modern garment we know as the moulded bra.

These not so new developments are now clearly influencing the two concurrent major developments in modern bra design and technology. The industry has become increasingly bifurcated with most of the larger players (e.g. Triumph International) having separate design, research, and development sections for the cut and sewn and moulded products as well as clearly distinct production, and even marketing, processes. However, one area which both design developments have in common is the issue of inadequate sizing protocols, which probably persist for largely commercial reasons, but which are now increasingly exposed as a result of the globalisation of the bra industry.

There is no doubt that a wider and clearer understanding of flat patternmaking within the industry would make it possible to design cut and sewn bras that take into account ethnic and body type differences. The current reliance in the industry on copying or 'knock-off' approaches to patternmaking, and the secrecy and lack of informed debate about bra patternmaking in general, is stifling rapid development in this area. Many graduates of underwear design courses leave university or college without grasping, or even being taught, the basic skills of flat patternmaking, and their 'designs' must be interpreted by patternmakers (usually time served apprentices) who consequently interpret them in terms of what can currently be copied and adapted. The result is a lack of real innovation in terms of design, patternmaking, and sizing. This means a restricted choice for all consumers and a fairly static situation in terms of bra style and sizing protocol development. The patternmaking study presented in chapter 8 is designed to address this shortfall, and stimulate debate about the future directions of flat patternmaking for the cut and sewn variety of bra. As such, it tackles some of the salient current issues in terms of this particular strand of bra development. The other significant strand of bra development lies with the growing area of moulding technology, supported by fairly recent innovations in textiles, bonding, and lamination technology. Moulded bra technology is undoubtedly changing the face of the industry but currently still faces some considerable challenges if it is to capture a larger market share and gain a competitive edge over the cut and sewn product. These challenges relate to finding ways to incorporate natural, breathable fibres and supportive durable underwires into the design of the moulded product, as well as ensuring that the industry rises to the challenges posed by the advent of three-dimensional body scanning technology. The latter not only overtly raises questions about the suitability of existing sizing and fit protocols for what is now an established global market for the bra, but also begins to provide insights into possible solutions in the not too distant future. It is to these potential future directions that we now turn.

10.7.3 Future Directions

This biography of the bra has identified a clear fork in the road in terms of the future development of the product. On the one hand, there is the still highly popular cut and sewn bra product which is dependent for its structure and fit on highly technical flat patternmaking skills. On the other hand there is the advent of the moulded bra which is becoming increasingly popular amongst some segments of the population, but relies heavily on technological developments in textiles, moulding, bonding and lamination. At first glance, the use of three-dimensional body scanning to gather a wide range of accurate body measurements might appear better suited to the latter moulded type of bra than its cut and sewn counterpart. In fact, plotting three-dimensional body measurements onto a three-dimensional mould should not, in the future, be too difficult or expensive, particularly if fully adjustable moulds can be developed which are capable of taking into account all the key parameters of a particular body shape. Consequently, subject to these developments taking place, it might be expected that this strand has the most promising future in terms of bra design and construction. However, to some extent, the same is true of flat patternmaking for the cut and sewn bra. It is currently possible, and relatively easy, for a skilled patternmaker to produce a bespoke bra based on the range of measurements identified in chapter 9, and there is little doubt that in time, some of the world's largest bespoke bra manufacturers will incorporate three-dimensional scanning technology into their measurement and fit protocols. However, incorporating this technology into the mass produced product is currently not possible because it would not be commercially viable, without large price increases, to develop a new flat pattern for each consumer. Despite this initially poor prognosis for utilising three-dimensional body scanning technology in the development of flat patterns for the mass produced market, there is hope. Many in the industry, including the author, are currently working with academics from other disciplines such as mathematics and engineering to develop computer based algorithms which take into account the larger range of body measurements obtained from scanned data, and automatically produce a 'best fit' flat pattern for the cut and sewn bra product. According to this approach, a series of initial flat patterns can be developed for one core size, parameters are selected based on the most significant measurements (in terms of fit) from the scanning data, and then these parameters are adjusted to match the individual consumer's three-dimensional body measurements. The initial core pattern and the consumer's measurements are then input to a computer loaded with the algorithm and a bespoke flat pattern is produced. For both the moulded bra and the cut and sewn alternative, the development of these algorithms could potentially bring about significant changes in terms of comfort and support, and the development of the basic structure of the bra. They would also bring down the cost of production considerably since the industry is currently heavily labour intensive and this approach has few implications in terms of increased production costs. Nonetheless, one very significant problem remains, that of obtaining the accurate three-dimensional measurements from the consumer. In fact, unless each retail outlet for the bra possessed a currently very expensive three-dimensional body scanner, and trained staff with the expertise to operate it correctly, this technology would be useless. However, in an age when more and more consumers are turning to the internet to order and buy products like the bra, (an example is the internet sales success of the 'La Senza' bra range) it should be possible in the next decade or so to produce three-dimensional body scanning technology that can be accessed through a home computer. The consumer simply stands at an appropriate distance in front of the computer and their measurements are scanned in and sent to the retailer/manufacturer who then uses the algorithms to produce a perfectly fitting mould or flat pattern which in turn, is used to produce the particular design and style of bra required. All the consumer has to do is select the design, style, material, and colour of the product and they are guaranteed an excellent fitting bra whatever their ethnic origin, size, or body shape.

10.8 Conclusion

In chapter 1, this research was described as the first comprehensive biography of the bra from the perspective of a professional designer and patternmaker. Unlike biographies which deal with human beings who have a finite lifespan, this product biography of the bra is a continuing story affected by a wide range of factors which include socio-cultural, political, economic, and technological changes. Throughout the developmental history of underwear in general, and the bra in particular, each of these factors have exerted a significant impact upon bra design at various times and in various ways. The relative importance of the five core functions of underwear identified in chapter 2; protection of the body from cold weather, hygiene, sex appeal, outer costume shape support, and class distinction, have varied dependent upon the predominant trends and beliefs of the time. However, over the past three decades, the pace of change in terms of the structure and framework of the bra has increased to unprecedented levels, and yet the core functions of this garment have remained unchanged. Never before in the history of the bra has there been a time when two such distinct and divergent directions, largely based on technological developments, have been so clearly evident. Consequently, it seems highly likely that, for the foreseeable future, it will be technology that continues to be a major factor in terms of developmental direction.

Whether this direction continues to be divergent along the two strands identified in the latter chapters of this thesis, or whether it becomes more convergent will depend on the relative impact of the same range of other factors which have influenced bra design throughout its developmental history. One thing is for sure, the humble bra will continue to evolve and develop driven by both utilitarian and non-utilitarian functions.

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APPENDIX CONTENTS

APPENDIX A: CONSENT FORM FOR BODY SCANNING

You are cordially invited to participate in the body scanning session for a research study entitled ‘The bra and its pattern: Developmental history and future directions’. This research study is a requirement for PhD conferment undertaken by Kristina Woo Kyung Shin at the School of Design of the Northumbria University, Newcastle, United Kingdom.

The aims of study

The purpose of this study is to investigate whether there is any significant difference in body measurements between Asian and Caucasian women, in particular key body measurements used in bra design. A 3D body scanner by [TC]² is employed to collect the body measurements. The [TC]² Body scanner is using a white-light projection which is completely harmless and the total procedure will take only 10 minutes of your time. This study will help improve the bra design, patternmaking and manufacture to better fit the wearers. Therefore, your cooperation in taking a part in this body scanning session would be much appreciated.

Procedure

You are required to be naked except your underpants in order to be scanned. However, you will be in a closed environment where you cannot be seen and a dressing gown will be provided. After the session, a print of two of your scanned body images (full front view and profile) with over 200 body measurements will be given to you as a token of appreciation. Your scanned body image and body measurements which are collected from this session will only be used for this research study and other related studies. The information from this study will be handled in a strictly confidential manner and we will not reveal your identity.

The body measurement data will only be published in the form of statistical summaries without reference to individuals. The information will help the research community and fashion industry to understand how the bra design and patternmaking should be developed.

Consent and signature

By signing this document, you will be allowing the researcher to use your scanned body image as well as body measurement data together with demographic information for this research study.

Please read the paragraph below, and sign if you agree:

I agree to take a part in this body scanning session and for the researcher to use my scanned body images and body measurement data for this research project and other studies related to this research study. I have read and listened to the information, I have asked any questions, and all my questions were answered to my satisfaction. I am therefore taking part in this study of my own free will and volition and permit the use of my scanned data for the prescribed purposes.

Name:____

Signature:____

Date: ____

APPENDIX B: ANALYSIS OF ALL DATA

	Group	N=90 (in each group)			
		Mean	SD	p-value	adjusted p-value
DWR (L)	Asian	0.39	0.07	0.922	0.453
	Caucasian	0.38	0.05		
DWR (R)	Asian	0.37	0.07	0.493	0.109
	Caucasian	0.37	0.06		
Prominance(L)	Asian	9.55	0.56	0.401	0.089
	Caucasian	9.62	0.53		
Prominance(R)	Asian	9.39	0.55	0.938	0.420
	Caucasian	9.40	1.12		
BustGirth	Asian	35.56	0.82	0.051	**0.035**
	Caucasian	35.73	0.25		
Underbust girth	Asian	29.56	0.53	0.306	0.269
	Caucasian	29.64	0.54		
Bust point to bust point	Asian	7.31	0.47	**0.002**	**0.003**
	Caucasian	7.52	0.43		
Sternum	Asian	1.47	0.57	0.070	**0.032**
	Caucasian	1.33	0.47		
Full bust width	Asian	11.66	0.44	0.232	0.846
	Caucasian	11.74	0.43		
Full bust depth	Asian	8.37	0.45	0.851	0.727
	Caucasian	8.36	0.40		
Under bust width	Asian	10.38	0.30	**0.021**	0.360
	Caucasian	10.49	0.37		
Under bust depth	Asian	7.91	0.47	0.286	0.766
	Caucasian	7.84	0.39		
Bust Arc	Asian	18.53	0.95	0.531	0.247
	Caucasian	18.61	0.87		
LBIA	Asian	3.06	0.78	0.098	0.086
	Caucasian	3.26	0.82		
LBOA	Asian	1.72	0.39	0.690	0.890
	Caucasian	1.74	0.35		
Front neck to bust point (L)	Asian	8.25	0.65	0.244	0.580
	Caucasian	8.35	0.54		
Front neck to bust point (R)	Asian	8.22	0.70	0.516	0.806
	Caucasian	8.28	0.60		
Front neck to bust level	Asian	7.42	0.70	0.545	0.935
	Caucasian	7.47	0.59		
Side N to under bust to W (R)	Asian	18.78	2.95	0.742	0.256
	Caucasian	18.67	1.15		
Side N to under bust to W (L)	Asian	19.01	5.29	0.574	0.309
	Caucasian	18.69	1.10		
Bust to waist (R)	Asian	7.61	1.02	0.569	0.320
	Caucasian	7.70	1.06		
Bust to waist (L)	Asian	7.66	1.00	0.690	0.256
	Caucasian	7.72	1.04		
Side neck to underbust (R)	Asian	13.36	0.79	0.722	0.740
	Caucasian	13.40	0.77		
Side neck to underbust (L)	Asian	13.35	0.78	0.516	0.997
	Caucasian	13.42	0.81		
Back neck to bust point (R)	Asian	13.07	0.64	0.785	0.303
	Caucasian	13.05	0.62		
Back neck to bust point (L)	Asian	13.05	0.64	0.797	0.544
	Caucasian	13.07	0.61		
Side neck to bust (R)	Asian	9.99	0.69	0.648	0.954
	Caucasian	10.04	0.64		
Side neck to bust (L)	Asian	9.97	0.70	0.333	0.641
	Caucasian	10.06	0.62		
Bust height	Asian	44.36	2.01	**0.000**	0.729
	Caucasian	46.03	2.07		
Underbust height	Asian	41.65	1.94	**0.000**	0.171
	Caucasian	43.38	2.04		

