A Comparative Study of Pattern Engineering for the Current Size and Shape of Australian Women

Kathleen Margaret Berry
Master of Medical Sciences
In Anatomical Sciences
(The University of Adelaide)

This thesis was undertaken within the Department of Anatomy and Pathology at
The University of Adelaide in fulfilment of the requirements of
PhD in Medicine / PhD in Medicine Human Biology

Supervisor
Professor M. Henneberg

Candidate's Declaration

Thesis Title: **A Comparative Study of Pattern Engineering for the Current Size and Shape of Australian Women**

Candidate's name: **Kathleen M Berry**

I declare that this thesis is the result of my own research and that it does not incorporate without acknowledgement material submitted for a degree or diploma in any University and that it does not contain any material previously published, written or produced by another person except where due reference is made in the text.

Signed……………..……..
Date……………………....

Name: K M Berry **Course: PhD in Medicine / Human Biology**

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Kathleen M Berry and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the library catalogue, the Australasian Digital Theses Program (ADTP) and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Signature: **Date:**

The careful observer of the many types of female figure will not be long in reaching the conclusion that very few of them conform to the generally accepted artistic and sartorial ideals. There may be aspects of the latter to be found in quite a large number of figures but rarely is there found a perfect combination. The Venus of the poet, the painter and the sculptor is a very elusive lady

Assessing Female Figure Proportions (p 212)
Hard's Year Book for the Clothing Industry (1954)

ABSTRACT

This thesis examines and analyses from an anatomical and anthropometric perspective, two pattern engineering systems currently used by the clothing industry for the production of female garments. To the best of the researcher's knowledge no similar study has been previously conducted in Australia. The research is significant in that pattern engineering systems provide the basis from which all garments are produced.

Biological changes in human female morphology over the past century have impacted significantly on the clothing industry's ability to provide garments that meet an acceptable fit standard. Rising concerns regarding the increase in overweight and obesity provide an even greater challenge for the production of well fitting female garments.

Many pattern engineering systems rely on a long standing assumption of proportionality based on a fixed relationship between specific body dimensions, such as height and breadth, to calculate other body dimensions. These systems overlook relative changes in body dimensions that have occurred and are continuing to occur at the present time. In contrast, the use of direct measurements requires no assumptions regarding body shape and accommodates all body types with equal proficiency.

This study compared two such systems, testing the fit of dress toiles made in compliance with the specifications of both types of systems, and fitted on a group of adult females, each of whom conformed to one of 5 body types anthropometrically identified in the Australian population by the author in earlier research. The dress toiles constructed according to direct measurement principles were significantly superior in fit to those constructed according to calculated proportional principles. They were also the preferred choice of 100% of subjects when rated for comfort and ease of movement.

The following conclusions were made: (i) that the assumptions concerning body size and proportions underlying calculated proportional pattern drafting systems are questionable, particularly in view of the accelerating secular trend of obesity, and (ii) that direct measurement pattern cutting systems which focus on and use current body shape data are better able to accommodate unpredictable and unspecified variations in the size and shape of the human female body. The lack of standardisation of body measurement techniques was discussed with particular emphasis on the bust circumference which is fundamental in calculated proportional systems. Note was also made of the divergence away from technical skills and expertise in anthropometry which may be a result of the restricted curriculum currently offered by training institutions in Australia and elsewhere.

There was strong agreement between the results and conclusions of this study with recent industry initiatives, which are pressing for an anthropometric survey of the population in order to obtain data for new practical clothing size standards. In this regard it was proposed that body shape categories should be considered in clothing size [shape] standards, as a focus on body shape may provide a more workable approach for classification of the relationship between key components of female morphology.

Acknowledgements

I wish to thank my principal supervisor, Professor Maciej Henneberg, and co-supervisor, Doctor Renata Henneberg, for their confidence, encouragement, support, patience, and guidance throughout my academic journey. This study has enabled me to fulfil a dream associated with my lifelong passion of the study of the human female body from the perspective of pattern engineering with the aim to achieve aesthetically pleasing garments for a variety of anatomically different figure types. The outcomes I have achieved are more than I had ever anticipated. For this I am eternally grateful.

I would like to dedicate this thesis to my beautiful grandchildren, Tom, Ben, Bella, Tayla, Lily and Gracie. I hope that each of you will also achieve your dreams throughout your life.

To my husband Ken for his most welcome vocabulary skills, son David for just being there [you were lucky to escape the tape measure], and daughters Suzanne and Carolyn in particular for their willingness [under a little coercion!!!] to participate in the endless round of measuring, and *toile* testing, over the past several decades. This contributed enormously to me realising my dreams. I sincerely thank you all.

To Jane Dowling who was brave and patient enough to help me get started on the computer initially, as well as assisting me in the more complex areas of computer applications. Without her untiring help, regardless of the time of day [or night] I could never have achieved these outcomes.

I wish to acknowledge and thank Lois Hennes for her mentoring and guidance in relation to the Metric S. I. Method, [Systeme Internationale]. Her knowledge and expertise in this area were invaluable.

I would like to thank Catherine Newman for her editing and proof reading, as well as sharing her skills in academic writing.

To my colleagues and students past and present: I dedicate this thesis to you all. I admire you for your dedication in a very challenging field that in many respects does not get the recognition that it deserves.

Table of Content

List of Tables

Table **Page**

List of Figures

List of Plates

Plates **Page**

Materials and Methods

Results **Analysis of Subjects**

Introduction

This work is an extension of preliminary studies summarised in a thesis “The Changing Size and Shape of Australian Women” presented for the Master of Medical Science Degree (Berry 2001). The data from that study led to the identification of five female figure type categories that were considered to be representative of the broader South Australian female population, and hence the Australian population. The data provided the basis for a new study to obtain more in-depth knowledge of broader aspects of the subject area. In particular this thesis examines implications for the production of female garments, due to changes in human morphological characteristics, which have affected the external form and structure of the female body.

The thesis first reviews studies of changes in human morphological characteristics of the female body and traces the historical impact of these morphological changes and other related subjects, on the production of clothing to the present day. The primary aim of this study is to compare two contrasting pattern engineering systems which differ markedly in their conceptual framework, specifications and procedures.

The uniqueness of the human body, together with many of the variables associated with morphological size and shape, present a major challenge for the design and production of garments whether for couture (individual or custom made), or for the mass production of ready-to-wear garments. This challenge becomes even greater with the design and production of female garments due to the more complex anatomical structure of the female body and the morphological changes brought about by the recent secular trend of overweight and obesity. Critical to the study of design and production of female garments is knowledge of the underlying aspects of the human body such as; basic anatomy (skeletal and muscular structures), the external morphological size and shape of the human body, and anthropometry – the tool for measuring the body.

A comprehensive analysis of pattern engineering systems that include garment cutting and pattern making indicates that there are many and varied types of systems. Two of the main types of systems used nationally and internationally are proportionate systems and direct measurement systems (Kidwell, 1979; Zakim 1998; Aldrich, 2007).

Proportionate systems are based primarily on a traditional assumption of body proportionality, which means that most of the body measurements needed to construct a garment pattern are calculated according to a predetermined formula of body proportions. As a result, only a few measurements need to be taken directly on the figure (Wampen, 1853; Poole, 1927; New South Wales TAFE School of Fashion, 1977). This type of system was developed to make the drafting process quicker, and not tied, as is often assumed, to the time consuming and intrusive process of taking direct measurements. It also became the basis of the readymade and wholesale trade in women's apparel in the latter part of the 18th century (Zakim, 1998).

Additionally, proportional pattern drafting was devised at a time when the trend in female fashion was for garments to be so tightly fitted that the external morphological shape of the female body changed radically. To follow the fashion of the period and achieve the structured unnatural shape, controlled undergarments such as corsets were essential. In recent decades, the external morphological shape of females has changed dramatically to one that now reflects the more natural contours of the body. These changes have placed significant demands on pattern engineering systems as they are now required to cater for the increasing variation in the morphological size and shape of the human female body. It will be argued in this thesis that such requirements are not being adequately met by systems based on proportionality.

Direct measurement systems on the other hand, are based on actual measurements taken on the human body. Such measurements may be taken individually, as when required for a couture (custom made) garment, or taken from a large number of individuals, as in the case of an anthropometric survey. In each of these cases, the measurements provide a true reflection of actual body dimensions of real people. Direct measurement systems originated with many of the earlier artisans and master tailors and are historically associated with the well fitted tailored garments epitomised in the expression 'tailor made'. The virtue of a direct measurement system is that measurements taken on the human body are those used in the drafting process (Aldrich, 2007; Berry and Hennes, 2008). Consequently this system involves no assumption regarding body size or shape, accommodates all figure types with equal proficiency and caters more than adequately for the continual change in fashion trends.

As stated previously the foremost aim of this study is to compare a proportionate system with a direct measurement system of pattern engineering.

The two systems, which differ markedly in their conceptual framework, specifications and procedures, are as follows:

1. Pattern Making: Metric S.I. Method (N.S.W TAFE School of Fashion, 1977) hereinafter referred to as (MSI) based on a **Calculated Proportionate** system
2. Fashion Design System (Berry and Hennes, 2008) hereinafter referred to as (FDS) based on a **Direct Measurement** system

To test the relative merits of each system, dress *toiles* will be constructed from master block patterns using (1) a calculated proportionate system of drafting, and (2) a conceptually new approach to a direct measurement system, based on the application of shape classification as opposed to size classification for the process of pattern engineering. The dress *toiles* will be evaluated through objective and subjective testing which includes the fitting procedure, visual observation and participant questionnaire.

Hypothesis and Rationale

The fit of female garments made from a direct measurement system based on female shape, will be superior to the fit of garments made from a drafting system based on proportionality of female body characteristics. This hypothesis is tested using statistical analysis of objective characteristics (measurements) and subjective characteristics (observation and questionnaire).

Presentation of the Thesis

The thesis is presented using the following headings:

Chapter 1: Literature Review

This literature review will focus on and critically analyse studies which investigate changes in human female biological characteristics in relation to morphology, secular trends, anthropometry, somatotypes, typology and theories of human body proportions The origins of clothing and fashion will also be reviewed together with clothing size standards, philosophies and assumptions underlying traditional and current pattern engineering systems and the rationale and process of measurement utilised by the proportionate and direct measurement systems in particular.

Medical literature has shown comprehensively that numerous changes in certain biological characteristics of the human body have taken place over the past centuries, (Wolanski, 1978; Roche, 1979; Boyd, 1980; van Wieringen, 1986; Henneberg, 1992; Henneberg, 2001). Of particular interest to this study are the consistently reported morphological changes relating to height, body size and shape (Hertzberg, 1972; Meredith, 1976; Tobias, 1985; Henneberg and van den Berg, 1990; Mosk, 1996). The reported incidences of some such changes occurring within several decades, or between consecutive generations (Henneberg, 2001; Daanen and Reffeltrath, 2007; Eknoyan, 2007), particularly in reference to body weight and shape (Simmons et al., 2004a; [TC]^2 2004; Bougourd, 2005; Honey and Olds, 2007), not only raise concerns about the health and welfare of the our nation, and beyond; (World Health Organisation (WHO), 2000; National Health and Medical Research Council (NHMRC), 2003; Swinburn et al., 2004; Australian Bureau of Statistics (ABS) 2009) but also present a major challenge for the production of ready-to-wear apparel for the 21st century (Berlei, 1928; Lancaster, 1957; Patterson and Brown, 2000; Berry, 2001; Henneberg and Berry, 2003; Standards Australia Limited, 2003; Lee et al., 2007).

As the Australian garment industry moves into the 21st Century, it is confronted by significant challenges, many stemming from its entrenched mode of operation at the present time. Difficulties which already exist include a lack of current published scientific data which detail the size and shape of the Australian population (Patterson and Brown, 2000; Henneberg and Berry, 2002; Henneberg and Veitch, 2003), together with outdated clothing size standards particularly for the female figure (Honey and Olds, 2007). According to Ashdown (2007) and Bougourd (2007) this state of affairs exists worldwide. These problems are compounded by the continued use of pattern engineering systems that fail to take into account the morphological changes widely documented in the relevant literature (NHMRC, 1997; Simmons et al., 2004a Ashdown 2007; Lee et al., 2007), changes which may well continue further into and beyond the 21st century. It could be argued moreover, that the artistry, skills and knowledge required to produce a well fitting garment that once was the hallmark of the garment making industry has increasingly been sacrificed and is slowly being lost.

Historically, the artist, and craftsmen such as the master tailors, shared a common theme of artistry and beauty. Both disciplines applied knowledge of the human body's shape and form, to drape the body with fabric to obtain aesthetically pleasing lines. The human body draped in fabric with well balanced lines and proportions conveys a feeling of harmony and beauty. Over time, the master tailor incorporated a new approach to his practice of artistically clothing the human form. This approach was a scientific system of pattern and garment cutting (Compaing, 1828 in Aldrich, 2007; Wampen, 1864) to make garments with pleasing lines and proportions that were also comfortable and functional. The implementation of this systematic pattern cutting was necessary to achieve an efficient and effective outcome in the shortest period of time (Poole, 1927). For many of the master tailors such a system had its origins in the measurement process known as anthropometry.

Anthropometry

The exact origin of anthropometry is difficult to trace. Tanner (1981) has suggested that anthropometry dates back to the 5th century BC when sculptors such as Polyclitus measured the human body using mathematical formulae to obtain human body proportions. Tanner therefore presents an artistic and philosophical impression of anthropometry particularly in relation to the human shape and its proportions by proposing that anthropometry originated not from the fields of medicine or science, but of the Arts, heavily influenced by the 'spirit of Pythagorean philosophy' (Tanner, 1981). According to Boyd (1980), the notion of anthropometry was foreshadowed by Alberti in the 15th century with his use of direct measurements in his paintings rather than of ideal proportions.

The earliest documented use of the term 'Anthropometry' was in the 17th century however. Elsholtz, who was the first medical person to place importance on measuring the human body, is reported to have described the instrument he used for this purpose as an Anthropometer (Tanner, 1981; Carter and Honeyman Heath, 1990). More recently, Belgian born Adolphe Quetelet (1796–1874) an astronomer and statistician with a passion for mathematics also had strong links to anthropometry. Quetelet made extensive use of anthropometric measurements of height and weight in his surveys and studies (Quetelet, 1842 in Diamond, 1969), which contributed greatly to the development of statistical techniques, and led subsequently to him being referred to the founding father of social statistics (Diamond, 1969; Tanner, 1981).

In a lecture titled, 'Human Proportion in Art and Anthropometry', delivered at the Washington National Museum in 1883, Robert Fletcher defined anthropometry as the attempt to ascertain the relative proportions of the different parts of the human body by uniform methods (Fletcher, 1883). Clauser et al., (1988) define anthropometry as the systematic measuring of the human body, the term derived from the Greek words *anthropos,* human being or man, and *metron,* to measure, and as such is a subdivision of anthropology – the study of man. Damon (1963) gave a broader definition by saying that physical anthropology is concerned with human biology and human variation, for which a primary area of research is that of measurable changes in human morphology.

The National Health and Nutrition Examination Survey (1988) expressed the view that anthropometry is the study of the measurement of the human body in terms of bone, muscle and adipose tissue. Robinette (1997) on the other hand refers to anthropometry as the study and technique of human body measurements which incorporates other aspects such as the measuring process itself, data recording, summarisation, and analysis documentation. Hertzberg (1972) offers a broader definition of anthropometry as the technology of measuring aspects of human physical traits such as size, mobility and strength, while human biologists refer to anthropometry as a scientific tool used for measuring the human body in terms of its size and shape.

In recent times, studies based on anthropometric measurement have reported using the Martin technique (Martin and Saller, 1957 in Henneberg and Louw, 1998; Livshits et al., 2002; Henneberg and Veitch, 2005). Boyd notes that in 1914, Rudolf Martin was responsible for combining definitions of how to measure subjects, descriptions of the instruments to be used, and methods of analysing measurements by indices (Boyd, 1980). Lasker also attributes the standardization of anthropometric techniques to Martin and noted that an upcoming fourth edition of Martin's descriptions was in preparation (Lasker, 1994).

In summary, anthropometry is characterised by precise measurements of anatomical characteristics of the human body to obtain data from which to make further evaluations, and/or comparisons. de Onis and Habicht (1996), claimed that when assessing human body proportions, the tools of anthropometry provided the best available methods as they were inexpensive, transportable, universally applicable, non intrusive and could be applied for assessing health, nutrition and social well-being as well as predicting performance, health and survival. Since that time however, 3-D body scanning has had a major impact with respect to anthropometry and human morphology (Bye et al., 2006) and will be addressed later in this thesis.

Morphology / physique

Morphology, as the science of biological form and structure, is the primary focus of anthropometry. The study of human form and structure can be traced back through many centuries, including the Byzantine era, the early Greek and Arabic periods through to the times of great artists such as Leonardo da Vinci. Hippocrates, the Greek philosopher and founder of modern medicine, has been attributed with the proposal that certain diseases are likely to be found in people with certain physical characteristics (Tucker and Lessa, 1940; Wells, 1983; Carter and Honeyman Heath, 1990). According to Boyd (1980), da Vinci emphasised the variations in human physique in many of his works rather than the notion of an ideal human form which dominated much of the thinking of that time.

In this same period in the medical field, physicians traditionally focused on the physical shape and form of the human body for diagnosis and prognosis and to identify susceptibility to specific diseases (Lasker, 1994). For this purpose, classification systems under the general term of typology progressively came into use.

Typology

Typology describes a system for the classification of the form and structure of the human body (Jones and Rioux, 1997; Advisory Group for Aerospace Research and Development (AGARD), 1997). The use of typologies can also be traced back to the ancient Greeks who studied human morphology for the purpose of classifying persons with physical ailments. As early as 500 BC, Hippocrates classified two human body types and their associated diseases. These included (i)- *apoplectic habitus* – stocky type prone to hypertension and cerebrovascular disorders, and (ii) – *phthisis habitus* – slender type prone to tuberculosis. Subsequently, centuries later, Viola divided the classification of *apoplectic habitus* into two parts (a) – *pyknic* which he referred to as stout and (b) – *athletic* as muscular, and he also added the term (c) – *asthenic* which referred to a lean body type (Damon, 1963).

While an association between body type and disease susceptibility continued to interest the medical profession, a vastly improved knowledge of anatomy prompted the study of the mathematics of body proportions, and the scientific anatomical measurement of the human body also began to influence other guilds such as those of the artisans and master tailors. By the early 1800s this led to the development of various cutting systems by tailors, which were based on either direct measurements, calculated proportionate measurements or a combination of both (Kidwell, 1979). By 1815, tailors such as Cook and Golding had jointly set up a school for the study of cutting, based on 'true scientific principles' (Cook and Golding, 1815, in Aldrich, 2007), which included theories of proportion expressed in tables, or in another instance, included the identification of three body shapes: (i) proportionate, (ii) slender and (iii) broad (Wampen, 1853).

The long held belief in an association between body shape and specific illnesses continued into the twentieth century. Although primarily in the area of psychiatric illness, by this time body type studies had been broadened to include criminality and delinquency (Sheldon, 1949; Quetelet, 1835 in Beirne 1987; Hooton, 1932 in Garn and Giles, 1995). Kretschmer (1936) was also of the opinion that studies relating to the build and shape of the human body belonged in the area of medical science, although he included healthy males and females in his studies of body types, and as a result he found that the same body types were present in healthy people and had no basis in disease. Kretschmer defined three physical body types as (a) asthenic – lean body types with narrow shoulders, (b) athletic – strong skeletal and muscular types with broad shoulders, and (c) pyknic – prominent abdominal area types.

Kretschmer (1936), also stressed the importance of using a systematic process for describing the human body which should start with a prepared inventory covering each detail of the physique, this to be used for visual analysis. He took photographs of each person he examined, and emphasized the need for accurate and replicable methods of measurement. Kretschmer is notable in that he departed from the traditional method of classification of types and criticised them as being arbitrarily created according to predetermined values. His approach was to study morphological similarities and to look for average characteristics in a large number of individuals, which could be scientifically validated.

Whilst the earliest use of typology was concerned almost exclusively with classification for medical purposes, such as the diagnosis and prognosis of disease and illness, as referred to previously, the work of Kretschmer stands out for having expanded morphological classification into the area of healthy individuals. At the same time, typological research into other areas which focussed as much on the mind as the body was being carried out. For example, typology also extended into the area of psychology. Allport (1937) summarised numerous applications of the notion that body type or conformation could indicate certain personality traits and he concluded that empirical evidence had failed to prove that a body type can be associated with a personality trait. Allport suggested that such associations are only found in cases of mental disease. He also questioned whether personality traits are innately determined and proposed that a better terminology would be to use ‘temperament’ in place of personality or character.

This area of research into classification of body types led ultimately to the use of typology in a broader sense which also had its origins in a scientific approach to morphological classification. The commonly accepted term in reference to such typologies, is that of somatotyping, which was introduced by William Sheldon in the 1940s.

Somatotyping

Somatotyping in its earliest days described quantitatively the varying physical characteristics of the male human physique, in terms of (i) endomorphy – relative degrees of fullness, or fat rotundity; (ii) mesomorphy – squareness, large bones and muscularity, and (iii) ectomorphy – thinness or linear fragility, characteristics which Sheldon considered to be the three basic and permanent components of physique (Damon, 1963; Sheldon et al., 1970; Carter and Honeyman Heath, 1990). The particular pattern of these three morphological components was then expressed by three numerals which collectively comprised the ‘somatotype’ of an individual (Sheldon et al., 1970).

Since its inception, Somatotyping has been utilised in the fields of clinical medicine, biology and anthropometry, in addition to its use in studies that deal with behaviour and temperament (Spillman and Everington, 1989), perception, sports science and criminology (Carter and Honeyman Heath, 1990). However, while Sheldon’s system of classifying the male human physique made a major contribution to physical anthropometry at the time of its publication, significant modifications were needed to address limitations and correct false assumptions associated with the original method (Honeyman Heath and Carter, 1967; Norton and Olds, 1996; Vertinsky, 2007). It is this modified version which is widely used at the present time by many disciplines.

One major drawback of the earlier somatotyping research was the limited number of studies which focused on female somatotypes. Sheldon, in collaboration with others, published his Atlas of Men (Sheldon, 1954, in Carter and Honeyman Heath, 1990) and prior to that time, had advised that an ‘Atlas for Somatotyping for women’ was to be published at a later date (Sheldon, 1949). Vertinsky (2007) notes, however, that the ‘Atlas of Women’ which was intended to be a sister volume to Sheldon’s Atlas of Men never materialized, leaving a vacuum in the area of data relating to female figure types.

Subsequently, a focus on female figure typing has been addressed in other studies which were driven by a variety of needs. These included a growing interest in the changing size and shape of women and/or the resultant implications for women's health and well-being (Cabot and Cooper, 1997; Treleaven and Wells, 2007). Equally of interest was the identification of body types and shapes for the production for female garments (Berlei, 1928; Berry, 2001; [TC]^2 2004; Simmons et al., 2004a and 2004b; Bougourd, 2005; Lee et al., 2007).

Female somatotyping

In the area of women's health, terminology introduced by Sheldon et al., (1970) has also been used in 'Anatomica', (Imwold et al., 2007) to define three body types which are based on a female's fat storage tendency. These are described as: Ectomorph – lean frame, an angular shape, fragile appearance and low in fat; Mesomorph – strong frame, muscular, evenly proportioned; and Endomorph – soft with rounded body shape with tendency to store fat as shown in Figure 1.

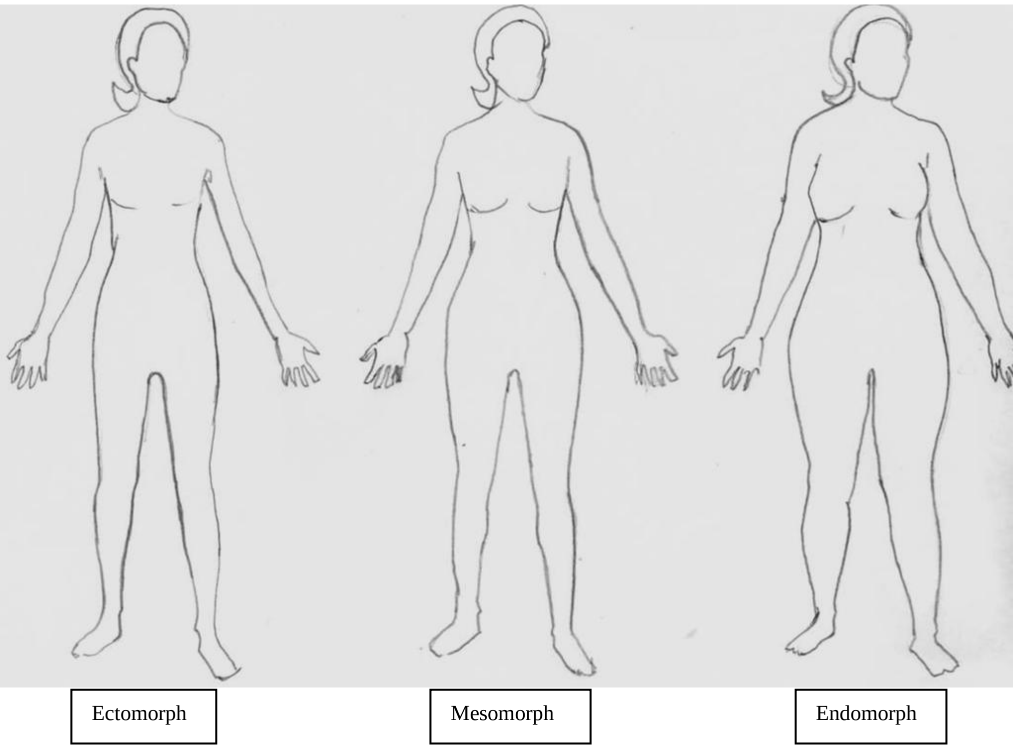


Figure 1: Female body shapes (modified from Imwold et al., 2007)

Apparently in agreement with Sheldon's premise that somatotypes are permanent and will not change, Imwold et al., (2007) assert that a body type cannot be altered by diet, but the shape can be altered by a change in the amount of fat stored at hips, thighs, abdomen and breasts. The writers assert also that fluid and exercise will alter body shape to some degree, but will not alter body type.

However, this latter claim has been refuted in the literature. Lasker (1994) refers to a study of partial starvation which, he argues, contradicts Sheldon's assertion that somatotypes are an immutable aspect of human personality. The findings in that study showed that the ratings for each somatotype component changed dramatically after a period of several months. Lasker concluded that as the physique of the subjects had changed significantly, Sheldon's contention was not supported. Other researchers support Lasker by arguing that each individual has numerous potential somatotypes, which makes somatotype permanence a fiction (Carter and Honeyman Heath, 1990).

Also focussing on the area of women's health, Cabot and Cooper (1997) provide a classification of female figure types for the purpose of identifying nutritional and hormonal deficiencies. The four figure types are: Android – thick set skeletal frame, muscular with large shoulders; Gynaeoid - pear shaped with width increasing towards the hip and thighs; Lymphatic – thickness and puffiness, thick limbs, small to average shoulders, and protruding abdomen; and Thyroid - lean body and long limbs, as shown in Figure 2.

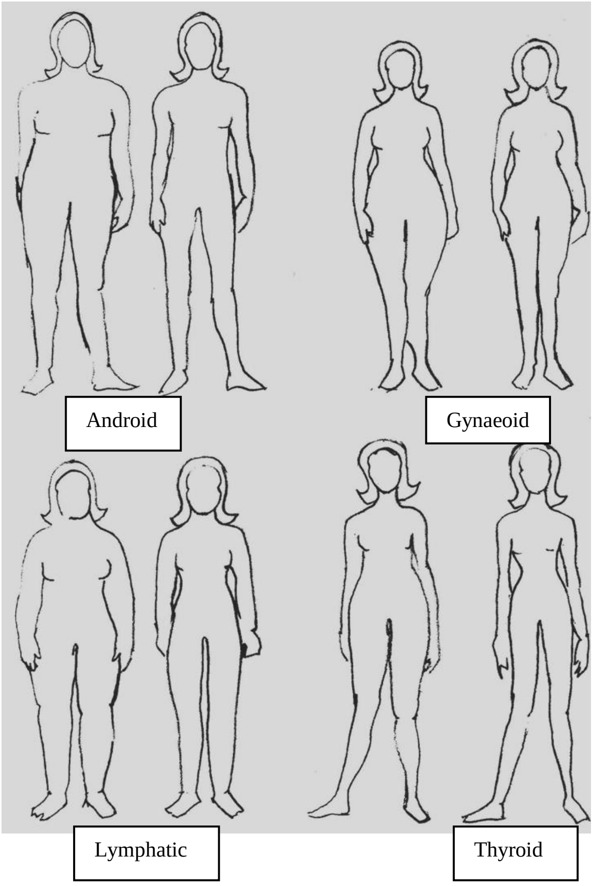


Figure 2: Female figure types indicating nutritional or hormonal deficiencies (modified from Cabot and Cooper, 1997)

In reference to the above illustrations, it is interesting to note that in portraying the overweight versions of the four figure types, the authors have retained the fundamental shape of each and expanded certain key areas such as waist/abdomen, hips, thighs, breasts and shoulders. This has resulted in a proportionately larger version of the same basic figure type in each category. It seems that this classification system complies with Sheldon's premise of body type permanence also, and presents what might be described as a proportionate model to demonstrate the pattern of increases in adiposity of each body type. In this regard, Carter and Honeyman Heath (1990) have reported that the three somatotype components in Sheldon's original method, needed to be modified due to endomorphy (roundness) increasing out of proportion to mesomorphy (muscularity) and ectomorphy (leanness). This suggests that body shape does not follow a predictable pathway in the changes that occur with overweight or obesity. Aldrich (2007) notes for example that proportional differences between the bust and waist measurements may not be the same amongst different women, and nor will the 3–dimensional change in shape of the breast increase proportionately in larger sizes. This issue has also been addressed by various other authors (Simons, 1933; Kidwell, 1979; Bye et al., 2006).

The production of female garments presupposes a different focus for the use of body type classifications. In this instance the primary goal must be to identify clear cut variation in body shapes with regard to body frame, muscularity and adiposity. This needs to be achieved to enable clothing to be made in a comprehensive range of sizes based on shape that should fit a large majority of the female population with a high degree of certainty. What is required therefore is a representative set of body types that take into account documented secular trends and evidence of female morphological changes. Attempts to address this issue have been limited, both in Australia and internationally. Interestingly, the first of these was a study conducted by Berlei Ltd. in Australia during the late 1920s (Lancaster, 1957).

The Berlei scientific study was reported at the time as being the first, or largest of its type worldwide (Burley, 1926; *Labour Daily*; 1926; *The Sunday Sun*, 1926; Beedee, 1926; *Melbourne Herald*, 1927). It was also stated that enquiries made abroad by a Berlei designer indicated that this census was the first of its type ever to be attempted, a claim which certainly applied in Australia (Berlei Review, 1926).

As a manufacturer of foundation garments, Berlei required data of their clients to identify and classify the size and shape of Australian women at that time. From this anthropometric survey of some 5000 Australian females, which was conducted in conjunction with Sydney University, four figure types were identified and documented by Berlei (1928). The four figure types were classified as: Sway Back, Average, Big Hip, and Big Abdomen, as shown in Figure 3.

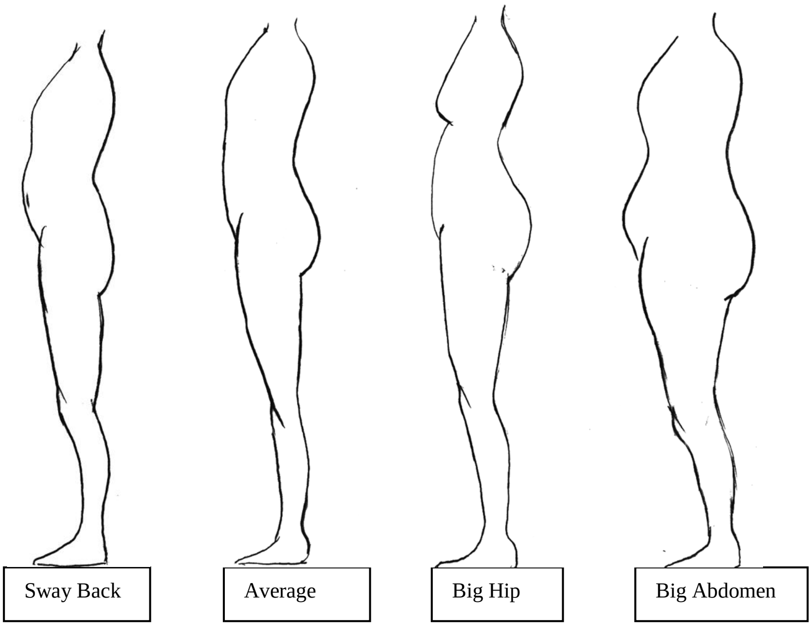


Figure 3: Classification of four Figure Types from Research Department Report (Berlei 1928)

With an emphasis also on variation in the size and shape of the human female body, research by Berry (2001) using a combination of anthropometric measurements with photographs, documented five main figure types considered to be a representative sample of the Australian female population. One way ANOVA showed there were highly significant differences between the five figure types on the anthropometric variables of weight, bust, waist circumference and hip circumference. These figure types which express specific body build characteristics also incorporate different sizes of measurements in the areas of height, bust, waist and hip circumferences, thereby encompassing a range of variation in body size without referring to standard sizes as used in proportional systems. Thus constructing garments for body **types** automatically covers traditional size ranges.