APPENDIX C: ANALYSIS OF ALL DATA RELEVANT TO BRA SIZE

	US Cup Size	Group	Data_90			
			Mean	SD	p-value	adjusted p-value
DWR (L)	34A	Asian (n=32)	0.38	0.06	0.267	0.546
		Caucasian (n=15)	0.36	0.04		
	34B	Asian (n=29)	0.40	0.09	0.640	0.637
		Caucasian (n=75)	0.39	0.06		
DWR (R)	34A	Asian (n=32)	0.36	0.07	0.120	0.494
		Caucasian (n=15)	0.34	0.05		
	34B	Asian (n=29)	0.38	0.07	0.855	0.369
		Caucasian (n=75)	0.38	0.06		
Prominance(L)	34A	Asian (n=32)	9.38	0.46	0.148	0.193
		Caucasian (n=15)	9.21	0.35		
	34B	Asian (n=29)	9.67	0.46	0.787	0.228
		Caucasian (n=75)	9.70	0.53		
Prominance(R)	34A	Asian (n=32)	9.28	0.39	0.163	0.120
		Caucasian (n=15)	9.07	0.48		
	34B	Asian (n=29)	9.55	0.55	0.632	0.729
		Caucasian (n=75)	9.46	1.20		
Bust girth	34A	Asian (n=32)	35.09	0.27	0.001	0.216
		Caucasian (n=15)	35.29	0.13		
	34B	Asian (n=29)	36.00	0.27	0.002	0.000
		Caucasian (n=75)	35.82	0.15		
Underbust girth	34A	Asian (n=32)	29.46	0.47	0.000	0.000
		Caucasian (n=15)	30.15	0.16		
	34B	Asian (n=29)	29.64	0.49	0.321	0.501
		Caucasian (n=75)	29.53	0.53		
Bust point to bust point	34A	Asian (n=32)	7.25	0.43	0.680	0.807
		Caucasian (n=15)	7.30	0.37		
	34B	Asian (n=29)	7.47	0.44	0.322	0.287
		Caucasian (n=75)	7.57	0.43		
Sternum	34A	Asian (n=32)	1.44	0.56	0.526	0.749
		Caucasian (n=15)	1.54	0.48		
	34B	Asian (n=29)	1.44	0.46	0.153	0.078
		Caucasian (n=75)	1.29	0.45		
Full bust width	34A	Asian (n=32)	11.62	0.44	0.052	0.263
		Caucasian (n=15)	11.88	0.40		
	34B	Asian (n=29)	11.64	0.41	0.451	0.375
		Caucasian (n=75)	11.71	0.44		
Full bust depth	34A	Asian (n=32)	8.26	0.37	0.763	0.776
		Caucasian (n=15)	8.22	0.44		
	34B	Asian (n=29)	8.60	0.41	0.019	0.016
		Caucasian (n=75)	8.39	0.39		
Underbust width	34A	Asian (n=32)	10.36	0.31	0.001	0.070
		Caucasian (n=15)	10.79	0.36		
	34B	Asian (n=29)	10.38	0.30	0.439	0.912
		Caucasian (n=75)	10.43	0.34		
Underbust Depth	34A	Asian (n=32)	7.80	0.39	0.996	0.508
		Caucasian (n=15)	7.80	0.43		
	34B	Asian (n=29)	8.09	0.39	0.007	0.113
		Caucasian (n=75)	7.85	0.38		
Bust arc width	34A	Asian (n=32)	18.21	0.70	0.200	0.236
		Caucasian (n=15)	17.84	0.97		
	34B	Asian (n=29)	18.81	0.71	0.798	0.648
		Caucasian (n=75)	18.76	0.76		
LBIA	34A	Asian (n=32)	3.15	0.85	0.511	0.216
		Caucasian (n=15)	3.32	0.75		
	34B	Asian (n=29)	3.01	0.73	0.171	0.469
		Caucasian (n=75)	3.25	0.84		
LBOA	34A	Asian (n=32)	1.76	0.37	0.023	0.011
		Caucasian (n=15)	1.53	0.28		
	34B	Asian (n=29)	1.68	0.34	0.175	0.226
		Caucasian (n=75)	1.78	0.35		
Front neck to bust point (L)	34A	Asian (n=32)	8.13	0.68	0.783	0.147
		Caucasian (n=15)	8.18	0.44		
	34B	Asian (n=29)	8.34	0.55	0.712	0.646
		Caucasian (n=75)	8.38	0.55		
Front neck to bust point (R)	34A	Asian (n=32)	8.11	0.73	0.991	0.122
		Caucasian (n=15)	8.11	0.59		
	34B	Asian (n=29)	8.33	0.66	0.907	0.496
		Caucasian (n=75)	8.32	0.60		
Front neck to bust level	34A	Asian (n=32)	7.30	0.74	0.952	0.132
		Caucasian (n=15)	7.31	0.56		
	34B	Asian (n=29)	7.50	0.62	0.990	0.436
		Caucasian (n=75)	7.51	0.59		
Bust to waist (L)	34A	Asian (n=32)	18.37	0.96	0.188	0.898
		Caucasian (n=15)	18.89	1.32		
	34B	Asian (n=29)	19.25	4.99	0.504	0.132
		Caucasian (n=75)	18.62	1.12		
Side N to under bust to W (R)	34A	Asian (n=32)	18.35	0.96	0.186	0.880
		Caucasian (n=15)	18.86	1.30		
	34B	Asian (n=29)	19.90	9.23	0.477	0.153
		Caucasian (n=75)	18.66	1.06		
Side N to under bust to W (L)	34A	Asian (n=32)	7.61	0.99	0.074	0.287
		Caucasian (n=15)	8.21	1.04		
	34B	Asian (n=29)	7.30	0.80	0.116	0.752
		Caucasian (n=75)	7.60	1.04		
Bust to waist (R)	34A	Asian (n=32)	7.65	0.96	0.091	0.333
		Caucasian (n=15)	8.21	1.04		
	34B	Asian (n=29)	7.33	0.76	0.123	0.760
		Caucasian (n=75)	7.62	1.02		
Side neck to underbust (R)	34A	Asian (n=32)	13.26	0.69	0.059	0.006
		Caucasian (n=15)	12.88	0.59		
	34B	Asian (n=29)	13.42	0.83	0.628	0.818
		Caucasian (n=75)	13.50	0.76		
Side neck to underbust (L)	34A	Asian (n=32)	13.24	0.75	0.064	0.008
		Caucasian (n=15)	12.85	0.62		
	34B	Asian (n=29)	13.29	0.60	0.086	0.389
		Caucasian (n=75)	13.54	0.80		
Back neck to bust point (R)	34A	Asian (n=32)	12.94	0.62	0.962	0.029
		Caucasian (n=15)	12.95	0.62		
	34B	Asian (n=29)	13.20	0.54	0.278	0.109
		Caucasian (n=75)	13.07	0.62		
Back neck to bust point (L)	34A	Asian (n=32)	12.94	0.63	0.938	0.028
		Caucasian (n=15)	12.96	0.66		
	34B	Asian (n=29)	13.11	0.50	0.873	0.416
		Caucasian (n=75)	13.10	0.61		
Side neck to bust (R)	34A	Asian (n=32)	9.88	0.71	0.664	0.125
		Caucasian (n=15)	9.80	0.54		
	34B	Asian (n=29)	10.10	0.64	0.904	0.636
		Caucasian (n=75)	10.08	0.65		
Side neck to bust (L)	34A	Asian (n=32)	9.89	0.74	0.688	0.117
		Caucasian (n=15)	9.81	0.53		
	34B	Asian (n=29)	10.01	0.57	0.433	0.756
		Caucasian (n=75)	10.11	0.63		
Bust height	34A	Asian (n=32)	44.26	1.67	0.000	0.049
		Caucasian (n=15)	46.98	1.70		
	34B	Asian (n=29)	44.01	1.91	0.000	0.697
		Caucasian (n=75)	45.84	2.10		
Underbust height	34A	Asian (n=32)	41.57	1.68	0.000	0.003
		Caucasian (n=15)	44.49	1.71		
	34B	Asian (n=29)	41.38	1.74	0.000	0.991
		Caucasian (n=75)	43.16	2.04		

APPENDIX D: ANALYSIS OF SMALL MESOMORPHS

h <= 60, w <= 120	Group	Data_56		
		Mean	SD	p-value
DWR (L)	Asian (n=40)	0.39	0.08	0.889
	Caucasian (n=16)	0.40	0.05	
DWR (R)	Asian (n=40)	0.37	0.08	0.292
	Caucasian (n=16)	0.39	0.06	
Prominance(L)	Asian (n=40)	9.62	0.53	0.574
	Caucasian (n=16)	9.74	0.71	
Prominance (R)	Asian (n=40)	9.40	0.45	0.498
	Caucasian (n=16)	9.51	0.61	
Bust girth	Asian (n=40)	35.46	0.78	0.059
	Caucasian (n=16)	35.72	0.19	
Underbust girth	Asian (n=40)	29.55	0.54	0.564
	Caucasian (n=16)	29.45	0.54	
Bust point to bust point	Asian (n=40)	7.20	0.45	**0.016**
	Caucasian (n=16)	7.53	0.43	
Sternum	Asian (n=40)	1.50	0.53	0.307
	Caucasian (n=16)	1.35	0.47	
Full bust width	Asian (n=40)	11.59	0.38	0.687
	Caucasian (n=16)	11.64	0.36	
Full bust depth	Asian (n=40)	8.41	0.42	0.240
	Caucasian (n=16)	8.24	0.51	
Underbust width	Asian (n=40)	10.28	0.27	0.280
	Caucasian (n=16)	10.37	0.30	
Underbust depth	Asian (n=40)	7.94	0.44	0.365
	Caucasian (n=16)	7.81	0.49	
Bust Arc	Asian (n=40)	18.55	0.80	0.571
	Caucasian (n=16)	18.70	0.88	
LBIA	Asian (n=40)	2.92	0.72	0.155
	Caucasian (n=16)	3.29	0.89	
LBOA	Asian (n=40)	1.74	0.38	0.779
	Caucasian (n=16)	1.71	0.40	
Front neck to bust point (L)	Asian (n=40)	8.22	0.61	0.787
	Caucasian (n=16)	8.18	0.43	
Front neck to bust point (R)	Asian (n=40)	8.23	0.66	0.281
	Caucasian (n=16)	8.05	0.50	
Front neck to bust level	Asian (n=40)	7.43	0.67	0.229
	Caucasian (n=16)	7.23	0.46	
Side N to under bust to W (R)	Asian (n=40)	18.90	4.33	0.393
	Caucasian (n=16)	18.26	1.15	
Side N to under bust to W (L)	Asian (n=40)	19.45	7.90	0.348
	Caucasian (n=16)	18.23	1.17	
Bust to waist (R)	Asian (n=40)	7.43	0.98	0.758
	Caucasian (n=16)	7.52	0.99	
Bust to waist (L)	Asian (n=40)	7.50	0.95	0.918
	Caucasian (n=16)	7.53	1.01	
Side neck to underbust (R)	Asian (n=40)	13.24	0.82	0.746
	Caucasian (n=16)	13.15	0.91	
Side neck to underbust (L)	Asian (n=40)	13.17	0.74	0.903
	Caucasian (n=16)	13.14	1.00	
Back neck to bust point (R)	Asian (n=40)	12.98	0.60	0.183
	Caucasian (n=16)	12.74	0.59	
Back neck to bust point (L)	Asian (n=40)	12.94	0.57	0.230
	Caucasian (n=16)	12.74	0.56	
Side neck to bust (R)	Asian (n=40)	9.92	0.69	0.682
	Caucasian (n=16)	9.84	0.63	
Side neck to bust (L)	Asian (n=40)	9.89	0.69	0.798
	Caucasian (n=16)	9.84	0.57	
Bust height	Asian (n=40)	43.29	1.33	0.379
	Caucasian (n=16)	43.62	1.20	
Underbust height	Asian (n=40)	40.66	1.30	0.372
	Caucasian (n=16)	41.02	1.35	

APPENDIX E: ANALYSIS OF ENDOMORPHS

h <= 60, w > 120	Group	Data_18		
		Mean	SD	p-value
DWR (L)	Asian (n=11)	0.39	0.06	0.190
	Caucasian (n=7)	0.43	0.05	
DWR (R)	Asian (n=11)	0.38	0.07	0.144
	Caucasian (n=7)	0.42	0.05	
Prominance(L)	Asian (n=11)	9.66	0.58	0.787
	Caucasian (n=7)	9.72	0.33	
Prominance (R)	Asian (n=11)	9.69	0.51	0.715
	Caucasian (n=7)	9.62	0.29	
Bust girth	Asian (n=11)	36.21	0.52	0.044
	Caucasian (n=7)	35.83	0.19	
Underbust girth	Asian (n=11)	29.87	0.37	0.241
	Caucasian (n=7)	29.57	0.56	
Bust point to bust poin	Asian (n=11)	7.48	0.51	0.490
	Caucasian (n=7)	7.62	0.36	
Sternum	Asian (n=11)	1.43	0.68	0.513
	Caucasian (n=7)	1.23	0.54	
Full bust width	Asian (n=11)	11.53	0.52	0.616
	Caucasian (n=7)	11.42	0.40	
Full bust depth	Asian (n=11)	8.71	0.38	0.017
	Caucasian (n=7)	8.34	0.21	
Underbust width	Asian (n=11)	10.35	0.18	0.626
	Caucasian (n=7)	10.42	0.36	
Underbust depth	Asian (n=11)	8.39	0.21	0.056
	Caucasian (n=7)	8.04	0.38	
Bust Arc	Asian (n=11)	19.01	0.64	0.223
	Caucasian (n=7)	18.70	0.39	
LBIA	Asian (n=11)	3.32	0.89	0.191
	Caucasian (n=7)	2.78	0.76	
LBOA	Asian (n=11)	1.61	0.32	0.206
	Caucasian (n=7)	1.80	0.26	
Front neck to bust point (L	Asian (n=11)	8.39	0.70	0.242
	Caucasian (n=7)	8.04	0.52	
Front neck to bust point (R	Asian (n=11)	8.39	0.63	0.271
	Caucasian (n=7)	8.07	0.53	
Front neck to bust leve	Asian (n=11)	7.56	0.71	0.217
	Caucasian (n=7)	7.17	0.58	
Side N to under bust to W (R)	Asian (n=11)	18.67	1.18	0.192
	Caucasian (n=7)	17.88	1.20	
Side N to under bust to W (L)	Asian (n=11)	18.55	1.08	0.247
	Caucasian (n=7)	17.91	1.11	
Bust to waist (R)	Asian (n=11)	7.48	1.00	0.337
	Caucasian (n=7)	6.99	1.02	
Bust to waist (L)	Asian (n=11)	7.50	1.01	0.343
	Caucasian (n=7)	7.02	1.01	
Side neck to underbust (R	Asian (n=11)	13.49	0.84	0.367
	Caucasian (n=7)	13.22	0.41	
Side neck to underbust (L	Asian (n=11)	13.48	0.85	0.548
	Caucasian (n=7)	13.27	0.57	
Back neck to bust point (R	Asian (n=11)	13.33	0.55	0.033
	Caucasian (n=7)	12.79	0.42	
Back neck to bust point (L	Asian (n=11)	13.25	0.66	0.181
	Caucasian (n=7)	12.83	0.59	
Side neck to bust (R)	Asian (n=11)	10.21	0.63	0.062
	Caucasian (n=7)	9.75	0.35	
Side neck to bust (L)	Asian (n=11)	10.13	0.71	0.258
	Caucasian (n=7)	9.79	0.53	
Bust height	Asian (n=11)	42.64	0.86	0.001
	Caucasian (n=7)	43.91	0.34	
Underbust height	Asian (n=11)	39.99	0.74	0.000
	Caucasian (n=7)	41.29	0.35	

APPENDIX F: ANALYSIS OF ECTOMORPHS

h > 60, w <= 120	Group	Data_35		
		Mean	SD	p-value
DWR (L)	Asian (n=16)	0.38	0.05	0.717
	Caucasian (n=19)	0.37	0.06	
DWR (R)	Asian (n=16)	0.36	0.06	0.424
	Caucasian (n=19)	0.37	0.07	
Prominance(L)	Asian (n=16)	9.33	0.65	0.109
	Caucasian (n=19)	9.66	0.46	
Prominance(R)	Asian (n=16)	9.17	0.62	0.129
	Caucasian (n=19)	9.47	0.49	
Bust girth	Asian (n=16)	35.10	0.85	**0.010**
	Caucasian (n=19)	35.74	0.22	
Underbust girth	Asian (n=16)	29.15	0.48	0.074
	Caucasian (n=19)	29.48	0.57	
Bust point to bust poin	Asian (n=16)	7.27	0.45	0.192
	Caucasian (n=19)	7.50	0.56	
Sternum	Asian (n=16)	1.38	0.57	0.949
	Caucasian (n=19)	1.39	0.52	
Full bust width	Asian (n=16)	11.67	0.42	0.600
	Caucasian (n=19)	11.75	0.43	
Full bust depth	Asian (n=16)	8.00	0.45	**0.006**
	Caucasian (n=19)	8.43	0.40	
Under bust width	Asian (n=16)	10.45	0.34	0.253
	Caucasian (n=19)	10.32	0.36	
Under bust depth	Asian (n=16)	7.48	0.53	**0.031**
	Caucasian (n=19)	7.84	0.39	
Bust Arc	Asian (n=16)	18.10	1.22	**0.019**
	Caucasian (n=19)	18.97	0.74	
LBIA	Asian (n=16)	2.99	0.85	0.245
	Caucasian (n=19)	3.31	0.71	
LBOA	Asian (n=16)	1.79	0.40	0.560
	Caucasian (n=19)	1.72	0.28	
Front neck to bust point (L	Asian (n=16)	8.02	0.69	0.118
	Caucasian (n=19)	8.40	0.70	
Front neck to bust point (R	Asian (n=16)	7.90	0.79	0.054
	Caucasian (n=19)	8.40	0.68	
Front neck to bust leve	Asian (n=16)	7.11	0.75	0.080
	Caucasian (n=19)	7.56	0.71	
Side N to under bust to W (R)	Asian (n=16)	18.85	0.77	0.378
	Caucasian (n=19)	18.58	1.03	
Side N to under bust to W (L)	Asian (n=16)	18.84	0.87	0.437
	Caucasian (n=19)	18.59	1.00	
Bust to waist (R)	Asian (n=16)	8.23	1.22	0.271
	Caucasian (n=19)	7.76	1.24	
Bust to waist (L)	Asian (n=16)	8.26	1.20	0.256
	Caucasian (n=19)	7.79	1.23	
Side neck to underbust (R	Asian (n=16)	13.25	0.67	0.789
	Caucasian (n=19)	13.32	0.84	
Side neck to underbust (L	Asian (n=16)	13.26	0.75	0.828
	Caucasian (n=19)	13.32	0.88	
Back neck to bust point (R	Asian (n=16)	12.72	0.69	0.214
	Caucasian (n=19)	13.02	0.74	
Back neck to bust point (L	Asian (n=16)	12.72	0.72	0.225
	Caucasian (n=19)	13.02	0.69	
Side neck to bust (R)	Asian (n=16)	9.74	0.78	0.298
	Caucasian (n=19)	10.02	0.79	
Side neck to bust (L)	Asian (n=16)	9.74	0.80	0.309
	Caucasian (n=19)	10.02	0.75	
Bust height	Asian (n=16)	45.71	1.66	0.182
	Caucasian (n=19)	46.44	1.46	
Underbust height	Asian (n=16)	42.84	1.75	0.083
	Caucasian (n=19)	43.81	1.40	

APPENDIX G: ANALYSIS OF LARGE MESOMORPHS

h > 60, w > 120	Group	Data_71		
		Mean	SD	p-value
DWR (L)	Asian (n=23)	0.37	0.05	0.590
	Caucasian (n=48)	0.38	0.05	
DWR (R)	Asian (n=23)	0.36	0.06	0.975
	Caucasian (n=48)	0.36	0.05	
Prominance(L)	Asian (n=23)	9.51	0.54	0.779
	Caucasian (n=48)	9.54	0.52	
Prominance(R)	Asian (n=23)	9.38	0.66	0.754
	Caucasian (n=48)	9.30	1.46	
Bust girth	Asian (n=23)	35.72	0.80	0.985
	Caucasian (n=48)	35.72	0.28	
Underbust girth	Asian (n=23)	29.70	0.46	0.552
	Caucasian (n=48)	29.77	0.51	
Bust point to bust point	Asian (n=23)	7.43	0.48	0.499
	Caucasian (n=48)	7.51	0.40	
Sternum	Asian (n=23)	1.51	0.61	0.179
	Caucasian (n=48)	1.32	0.44	
Full bust width	Asian (n=23)	11.82	0.46	0.919
	Caucasian (n=48)	11.81	0.45	
Full bust depth	Asian (n=23)	8.39	0.35	0.827
	Caucasian (n=48)	8.37	0.38	
Under bust width	Asian (n=23)	10.51	0.32	0.221
	Caucasian (n=48)	10.62	0.36	
Under bust depth	Asian (n=23)	7.93	0.31	0.196
	Caucasian (n=48)	7.83	0.35	
Bust Arc	Asian (n=23)	18.55	1.01	0.615
	Caucasian (n=48)	18.43	0.92	
LBIA	Asian (n=23)	3.22	0.77	0.718
	Caucasian (n=48)	3.30	0.85	
LBOA	Asian (n=23)	1.69	0.43	0.526
	Caucasian (n=48)	1.76	0.38	
Front neck to bust point (L)	Asian (n=23)	8.38	0.66	0.752
	Caucasian (n=48)	8.43	0.48	
Front neck to bust point (R)	Asian (n=23)	8.34	0.70	0.999
	Caucasian (n=48)	8.34	0.60	
Front neck to bust level	Asian (n=23)	7.53	0.69	0.858
	Caucasian (n=48)	7.56	0.56	
Side N to under bust to W (R)	Asian (n=23)	18.55	0.87	0.109
	Caucasian (n=48)	18.95	1.12	
Side N to under bust to W (L)	Asian (n=23)	18.60	0.92	0.106
	Caucasian (n=48)	19.00	1.03	
Bust to waist (R)	Asian (n=23)	7.57	0.81	0.224
	Caucasian (n=48)	7.84	1.00	
Bust to waist (L)	Asian (n=23)	7.59	0.80	0.226
	Caucasian (n=48)	7.86	0.96	
Side neck to underbust (R)	Asian (n=23)	13.58	0.77	0.842
	Caucasian (n=48)	13.54	0.71	
Side neck to underbust (L)	Asian (n=23)	13.65	0.77	0.731
	Caucasian (n=48)	13.58	0.73	
Back neck to bust point (R)	Asian (n=23)	13.37	0.59	0.259
	Caucasian (n=48)	13.20	0.57	
Back neck to bust point (L)	Asian (n=23)	13.37	0.58	0.390
	Caucasian (n=48)	13.24	0.55	
Side neck to bust (R)	Asian (n=23)	10.18	0.63	0.843
	Caucasian (n=48)	10.15	0.60	
Side neck to bust (L)	Asian (n=23)	10.18	0.62	0.932
	Caucasian (n=48)	10.19	0.57	
Bust height	Asian (n=23)	46.12	1.71	0.056
	Caucasian (n=48)	46.98	1.79	
Underbust height	Asian (n=23)	43.33	1.66	**0.029**
	Caucasian (n=48)	44.30	1.75	