Berry's classifications are as follows: Figure Type I – slim with shoulders and hips almost in a straight line; Figure Type X – may be likened to an average figure type, thick set, with some waist definition; Figure Type A – small waist large thighs, a line drawn from the shoulder to the thigh would present with a slight angle; Figure Type H – fuller waist and abdomen, has very little or no waist definition; Figure Type XH – a combination of Figure Type X and H – thickset, muscular, with waist definition and fullness around the abdominal region, as shown in Figure 4.

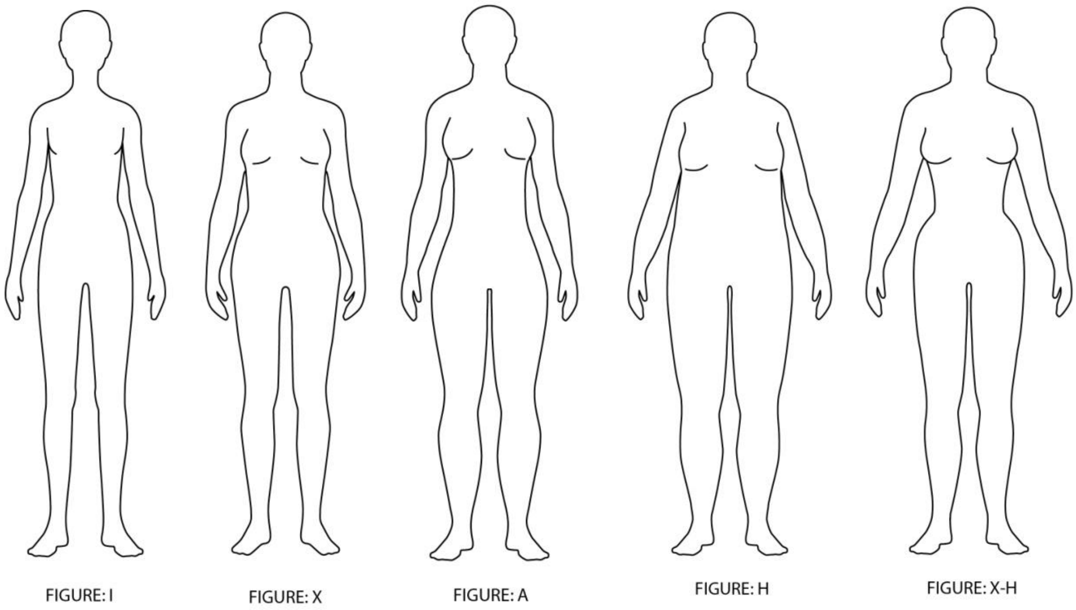


Figure 4: Classification of Five Figure Types (modified from Berry, 2001)

A major objective of the latter two studies was to obtain current data pertaining to the size and shape of the Australian female. In the case of Berlei (Burley, 1926) the aim was to identify a national figure type and at the same time improve the fit of their merchandise. In the Berry (2001) study the primary aim was to obtain up-to-date data of the female body in view of outdated Clothing Size Standards for Female Garments (Australian Standard, 1997). Both studies were largely initiated because of the absence of current data relating to female body size and shape, which could be applied with confidence in the area of clothing design and production.

Issues with poor fit and size discrepancies were known to be a problem at the time of both studies. One possible cause could be attributed to the morphological changes in the human body which have occurred over the past century as reported in the literature (Henneberg, 1992; Henneberg, 1997; National Health and Medical Research Council, 1997; Swinburn, et al., 2004; Australian Bureau of Statistics, 2009).

Secular trends

When a morphological change which lies outside conventional norms occurs in a specified human group from one generation or more to the next, or from one century or more to the next, (for example the tendency to get larger and/or to mature earlier), researchers describe such a change as a secular trend (Tanner, 1981; van Wieringen, 1986; Henneberg and George, 1995; Louw and Henneberg, 1997). Some such changes occur in a positive direction, while others have been noted to occur in a negative direction (Roche, 1979; Henneberg and van den Berg, 1990; Tobias, 1992; Henneberg, 2001) and some have been confined to only one segment of a population at a given time (Tobias, 1985; Gordon–Larsen, et al., 1997). Loesch et al., also note that whilst the secular increase in stature has slowed down markedly in Australia over the past two decades, increases in body weight have risen significantly particularly in respect to females (Loesch et al., 2000).

A secular trend such as an increase or decrease in body size is often associated with biological responses to a changing environment, which might include factors such as war, famine/hunger, improved nutrition, hygiene or sanitation, and change of climate, (Meredith, 1976; Gordon and Greiner, 1993).

Socio-economic factors such as improved living conditions and nutrition were generally considered to be the main contributors to a trend of increases in height, although Mosk (1996) notes that such factors alone are not fully accountable for the trend. Henneberg (2001a), also refers to the possibility of such changes over a short period being eco-sensitive responses, but notes that in some such instances secular trends may have a genetic component. For example the finding of changes in height of up to 200mm in one century, where a change of perhaps 70mm or more may have resulted from improved living conditions, but with a further region-specific micro-evolutionary component amounting to more than 70mm. A similar finding of a genetic influence in relation to body shape and configuration has also been reported by Livshits et al., (2002).

As early as 1842, Quetelet, in his study of normal man expressed the view that biological outcomes such as changes in height and weight were influenced by natural and socio-economic factors (Eknoyan, 2007). Komlos (1994) supports this point of view and states that changes in physical characteristics of a population such as increases in height demonstrate good biological health.

There are problems with this interpretation, however, in view of reported instances of improvement in socio-economic factors with no concomitant biological changes, and conversely, significant biological changes without an associated improvement in socio-economic factors (Henneberg and van den Berg, 1990; Henneberg, 2001).

In other studies relating to a secular trend of increase in height, Hertzberg (1972), cites Dahlberg (1942), and Hulse (1957) who noted that heterosis (interbreeding between different physical types) may be a contributing factor. The premise that body proportions of people differ according to their racial origins is the basis for this point of view. A similar rationale has been applied in relation to transformations that occur in demographics due to increased interracial mixes resulting from greater worldwide travel and interaction (Simmons et al., 2004a). Lee et al., (2007) present a similar viewpoint in relation to changes in body size and shape. In this regard, Henneberg (1997) also put forward the view that as the gene flow between racially different populations increases, and assuming a continuation of the relaxing of natural selection (survival of the fittest in the prevailing environments) due to improved health care and better living conditions, the variability within human populations will increase. A logical assumption therefore is that the increase in variability will be manifested in changes in morphological characteristics.

Such increased variability will have important ramifications for the apparel industry. For example it has been argued that an ideal body type will become progressively irrelevant and in this event the concept of Mr or Ms Average may need to be reconsidered (Bridger, 1995). Designers in the future may therefore need to take into account the increasing human variability and to accommodate this with appropriate measurement procedures (Bridger, 1995; Bye et al., 2006). While the rise in stature that has been reported over the past century appears to have levelled off in many instances (Tobias, 1992; Loesch et al., 2000) the reported increase in weight has reached epidemic proportions (World Health Organisation, 2000; National, Health and Medical Research Council, 2003; Australian Bureau of Statistics, 2009) and childhood as well adolescent obesity is also on the increase at an alarming rate (Berkowitz, 2006*)*. As has been noted already, increases in weight particularly in women, raise concerns not only because of associated health issues, but also because of the problems this raises with the fitting and production of women's clothing (Holzman, 1996; Simmons et al., 2004a; Ashdown, 2007). This growing incidence of overweight and obesity presents the garment industry with a major ongoing challenge in terms of the increasing unpredictability of its target market and the exacerbation of existing problems with sizing and fit.

Overweight and obesity

The World Health Organisation (2006) has defined overweight and obesity as 'abnormal or excessive fat accumulation that may impair health'. On the other hand Uwaifo and Arioglu (2009) consider that overweight is simplistically defined as excessive body weight for height while obesity represents a state of excess storage.

Obesity is not a new phenomenon: it can be traced as far back as the Stone Age through archaeological excavation which has uncovered obese statuettes from that period together with later evidence of obesity in Egyptian mummies and Greek Sculpture (Blumenkrantz, 1998). Obesity has generally been associated with societies where food was plentiful and physical activities reduced. Hippocrates also identified a link between obesity and food intake and claimed that the consumption of more food than is necessary will cause disease (Rimm et al., 1988). As late as the 18th century, however, it was universally accepted that people who were "corpulent' were believed to be healthy and fat-ness was considered to be advantageous (Eknoyan, 2007). Even to the present day certain cultures place a high value on being large. However, by the first decade of the 20th century an association between morbidity and obesity had come to the notice of the insurance industry, and from this point onwards there has been a steadily growing awareness of obesity as a medical concern (Boyd, 1980; Swinburn et., 2004, Eknoyan, 2007).

The prevalence of obesity worldwide has now reached alarming proportions. The volume of literature on overweight and obesity trends shows the concern felt by governments, as well as the medical and health professions, as to the current and future health and welfare of their populations. For the purposes of this study the high incidence of overweight and obesity, and the rate of its increase, also present a major concern for the garment industry particularly its impact on the size and shape of the Australian female body form.

Prevalence of overweight and obesity

The Parliamentary paper titled 'Overweight and Obesity in Australia' (Parliamentary Library of Australia, 2006) shows a graph from the World Health Organisation which indicates the prevalence of overweight and obese male and female adults in six of the world's major countries, including Australia. It is noted that in the USA, Australia and the UK the percentage of obese females exceeds the percentage of obese males. It is also noted that the percentage of Australian overweight females is second only to the USA, with the UK marginally lower than Australia. These data were based on BMI values designating overweight (25 to < 30) and obesity (> 30) as suggested by the World Health Organisation 2000, (WHO) in the Parliamentary Library of Australia, 2006), (Figure 5).

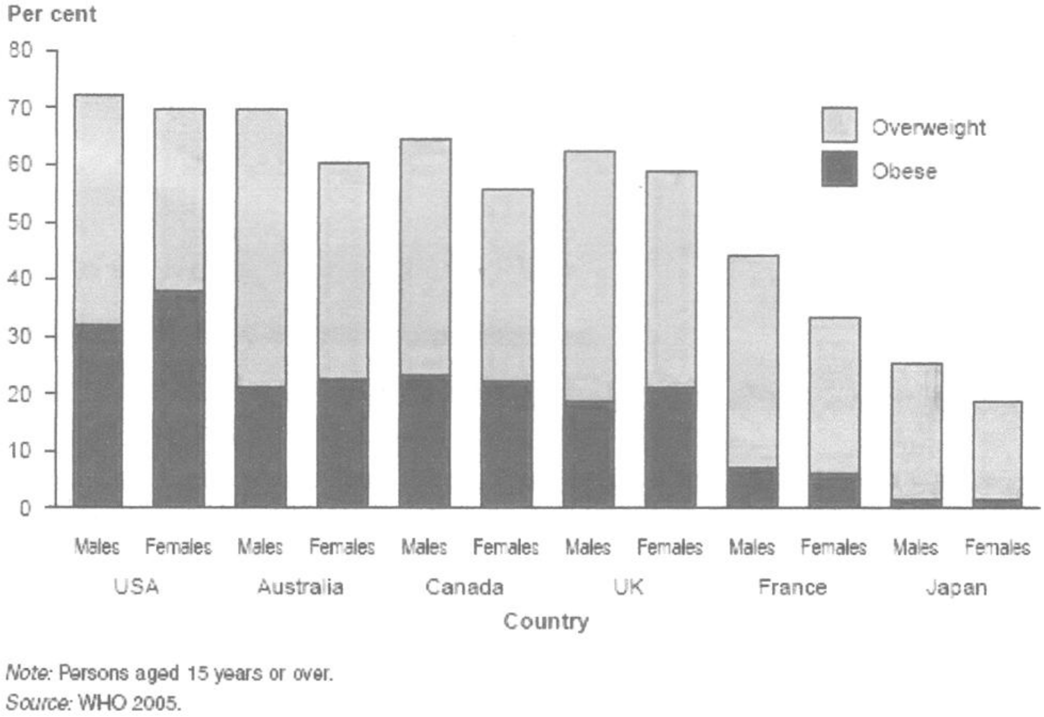


Figure 5: Comparison of overweight and obesity of males and females in six countries. Source: (modified from World Health Organisation 2005 in *Overweight and obesity in Australia*) (Parliamentary Library, 2006)

International BMI classifications

A full international classification of BMI values which indicate the cut-off points designating adult underweight, overweight and obesity, is shown in Table 1 (World Health Organisation, 2006). It can be seen by this table that the classification has been expanded to include additional categories both in the underweight and obese sections.

Table 1: The International classification of adult underweight, overweight and obesity according to BMI (modified from World Health Organisation, 2006)

Classification	**BMI Category (kg/m$^{2)}$**	**BMI Category (kg/m$^{2)}$**
	Principal cut off points	Added cut off points
Underweight	<18.50	
Severe thinness	<16.00	
Moderate thinness	16.00-16.99	
Mild thinness	<17.00-18.49	
Normal	18.50-24.99	18.50-22.99
		23.00/24.99
Overweight	≥ 25.00	
Pre-obese	25.00-29.99	25.00-27.49
		27.50-29.99
Obese	≥ 30.00	
Class I	30.00-34.99	30.00-32.49
		32.50-34.99
Class II	35.00-39.99	35.00-37.49
		37.50-39.99
Class III	≥ 40.00	

It is of interest to note that Bouchard and Perusse (1993) describe four different phenotypes relating to obesity which are characterised by fat distribution in different regions of the body. These phenotypes have been identified as: Type I – excessive fat and/or mass distributed across all body regions; Type II – excessive subcutaneous fat in the abdominal region or android fatness; Type III – excessive deep abdominal fat and Type IV – excess fat in the gluteal and femoral regions, or gynaeoid fatness. The effect of such variation will impact significantly on the external size and shape of the human female body and pose an ongoing challenge for the production of female garments, in view of the percentage of overweight and obese females in the population as reported in the National Preventative Health Taskforce (NPHT) (2009).

Application of BMI classifications of Australian women

Body mass classifications have been applied to data reported by the NPHT (2009) to show the results of surveys taken in 1990, 1995 and 2000. The BMI of Australian Women was measured in three specific age groups which consisted of females 40 to 44, 55 to 59, and 70 to 74 years of age. The trend in mean BMI increase in Australian females is shown in Figure 6. Of particular note is the level of increase shown by the so called Generation *X* group, referred to in Technical Paper: 1, as those born between 1966 and 1970. At the time of writing the authors predicted that the Generation X women across Australia would have a BMI **increase** of 10.8%, while the Baby Boomer generation was predicted to have the highest average BMI by 2010 of all of the generational cohorts. The particular concern with regard to Generation X trends is the fact that many mothers in this age group have children who are already showing signs of overweight and obesity.