APPENDIX H: BODY MEASUREMENTS OF ASIAN PARTICIPANTS

Sample	DWR (L)	DWR (R)	Prominance (L)	Prominence (R)	Bust girth	Underbust girth	Bust arc	LBIA	LBOA	B.P to B.P.	Sternum	Full bust width	Full bust depth	Under bust width	Under bust depth	BK NK to B.P.(R)	BK NK to B.P.(L)	FT NK to B.P.(L)	FT NK to B.P.(R)
1	0.44	0.35	9.23	9.19	36.79	29.06	18.47	3.71	1.4	6.1969	2.4	11.96	8.41	10.39	7.79	12.68	12.7	7.01	7.09
2	0.41	0.41	8.97	9.27	36.11	29.91	17.78	2.11	1.58	7.1139	1.67	11.65	8.21	10.72	7.79	12.23	12.08	7.44	6.99
3	0.38	0.42	9.68	9.5	34.06	28.61	18.97	2.75	1.99	7.0691	0.97	11.52	7.46	10.32	6.78	12.75	12.65	8.13	7.99
4	0.36	0.3	9.36	8.64	34.4	30.47	17.99	2.66	0.91	6.9274	3.38	11.75	8.7	10.75	7.88	12.12	12.28	7.85	7.74
5	0.33	0.35	10.36	10.41	36.95	29.93	20.79	2.55	2.55	7.5125	0.98	12.01	8.5	10.33	7.99	14.65	14.59	9.73	9.69
6	0.31	0.32	8.63	8.62	34.33	30.15	16.86	3.97	1.5	6.926	0.99	12.04	8.05	11.12	7.5	12.85	12.86	8.03	7.74
7	0.77	0.34	9.12	8.72	36.46	30.07	18.02	2.42	1.98	7.45	1.58	12.01	9.07	10.13	8.15	13.79	13.84	9.71	9.79
8	0.44	0.42	9.56	10.05	35.2	29.64	19.44	2.58	2.01	7.8979	1.37	11.06	8.32	10.12	8.1	12.96	12.65	7.8	7.83
9	0.44	0.38	9.59	9.97	36.58	29.67	19.13	2.99	1.68	7.3719	1.36	11.2	8.9	10.28	8.48	13.19	13.17	8.2	8.41
10	0.42	0.44	9.86	10.05	36.76	28.9	19.25	3.25	1.77	7.8801	1.1	11.96	8.11	10	7.5	12.48	12.37	8.15	8.1
11	0.39	0.4	9.85	9.2	35	29.4	18.5	4.3	1.69	7.5669	0.59	11.05	8.65	10.12	8.07	12.28	12.69	8.01	7.47
12	0.38	0.4	10.04	9.49	35.92	28.92	19.18	2.79	1.71	7.4423	1.52	11.62	8.55	9.71	7.98	13.21	13.23	8.68	8.78
13	0.37	0.31	8.58	8.84	34.45	28.79	17.02	2.49	1.54	6.9266	1.95	11.21	7.68	10.46	7.25	11.38	11.12	6.75	6.96
14	0.35	0.31	9.4	9.36	36.61	29.59	18.96	3.03	1.23	6.6835	2.38	12.34	8.55	10.38	7.88	13.27	13.11	7.97	8.01
15	0.44	0.37	10.4	10.26	36.56	30.03	20.04	3.69	1.78	7.9645	1.33	12.55	8.33	10.41	8.14	13.64	13.53	8.94	8.92
16	0.41	0.34	8.53	8.03	34.11	28.69	15.98	3.21	1.35	7.2049	1.54	11.64	7.43	10.5	6.85	12.2	12.22	7.62	7.39
17	0.4	0.39	9.53	9.35	34.74	28.51	19.07	4.34	1.63	7.134	0.59	11.46	8.18	10	7.69	12.81	12.96	8.7	8.41
18	0.36	0.3	9.84	9.37	35.7	29.92	19.04	2.68	1.6	7.2872	1.87	11.55	8.83	10.25	8.17	12.81	13.05	8.5	8.53
19	0.29	0.23	9.41	9.12	35.36	29.27	18.31	2.96	1.86	6.8028	2.68	12.34	7.98	10.6	7.18	12.38	12.67	7.92	7.41
20	0.42	0.33	9.86	9.19	34.12	29.18	18.6	2.89	1.83	6.6363	1.61	10.77	8.08	9.65	8.26	12.47	12.43	7.72	7.18
21	0.41	0.42	9.13	9.73	35.27	29.07	18.37	2.11	2.55	7.3418	1.32	12.05	7.58	10.12	7.26	12.8	12.71	7.93	8.28
22	0.38	0.28	9.61	8.5	35.23	30.04	17.04	2.05	1.58	7.19	2.57	11.73	8.74	10.82	8.01	13.44	13.78	8.99	8.54
23	0.36	0.39	9.58	9.47	34.86	29.48	19.02	3.05	1.85	7.8388	1.85	11.09	8.25	9.97	7.55	12.89	12.52	8.18	8.45
24	0.35	0.35	9.29	9.42	35.36	28.7	18.76	3.05	1.57	7.4426	1.57	11.5	8.32	9.91	7.81	14.27	14.1	9.05	9.32
25	0.35	0.36	9.46	9.59	35.2	29.96	18.77	3.53	1.92	7.3363	1.27	12.41	8.43	10.61	8.05	14.16	14.1	9.41	9.56
26	0.33	0.37	10.02	9.46	35.58	30.42	19.47	3.39	1.25	6.807	1.78	11.57	9	10.05	8.31	12.7	12.85	7.92	7.77
27	0.33	0.32	8.88	9.25	36.06	30.36	17.76	3.9	1.44	7.8633	1.47	12.44	8.27	11.21	7.93	13.44	13.32	8.24	8.51
28	0.31	0.35	9.92	9.69	36.94	30.14	19.93	1.99	2.02	7.8268	1.73	12.06	8.49	10.4	8.04	12.9	12.94	7.77	7.84
29	0.3	0.32	8.57	8.73	35.36	29.5	17.37	4.4	1.15	7.5003	1.56	12.51	7.88	10.61	7.29	12.63	12.53	8.12	8.01
30	0.46	0.39	10.73	10.06	36.63	30.21	19.98	4.74	1.47	6.8052	0.91	11.94	8.26	10.38	8.59	14.53	14.57	10.04	9.84
31	0.37	0.34	9.41	9.17	34.75	29.4	18.65	2.81	1.28	6.8514	1.57	11.23	8.39	10.39	8.05	12.75	12.57	8.2	8.38
32	0.37	0.3	9.66	10.07	35.95	28.98	19.8	2.84	1.76	7.2389	1.48	11.65	8.5	9.98	8	13.42	13.23	8.51	8.62
33	0.36	0.37	10.17	8.85	35.01	29.07	19.37	2.7	2.79	7.4297	0.59	11.59	8.69	10.32	7.69	13.62	14.04	9.01	8.67
34	0.34	0.33	8.98	9.4	34.82	29.63	18.07	3.03	1.72	7.7775	1.25	11.34	7.97	10.52	7.57	13.16	13.07	8.12	8.46
35	0.37	0.33	10.31	9.87	36.6	29.62	20.03	1.89	2.73	7.1596	1.13	11.78	8.08	10.79	7.45	13.41	13.41	8.49	8.58
36	0.37	0.36	8.97	8.99	34.43	29.21	17.46	3.42	1.67	7.089	1.06	11.95	7.94	10.49	7.35	13.41	13.24	8.66	8.6
37	0.49	0.55	10.1	10.65	36.38	29.33	18.91	2.64	2.1	8.3314	0.59	11.42	7.9	10.7	7.57	13.39	13.35	8.7	8.75
38	0.44	0.4	9.98	10.11	36.06	29.75	19.37	3.65	1.49	8.0458	1.48	11.32	8.6	10.46	8.25	13.04	12.74	8.52	8.4
39	0.39	0.26	9.91	10.09	36.68	30.35	19.19	2.46	2.32	6.766	1.71	11.85	8.1	10.34	8.57	12.87	13.43	8.08	8.15
40	0.39	0.38	10.29	9.21	36.96	29.27	18.93	2.25	2.42	7.5509	0.94	12.37	8.56	10.32	7.95	13.4	13.74	8.81	8.33
41	0.46	0.48	9.76	9.78	36.29	30	18.73	2.74	1.54	7.3945	1.66	11.54	9.12	10.31	8.84	12.59	12.43	7.74	7.84
42	0.44	0.44	10.28	10.22	36.04	28.51	20.01	2.5	2.48	7.5656	0.77	11.32	8.3	10.22	7.48	12.42	12.38	8.11	7.84
43	0.41	0.37	9.04	8.6	35.16	29.72	17.07	4.73	1.66	6.4509	0.59	12.1	7.78	10.35	7.36	12.15	12.15	6.99	7.06
44	0.39	0.4	10.1	9.48	36.41	30.11	19.18	2.38	1.92	7.9476	1.78	12.23	8.13	10.82	7.49	14.14	13.5	8.66	8.72
45	0.37	0.3	9.28	9.03	35.08	30.05	17.69	4.79	1.33	7.6129	1.79	11.86	8.08	10.75	8.05	12.73	13.08	7.94	7.72
46	0.37	0.32	9.3	9.02	35.1	30	18.45	4.18	1.34	7.1249	1.75	11.8	8.06	10.93	7.52	11.17	11.06	6.4	6.06
47	0.33	0.33	9.67	9.1	35.81	29.62	18.98	5.03	1.03	7.6719	2.07	11.23	8.7	10.38	7.96	12.84	12.71	8.06	7.74
48	0.49	0.48	9.79	9.4	35.68	29.12	18.15	2.92	1.73	6.931	0.76	11.8	7.99	10.29	7.58	13.68	13.51	8.75	8.66
49	0.47	0.47	9.07	9.28	35.45	29.45	17.54	2.8	2.36	7.1408	0.59	11.95	8.05	10.64	7.57	12.33	12.28	7.02	7.15
50	0.45	0.38	10.02	9.71	35.25	30.28	18.24	2.57	2.04	7.7777	1.04	11.15	8.35	10.49	8.13	12.75	13.03	8.26	8.05
51	0.44	0.37	10.12	9.69	35.12	28.76	18.99	3.81	1.62	6.9024	1.72	11.68	7.28	10.58	6.83	12.81	12.95	8.26	7.97
52	0.4	0.67	10.65	10.1	36.61	30.38	19.86	2.68	2.02	6.615	0.59	10.74	8.99	10.09	8.3	13.48	13.45	8.73	8.62
53	0.38	0.36	10.31	9.54	36.03	29.68	18.41	2.6	2.3	7.25	1.2	11.66	8.63	10.33	8.3	12.66	12.69	7.51	7.59
54	0.35	0.33	9.29	9.26	34.66	29.5	18.44	2.15	2.01	7.4561	1.3	11.55	7.95	10.3	7.66	13.51	13.61	8.37	8.51
55	0.27	0.19	9.72	9.23	34.6	28.85	18.3	2.61	1.97	6.9302	1.62	11.32	8.11	10.06	7.57	13.04	13.18	8.78	8.42
56	0.43	0.37	10.79	10.57	36.7	30.24	20.24	4.28	1.6	8.4729	0.9	12.08	8.35	10.8	8.22	13.09	13.43	8.36	8.24
57	0.42	0.4	9.74	9.48	36	29.44	19.19	3.21	1.61	7.9608	1.38	11.68	8.46	10.39	8.12	14.22	13.94	9.57	9.88
58	0.33	0.33	8.84	8.91	34.24	29.74	17.49	2.76	1.52	7.2147	1.84	11.59	8.14	10.56	7.67	13.15	13.05	8.48	8.66
59	0.31	0.3	9.05	8.3	36.09	29.95	17.4	3.91	1.12	7.2641	2.24	12.41	9.11	10.43	8.65	13.25	13.38	7.97	7.92
60	0.33	0.31	8.7	8.69	34.1	28.81	17.19	4.3	0.99	7.219	1.87	11.41	8.27	10.17	7.27	12.8	12.36	8.6	8.88
61	0.42	0.39	9.82	9.81	35.67	29.26	19.14	2.41	2.19	7.5469	1.64	11.51	8.28	10.49	8.03	12.84	12.7	7.74	7.8
62	0.32	0.27	9.45	9.11	36.75	29.83	18.83	4	1.05	7.7352	2.94	12.18	8.68	10.31	8.33	13.48	13.71	8.91	8.5
63	0.3	0.27	9.55	9.61	34.3	29.27	19.07	2.45	2.09	6.4355	1.51	11.85	8.12	10.05	8.04	12.88	13.1	8.03	8.12
64	0.39	0.41	10.09	9.91	35.65	29.65	19.67	2.7	1.76	8.0384	0.89	11.44	8.02	10.6	7.73	14.23	14.08	9.05	9.02
65	0.36	0.38	8.82	9.25	35.32	30.12	17.42	2.61	1.72	7.1285	1.29	11.91	8.14	10.62	7.81	13.01	12.89	7.68	7.81
66	0.35	0.32	9.3	8.61	35.56	29.09	17.85	2.75	2.1	7.0425	1.35	11.45	8.68	10.35	7.45	12.48	12.75	7.92	7.29
67	0.35	0.39	9.6	10.15	36.13	29.59	19.33	5.07	1.45	7.7804	1.57	11.73	8.75	10.55	8.33	13.15	12.97	8.67	8.6
68	0.3	0.28	8.43	8.57	36.36	30.39	17.41	3.01	1.36	6.5069	1.85	12.26	9.48	10.64	8.58	12.54	12.37	7.45	7.37
69	0.38	0.41	10	10.12	35.92	29.38	19.29	3.5	1.61	7.8671	1.2	12.14	7.98	10.7	7.67	13.65	13.45	8.59	8.52
70	0.27	0.29	8.63	8.72	34.69	29.59	17.37	1.8	1.53	6.5373	2.33	11.64	8.59	10.51	8.27	12.35	12.61	8.15	8.35
71	0.33	0.38	8.75	9.22	34.65	28.51	17.46	2.12	1.73	7.1069	2.29	11.29	8.45	9.7	7.9	13.21	13.03	8.33	8.7
72	0.42	0.44	9.16	9.63	35.5	29.54	17.7	2.17	2.1	7.5546	0.9	11.86	8.08	10.89	7.45	13.2	12.97	8.15	8.3
73	0.46	0.43	9.53	9.65	35.22	29.24	18.05	2.43	1.92	7.6748	1.43	10.57	8.47	10.4	7.87	14.11	13.89	9	9.09
74	0.42	0.42	9.88	10.2	35.71	29.78	19.35	3.27	1.47	7.1482	0.59	10.69	8.78	10.35	8.65	13.06	12.72	8.09	8.2
75	0.37	0.36	9.48	9.19	36.04	29.32	18.31	2.02	1.5	6.9343	1.97	11.89	8.55	10.47	8	13.61	13.35	8.23	8.4
76	0.33	0.33	9.2	9.29	36.02	29.98	18.66	2.9	1.48	7.3101	1.88	11.82	9.16	10.21	8.51	13.69	13.45	8.34	8.72
77	0.37	0.35	10.7	9.85	35.24	29.93	19.74	2.89	2.02	7.7465	1.13	11.8	8	10.64	7.9	12.72	12.69	8.39	8.23
78	0.57	0.58	9.07	8.88	34.85	30.02	17.25	2.99	1.73	6.969	1.49	11.09	8.73	10.33	8.32	12.94	12.81	7.37	7.13
79	0.4	0.4	9.27	9.43	35.37	29.73	18.21	2.51	1.76	7.1694	0.93	11.41	8.88	10.08	8.61	13.03	12.86	8.21	8.45
80	0.42	0.37	8.5	8.3	34.33	28.5	16.33	1.36	1.72	7.1635	2.12	11.51	6.88	10.87	6.4	11.69	11.59	7.17	7.09
81	0.42	0.38	9.6	8.74	35.44	29.37	17.88	4.32	1.48	7.089	1.58	11.88	8.6	10.08	8.09	12.55	13.08	8.15	7.82
82	0.38	0.39	9.48	9.99	36.18	29.12	18.73	2.84	1.93	7.578	1.12	11.2	9.2	10	8.49	13.42	13.49	8.16	8.44
83	0.33	0.33	9.29	9.43	34.75	29.05	18.17	3.5	1.43	7.4464	1.75	11.57	8.46	10.23	7.99	13.35	13.37	8.5	8.79
84	0.33	0.33	10.02	9.59	35.72	30.31	19.31	2.55	1.47	7.2085	1.64	11.34	8.73	10.29	8.47	13.07	13.31	8.53	8.49
85	0.4	0.38	10.3	9.24	36.59	30.24	19.06	2.52	1.96	7.4591	1.1	11.71	8.93	10.44	8.62	14.39	14.03	8.91	9.27
86	0.42	0.36	10.23	9.63	36.88	30.48	18.89	2.82	1.78	8.0616	0.97	11.55	8.78	10.48	8.53	13.85	13.95	8.62	8.48
87	0.36	0.33	9.09	9.68	35.12	29.19	17.19	4.12	1.07	6.0607	1.78	12.11	8.84	9.97	8.51	12.36	12.3	6.75	7.09
88	0.39	0.52	9.78	9.7	36.4	29.71	18.92	2.68	1.79	8.1026	0.62	10.87	8.47	10.04	8.18	13.31	13.46	8.47	8.5
89	0.36	0.32	8.82	8.23	34.33	29.44	17.49	2.96	1.17	7.0966	2.49	10.87	8.64	9.97	8.44	13.6	13.62	8.16	8.46
90	0.33	0.33	9.02	8.83	34.54	28.93	17.15	2.88	1.59	7.1515	1.07	11.46	8.21	10.15	7.74	13.08	13.25	8.16	7.72

FT NK to bust level	S.N. to Underbust to waist (R)	S.N. to Underbust to waist (L)	Bust to waist (R)	Bust to waist (L)	NK to Underbust (R)	NK to Underbust (L)	Side neck to bust (R)	Side neck to bust (L)	Bust height	Underbust height	Height	Weight	US	UK	Asian	Age
6.33	19.7	20.23	9.24	9.24	13.68	14.26	9.34	9.35	46.49	42.95	61.43	127	34C	34C	75D	19
6.34	18	17.71	8.07	7.93	13.55	13.27	9.29	9.14	49.35	45.8	64.89	148	34B	34C	75C	19
7.26	20.36	20.26	10.03	10.01	12.43	12.47	9.71	9.61	50.61	48.25	66.44	106	34AA	34A	75AA	19
7.03	18.38	19	8.25	8.54	11.91	12.17	9.15	9.31	45.18	42.82	59.79	105	34AA	34A	75A	19
8.96	19.73	19.53	7.76	7.79	15.31	15.09	11.42	11.36	45.13	41.98	61.45	128	34C	34C	75D	19
7.06	18.92	18.94	8.63	8.63	13	13.02	9.73	9.74	45.4	42.44	60.94	124	34AA	34A	75A	19
9.09	44.73	67.73	5.5	5.54	13.18	13.31	10.85	10.9	44.63	42.46	60	116	34B	34C	75C	20
6.9	18.39	18.14	7.73	7.75	13.03	12.86	10.07	9.76	42.4	40.03	57.34	122	34A	34B	75B	20
7.48	20.14	20.07	9.25	9.29	13.71	13.55	9.61	9.59	44.06	40.91	59.44	132	34C	34C	75C	20
7.17	17.81	17.9	7.54	7.63	12.87	12.91	9.49	9.38	43.36	40.8	57.68	109	34C	34C	75D	20
6.86	19.77	20.12	9.78	9.65	13.63	13.98	9.25	9.65	45.17	41.43	59.84	114	34A	34A	75A	20
7.91	17.41	17.45	6.96	7.2	13.39	13.3	10.09	10.11	44.69	41.94	59.71	100	34B	34B	75C	20
5.98	18.77	18.36	9.48	9.59	12.62	12.23	8.36	8.11	45.83	42.29	60.12	105	34AA	34A	75A	20
7.32	18.7	18.71	8.14	8.24	13.43	13.41	9.96	9.8	49.81	46.86	65.81	136	34C	34C	75C	20
8.03	19.2	19.67	7.89	7.88	14.33	14.84	10.43	10.32	46.46	43.51	62.83	126	34C	34C	75C	21
6.6	19.63	19.54	9.64	9.69	12.63	12.48	8.92	8.94	47.14	44.19	62.7	118	34AA	34A	75AA	21
7.83	19.63	19.57	8.98	8.96	13.65	13.71	9.89	10.04	45.54	42.39	60.76	113	34A	34A	70D	21
7.76	16.98	17.26	6.89	7.02	12.5	12.72	9.72	9.96	40.78	38.42	54.96	104	34B	34B	75B	21
6.91	18.61	18.77	8.48	8.51	12.81	13.03	9.34	9.62	45.3	42.35	60.18	116	34A	34B	75B	21
6.63	18.81	18.5	8.97	8.93	12.57	12.49	9.43	9.39	45.47	42.72	60.27	107	34AA	34A	75AA	22
7.23	18.58	18.9	7.93	7.85	12.87	12.78	9.96	9.87	44.69	42.33	59.87	116	34A	34B	75B	22
8.01	18.26	18.57	7.36	7.36	13.56	13.98	10.28	10.61	47.3	44.54	63.95	127	34A	34B	75B	22
7.43	17.49	16.97	7.29	7.39	13.08	12.39	9.75	9.38	44.7	41.94	59.89	114	34A	34A	75A	22
8.42	18.9	18.63	6.98	7.04	14.61	14.33	11.16	10.99	48.78	46.02	66.07	129	34A	34B	75B	22
8.75	18.45	18.54	6.93	7.11	14.01	13.99	11.06	11	45.09	42.53	61.82	128	34A	34A	75A	22
7.08	17.42	17.64	7.59	7.65	11.95	12.2	9.51	9.66	43.04	40.88	57.29	119	34B	34B	75B	22
7.41	18.94	19.27	8.23	8.25	12.81	12.89	9.92	9.8	47.2	44.64	62.82	133	34B	34C	75C	22
6.81	17.01	16.94	6.64	6.61	12.32	12.52	9.71	9.75	48.4	46.23	64.2	139	34C	34C	75D	22
7.11	17.59	17.36	7.34	7.38	12.69	12.5	9.69	9.59	45.34	42.78	60.59	114	34A	34B	75B	22
9.34	21.14	20.89	8.17	8.28	15.55	15.58	11.76	11.79	42.69	39.74	59.36	142	34C	34C	75C	23
7.61	18.28	17.94	7.52	7.56	12.46	12.19	9.93	9.75	43.47	41.5	58.68	118	34A	34A	75A	23
7.81	18.23	18.27	7.39	7.33	13.74	13.73	10.52	10.34	44.24	41.48	59.36	114	34B	34B	75C	23
8.05	18.27	18.69	7.09	7.17	13.66	14.22	10.59	11	44.13	41.38	60.14	127	34A	34A	75A	23
7.42	19.1	18.93	8.28	8.33	12.98	12.76	9.97	9.88	44.29	41.93	59.65	114	34A	34A	75A	23
7.71	19.09	18.9	7.23	7.33	13.93	13.83	10.59	10.59	43.55	40.99	60.2	104	34C	34C	75C	24
7.88	18.44	18.23	7.52	7.51	13.29	13.06	10.26	10.09	44.31	41.75	60.28	122	34AA	34A	75A	24
7.73	20.07	19.82	7.36	7.36	14.89	14.93	10.91	10.88	44.92	42.16	60.61	124	34B	34C	75C	25
7.48	19.47	19.36	8.01	8.04	13.93	13.71	10.09	9.79	41.83	39.07	57.42	117	34B	34C	75C	25
7.52	18.82	19.41	7.96	7.96	13.52	14.23	10.19	10.75	43.34	40.58	58.55	117	34C	34C	75D	25
7.68	19.99	20.04	8.25	8.35	14.05	14.52	10.36	10.71	44.33	41.38	60	115	34C	34C	75D	25
6.89	17.55	17.23	7.19	7.29	12.94	12.71	9.22	9.06	42.59	39.83	58.04	118	34B	34C	75C	26
7.14	18.75	18.62	8.54	8.49	13.91	13.82	9.45	9.42	45.41	41.87	59.63	114	34B	34B	70E	27
6.27	17.63	17.66	7.7	7.71	11.98	12.01	9	9	41.61	39.25	55.6	107	34A	34B	75B	27
7.76	20.78	18.89	7.33	7.38	15.71	13.61	11.29	10.65	43.94	41.57	59.61	118	34B	34C	75C	27
6.91	19.66	19.58	8.88	8.9	13.43	13.44	9.66	10.02	45.09	42.14	60.78	127	34A	34B	75B	27
5.08	18.47	18.05	10.1	10.17	11.82	11.47	7.64	7.53	45.37	41.83	58.83	115	34A	34B	75B	27
7.07	17.25	17.33	7.41	7.42	12.61	12.71	9.65	9.52	47.34	44.58	62.74	124	34B	34B	75B	27
8	19.48	19.37	7.54	7.63	13.62	13.31	10.36	10.19	43.53	41.37	59.09	120	34B	34B	75B	28
6.18	18.5	18.74	8.14	8.11	13.33	13.47	9.34	9.29	45.1	41.95	60.04	110	34A	34B	75B	28
7.27	19.27	19.44	8.34	8.4	13.48	13.79	9.45	9.73	44.56	41.61	60.09	123	34A	34B	75B	28
7.34	17.72	17.9	6.62	6.75	13.71	13.76	9.8	9.94	44.34	41.58	59.87	116	34A	34B	75B	28
7.9	20.06	20.52	8.73	8.77	13.74	13.96	10.4	10.37	42.58	40.02	57.58	117	34C	34C	75C	28
6.67	17.31	17.45	7.51	7.5	12.73	12.8	9.16	9.19	44.01	40.86	58.34	117	34B	34B	75C	28
7.68	19.4	19.44	7.95	8.03	13.6	13.56	10.76	10.86	43.28	40.91	58.71	110	34A	34A	75A	28
7.88	18.01	18.13	7.2	7.28	13.31	13.52	10.17	10.31	42.97	40.41	58.33	106	34A	34A	75A	28
7.25	18.95	19.63	7.72	7.78	14.54	15.02	10.44	10.78	44.79	41.44	60.47	118	34C	34C	75D	29
8.94	18.12	17.8	5.99	6.09	14.66	14.33	11.51	11.22	44.19	41.63	60.49	119	34B	34B	75C	30
7.81	17.55	17.65	7.13	7.27	12.49	12.48	10.01	9.91	44.33	42.16	60	114	34AA	34A	75AA	30
7.12	18.15	18.21	7.84	7.87	12.53	12.62	9.65	9.78	44.8	42.24	60.62	129	34B	34C	75C	30
8.08	16.47	16.28	6.31	6.37	12.4	12.17	9.79	9.36	42.13	39.77	50.75	102	34AA	34A	75AA	31
6.85	19.48	18.87	8.17	8.23	13.79	13.45	9.75	9.61	42	39.05	56.95	121	34B	34B	75B	32
7.92	17.41	17.75	6.67	6.68	13.32	13.73	10.13	10.36	42.36	39.41	57.53	131	34C	34C	75D	32
7.45	17.17	17.49	7.07	7.24	13.06	13.38	10	10.22	43.48	40.52	58.91	115	34AA	34A	75A	32
8.2	17.87	17.41	5.97	6.08	14.25	14.07	10.91	10.76	44.12	41.56	60.52	127	34B	34B	75B	35
6.9	17.49	17.69	7.34	7.28	12.48	12.46	9.61	9.49	45.88	43.52	61.04	138	34A	34B	75B	35
6.75	18.82	18.96	8.64	8.65	13	13.25	9.27	9.54	46	42.85	60.9	114	34B	34B	75B	35
7.72	17.82	17.54	7.22	7.14	13.3	13.07	9.86	9.68	44.09	41.33	59.64	123	34B	34C	75C	36
6.7	17.88	17.72	7.9	7.83	12.15	12.14	9.49	9.31	43.02	40.47	57.69	133	34B	34C	75C	37
7.71	19.39	19.39	7.56	7.57	13.79	13.65	10.64	10.43	44.88	42.51	60.62	132	34B	34B	75C	40
7.63	15.79	15.65	5.73	5.76	12.26	12.16	9.72	9.48	42.98	40.62	58.17	115	34A	34A	75A	42
7.8	20.22	19.97	9.02	9.04	13.28	13.11	9.98	9.79	43.02	40.46	58.55	111	34A	34A	70C	43
7.42	18.96	18.34	7.13	7.19	13.33	12.99	10.14	9.91	46.92	44.75	62.62	116	34A	34B	75B	44
8.19	19.36	19.06	6.37	6.39	14.98	14.61	11.34	11.12	42.06	39.89	58.39	114	34A	34B	75B	45
7.4	18.71	18.41	7.6	7.55	13.7	13.46	10.18	9.84	42.17	39.41	57.17	127	34B	34B	75B	45
7.58	18.07	17.25	6.15	6.36	14.05	13.27	10.68	10.41	42.8	40.44	58.53	117	34B	34B	75C	45
7.75	18.87	18.8	7.67	7.75	13.25	13.07	10.57	10.33	42.98	40.62	58.97	121	34B	34B	75C	45
7.4	16.71	16.85	6.19	6.44	13.42	13.51	9.96	9.93	42.49	39.73	57.55	117	34A	34B	75B	47
6.35	17.44	17.83	6.88	6.88	12.77	13.12	9.71	9.59	43.43	40.87	58.3	111	34A	34A	75A	48
7.56	18.13	18.14	7.28	7.33	12.99	12.94	9.93	9.76	41.73	39.37	56.72	116	34A	34B	75B	48
6.24	19.83	20.39	9.86	9.85	13.32	13.52	8.81	8.7	46.86	43.32	61.91	111	34AA	34A	70C	49
7.25	19.02	18.59	7.31	7.29	13.85	13.67	9.98	10.51	42.82	40.26	57.8	114	34A	34B	75B	49
7.44	17.44	17.44	6.39	6.37	13.56	13.62	10.04	10.1	44.94	42.19	60.76	125	34B	34C	75C	50
7.83	17.49	17.64	6.55	6.65	13.2	13.35	10.38	10.4	44.55	42.19	60.71	115	34A	34A	75A	50
7.78	17.21	17.38	6.66	6.73	12.75	12.99	10.05	10.29	41.56	39.39	56.81	116	34B	34B	75B	50
8.29	18	18.22	6.27	6.5	13.92	13.92	10.88	10.52	39.39	36.83	55.09	108	34C	34C	75C	51
7.62	17.35	17.45	5.62	5.67	13.76	14	10.65	10.75	42.01	39.65	58	127	34C	34C	75D	53
6.22	17.4	17.35	7.25	7.19	14.17	14.12	8.69	8.63	42.04	37.71	56.54	120	34A	34B	75B	53
7.53	18.19	18.42	6.29	6.33	12.84	13.37	10.27	10.42	41.26	39.29	56.57	123	34B	34C	75C	60
7.55	17.64	17.86	6.48	6.56	13.73	13.74	10.48	10.51	46.31	43.56	62.85	133	34AA	34A	75A	60
7.15	18.48	18.66	7.51	7.51	13.32	13.5	10	10.17	44.1	41.34	60.69	118	34AA	34A	75A	62