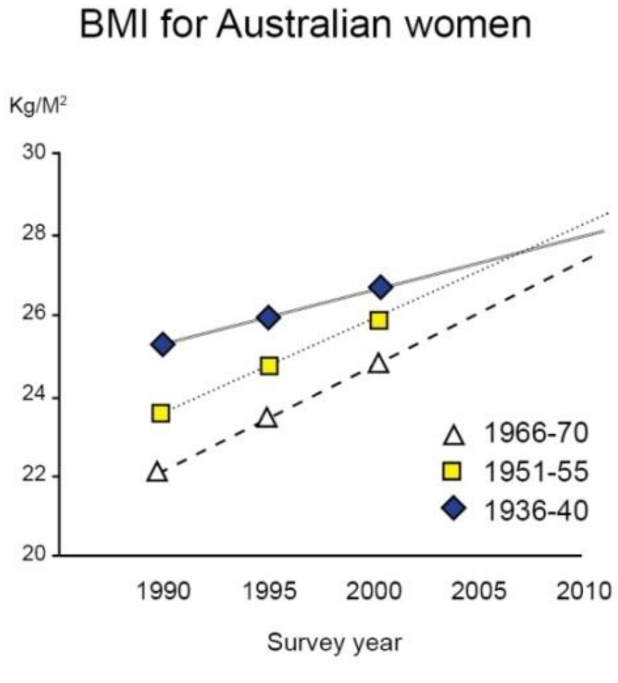


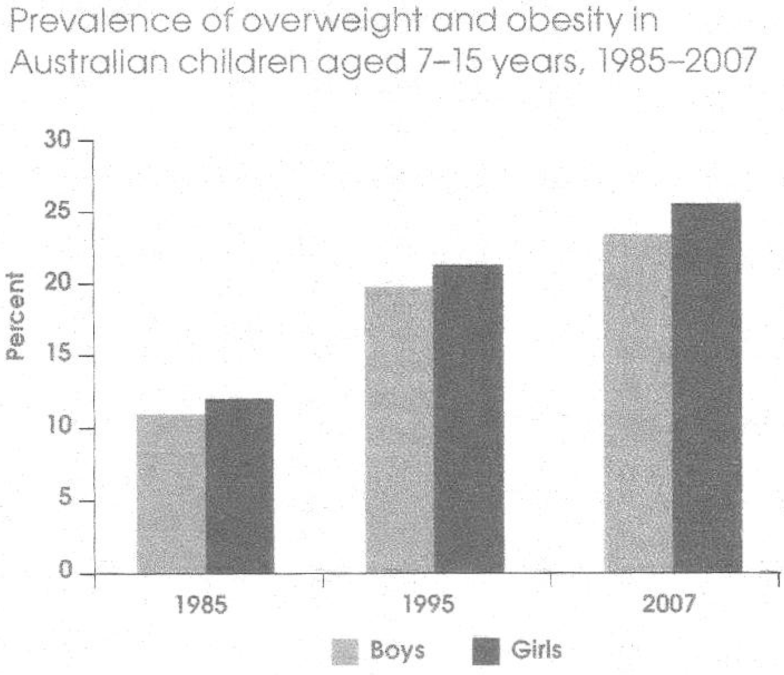
Figure 6: Mean BMI by birth cohort for women in Australia in 1990 – 2000 and 2010 projections. Source: (modified from Allman-Farinelli et al., 2006 in National Preventative Health Taskforce, 2009)

Overweight and obesity in children and adolescents

The National Preventative Health Taskforce (2009) cite data from the 2007 National Children's Nutrition and Physical Activity Survey (NCNPAS) which show that approximately one quarter of all Australian children are now overweight or obese. These are our future generation!

Additionally, the NPHT paper suggests that the prevalence of overweight and obesity in children may be far more pronounced in specific groups such as indigenous communities, certain ethnic populations, and those in low socio economic circumstances and cites numerous authors in this regard.

Of concern is the high probability that these overweight children will develop into obese adults (Allman-Farinelli et al., 2007 in NPHT, 2009). Figure 7 illustrates graphically, data spanning the past 20 years which show the alarming trend of the increase in overweight and obesity of Australian children over that period. An example in this trend amongst boys 7 to 14 years was an increase from 11% to 24 % between 1985 and 2007. Amongst girls the figures were reported to be even higher, showing an increase from 12% to 25.85 % between 1985 and 2007.



* Data weighted for age, gender and region.

Source: Roberts L, Letcher T, Gason A, et al., (2009).(19)

Figure 7: Prevalence of overweight and obesity in Australian children aged 7-15, 1985-2007 (modified from Roberts et al., 2009, in National Preventative Health Taskforce, 2009)

Trends in prevalence of overweight and obesity in Australia

The alarming level of current figures in relation to overweight and obesity is predicted to become even more extreme by the year 2028, assuming that there is a constant increase in line with current trends. Conservative estimates which assume no change in the rate of prevalence suggest that as many as 4.6 million Australians representing 18.3% of the population will be obese by 2025. At the other end of the spectrum the number in the population could be as high as 6.9 million (Department of Human Services (DHS) 2008, in National Preventative Health Task Force, 2009). The graph in Figure 8 presents data which falls between the ranges of estimates outlined above. Such a wide disparity in these projections indicates the difficulty which exists in the area of predicting such future trends and/or outcomes.

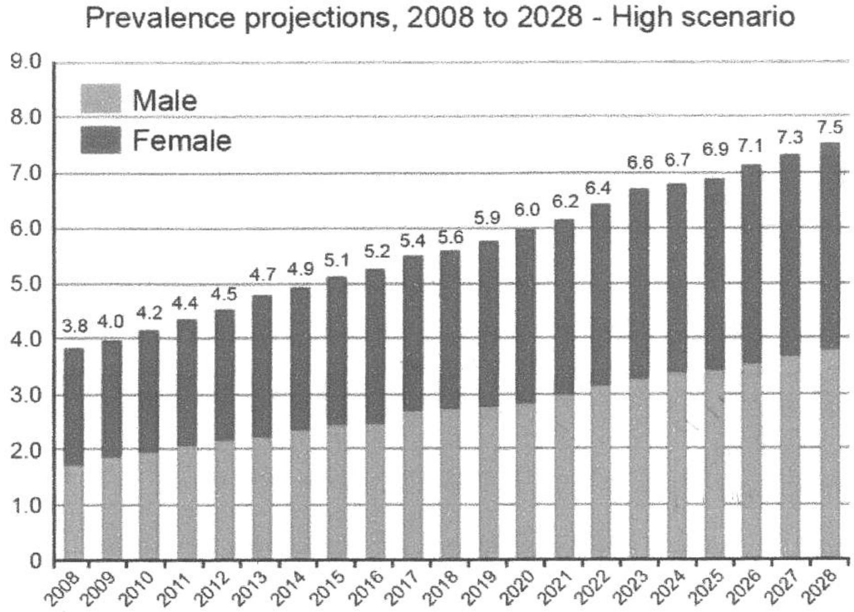


Figure 8: Population obesity prevalence projections, Australia, 2008-2028 (assuming current trends continue) Source: (modified from Access Economics 2008 in National Preventative Health Taskforce, 2009)

Whilst it goes without saying that prevention is better than cure, a growing difficulty in the area of prevention of overweight and obesity is the complexity and multiplicity of its possible causes. An additional source of uncertainty relates to possible interactions between identified aetiological factors, which are reviewed in the following section.

Aetiology of obesity

Numerous factors have been identified or proposed as contributors to the increase in weight and obesity and associated changes in shape reported *en-masse* and consistently in the literature (Pi-Sunyer, 1994; National Health and Medical Research Council, 1997; Drummond, 2000; Swinburn et al., 2004; World Health Organisation, 2006; Uwaifo and Arioglu, 2009). The most fundamental of these factors is an energy imbalance between calories consumed and calories expended. Such an imbalance has been attributed to more sedentary lifestyles, a change in diet, such as the movement away from protein to a higher reliance on carbohydrate and fat, or the faster pace of life making ready-to-eat food, often high in fat an easier and attractive alternative to the home cooked variety. Industrialization and less participation in hard manual labour together with greater reliance on motor vehicles in place of walking or bike riding has also resulted in a lack of physical exercise, and thus less calories being expended.

High stress levels which increase production of cortisol and lead to higher satiety levels (Pi-Sunyer, 1994) have also been proposed together with factors such as prescribed medications, including the contraceptive pill, some of which may lead to fluid retention, or increased adiposity. Other unsuspected sources of hormone exposure or ingestion have also been implicated as possible influences, one example being food subjected to growth hormones which are used to maximise commercial potential (Henneberg, 2001; Swinburn et al., 2004; Uwaifo and Arioglu, 2009).

Additionally, there is an abundance of studies in the literature that suggest other potential contributors such as the action of leptin, a hormone secreted by adipose tissue (Friedman and Halaas, 1998), vitamin D deficiency (Foss, 2009), endocrine diseases such as hypothyroidism, a high sitting height ratio linked to under-nutrition in early childhood (Bogin et al., 2002; Bogin, 2006), food allergies which may lead to abnormal absorption of nutrients and result in weight changes, and a decline in oestrogen and associated increase in testosterone in menopausal women (Janssen et al., 2010).

More recently attention has been drawn to data which suggest a marked inflammatory and possibly an infective cause for obesity given the 20% to 30% prevalence of adenovirus 36 infection in the obese compared to 5% in the non obese. The authors suggest also that the eventual answer to this question may be found in the same way as that which proved *helicobacter pylori* as the principal cause of peptic ulcer disease (Uwaifo and Arioglu, 2009).

While each of the above factors may well contribute in various degrees, the most commonly held view as noted previously has been that overweight and obesity are associated with ‘gluttony and sloth’ or energy input being greater than energy output (National Health and Medical Research Council, 1997). This statement is open to debate, however, as the evidence indicates that issues of overweight and obesity are highly complex and other factors such as genetic inheritance, life style, social customs, socio-economic status, and the likely interaction between these factors must also be considered (Gordon-Larsen et al., 1997; Huang et al., 2009).

Despite the possibility of such multiple contributory factors, it still seems paradoxical that with the almost daily bombardment in the media of yet another “diet” or “miraculous slimming panacea” the levels of overweight and obesity appear to show no signs of abating. Additionally the trend to limit fat intake and the obsession with body shape which seems to dominate the thinking of the population as a whole, together with innumerable fitness programs and a booming fitness industry, appear to have had little impact on the prevention of overweight and obesity. This may be interpreted perhaps as further evidence that there are indeed other subtle and yet to be identified factors behind this epidemic. Although there is a lack of general consensus as to the cause or causes of obesity, studies in this field require appropriate methods and techniques for assessment and the most common of these are reviewed in the following section.

Method for assessment of body mass

One traditional tool which has been adopted for assessment of overweight and obesity was known as the Quetelet Index until the 1970’s. Adolphe Quetelet, the Belgian mathematician who described the index in 1832 had no interest in obesity *per se*. His purpose for developing the index was to document characteristics of the normal man in terms of the development of weight and its relationship to the development of height. His conclusion that normal body weight is proportional to the square of the height led to the establishment of a practical index for the classification of body mass, which is now generally known as the Body Mass Index (BMI), (Diamond, 1969; Keys et al., 1972; Boyd, 1980; Eknoyan, 2007) and is calculated as weight in kilograms divided by the square of the height in metres (Wt/Ht^2).

However while the BMI is generally the most commonly used method for body mass assessment, several researchers have noted its limitations. Wells et al., (2007a), note that BMI can be used as an indicator of body characteristics, but state it is not an accurate marker. Gadzik (2006), puts forward a similar point of view and argues that BMI fails to present a quantitative aspect of obesity. Others have also noted the limitations of BMI in the cases of growing children or pregnant women, and in assessing individuals with muscular physiques such as those of athletes or body builders (Norton and Olds, 1996; Ode et al., 2007). Attention has also been drawn to the fact that a typically normal BMI may conceal underlying excess adiposity, characterised by increased percentage of fat mass and reduced muscle mass, as in some instances of *sarcopenia* (especially among those of Asian descent) (Uwaifo and Arioglu, 2009).

Other concerns have been raised as to the usefulness of BMI in general, including its applicability and its cut off points to other populations, since it is derived largely from Anglo-Saxon population data (Eknoyan, 2007). The point has also been made, that two bodies of similar fatness may have different BMI values as a result of differences in proportions of various body parts (Henneberg and Ulijaszek, 2010). These authors and others note that as the BMI uses the total body weight it inevitably includes components of lean body mass and thus its increase may not solely reflect increasing adiposity (Henneberg and Veitch, 2005).

The consensus of opinion would seem to be that the BMI provides at best a crude population measure of obesity and it is gradually being replaced by the use of an individual's waist measurement as a simple and convenient means of assessing fat accumulation. A waist measurement of greater than 94 cm for men or 80 cm for women for example, is an indicator of internal fat deposits (World Health Organisation, 2000; National Health and Medical Research Council, 2003). However this method is recommended for use only with adults at this point in time to check the risk for developing a chronic disease.

A variation of the above method which is based also on a person's waist circumference is known as the Conicity Index (C) (Mueller et al., 1998). This an index of body fat distribution which expresses a person's waist circumference relative to the circumference of a cylinder which has been derived using the same person's weight and height assuming a constant for body density (Valdez, 1991, in Mueller et al., 1998). The authors report that the value of (C) becomes higher when a person's fat distribution is more central and claim its use is superior to both waist circumference alone, and skin fold ratios, which "over-correct" for total fatness.

Other studies report assessing overweight and obesity (and nutritional status) by the measurement of skinfold thickness using callipers in designated positions on the body such as the subscapular, triceps, biceps and suprailiac (Norton and Olds, 1996). More recently it was found that body frame circumferences obtained by the use of an anthropometer or by spreading calipers correlated 'consistently, significantly and substantially' with skin fold thicknesses as a measure of fatness (Henneberg and Ulijaszek, 2010).

There are several other methods for assessing body fat distribution which are used primarily by the medical profession, for a variety of diagnostic purposes. Such methods include computerised tomography (CT), and magnetic resonance imaging (MRI), (Blumenkrantz, 1998); bioelectrical impedance analysis (BIA) (Kyle et al., 2004); and dual energy X-ray, (DEXA) (Benardot, 2006), but the costs of these methods would undoubtedly restrict their general use. With the growth in levels of obesity it seems timely therefore that a low cost, convenient and reliable method of monitoring this problem is agreed upon and adopted across the globe.

The focus on adiposity together with methods of assessment and its effect on the human body in terms of health have been addressed at some length. The fact that increased adiposity and the resultant changes in the size and shape of the adult female body present a major concern for the garment production industry has also been noted. Another field of study in relation to the shape of the human body can be traced back from the classical era to the times of the ancient Egyptians. These periods in history are characterised by the importance placed on proportion in their art, architecture, and sculpture, which were said to have been derived from the ideal dimensions of a proportionate human body in which symmetry and harmony were synonymous with beauty and perfection.

Historical aspects of human body proportion

The earliest documented evidence of the use of proportion and mathematical knowledge can be traced back to around 3000 BC and the Ancient Egyptian civilization, whose architectural monuments, art and sculptures are thought to have been designed and constructed using basic geometrical forms and according to strict mathematical principles (Fletcher, 1883; Macnoriute, 2000; McPhee, 2008). It was in this period also that the notion of an ideal human form with specified proportions is thought to have originated (Kaelin, 2009).

Although a simple hieroglyphic system of counting had been established in the time of the ancient Egyptians which was easy to use and understand, it was severely limited in that multiplication and division were virtually impossible (McPhee, 2008). A question of interest therefore is how the Egyptians achieved the correct angles in the geometrical forms which are believed to have been the basis of their architectural designs, to enable them to produce such remarkable architectural structures. A further question is what methods might have been used to reproduce and/or replicate these geometrical forms in greater or lesser degree as the need arose. Additionally, how were the proportions of human figures in Egyptian friezes and sculptures replicated in the oversized effigies of their Gods and Pharaohs?

The early Egyptians were skilled surveyors and were proficient at reproducing measurements as a result of the regular flooding of the Nile and the likely need to replace boundaries of plot and farm areas washed away by flood waters (Lawlor, 2000). According to Alexander Badawy's 'Ancient Egyptian Architecture Design: a study of the harmonic system' cited in Suchar and Rossi (1997), the early Egyptians developed a grid system for replicating a proportionate relationship from a smaller item to a larger item such as a statue or a piece of sculpture. Suchar suggests that the Egyptians used a system of proportions and a system of triangulation in their architecture and sculpture, and notes furthermore that the system of proportions based on dimensions derived from the human figure, enabled the grid system to be used on different scales (Suchar and Rossi, 1997).

Golden ratio / (Phi Φ).

It is this set of proportions, or Golden Ratio, which is thought to have been a key factor in the 'layout' of monumental buildings, and in achieving the desired proportions in both the human face and human bodies which feature in the art of the ancient eras. Having only rudimentary tools and equipment such as knotted string, and simple grids, the Golden Ratio is claimed to have enabled early civilizations such as the ancient Egyptians, to design and build complex structures and create life-like sculptures. However, claims concerning the golden ratio have been the subject of considerable debate in the literature (Huntley, 1970; Markowsky, 1992; Ifrah, 1998 in Ostwald, 2004; Falbo, 2005).

One of the main sources of dispute is the contention that the golden ratio represents an ideal proportionate relationship that occurs widely in nature, and when utilised in art or architecture presents a harmonious and pleasing result (Huntley, 1970). What are not disputed are the actual mathematical properties of the ratio which enable geometrical forms to be easily replicated (Markowsky, 1992; Falbo, 2005).

It is not known definitively when the mathematical phenomenon referred to above, was first discovered and put to practical use (Huntley, 1970). According to Huntley, it is reasonable to assume that it has appeared and reappeared throughout history and was periodically used by various groups in society such as philosophers, mathematicians or architects and those associated with the arts such as sculptors, composers and artists. This state of flux is thought to account for the different names by which it was known at different periods in history. Such names include: The Golden Ratio, The Golden Mean, The Divine Proportions, The Divine Section, and the Golden Cut, each of which has been linked directly to a mathematical value represented by the Greek letter Φ (*Phi*).

The term, Golden Ratio for example, arose in reference to dividing a line into unequal segments so that the ratio of the whole line to the larger segment is the same as the ratio of the larger segment to the smaller segment. The ratio (or 'irrational' indivisible number) designated *Φ*, has a value of 0.6180339 (recurring) although according to Markowsky (1992) some authors represent *Φ* as 1.6180339, due to the fact that the reciprocal (1÷0.6180339) is 1.6180339. In view of this seemingly unique property, the Golden Ratio (*Φ*) has been described as the world's most astonishing number (Livio, 2002). However (Falbo, 2005) disputes this claim by proving that several other irrational numbers have similar properties.