APPENDIX I: BODY MEASUREMENTS OF CAUCASIAN PARTICIPANTS

Sample	DWR (L)	DWR (R)	Prominance (L)	Prominance (R)	Bust girth	Underbust girth	Bust arc	LBIA	LBOA	B.P. to B.P.	Sternum	Full bust width	Full bust depth	Under bust width	Under bust bepth	BK NK to B.P.(R)	BK NK to B.P.(L)	FT NK to B.P.(L)	FT NK to B.P.(R)
1	0.32	0.26	9.07	9.26	35.62	28.94	18.63	2.53	1.97	6.9772	2.1	11.94	8.25	10.12	7.49	12.45	12.41	7.88	7.83
2	0.35	0.38	9.75	9.84	35.88	28.57	19.5	2.43	2.23	8.542	1.78	11.86	8.37	10.1	8.1	12.66	12.65	8.15	8.2
3	0.4	0.36	9.31	9.12	35.9	29.56	18.34	3.22	1.51	7.6358	1.65	11.11	8.94	9.88	8.07	12.59	12.52	7.91	7.92
4	0.4	0.34	9.42	8.82	35.45	30.31	17.54	3.97	1.27	7.3652	1.44	11.69	8.17	10.84	8.11	12.02	12.19	7.67	7.29
5	0.42	0.36	9.84	9.3	35.69	29.28	18.06	4.19	1.6	7.4802	1.22	12.68	7.51	10.48	7.23	12.64	12.71	8.17	8.19
6	0.38	0.33	9.32	9.13	35.38	30.19	18.81	3.37	1.96	7.5855	0.96	12.25	7.9	10.97	7.35	12.78	13.01	8.21	7.91
7	0.31	0.36	8.81	10	35.88	30.03	17.87	3.23	1.46	7.7031	2.25	11.85	9	10.7	7.78	13.15	12.9	8.21	8.34
8	0.51	0.39	11.15	9.72	35.89	29.38	19.27	3.74	1.58	8.2962	2.08	11.09	7.34	10.21	8.03	12.64	12.61	8.68	8.55
9	0.3	0.3	9.66	9.67	35.31	29.87	19.94	2.27	1.72	6.841	1.51	11.49	8.78	10.41	8.25	13.02	12.72	8.17	8.32
10	0.4	0.38	10.76	10.53	35.84	29.21	20.31	2.63	2.04	7.1368	1.24	11.36	8.24	10.35	7.4	13.7	13.58	8.52	8.7
11	0.4	0.39	9.51	9.18	35.81	30.46	18.36	2.55	1.87	7.3817	1.75	12.15	8.65	9.99	8.33	12.75	12.72	8	7.71
12	0.39	0.42	9.56	9.72	35.66	29.5	19.38	1.91	2.44	7.1072	1.29	11.93	8.1	10.76	7.3	13.64	13.48	8.83	8.82
13	0.34	0.31	9.09	8.65	35.55	28.76	17.57	5.43	1.19	7.6203	1.1	12.32	8.35	10.09	7.97	12.01	12.26	8.1	7.77
14	0.41	0.39	9.83	9.13	35.96	29.74	17.82	2.65	2.17	7.265	0.74	12.3	7.81	11.25	6.97	13.13	13.34	8.7	8.27
15	0.45	0.43	10.06	10.09	35.86	29.29	19.56	5.02	1.7	7.591	0.59	11.89	8.97	10.4	8.33	13.52	13.85	8.92	8.85
16	0.37	0.33	9.71	9.31	35.93	29.82	18.63	3.19	1.69	7.6708	1.79	11.2	8.23	10.32	8.43	12.6	13.04	7.63	7.61
17	0.36	0.36	9.65	9.93	35.55	30.18	19.62	2.46	1.61	7.4501	1.46	11.81	8.45	10.7	7.99	13.28	12.75	8.05	8.25
18	0.31	0.37	9.34	9.84	35.89	28.65	18.9	3.25	2.17	7.941	1.31	11.78	8.52	9.75	7.76	12.96	12.95	8.2	8.69
19	0.46	0.42	10.7	10.86	36.04	28.61	20.25	3.1	2.09	8.0207	0.99	11.34	7.89	10.53	7.37	13.06	13.21	8.66	8.61
20	0.38	0.38	9.52	9	35.69	29.52	18.22	4.3	1.33	6.7692	0.92	11.76	8.63	10.2	7.66	12.13	12.08	7.72	7.52
21	0.44	0.44	9.87	10.36	35.6	29.03	18.73	3.68	1.72	8.3638	0.86	11.22	8.18	10.28	7.76	13.34	13.24	8.23	8.38
22	0.32	0.34	9.92	9.77	35.69	29.14	19.99	2.76	1.78	7.4428	2.07	11.44	9.05	10.24	7.89	14.05	13.8	9.57	9.38
23	0.4	0.36	9.21	9.1	35.34	29.98	18.07	3.24	1.51	7.6132	1.94	11.4	7.94	10.19	7.48	12.6	12.54	8.01	8.09
24	0.32	0.3	8.79	9.56	35.68	28.5	18.6	2.13	2.86	8.1419	1.42	12.24	8.26	10.39	7.44	13.08	13.06	8.5	8.35
25	0.37	0.34	9.76	10.22	35.86	30.03	19.3	2.32	1.88	7.1558	1.28	11.56	7.92	10.7	7.54	12.66	12.45	7.88	7.93
26	0.36	0.34	10.08	9.92	35.89	29.54	19.48	2.73	2.34	7.5983	0.98	11.06	8.82	10.13	7.99	13.66	13.87	9.74	9.57
27	0.38	0.4	9.45	10.05	36.03	29.77	18.91	3.3	1.91	8.0219	0.87	11.65	7.92	10.88	7.31	14.4	14.35	9.27	9.67
28	0.4	0.38	9.11	9.15	36	29.36	18.06	4.02	0.93	7.8738	2.5	11.68	8.13	9.9	7.48	12.41	12.65	8.23	8
29	0.31	0.23	8.52	8.43	35.27	29.99	16.68	4.17	1.35	7.067	1.54	12.57	8.24	11.1	7.88	13.03	12.7	7.96	8.06
30	0.35	0.4	9.3	9.59	36.02	29.81	18.44	1.58	2.87	7.4888	1.25	12.56	8.35	10.76	7.75	13.23	12.96	8.39	8.21
31	0.42	0.36	10.14	9.94	35.94	30.01	19.24	3.32	1.81	7.2871	1.06	10.91	8.88	10.19	8.48	13.36	13.67	9.01	8.85
32	0.37	0.34	8.7	8.01	35.29	30.16	16.33	4.17	1.35	7.1663	1.54	12.57	8.24	11.1	7.88	13.13	13.18	8.45	7.97
33	0.32	0.36	9.12	9.43	35.46	30.07	18.3	4.26	1.24	7.6723	1.44	11.89	8.02	10.77	7.53	12.6	12.35	8.21	8.27
34	0.46	0.39	9.87	9.95	36	29.67	18.77	2.25	2.14	7.6268	1.34	11.6	8.35	10.52	8.1	13.87	13.91	8.77	8.83
35	0.37	0.38	8.61	9.17	35.61	29.59	17.56	2.4	1.86	7.0549	1.29	11.27	9.24	9.76	8.84	11.99	11.88	7.57	7.71
36	0.37	0.34	9.02	9.59	35.74	29.01	18.23	2.73	2.15	7.2757	0.98	11.62	8.65	10.42	7.9	13.42	13.07	8.35	8.46
37	0.35	0.36	8.97	0.31	35.91	29.32	17.51	4.18	1.76	7.5914	0.59	12.33	8.46	10.7	7.95	12.92	13.08	8.14	7.87
38	0.3	0.26	9.43	9.14	35.32	30.06	18.78	1.94	1.77	6.7829	2.44	11.72	9.08	10.3	8.35	13.19	13.45	8.21	8.34
39	0.27	0.34	8.86	9.11	35.66	30.01	18	2.15	1.61	6.9757	1.81	12.17	8.51	10.9	7.45	12.57	12.53	7.56	7.52
40	0.4	0.38	9.74	9.21	35.8	28.94	18.92	3.5	1.78	7.2829	1.31	11.58	8.53	10.18	7.63	12.23	12.34	7.59	7.38
41	0.38	0.34	8.99	8.28	35.91	28.92	17.08	3.39	1.58	6.9475	1.16	12.63	8.25	10.21	7.49	11.89	12.09	7.57	7.15
42	0.36	0.41	9.09	10.47	35.92	29.55	18.83	2.82	1.97	8.2265	0.89	11.57	8.12	10.93	7.51	14.31	13.63	8.95	9.73
43	0.44	0.42	9.81	9.81	35.57	29.35	18.52	2.48	2.16	7.7058	1.25	11.83	8.55	10.34	8.33	13.63	13.77	8.93	8.96
44	0.36	0.37	9.15	9.35	35.64	29.79	17.9	4.11	1.43	7.9147	1.01	11.47	8.4	11.02	7.98	13.54	13.5	8.79	8.64