The practice of using specific mathematical proportions as a means of obtaining the most pleasing result in architecture and art continued from the ancient Egyptian civilisation to the time of the ancient Greeks, who were influenced greatly by the Egyptians in art, religion and other cultural practices. In addition to a passion for proportion, the Greeks also placed a strong emphasis on harmony, order, aesthetics and symmetry, and in the area of stone carving in particular. Woodford, (1982) noted that the Greeks copied Egyptian methods which had existed for centuries, by first making a drawing on a block of stone according to a fixed scheme of proportions to achieve the desired symmetry. According to Suchar, the golden ratio was the aesthetic expression of the laws of symmetry which defined the correct relationship between each part to the whole (Suchar and Rossi, 1997).

Smith and Wheeler (1988) contend that in the fifth century BC, a fixed scheme of proportions was used by the sculptor Polyclitus who was highly regarded by his peers for his contribution to the practice of using arithmetical calculations for measuring the proportions of the human body. The authors note that Polyclitus' calculations suggested that the height of the head should be seven and a half times the total body height, the length of the foot be three times the palm of the hand, the length between the foot and the knee be six times the palm of the hand, and knee to the centre of the abdomen also be six palm lengths. Fletcher (1883) stated however, that Polyclitus's scheme of human proportions became known as 'The Canon' – meaning absolute rule, and specified that the height of the head should be one eighth of the total body height. The Greek scholars also placed a high value on fostering and developing knowledge of mathematics and made extensive use of proportions in the design of their architecture. It is stated that Phidias (500 -432 BC) a Greek sculptor and mathematician studied and utilised mathematical ratios which he applied in the design of sculptures for the Parthenon (the ancient Greek temple built in the 5th century BC in honour of the Goddess Athena) (Huntley, 1970). There are numerous accounts in the current literature, of claims and counter claims, that the proportions of this monument indicate the use of the Golden Ratio (Markowsky, 1992; Livio, 2002; Ostwald, 2004; Falbo, 2005).

In this same period (500 BC) Pythagoras the noted Greek mathematician proposed his famous theorem (the square of the hypotenuse in a right angled triangle is equal to the summed squares of the two adjoining sides) which it is claimed he was taught during his extensive travels and studies in Egypt (O'Connor and Robertson, 1999). It has been suggested that its application in architecture and construction in the form of simple 3-4-5 triangle would provide one explanation of how the precision of the ancient monuments was achieved. It is interesting to note that as recently as the early 20th century the utilisation of the 3-4-5 triangle was outlined in a textbook titled 'The Science of Pattern Construction for Garment Makers' (Poole, 1927). A similar link between geometry and pattern cutting/making is a key component of some of the earliest published works in this area (Wampen, 1864; Poole, 1927; Morris, early 1940's) (Figure 9).

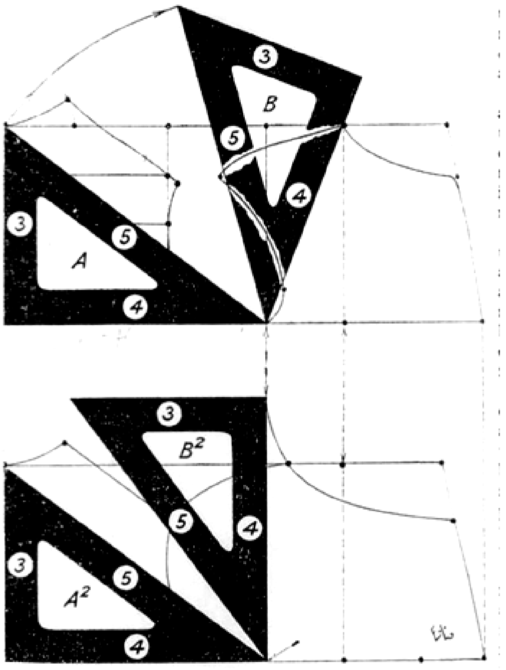


Figure 9 Trigonometrical ratios of a 3-4-5 triangle. *The Science of Pattern Construction for Garment Makers* (Poole, 1927)

Plato (circa 428-347 BC) the Greek philosopher, mathematician and astrologer was another noted contributor to the development of mathematical applications. In his 'Timaeus' which focused on natural science and the physical cosmos, Plato built on earlier work by Pythagoras and Theaetetus, relating to five solids or polyhedra (the platonic solids). Livio (2002) suggests that while Plato may not have known of the existence of the Golden Section (otherwise known as the Golden Ratio, as noted previously) there appears little doubt that some knowledge and understanding of this ratio would have been needed to construct the platonic solids. On the other hand Huntley (1970) attributes Plato with the comment that he considered the properties of the 'segments' or 'sections' to be the most fixed of all relationships in mathematics and the essence of the physics of the universe which implies that Plato had full knowledge of the properties of *Phi*.

Another famous Greek mathematician Euclid (365-300 BC), often referred to as the father of geometry, has been credited with writing one of the greatest mathematical works of classical antiquity titled 'The Elements' in which he effectively describes how to find the golden section point on a line (Huntley, 1970).

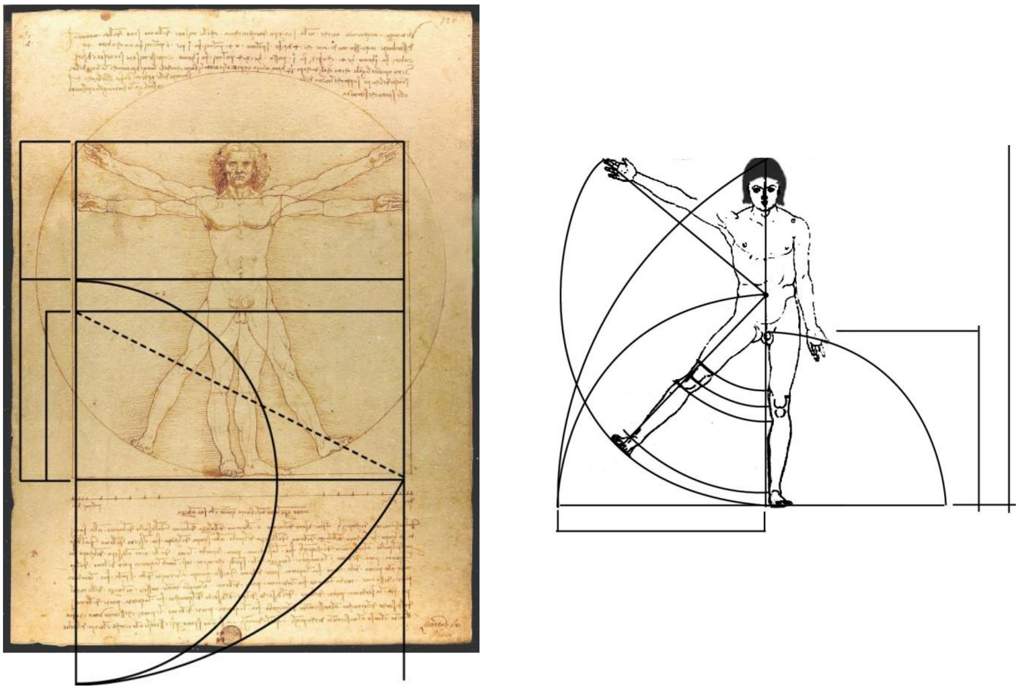
Human body proportions and art

Knowledge of the Golden Section/Golden Ratio, Φ, has also been attributed to the artists of the classic period who believed that in a perfectly proportioned face, the ratio of the top of the hairline to eyes, and eyes-to-chin should be the same as the ratio of eyes-to-chin to the whole of the head (Huntley, 1970). A similar canon of proportions was thought to have been followed by the artists and sculptors to obtain a perfectly proportioned body in which the ratio of head-waist and waist-feet should be the same as the ratio of waist-feet and the entire body height (Lawlor, 2000). A classic example of the application of this principle and one which is frequently cited in the literature is that of Leonardo da Vinci's Vitruvian Man (Schott, 1992; Ostwald, 2004), which shows the figure of a man with outspread arms drawn within a circle placed within a square, with the tips of the man's extremities and top of head in contact with the sides of both geometrical shapes.

According to Smith and Wheeler (1988), Vitruvius, a Roman architect, proposed in his treatise *De Architecture* that the proportions of buildings should be modelled on sections of a well shaped body which is the personification and measure of all things. The authors also state that Vitruvius declared that when the breadth of a man is equal to his height and the navel is at the exact centre, a body of perfect proportions will be achieved. More importantly, in his canon of proportions Vitruvius is claimed to have stated that distance from the chin to the crown of the head is one eighth of the height of the body (Vitruvius Book 3 in Smith and Wheeler, 1988).

On the other hand Fletcher, (1883) attributes Vitruvius as saying that the face, from the chin to the hairline is a tenth part of the stature while the head from the chin to the top of the scalp is an eighth. It would appear that the modulus chosen as the standard from which all others parts or dimensions could be expressed as proportions was arbitrarily decided on by the author of the canon. Fletcher notes that it was permitted for artists and sculptors to deviate from the designated canon of proportions in their works of art which depicted gods and heroes. Other departures from the canon included figures of ‘Wisdom’ and ‘Authority’ who had larger heads, whereas Hercules who was portrayed as muscular had a smaller than standard head.

Some 1,500 years after the death of Vitruvius, Leonardo da Vinci (1452-1519) who would have been familiar with the work of Vitruvius, produced his sketch of the Vitruvian Man in which the text surrounding it included in the instruction that the distance from the top of the head to the bottom of the chin is one eighth of a man’s height (iSculpt, 2008). It has been suggested that the only way Leonardo da Vinci was able to obtain the ideal proportions in this and other work was by utilising the Golden Ratio (*Φ*) (Jovanovic, 2003). Lawlor, (2000) notes that both da Vinci and Durer utilised the Golden Ratio in their canonical figures in which the body is divided in half by the phallus and by *Φ* at the navel as illustrated in Figure 10 and Figure 11.



Figures 10 and 11: Canonical figure as depicted by da Vinci and Durer (modified from Lawlor, 2000 p59)

Alternatively, some writers have linked the Vitruvian Man body in the square with the notion of a square and circle being the two most perfect geometrical forms. The relevance of the points above to this review, however, is the association between the human body form and mathematical principles of proportion.

Theories of human body proportions

It was not until the Renaissance period in the late 15th century that artists renewed interest in mapping proportions of the human body, and revisited notions of an ideal human figure and how to mathematically define it (iSculpt, 2008). Tanner (1981) claims that Leon Baptista Alberti (1404-1472) was the first person since ancient times to have constructed an instrument for the purpose of measuring people which was based on principles of proportionate relationships between various sections of the body. Boyd (1980) notes that Durer (1471-1528) came under the spell of classical Greek proportions and as a result of experimenting with various systems of proportions he introduced a system of coordinates to demonstrate differences in human physique. Tanner claims that Durer's work was a leading text on human proportions at that time (Tanner, 1981). Figure 12 illustrates applications of Durer's concepts of proportions.

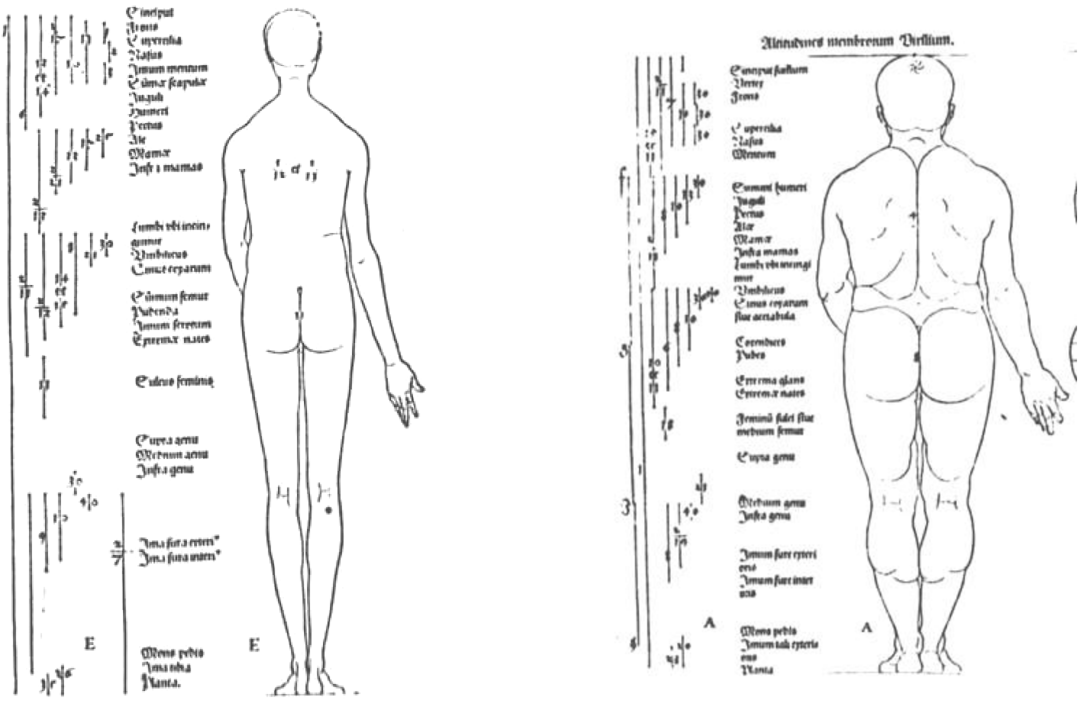


Figure 12: Source: modified from Durer's illustration of slender and robust form. From the Latin edition of *Proportionslehre* (1557), *courtesy of the Wellcome Trustee* (modified from Tanner, 1981 p43)

Boyd (1980) also refers to a Spanish teacher of art, Juan de Arfe y Villafane (1806) who adopted the eight head height canon as did Durer from the Italian quattrocento artists' tradition. It is of interest to note that one of the earliest documented pattern cutting systems also originated in Spain in the mid 1500s (Seligman, 1996). Figure 13 (left) illustrates two systems of proportion for an adult male, the first being eight head heights, and the other ten and one third face heights. The text notes that the eight head height system also applies for the adult female figure (right). The illustrations were taken from the 1806 edition of the manual of Juan de Arfe y Villafane (Boyd, 1980).

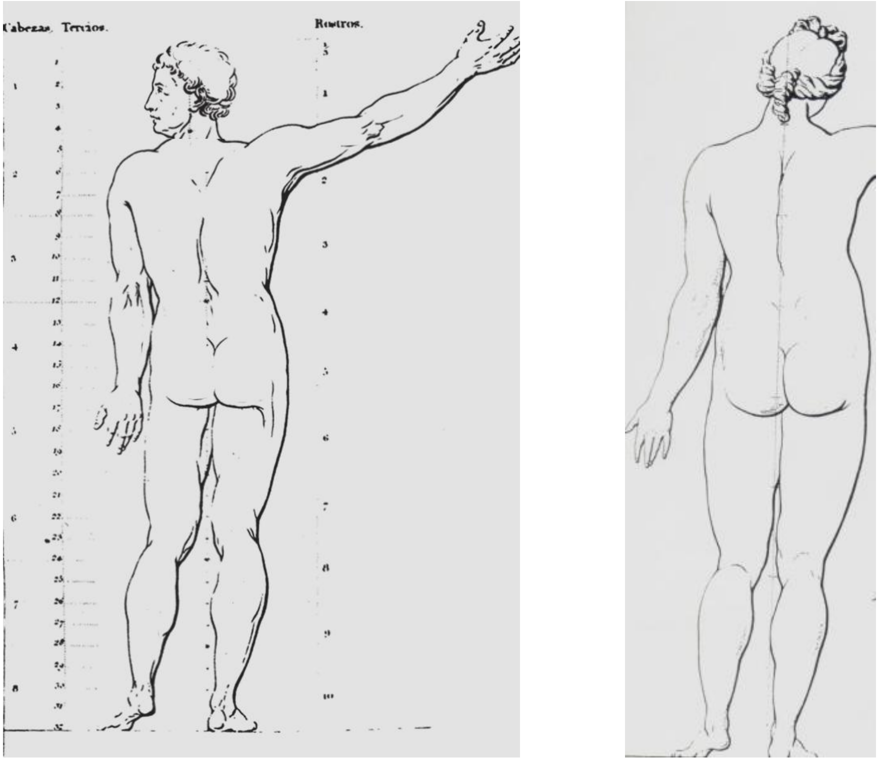


Figure 13: Systems of proportions as applied to adult male and adult female (modified from Boyd, 1980)

The emphasis on classical body proportions as the source of beauty and perfection of the human form continued to influence many of the artists of the early 1800's. This period in history, or 'Age of Enlightenment' was so called because experience and reason came to be considered as more important than divine revelation (Kidwell, 1979). It has been described by historians as an explosion of knowledge and development in the areas of art and science and was characterised by a movement away from a mystical or strongly religious emphasis to one based more on science and nature (Boyd, 1980).

Tanner (1981) Boyd (1980) and Smith and Wheeler (1988) put forward the view that the mathematical proportionate tradition which was revived in the Renaissance for its artistic merits, and continued into the 16th and 17th century by the neo-Platonist school, was again used in the 19th century by Quetelet in the field of social science in relation to a mathematical formula for the ideal growth curve (Boyd, 1980; Eknoyan, 2007). Tanner adds that in the same period, a German professor of mathematics Dr Henry Wampen provided instruction to tailors and first year art students based on the mathematics of proportion. The diagram in Figure 14 which was taken from Wampen's 1864 publication indicates the one head height or one eighth principle of proportion.

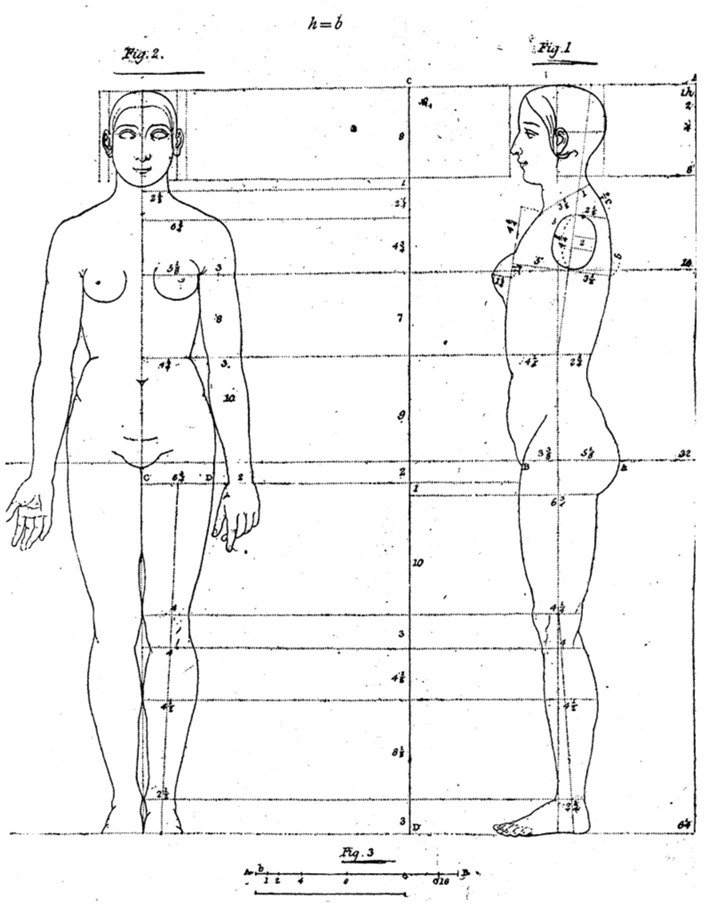


Figure 14: Wampen's eight head concept: *Anthropometry or Geometry of the Human Figure* (Wampen, 1864)

A more recent example of the use of proportion as a means of describing body dimensions is that of Simons (1933), who published a chart of comparative proportions compared with different parts of the human body which he attributes to Stratz (1898). In this instance it can be seen that specific proportions of the female figure are expressed in terms of: the total height being equal to 7 foot lengths, eight head heights, nine hand lengths or ten face heights. It is of interest that this illustration appears in a publication written by the editor of The Clothing Trade Journal (USA) (Simons 1933) (Figure 15).

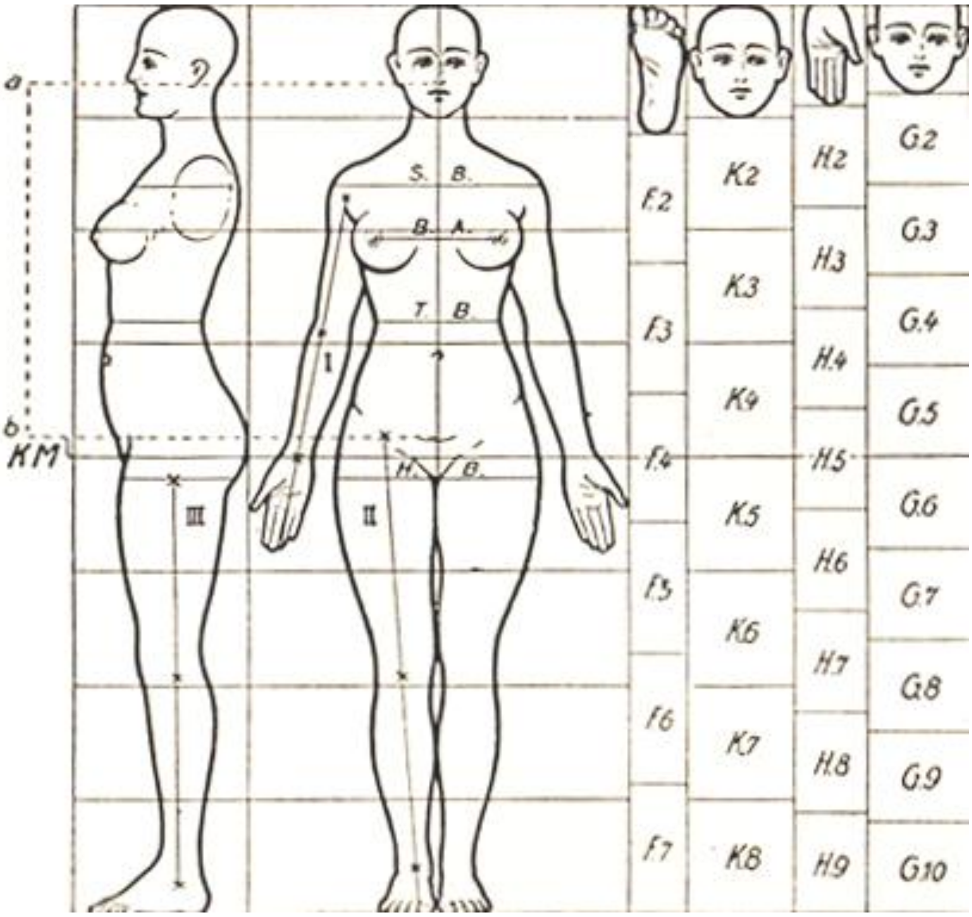


Figure 15: Comparative proportions compared with parts of the body (Simon, 1933)

Another documented source in the literature that details a mathematical approach to defining human body proportions and their association with pattern cutting is the work of Morris. In the early 1940's Morris published a standard textbook titled 'Ladies Garment Cutting and Making' in which he stated that it is an accepted principle put forward by scientists and artists that the head of a figure is one eighth of the total height. Morris claimed that the eight head height theory is centuries old dating back to the Egyptian times, and is a geometrical principle used for measuring the human body that can be applied to scientific pattern construction. Morris highlighted two divisions, one being from the nape of neck (C7) to waist and the other being the nape of neck to base of arm (Morris,1940s) (Figure 16).

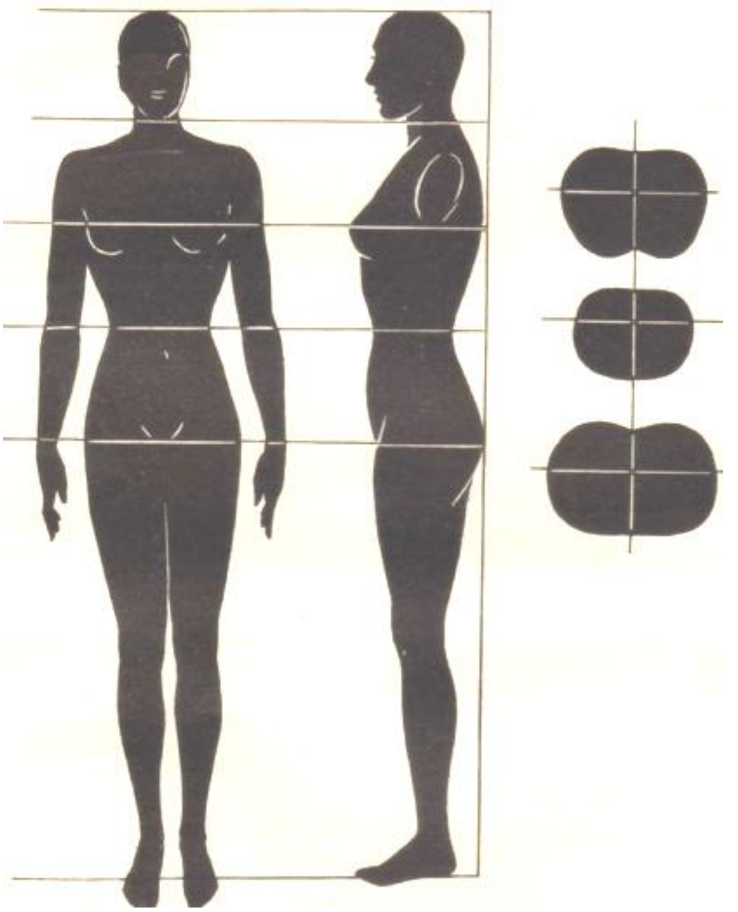


Figure 16: Figure measured on the basis of the eight-head height theory (Morris, 1940's)

In following the theory of proportions used in relation to pattern cutting/making, two further examples are included in this review. The first of these is taken from the New South Wales TAFE School of Fashion (1977) in which, the eight head height theory is used as the basis for deductional proportional calculations of the human body (Figure 17.

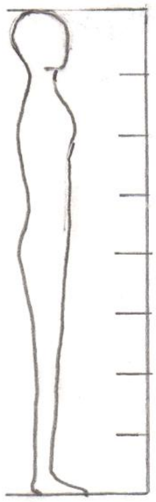


Figure 17: Illustration of the eight head height system (modified from New South Wales TAFE School of Fashion, 1977)

The second example of the use of the eight head height theory for pattern design was recently retrieved from the internet under the title Pattern Drafting by Height (Weekend Designer, 2007). It is of interest to note that reference is made to the Golden Mean as a basis for determining measurements from a given figure height for drafting purposes. Figure 18 shows a scale from the text indicating that one head equals one eighth of the total height.

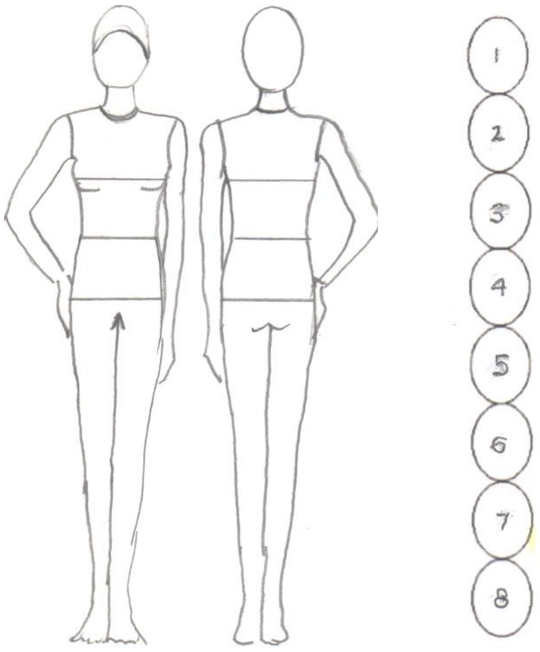


Figure 18: Illustration of eight head height theory (modified from Weekend Designer, 2007)

In conclusion, an analysis of the literature in relation to body proportions highlights one significant omission, which is that little or no reference is made to the actual size or shape of the human body (Tanner, 1981). In fact, it has been noted that there was a denial of realistic sizes and proportions in the art works from the classical and renaissance period (Vegter and Hage, 2000; Naini et al., 2009). For example, studies have shown that the proportions of the Vitruvian man (distance between extended arms is equal to height) only exist in a small percentage of the population (Schott, 1992). This finding is supported by Simons (1933) who cited experiments conducted by Joseph Beonomi, curator of The Soane Museum [sic] (London). Simons reported that Beonomi's experiment showed that of 84 figures measured, 54 were found to be long armed, 24 short armed and only 6 were found to have extended arms equal to the height.

Understandably for painters and sculptors, ideal proportions were more appealing than the absolute size of real human bodies (Tanner, 1981). For garment construction, however measurements that reflect the true dimensions of the human body are desirable. This being the case, reliance on the notion of a proportionate relationship between various body segments and calculations based on the eight head principle are questionable. Kunick (1967) argues for example that measurements based on proportional calculations are only theoretical and do not provide a reliable foundation for pattern cutting systems.

Simons (1933) states moreover, that for pattern cutting and garment construction, measurements that reflect the true body dimensions are critical, and can only be achieved by accurately measuring large numbers of men women and children to ascertain the average proportions within each group. Simons also asserts that it is absurd to attempt to cover or drape a body without obtaining accurate measurements as these are essential for a garment to fit and fall correctly.

In summary, literature focusing on the use of proportions in early architecture and art, and its association with garment and pattern cutting has been extensively reviewed. A related area of interest is the origin and development of clothing.

Origin of clothing

The emergence of modern humans undoubtedly was a major contributor to the nature and timing of clothing worn in pre-historic times (Beals and Hoijer, 1961). Of equal importance was the influence of the prevailing climatic conditions which would also have contributed to the type of clothing worn. The timing of the emergence of modern humans is open to question, however, and there are two conflicting theories in regard to their origin and distribution. One theory proposes that modern humans originated in Africa and populated the rest of the world some 200-300 thousand years ago (Beals and Hoijer, 1961; Johanson, 2001; Randerson, 2003; Manica, 2007). Figure 19 shows a possible timeframe of the movement of these modern humans out of Africa to settlements in the other continents (Kanagasingam, 2008).

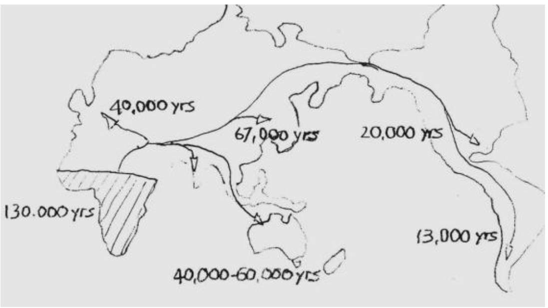


Figure 19: Journey of the modern man: Africa to America! (modified from Kanagasingam, 2008)

The second theory proposes multiregional origins of modern humans, and suggests that similar evolutionary changes occurred on other continents such as Asia for example, within a comparable time frame, leading to the emergence of modern *Homo sapiens* (Thorne and Wolpoff, 1992; Johanson, 2001).

Henneberg (2001) uses population genetic modelling to demonstrate the plausibility of a single eurytopic species existing in an area covering parts of the European, African and Asian continents of the Old World. Henneberg postulates that a mechanism of a ‘self-amplifying feedback’ between biological endowment and living conditions, which commenced at the time of the Miocene, brought about the gradual evolution of modern humans from Miocene Apes, and he notes that Miocene hominid (*sensu lato*) fossils are evident on all three continents of the Old World while fossils of hominids (*sensu stricto) are* evident from 2 Ma onwards.

Whether modern humans originated in Africa and subsequently migrated to other continents, or whether they evolved into a single lineage in many regions of the world within a similar time frame, these humans were exposed to vast changes in weather and changes in climate over time, such as advances of glacials in Europe for example. In order to survive such conditions of extreme cold, these modern humans covered their bodies with non-constricting materials, and this action was arguably the first step towards the practice of wearing clothes (Beals and Hoijer, 1961; O'Neil, 2007).

In later times with the development of culture, the intermingling of diverse cultural traditions became an important contributor to the variety of structure and forms of clothing (Gilligan, 2007). As establishment of different cultures took place and with the advent of cultivation, fibre crops such as hemp, jute, and ramie provided a valuable source not only of fishing nets and rope but also a source for clothing (Chang, 1986, in Gilligan, 2007). Chang notes that silk from silk-worms also became a valued commodity, particularly for clothing, as early as 7,000 years ago and continues to be much in demand to the present time.

As the different cultures developed, so too did the inventiveness and creativity of the people in adapting to their environment (Beals and Hoijer, 1961), resulting in an ever-broadening range of materials used for clothing, and adornments to be used for functional purposes and cultural practices (Gilligan, 2007). The growth of trade also presented greater scope to add variety and colour to the customary form of clothing worn at the time, as well as an opportunity to see and examine clothing worn in far off lands (Jenkyn Jones, 2005).