45	0.42	0.42	9.45	9.28	35.87	28.77	18.84	2.59	1.71	7.5878	1.83	11.26	8.49	10.04	7.49	12.64	12.61	7.67	7.52
46	0.33	0.29	9.63	9.14	35.83	30.22	18.4	4.71	1.29	7.5171	1.82	12.38	8.34	10.65	8.04	12.41	12.58	8.12	7.65
47	0.38	0.33	9.33	9.33	35.7	30.4	18.45	3.21	1.28	6.554	1.82	12.32	7.91	10.88	7.88	13.28	13.11	8.29	8.57
48	0.36	0.3	10.01	9.81	35.94	29.97	19.94	3.21	1.86	7.5588	1.64	11.4	8.94	10.39	8.43	12.66	12.66	7.86	7.95
49	0.28	0.25	9.18	9.01	35.96	29.58	18.25	3.08	1.64	6.9761	1.58	12.01	8.12	10.81	7.37	12.45	12.66	8.18	7.97
50	0.32	0.36	8.97	9.25	35.83	29.96	17.98	3.09	1.69	7.0286	1.55	11.97	8.99	10.1	7.96	13.1	12.99	8.14	8.42
51	0.42	0.38	9.52	9.39	35.97	29.28	18.1	3.83	1.54	7.9903	1.29	11.6	8.53	9.89	7.84	12.77	12.81	8.23	8.29
52	0.45	0.42	9.66	9.27	35.61	29.33	18.02	3.25	1.73	7.6963	1.09	12.21	7.72	10.47	7.2	12.97	13.06	8.28	8.29
53	0.34	0.4	9.17	9.85	35.78	29.79	18.98	3.12	1.71	6.9643	1.95	11.27	8.85	9.76	8.62	11.96	12.01	7.51	7.65
54	0.33	0.29	8.65	8.83	35.08	29.98	17.33	2.36	1.82	6.7496	2.31	12.21	8.09	10.91	7.63	12.88	12.66	7.69	7.83
55	0.35	0.32	9.54	9.67	35.63	29.25	18.84	3.82	1.76	7.3787	1.43	11.95	8.29	10.5	7.8	13.2	13.59	8.61	8.68
56	0.47	0.48	10.45	10.78	35.91	30.09	20.16	5.2	1.79	7.633	1.28	11.88	7.77	9.94	7.39	13.36	13.13	8.63	8.86
57	0.42	0.43	9.81	9.84	36.01	29.22	19.29	4.26	1.33	7.4949	0.59	11.56	8.13	10.59	7.6	12.59	12.28	7.67	7.63
58	0.38	0.38	9.6	9.6	35.18	30.42	17.96	2.71	1.86	6.9821	1.27	11.29	7.84	11.23	7.86	13.99	13.88	8.84	9.31
59	0.41	0.4	10.31	10.35	35.91	29.68	19.69	4.96	1.29	8.0341	0.59	11.73	8.08	10.85	7.63	13.67	13.74	9.45	9.23
60	0.44	0.4	10.19	9.41	35.7	29.91	19.02	3.61	1.55	8.071	1.42	11.3	8.35	10.56	8.21	13.01	13.23	8.5	8.19
61	0.37	0.32	9.6	8.18	35.98	30.24	17.62	4.69	1.34	7.4428	1.82	12.44	8.35	10.9	7.43	12.18	12.65	8.29	7.73
62	0.34	0.38	9.82	10.01	35.97	30.07	19.26	2.45	1.62	7.5779	1.72	12.06	8.32	10.42	7.9	12.8	12.93	8.27	8.12
63	0.32	0.36	9.02	9.38	35.59	29.63	18.69	2.49	1.92	7.005	1.35	11.85	8.74	10.49	7.96	12.86	13.02	7.84	7.85
64	0.33	0.3	9.74	9.49	35.77	30.4	18.91	2.93	1.98	6.8922	1.47	12.18	8.43	10.86	7.98	13.01	13.09	8.19	7.91
65	0.42	0.37	9.47	8.5	35.61	28.8	17.1	4.23	1.44	7.4292	1.83	11.96	8.29	10.42	7.51	13.06	13.46	8.57	8.21
66	0.44	0.38	9.8	9.48	35.97	30.14	18.75	3.85	1.45	7.6265	1.83	11.39	8.42	10.78	7.73	12.46	13.57	8.47	8.18
67	0.47	0.48	10.05	10.09	35.71	29.98	19.34	2.48	2.15	7.7325	1.01	11.35	8.25	10.96	7.79	13.24	13.12	8.63	8.15
68	0.42	0.39	10.53	10.23	35.99	28.53	19.98	3.05	2.28	8.2333	1.1	11.57	8.47	10.11	7.88	13.8	14.14	8.7	8.82
69	0.38	0.42	9.45	9.82	36.04	30.34	18.09	2.12	2	8.3407	0.89	11.9	8.2	11.15	8.03	12.68	12.57	7.93	8.28
70	0.36	0.39	9.29	9.48	35.71	29.93	18.01	4.68	1.21	7.4916	0.69	11.84	8.32	10.43	8.02	12.79	12.09	7.5	7.54
71	0.42	0.42	9.44	9.9	35.58	29.32	19.02	2.07	1.78	7.3733	1.66	11.42	8.16	10.31	8.01	12.34	12.14	7.83	8.06
72	0.31	0.42	10.06	9.8	36.04	29.5	19.55	4.12	1.4	8.2311	0.83	11.9	8.02	10.55	7.2	14.94	14.8	10.25	10.18
73	0.39	0.4	10.27	9.64	35.74	29.97	19.61	2.86	2	8.0426	1.08	11.09	8.88	10.65	8.48	13.62	13.61	8.59	8.59
74	0.34	0.33	9.21	8.54	35.33	30.35	17.46	4.01	1.17	7.0853	1.85	11.96	9.17	10.28	8.8	11.66	11.66	7.39	7.02
75	0.4	0.4	9.06	9.51	35.29	30.17	18.41	3.38	1.18	7.8222	1.64	11.63	8.11	10.65	7.83	14.09	14.18	9.01	8.97
76	0.38	0.36	9.21	9.07	35.11	30.13	18.34	3.12	1.36	7.3789	1.56	12.1	8.13	10.64	7.53	12.8	13.02	8.57	8.53
77	0.46	0.34	10.78	9.79	35.85	29.78	19.62	2.56	1.99	6.9469	1.13	11.29	8.04	10.66	8.07	13.39	13.54	8.28	8.38
78	0.41	0.36	9.54	9.52	35.48	30.31	16.77	3.03	1.88	7.6322	1.09	11.93	7.76	11.2	7.24	13.32	13.48	8.42	8.27
79	0.41	0.44	9.98	10.06	36.04	29.81	19.08	3.11	1.72	7.5576	1.06	11.62	8.24	10.71	7.58	13.01	13.26	8.58	8.5
80	0.37	0.33	10.49	9.87	35.77	28.8	20.2	3.25	1.73	7.3198	0.95	11.39	8.61	10.15	8.03	13.01	13.09	8.72	8.61
81	0.43	0.54	9.98	9.47	35.7	28.57	18.36	3.12	1.99	8.0172	0.81	11.29	8.37	10.24	7.79	13.49	13.16	8.48	8.2
82	0.31	0.29	9.45	9.28	35.9	30.21	18.32	4.03	1.4	7.2683	1.61	12.47	9.32	10.47	8.47	13.1	13.54	8.47	8.16
83	0.34	0.33	9.5	9.25	36	30.14	18.26	3.92	1.57	7.469	1.36	11.71	8.98	10.44	8.07	13.39	13.67	8.62	8.23
84	0.48	0.52	9.94	9.97	35.92	29.54	19.26	3.21	1.82	8.308	0.62	11.01	8.53	10.6	7.99	14.27	13.97	9.24	9.25
85	0.44	0.35	10.24	8.99	35.74	29.42	18.05	3.66	1.59	7.4603	1.35	11.37	8.6	10.49	8.35	13.38	13.52	8.21	7.66
86	0.53	0.54	10.41	8.06	35.73	28.87	19.81	3	2.04	7.9616	0.59	11.18	8.42	9.89	8.15	13.16	13.29	8.5	8.44
87	0.53	0.51	10.37	9.35	35.8	30.16	18.5	2.73	1.9	7.197	0.63	10.75	8.64	10.22	8.41	13.03	13.37	8.63	8.43
88	0.42	0.39	9.43	9.32	35.05	30.27	16.92	3.74	1.53	7.7618	0.59	11.55	7.81	11.24	7.35	13.08	13.39	7.82	7.49
89	0.39	0.48	10.11	9.48	35.82	30.03	18.67	2.81	1.94	7.4326	0.59	11.57	7.72	10.67	7.96	12.85	12.88	8.05	7.54
90	0.4	0.39	10.07	10.45	36.02	28.62	18.95	2.41	2.22	8.0085	0.71	11.73	8.35	10.34	7.64	14.63	14.37	9.42	9.46