The exact origins of these earliest types of clothing and adornments are difficult to trace. Unlike stone or solid objects such as, bone, ivory and horn, clothing material disintegrates over time and therefore in most cases has not been identifiable in archaeological findings. Indirect evidence, however, indicates that a certain type of clothing was worn by humans for warmth and protection in the late ice age in Europe during the Mousterian era (O'Neil, 2007).

The body louse

A surprising area of investigation into the origins of clothing suggests that the humble human body louse may provide the answer to the debate in the literature of when human beings began wearing clothes. It has been noted that head lice *Pediculus humanus capitus* only live and lay their eggs in hair on the human scalp whereas body lice *Pediculus humanus corporis* can only live and lay their eggs in the seams and joints of clothing (Kittler et al., 2003). As the body louse is an evolutionary offshoot of the head louse (Leo and Barker, 2005), it was reasoned that its appearance coincided with the wearing of clothes (Lucentini, 2003). Studies conducted by Kittler et al., (2003) found that DNA from the body louse suggests that as a result of genetic change the human body louse came into existence some 70,000 years ago give or take 42,000 years, making a time frame of 30,000 to 114,000 years. This time frame has been questioned, however, and it has been proposed that an alternative time frame may have been as early as 118,000 years ago (Reed et al., 2004 in Leo and Barker, 2005).

One source of indirect evidence of the earliest use of clothing has been the discovery of stone flake scrapers in the Wurm glaciation which indicate the possible use of stone scrapers to prepare skins and hides from animals for clothing. The Palaeolithic age, also known as the 'Old Stone Age' extended over a period from 500,000-10,000 BC. The Old Stone Age is said to have covered the longest period of time among all levels of civilisation. The people of this age obtained their tools from nature, and included: flint axes, obsidian cutters and scrapers. There appears to be no evidence of any sophisticated weapons or tools. Evidence that Palaeolithic Neanderthals could continue living in Europe, despite the cold climate of the first phase of the Wurm glaciation, suggests a crude use of furs and skins for body warmth and covering (Beals and Hoijer, 1961).

A view expressed by O'Neil (2007), supports the above in that the culture of pre-historic humans is known mostly through the excavation of stone tools and other relativity imperishable artefacts. O'Neil states that in the Neanderthal's culture it was probable that some sort of clothing was worn as protection from the cold, and that in all likelihood animal skins were used for that purpose. O'Neil cites two pieces of indirect evidence: one of these was the discovery of stone flakes shaped to a sharp beak-like projection on one end, perhaps used to punch or drill holes in softer material such as wood or leather skins. The second was the anatomical discovery of worn teeth noted on a skull, suggesting chewing of leather to soften the skins, a method which was known to be also used by Eskimo women in the 19th and early 20th century. The discovery of the first eyed bone needle from the Aurignacian period also suggests skins were cut and shaped into garments which were then possibly tailored in a similar way to garments of the present day Eskimo. If this is so, then it would appear that one of the first tailored garments may have been made and worn by hunters in the colder regions of the world (Beals and Hoijer, 1961; O'Neil, 2007).

The finding of the bone needle provides evidence that sewing of garments may have commenced at least 40,000 years ago (Fullagar, 2004). Fagan (2004), however, attributes the invention of the needle to the Cro-Magnon people who lived in the Ice Age period, some 25,000 years ago, and he also asserts that it was the most important invention in history. The needle enabled the Ice Age people to live comfortably all year around, by fitting together layers of hides and furs and other protective materials, to make clothing into layers that closely fitted to the body. The layers of clothing would have allowed for sudden changes in temperature due to seasonal variations, or easy removal during periods of exertion, such as when hunting or climbing.

According to Cosgrave (2000) knowledge of Egyptian life and clothing was more preserved than any other culture between the Roman and Gothic period due to environmental factors such as dryness of soil and hot climates. The excavation of Tutankhamun's tomb by archaeologist Howard Carter revealed many well-preserved garments, including a linen shirt dating back to 1,360 BCE.

Beals and Hoijer (1961) state that there is positive evidence that tailored textile garments occurred amongst the Chinese who appeared to have adopted their style of clothing and techniques from Nomadic Mongols. As noted previously, the Chinese began to use silk for clothing around 7,000 years ago (Chang, 1986 in Gilligan, 2007).

As early as 12,000 years ago prehistoric Indians who lived in shelters in the dry bluffs of northwest Arkansas North America, made clothing from plants, animals and minerals. The dry bluff conditions enabled the survival of many examples of even the most fragile articles of clothing. These consisted of leather or woven grass breech cloths, and women's skirts made of deerskin or mulberry cloth (Old State House Museum Arkansas, 1994).

Other evidence of the existence of woven material used for clothing is the finding of part of a linen skirt, in Turkey dated to the 7th millennium BC. It is also reported that the Chinese used thick mulberry paper for clothing as early as the 6th century BC (Fagan, 2004). Drury (1999) states that between 10,000 and 5,000 BC in Mesopotamia early settlers cultivated a variety of plants such as hemp, rush, papyrus, palm, and particularly flax and domesticated sheep and goats which provided them with linen and wool for their clothing and other items.

Another fascinating insight into the nature of clothing worn in a period in history which encompassed the transition from the Stone Age to the age of metal, and has also provided archaeologists and historians with additional information, is that of the finding of a clothed body buried in glacial ice some 5,300 years ago. A body given the name Otzi was discovered in the Otztal Alps (Austria) during 1991 (Casasnovas, 2001; Kritzon, 2006). Trapped in ice, the state of preservation of the body, clothes and implements, provided researchers with a unique view of what life may have been like for humans living during Neolithic times in Europe's cold mountainous areas. The clothing discovered included; a fur cap, an upper garment made of pieces of fur stitched together, a pair of leather leggings believed to have been held in position with a belt, a soft leather loincloth and leather shoes lined with grass cords, and it has been suggested that a form of sewing was being carried out over 5,000 years ago (Spindler, 1994). Spindler notes, however, that it is remarkable that no woven materials were found in the Ice Man's clothing in view of knowledge now available of clothing worn at that time. Spindler questions whether the clothes found on the Ice Man were the customary clothes of the time or clothing designed for a specific journey such as a prolonged absence in the high mountain wilderness.

Norris (1999), notes that primitive weaving instruments were found dating back to the Bronze Age (3,000 BC to 600 BC) indicating that the art of weaving was known at this time in parts of Europe. Gilligan (2007) cites Aikens and Higuchi (1982) who report that textile fragments and parts of wooden looms were found at the Toro site south west of Tokyo, which Gilligan suggests indicates a transition to full-scale farming approximately 2,500 years ago in Japan. Gilligan asserts therefore that textile farming and cultivation may have been adopted by humans when their basic needs expanded to include both clothing and food. Fagan (2004), states that from 2500 BC in South America, cotton was grown, and cloth was also made from llama, alpaca and vicuna wool, with the finest quality of woven cloth reserved for the Inca Kings and the Gods. As time progressed, however, it is apparent that clothing became more than just a covering for the human body, once it also embraced numerous social and cultural aspects of societies.

Philosophy of clothing

From earliest recorded history, the literature suggests that some form of covering, consisting of skins or fleeces of animals, plaited grasses, leaves or feathers, or a combination of any of the above, was used as a form of clothing, for protection, comfort, and cultural expression. While the term clothing, in its broadest sense, refers to coverings of the human body, it also encompasses other terms used universally, such as dress, garment, apparel and costume. Costume, for example, is defined by Boucher (1967) as being derived from the Italian word meaning 'custom or usage'. Additionally, Johnson et al., (2003) cite Crawley (1912) who states that the terms dress and clothing are used interchangeably. Another term that is invariably associated with clothing is that of fashion. However, since clothing existed far in advance of the notion of fashion, for the purposes of this study, clothing and fashion will be addressed as separate entities as far as practicable. The traditional use for clothing was undoubtedly to protect the body from extreme environmental factors such as heat and cold and to provide protection from insects and abrasive surfaces such as those found in cave dwellings (Beals and Hoijer, 1961). Langner (1991) suggests that the reason for wearing clothes was the need to become separated from the rest of the animal world. Couper (2008) cites Gilligan (2007) who claims that the wearing of clothing sets us apart from nature, literally and figuratively.

Certain styles of clothing also evolved within some cultures for the protection and promotion of modesty and for social, political, or occupational status (Beals and Hoijer, 1961). Another purpose for clothing according to Langner (1991) was to give a feeling of moral safety, and guard sexual areas from 'bewitching forces'. Various cultures almost certainly would have worn specific clothing for religious ceremonies (Beals and Hoijer, 1961), and social functions as is the case today in many parts of the world.

From a biblical perspective, Richards and Richards (1912), referring to the historical period designated as the 'Garden of Eden,' state that the most perplexing problem for women in that era was what could they clothe themselves with? The authors also assert that initially the main purpose for wearing clothes was to protect the body from the gaze of others, and only later for protection of the body from environmental elements.

In later eras three particular elements have been identified and include concealment relating to modesty and sexual attraction, decoration, and protection (Crawley, 1912). Cultural theorists and clothing analysts put forward reasons similar to Crawley but also add elements such as utility, and adornment (Jenkyn Jones, 2005), and more complex factors such as: 'symbolic differentiation, social affiliation, psychological self enhancement and modernism' as noted by Sproles, (1979) (in Jenkyn Jones, 2005 p 24). Other writers have included reasons, such as the prevailing attitudes towards morality and/or the need to satisfy the customs of the era or period (Beals and Hoijer, 1961). It can be argued that all of the above features play a role to a larger or lesser degree in the area of female clothing/fashion today.

Literature on the origins of clothing from early modern man to the present day shows a vast array of 'morphological transformations' of female garments (Shamuhitdinova et al., 2009) which have presented a diverse range of body types and shapes (Dorner, 1974). One reason for the variety in clothing styles may be attributed to the limited knowledge and skills of a particular era (Beals and Hoijer, 1961). Such degrees of experience, together with the state of technological progress at the time, would have played a major role in determining the cut and fit of clothing for the female body (Boucher, 1967; Dorner, 1974). Availability of suitable materials, lifestyle and climate would also have imposed limitations on what women could or should wear (Beals and Hoijer, 1961; Gilligan, 2007). A further impact on what women might have chosen to wear can be attributed directly to influence of the prevailing fashion trend (Dorner, 1974; Robinson, 1989; Jenkyn Jones, 2005).

Fashion defined

Fashion, as distinct from clothing, differs in that it is not static, but is in a constant state of change or flux (Young, 1937 in Johnson et al., 2003). Fashion has been defined as the latest trend in clothing which may incorporate aspects such as style, morphological shape, colour, hair, make-up and accessories (Dorner, 1974; Jenkyn Jones, 2005). Wilcox (2008) describes fashion as the 'Goddess of changeable whims', and asserts that there is nothing new in fashion and that it is only the modern interpretation of an earlier trend that makes it so. In a broad sense, fashion is claimed to provide an external manifestation of human behaviour in civilised human societies for short periods of time (Beals and Hoijer, 1961). It also influences, and is influenced by social and economic factors (Kybalova, et al., 1970). Fashion has been referred to as trends set by leading fashion designers and fashion houses or sometimes influenced by movies (Hirschhorn, 1983). It may also relate to the social status of the wearer (Beals and Hoijer, 1961) and incorporate current popular trends and styles resulting in many cases in a total look that may encompass colour, accessories such as; hats, gloves, shoes, makeup and hair styles (Jenkyn Jones, 2005).

DeBrohun (2001) puts forward the view that fashion can be described from four different perspectives; the first being a 'momentary instance' of fashion, the second being innovations that are more lasting than a 'fad', the third being a rapid and frequent change of styles with new fashions replacing old ones quickly, and lastly adornments that provide a total look, such as hair styles, jewellery, and cosmetics to enhance the wearers appearance.

Richards and Richards (1912) claim that clothing for women over time became a complex issue once the consideration of apparel shifted from an emphasis on appearance, durability, suitability and cost, to a point where women were willing to become veritable slaves to custom and fashion. At the present time, when leading fashion designers and fashion houses from Paris, Rome, London and New York present their collections twice yearly, these events attract worldwide interest (Robinson, 1989; Jenkyn Jones, 2005). Media attention and coverage is extensive, ranging from television news reports, daily newspapers, weekly periodicals and magazines. Such reports are also eagerly awaited by fashionistas or those otherwise involved both directly or indirectly in the fashion industry (Robinson, 1989).

The rise of fashion in the area of clothing is purported to have began between the 10th and 14th century (Wilcox, 2008). According to Dorner (1974) the earliest fashions comprised a sequence of varying shapes of clothing that evolved once the art of fitting a garment to the body contours was mastered.

An interesting example of how the external female morphological shape has changed over the centuries in different historical periods, as a result of undergarments which shaped the body to accommodate the fashion trends of the era from 1666 to 1870, is shown by Palmer and Alto (1998), (Figure 20)

Figure: 20 Fashion trends and external female morphological shape 1666-1870 (modified from Palmer and Alto, 1998)

It can be seen that the external morphological contours changed considerably from an unnatural distortion of the body to a more relaxed natural body contour from 1880 to 1954 (Palmer and Alto 1998), (Figure 21).

Figure: 21 Fashion trends and external female morphological shape 1880-1954 (modified from Palmer and Alto, 1998)

There is a vast amount of literature on fashion trends over time. A 2006 reprint of Auguste Racinet's *The Complete Costume History* originally published in 1888 provides a comprehensive and superbly illustrated historical reference of fashion over time for many cultures (Miller, 2006).

Fashion trends which can be traced from the 1500s prevailed to the turn of the 19th century and into the early 1900s and were influenced almost entirely by the upper echelons of society, as for example decrees by royalty or trends set by the aristocracy, and the ruling classes (Ewing, 1978; Langner, 1991). One such decree was made by the French Queen Catherine de Medici (1519-1589) who declared that a waist measurement of 13 inches (33 cm) was a requirement for ladies in her court (Banfield, 2000). Simons (1933) also refers to the edict by Catherine de Medici, and states that to attain a 13 inch waist measurement, women wore steel corsets which resulted in substantial discomfort. Simons also commented that when women's fashion and comfort compete, fashion will always prevail.

Whether as a result of decrees or not, corsets had become standard wear for women in society from about the 14th century and continued to be worn up to the 20th century. Leighton (1874) argued that wearing a corset was unequivocally harmful as it not only changed the natural morphological shape of the female body but also contributed significantly to various health issues due to the extreme tightness which encircled the body, restricted the blood flow, interfered with the nervous system, and displaced vital organs (Figure 22 A and Figure 22 B).

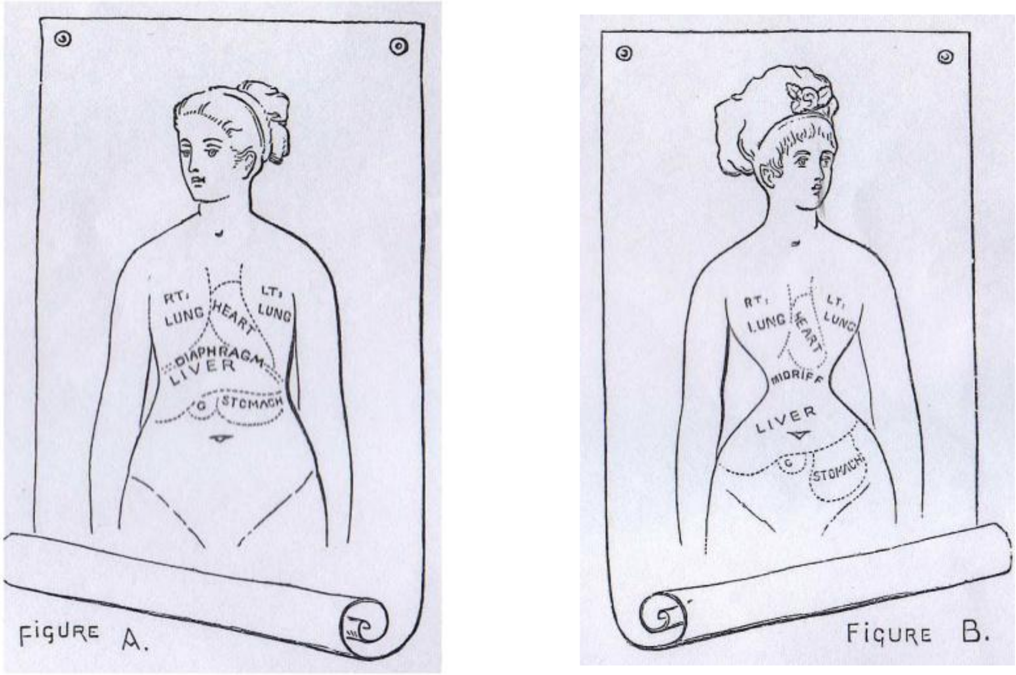


Figure 22: (Figure A) shows normal placement of vital organs, and (Figure B) shows the potential displacement of the same organs when a tightly constricting corset is worn (Leighton, 1874)

Richards and Richards (1912) supported Leighton's argument and noted that not only were the vital organs displaced but also the bony structures of the rib cage. Figure 23 (A) shows the normal position of rib cage and vital organs whilst Figure 23 (B) shows displacement of ribs and vital organs, resulting from the wearing of a very tight corset.