FT NK to bust level	.N. to Underbust to waist (	S.N. to Underbust to waist (L)	Bust to waist (R)	Bust to waist (L)	NK to Underbust (R)	NK to Underbust (L)	Side neck to bust (R)	Side neck to bust (L)	Bust height	Underbust height	Height	Weight	US	UK	Asian	Age
7.08	17.49	17.64	7.63	7.74	12.52	12.64	9.36	9.32	47.44	44.68	62.6	108	34B	34B	75B	19
7.01	18.29	18.07	7.87	7.85	12.71	12.73	9.38	9.37	46.94	44.38	62.78	118	34B	34B	75C	19
6.96	16.29	16.33	6.23	6.27	12.27	12.47	9.3	9.23	45.73	43.37	60.59	126	34B	34B	75C	19
6.58	17.96	18.2	8.15	8.22	12.94	13.18	9.17	9.33	47.57	44.42	62.72	131	34A	34B	75B	19
7.33	20.13	20.31	9.08	9.18	13.06	13.3	9.65	9.72	46.5	43.94	62.34	117	34B	34B	75B	19
7.16	19.37	19.63	9.1	9.07	13.31	13.58	9.54	9.77	48.06	44.91	63.81	124	34A	34B	75B	19
7.43	17.65	17.34	7.1	7.1	13.31	12.93	9.96	9.71	51.1	48.15	66.84	128	34B	34B	75C	20
7.57	19.33	19.44	8.57	8.56	13.33	13.51	10	9.96	43.76	41.01	58.06	98	34B	34B	75C	20
7.52	18.9	18.75	8.86	8.87	12.47	12.29	9.62	9.32	49.36	46.8	65.98	125	34A	34B	75B	20
7.82	18.29	18.23	6.66	6.73	13.62	13.59	10.59	10.46	44.13	41.97	59.24	108	34B	34B	75B	20
6.95	18.44	18.54	7.86	7.82	12.67	12.84	10.36	10.33	45.26	43.1	60.44	121	34B	34B	75B	21
8.16	18.91	18.36	7.51	7.43	14.55	14.08	10.53	10.37	42.93	39.78	58.68	110	34B	34B	75B	21
7.08	18.23	18.5	8.55	8.58	12.53	12.79	8.98	9.23	44.73	41.77	59.95	102	34B	34B	75B	21
7.61	19.6	19.59	8.44	8.48	13.32	13.48	9.91	10.13	48.82	46.26	65.07	131	34B	34B	75C	21
8.08	19.05	19.68	7.15	7.1	14.53	15.05	10.94	11.26	46.39	43.63	62.33	111	34B	34B	75C	21
6.66	18.07	18.25	7	6.97	13.44	13.73	9.6	10.04	44.06	41.3	58.98	122	34B	34B	75C	22
7.37	20.12	19.87	9.5	9.49	13.08	12.79	10.17	9.64	50.79	48.24	67.16	142	34B	34B	75B	22
7.5	19.07	18.99	8.21	8.17	13.84	13.58	10.19	10.18	48.13	45.17	64.2	110	34B	34B	75C	22
7.68	19.43	19.69	7.97	8.03	13.81	14.05	10.33	10.48	40.63	38.07	55.66	102	34B	34B	75C	22
6.78	19.21	18.85	9.31	9.32	13.13	12.86	9.02	8.98	49.41	46.07	64.66	115	34B	34B	75B	22
7.32	18.64	18.37	7.16	7.16	14.22	14.04	10.19	10.09	44.07	41.31	60.15	135	34B	34B	75B	22
8.77	18.82	18.71	7.34	7.28	14.38	14.17	11.13	10.88	46.7	43.94	63.38	120	34B	34B	75B	23
7.15	20.19	20.06	9.83	9.84	12.25	12.12	9.6	9.54	49.02	46.86	64.28	115	34A	34B	75B	23
7.62	18.36	18.69	7.29	7.2	13.68	13.65	10.04	10.01	46.24	43.28	61.84	126	34B	34B	70E	23
7.1	18.37	18.53	7.72	7.74	12.31	12.2	9.79	9.58	43.8	41.63	58.58	107	34B	34B	75C	23
8.93	19.76	19.91	7.76	7.75	14.17	14.13	10.91	11.12	46.15	43.59	62.61	129	34B	34B	75C	23
8.68	18.72	18.88	6.56	6.6	14.94	14.98	11.25	11.21	45.54	42.98	62.59	130	34B	34B	75C	23
7.15	16.7	16.7	6.28	6.31	12.03	12.3	9.3	9.53	44.03	42.06	58.81	113	34B	34B	75C	24
7.18	20.54	19.22	8.43	8.43	14.12	12.78	10.53	10.2	46.45	44.09	62.71	132	34A	34B	75B	24
7.47	21.28	20.37	8.93	8.88	14.19	13.89	10.14	9.87	47.25	44.3	63.45	125	34B	34B	75C	24
8.2	19.85	20.11	8.16	8.14	13.4	13.89	10.32	10.64	45.52	43.16	61.42	132	34B	34B	75C	24
7.47	19.01	19.15	8.64	8.62	12.83	13.05	9.86	9.91	46.93	44.17	63.02	141	34A	34B	75B	25
7.33	18.05	17.8	7.72	7.74	12.33	12	9.73	9.48	44.49	42.32	59.18	119	34A	34B	75B	25
7.97	20.41	20.35	8.28	8.3	14.29	14.2	10.87	10.91	49.47	46.91	66.57	147	34B	34B	75C	25
6.83	18.7	18.02	8.27	8.26	12.8	12.08	8.99	8.87	45.1	42.54	59.7	119	34B	34B	75B	25
7.63	17.56	17.56	6.87	6.85	13.74	13.61	10.33	9.99	46.26	43.31	62.29	122	34B	34B	75B	25
7.09	20.25	20.23	9.02	9.02	13.36	13.4	9.94	10.1	49.18	46.42	65.71	140	34B	34B	75C	25
7.61	19.02	19.22	8.49	8.49	12.55	12.79	9.97	10.22	47.54	45.18	63.33	127	34A	34B	75B	26
6.77	17.43	17.54	7.52	7.5	12	11.99	9.16	9.13	47.83	45.47	63.16	111	34B	34B	75B	27
6.55	19.66	19.4	9.32	9.31	13.43	13.21	9.45	9.57	44.72	41.57	59.24	117	34B	34B	75B	27
6.55	18.57	18.78	8.48	8.49	13.04	13.28	8.9	9.1	45.78	42.23	62.16	134	34B	34B	75C	27
8.49	20.44	19.9	8.08	8.11	14.47	13.68	10.92	10.25	46.13	43.77	63.24	135	34B	34B	75C	27
8.11	18.5	18.62	6.88	6.94	13.55	13.74	10.42	10.56	43.16	40.8	59.03	136	34B	34B	75B	28
7.83	19.45	19.62	7.87	7.87	13.35	13.45	10.41	10.37	45.35	42.99	61.7	130	34B	34B	75B	28
6.64	15.39	15.62	5.45	5.49	12.45	12.5	9.54	9.51	44.07	41.71	59.02	127	34B	34B	75C	30
6.94	17.34	17.51	7.23	7.26	12.77	12.92	9.43	9.6	46.02	43.27	61.43	123	34B	34B	75B	30
7.78	18.65	18.53	7.62	7.65	13.29	13.11	10.53	10.37	45.28	42.92	61.23	119	34B	34B	75B	30
7.02	18.3	18.11	7.89	7.94	13.4	13.17	9.73	9.74	46.38	43.42	61.41	119	34B	34B	75C	30
7.33	18.38	18.95	8.18	8.21	12.94	13.14	9.62	9.83	47.18	44.42	62.21	124	34B	34B	75C	30
7.46	20.44	20.5	9.41	9.42	13.49	13.48	10.57	10.46	46.02	43.26	61.09	129	34B	34B	75B	30
7.32	19.71	19.56	8.28	8.29	13.48	13.4	10.21	10.25	44.99	42.62	60.1	111	34B	34B	75C	30
7.4	19.01	19.28	8.32	8.34	12.6	12.73	9.86	9.95	43.33	41.16	58.32	113	34B	34B	75B	30
6.75	19.19	18.89	9.32	9.29	12.71	12.46	9.19	9.24	46.74	43.78	61.32	106	34B	34B	75B	32
6.98	20.03	19.78	9.8	9.8	12.82	12.55	9.48	9.26	47.83	44.88	63.58	147	34A	34B	75B	35
7.92	17.66	18.11	6.74	6.78	13.74	14.2	10.23	10.62	47.98	45.03	64.45	133	34B	34B	75B	35
7.95	19.76	19.19	8.64	8.52	13.46	13.21	10.33	10.1	44.74	42.19	60.59	124	34B	34B	75C	35
6.78	18.36	18.27	7.78	7.8	13.59	13.4	9.6	9.3	43.97	40.82	59.05	125	34B	34B	75C	35
8.39	19.94	19.96	8.23	8.27	13.47	13.39	10.83	10.72	48.92	46.95	65.92	138	34A	34B	75B	37
8.54	18.8	18.91	7.21	7.09	14.38	14.49	10.71	10.78	46.97	44.41	63.97	128	34B	34B	75C	37
7.4	18.5	18.7	7.45	7.61	13.17	13.36	9.68	9.9	42.65	40.29	58.14	106	34B	34B	75B	38
7.21	19.59	19.94	9.44	9.44	13	13.53	9.3	9.78	49.07	45.92	64.8	140	34B	34B	75C	40
7.37	18.15	17.89	8.35	8.3	12.43	12.15	9.19	9.31	48.03	45.47	63.67	125	34B	34B	75C	40
7.04	17.64	17.72	6.91	6.99	12.92	12.99	10.41	10.56	44.56	42.2	59.9	115	34B	34B	75B	40
7.4	19.88	19.93	9.15	9.13	13.3	13.28	9.96	10.04	45.07	42.32	60.15	118	34B	34B	75B	40
7.62	18.1	17.95	7.07	7.05	14.37	14.27	9.97	10.37	51.71	48.37	68.89	141	34B	34B	75B	41
7.56	17.77	18.63	7.55	7.52	13.12	14.06	9.31	10.41	46.21	43.45	62.15	122	34B	34B	75C	42
7.59	19.5	19.58	7.99	7.97	14.77	14.85	10.43	10.31	46.28	42.94	62.51	142	34B	34B	75B	42
7.87	17.92	17.93	6.38	6.53	14.58	14.63	10.49	10.82	44.92	41.96	61.11	127	34B	34B	75C	43
7.06	18.91	18.94	7.67	7.69	13.27	13.17	9.63	9.53	44.08	41.52	59.43	130	34B	34B	75C	44
6.61	19.1	18.81	8.34	8.43	13.18	12.84	10.35	9.65	45.49	42.93	60.23	126	34B	34B	75B	44
7.1	18.55	18.19	8.26	8.29	12.91	12.53	9.41	9.21	43.9	41.34	58.83	136	34B	34B	75B	45
9.43	18.15	17.99	5.3	5.46	14.79	14.58	12.09	11.95	44.92	42.95	61.8	105	34B	34B	75C	45
7.78	18.15	18.56	6.87	7.07	13.59	13.87	10.63	10.61	45.22	42.86	61.05	123	34B	34B	75B	48
6.34	16.25	16.1	6.63	6.58	12.27	12.11	9.2	9.2	44.44	41.69	58.89	112	34A	34B	75B	50
8.1	20.8	21.24	8.69	8.66	13.76	14.02	10.91	11	44.57	42.4	61.03	132	34A	34B	75B	50
7.81	16.76	16.9	6.69	6.67	12.15	12.41	9.57	9.79	45.28	43.11	60.77	113	34A	34B	75B	50
7.61	17.47	17.83	6.06	6.28	13.75	13.76	10.62	10.77	45.83	43.46	60.39	134	34B	34B	75C	50
7.46	18.47	18.29	6.86	6.87	12.79	12.78	9.43	9.59	48.31	46.14	65.98	157	34A	34B	75B	50
7.7	19.79	19.78	7.85	7.86	14.05	14.05	10.63	10.89	45.54	42.98	61.55	125	34B	34B	75C	50
7.84	17.84	18.3	7.31	7.65	13.08	13.36	9.91	9.98	46.3	43.75	61.97	117	34B	34B	75B	50
7.41	19.33	19.33	6.92	6.79	15.5	15.85	11.18	10.85	42.38	38.83	58.22	108	34B	34B	75B	50
7.56	17.87	18.35	7.36	7.3	12.99	13.41	9.89	10.33	46.79	44.23	62.87	139	34B	34B	75C	55
7.57	18.99	19.53	7.65	7.68	13.85	14.27	10.44	10.71	46.77	43.82	63.1	145	34B	34B	75C	55
8.34	17.92	18.16	5.7	5.8	14.61	14.64	10.74	10.45	44.79	42.23	61.42	116	34B	34B	75C	57
7.05	16.96	17.09	5.21	5.52	14.38	14.47	10.6	10.75	44.85	42.1	61.11	138	34B	34B	75B	58
7.5	16.95	16.99	6.29	6.12	13.87	14.25	10.01	10.13	44.17	41.22	60.07	114	34B	34B	75B	58
7.83	17.35	17.46	5.91	5.95	13.3	13.85	10.03	10.36	44.1	41.54	59.91	125	34B	34B	75B	60
6.64	18.12	18.63	7.06	7.05	13.19	13.63	9.54	9.85	45.98	43.42	62.03	132	34A	34B	75A	60
6.89	15.83	15.88	5.52	5.42	13.23	13.36	9.43	9.46	42.19	39.43	57.89	105	34B	34B	75B	62
8.61	20.35	20.48	6.96	6.96	15.35	15.59	11.62	11.36	49.28	46.72	67.42	142	34B	34B	75C	63

APPENDIX J: FIGURE 12 TIMELINES FROM 600,000BC TO 1000AD