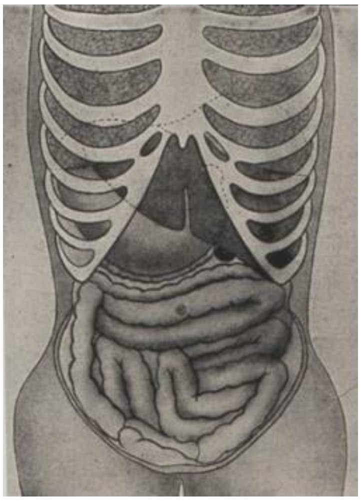


Figure 23 (A)
Normal position of ribs and vital organs
(Richards and Richards, 1912)

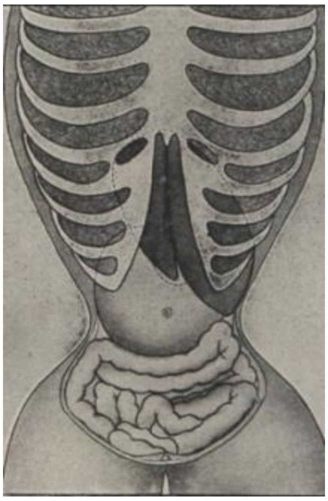


Figure 23 (B)
Displacement of ribs and vital organs
(Richards and Richards, 1912)

In addition to the distortion of internal organs it was also reported by Riolanus and Guilleman, two eminent French physicians, that the corset permanently affected the bony structure and symmetry of the body (in Leighton, 1874). These physicians claimed that nearly all French girls from upper class families of that period who wore tightly laced corsets developed a curvature of the spine (scoliosis). Additionally, the right shoulder of the girls affected was generally found to be higher than the left, due to the constrained use of the right arm (Leighton, 1874; Banfield, 2000). Figure 24 illustrates the spinal scoliosis and distorted shoulder line.

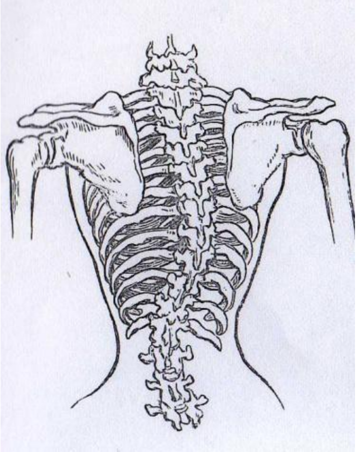


Figure 24: One effect on the vertebral column as a result of wearing a tight corset (Leighton, 1874)

The willingness of females to submit to such unnatural distortion has been traced back to the 18th Century BC. Boucher (1967) refers to the finding of a gold and ivory statuette of a Serpent Goddess wearing a corset formed by a framework of metal plates. This artefact is thought to depict the typical dress of the late Minoan culture (Figure 25).

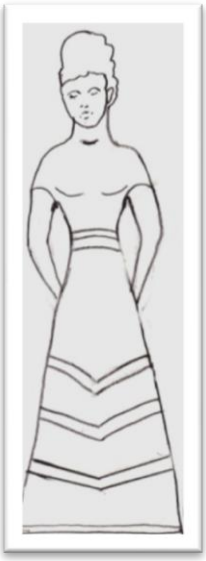


Figure 25: Minoan Serpent Goddess with corset of metal bands (modified from Boucher, 1967)

Banfield (2000) similarly reports that in the 7th century BC, the Samos Islanders wore a graded series of tight metal belts around their lower waists (Figure 26).

Figure 26: Graded tight metal belts worn by the people of Samos in 7th Century BC (modified from Banfield, 2000)

Langner (1991) also refers to the practice by females in Crete around 5,000 years ago of wearing wide metal girdles or bands that encircled the waist which he suggests became the ancient prototype of the ‘wasp waist’ of the late Victorian era.

Despite the discomfort and the possibility of health damage, figure altering garments such as corsets, (the earliest forms of which comprised heavy stays of whalebone, wood or metal), continued to be worn by females in all levels of society as a matter of course and to radically alter the natural size and shape of the bodies of the wearers (Hamilton Hill and Bucknell, 1969; Ewing, 1978; Peacock, 1993). By the middle of the 18th century, however, doctors, philosophers and reformers had begun to campaign against these practices on the basis of the harm they caused to the body of the wearer (Kybalova et al., 1970).

As early as 1874, Leighton was so incensed at the physical harm caused to women of his era by corsetry, that he likened English women who wore corsets to fair prisoners whom he described as being locked up in whited tombs, outwardly beautiful but inwardly full of ‘death and bones’. In another colourful phrase Leighton condemned the corset as an instrument of body torture (Leighton, 1874).

Not only were corsets considered to be physically harmful, but they were also claimed to have had a significant effect on academic performance! In a study of young college women in the early 1900’s, it was reported that of a class of 35, three quarters of those who took honours did not wear corsets, and moreover, of those who were awarded prizes for essays, none wore corsets (Hall cited in Mc Bride, 1903).

Other garments worn by females with figure altering characteristics include bras, step-ins and panty-girdles, corselettes and the more modern bustier. Hard’s Year Book for the Clothing Industry (1954) strongly advised that when assessing female figure proportions the effect of such undergarments must be taken into consideration. The author stated that it is important for cutters and pattern makers to be aware of the changes in specific areas of the figure resulting from the wearing of certain controlled undergarments, and strongly asserted that these changes will affect the pattern making process and the fitting of garments. Figure 27 for example, shows the lateral, anterior and posterior view of a female figure from the Hard’s Year Book for the Clothing Industry (1954). Figures 1 and 2 illustrate the changes from the natural position of the bust (slashed lines 1 and 6) to the altered position of the bust (solid lines 2 and 7) which can occur after adjustment of bra shoulder straps. Of particular note is the resulting difference in the length between the bust prominence’ and the back waist curvature (3) as can be seen in the difference between lines 1 to 3 and 2 to 3. A second example in Figure 27 (lateral view) relates to the lower segment of the body. As can be seen at (4) and (5), the change in shape brought about by the undergarment (solid line) has caused a reduction in the abdominal curve and buttocks and contours of the hips (8) and (10) with the dashed line indicating the natural figure. Figures 4 to 5 (in Figure 27) further illustrate this point and show variations that can occur with a figure with an average bust and one with full and heavier bust.

Any changes which improve the natural body shape whether caused by figure altering garments that may affect the bust position or an increase in breast size present a significant ongoing challenge for designers and pattern cutters.

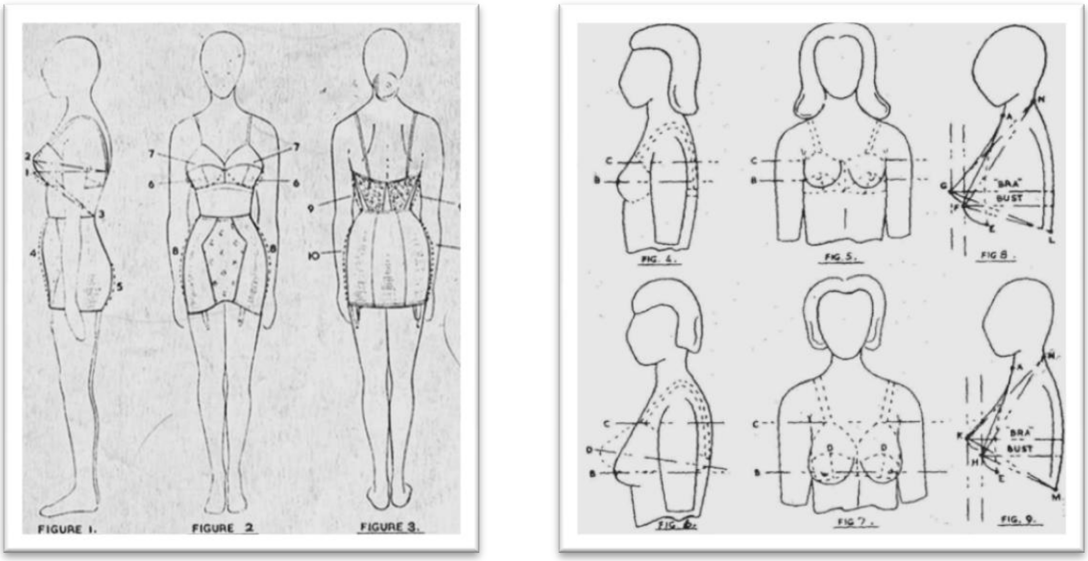


Figure 27: Female figure from lateral, anterior, and posterior aspect showing figure altering effect of wearing undergarments (Hard's Year Book for the Clothing Industry, 1954)

At the present time, the external shape and form of females, continues to be modified by choice, although not as drastically as with our female (and male) forebears. The more common practice today is for adult females to wear undergarments made from firm elasticised body shaping fabrics which pose fewer health issues.

Of particular interest in the area of female undergarments, is a specific emphasis on the bra. This is reflected in the recently reported trend of an increase in bust size (Fisher, 2010) and the earlier identification of specific shapes of female breasts, and the associated need for larger sized bra cups reported by Victoria's Secret ([TC]^2, 2006).

The *Daily Mail* (2007) reported that in the UK, Marks & Spencer introduced J cup fittings for slender figures, whilst Selfridges have produced a larger size cup for the slender figure referred to as a K cup range, and Debenhams, a KK cup range. Figure 28 shows a female wearing a J–Cup bra, whose figure may be classed as slender (*Daily Mail*, 2007).

Figure 28: Marks and Spencer's J-cup revolution (*Daily Mail*, 2007)

Table 1A illustrates changes in female body dimensions in Australia over the period of about 75 years between two large studies conducted in this country.

Table 1A: Comparison of body dimensions in Australia: 1926 (Berlei survey) and 2002-2003 SHARP Survey

Measurements (mm)	Year		% Increase
	1926	2002	
Height	1611.1*	1625.8#	0.9
Bust circumference	880.1*	1009.7+	14.7
Waist circumference	723.1*	878.1+	21.4
Hip circumference	1018.3*	1099.6+	8.0

***Lancaster (1957), #Henneberg and Ulijaszek (2010), + Veitch et al. (2007)**

The results show 14.7% increase in bust circumference but only 0.9% in body height. This increase is about fifteen times more than the increase in body height, which indicates a clear change in body shape. Waist circumference increased even more (21.4%), which suggests increasing weight, but with only 8.0% increase in hip circumference all these results clearly show major changes in body shape and not only in size.

The trend of an increase in bust size has attracted considerable media attention with reported comments by doctors, dieticians and retailers in relation to potential causes. Dr Stewart Hart a breast and oncology specialist at Monash University Australia is reported as saying that the increase in breast sizes in the last 10 years parallels the general increase in population weight, and that as breast tissue is largely made up of fat, it follows that an increase in weight will result in an increase in fat tissue of the breasts (Power, 2010).

On the other hand Fisher, (2010) refers to the effect of xenoestrogens as a possible cause of the increase in breast size and early onset of puberty in girls. Dr Ian Fentiman, professor of surgical oncology at Guy's, King's and St Thomas' School of Medicine in London is quoted in Fisher (2010) as saying that a possible exposure to xenoestrogens at a young age may be implicated, as the young breast is sensitive to a variety of stimuli. Dr Fentiman is also reported as saying that there is evidence of relatively young women having had exposure to a variety of mutagens and whose bodies have shown a response to many of these.

Power (2010), questions whether bra cup sizes may not have been large enough in the past, but also notes that retailers such as Karen Edbrooke, owner of Big Girls Don't Cry Anymore, report that there has been a huge growth in the number of young girls wearing a size 6 to 8 garment but requiring larger bra cup sizes as high as 8J. Power also notes that market research conducted by retailers highlighted the need to produce a range of larger fitting cup sizes to cater for the reported trend of smaller framed, narrow backed females, having larger breasts than would have been the norm 10 years ago.

Smaller framed, larger busted females are now being catered for with attractive comfortable and feminine bras that have larger cup sizes. As a result of the new ranges of expanded cup sized bras, retailers have reported significant increases in sales and in some cases have doubled their sales in the financial year period 2008-2009 (Power, 2010). In addition, Australian swimwear fashion designer Natashi Tanti notes that due to market demand there is now a wider range of choices for customers requiring a fuller cup size, and that sales for cup sizes D to F have increased approximately 25% over the past three years (Tanti, 2011). Furthermore, Sea Elements (2011) and Waterlily (2011), both leading swimwear retailers, report that cup sizes in speciality fit D, DD, E and F fittings have increased considerably over the past 3 to 4 years with an increase in sales of more than 25%.

Additionally, females in this category have reported experiencing a positive boost to their self esteem and feeling more confident as a result, (Fisher, 2010). This is testimony to the powerful effect that properly fitting garments can have on the female psyche, particularly in regard to self esteem and confidence, which have long been an important issue for many women. The concept of body image is another aspect of self esteem and confidence and will be now addressed.

Ideal body concept

What constitutes an ideal body image? The world's leading fashion designers, and fashion houses, modelling agencies and advertising agencies together with the print media invariably choose to display their garments on a female body that is tall, slim (and waif-like) despite the fact that such a body shape is atypical, and represents only a very small segment of the population (Body Image and Advertising, 2008). It has been argued in recent years that the 'ideal body' unceasingly promoted by media and industry, is unrealistic, given that the reported BMI values of the most favoured models are in the range of 18 or below, and these models are reported to weigh at least 23% less than the average woman (Media Awareness Network, 2010).

This argument is also supported by reports of substantial increases in human female body size and shape that have occurred throughout the world in the last five decades (Berry and Henneberg, 1998). Moreover, Bougourd reports an increase of 14cm in the waist measurement of UK females over the past 50 years, and notes that as a result of less waist definition the average woman today is less curvaceous than females of the 1950s (Kemsley, 1957 in Bougourd 2005).

Feedback on the findings from online consultations conducted as part of the National Strategy on Body Image (2009) indicates that the current cultural view which equates female beauty with thinness is considered by many to be detrimental, because such a view is contrived and unachievable for all but a small percentage of females. In this regard, Body Image and Advertising, (2008) cites Hamburg (1998) from Harvard who is reported as stating that the slim ideal reflected by the media, markets a misplaced desire, by reproducing ideals that are ludicrously out of line, do not reflect the reality of the true size and shape of females, and encourage unreal expectations and inevitable disappointment.

It was further reported that the fashion and advertising industry's promotion and marketing of 'thinness' as the ideal body image is having a negative impact on many females and has been implicated as a major contributor to increasing levels of depression (McCarthy, 1990), excessive and unnecessary dieting, and eating disorders in young women (Buist, 2000; Media Awareness Network, 2010) and middle aged and elderly women (Maine, 2005). It is of interest to note that a study conducted in 1989 showed that female college women were preoccupied with thinness and fitness at that time also. The authors claimed moreover, that this preoccupation was a direct result of media promotion of a thin body build as the ideal female figure (Spillman and Everington, 1989).

While there is now a growing outcry against the cult of thinness in the media, and so called 'plus-sized models', are being seen more frequently on the catwalks in some fashion capitals at the insistence of certain designers, there is still an ingrained preference for the tall thin 'clothes horse' because it is this type of figure which is considered to show clothes to best advantage (*Daily Mail*, 2006; Media Awareness Network, 2010).

It should be noted that what constitutes an ideal female figure can change considerably over time, and thinness was not always considered to be the ideal. Donohoe (2006) cites examples of changes in perceptions of the ideal female body in relation to weight and shape, and illustrates extreme variations in this area that include:-the rotund Venus of Willendorf of antiquity (Figure 29), the statuesque leggy flappers of the 1920's, the ultra-thin 'Twiggy'-inspired look of the 1960s, the 'heroin chic', and 'cachexia' of the 1990s.

Figure 29: Statue of Venus of Willendorf (modified from Donohoe, 2006)

Buist (2000) also draws attention to the changes in the notion of an ideal female form and compares the Rubenesque woman (in art) to the curves of Marilyn Monroe and the more recent emaciated appearance of models promoted in the media as images linking slimness to success. From another perspective, the statue of Venus de Milo (Figure 30) has often been cited as a naturally graceful and well proportioned female body. It is interesting to note, that the statue which has been universally admired for its natural well rounded shape, equates to a female of 160 cm in height with a waist measurement of 76.1 cm (47.6% of her height) (Richards and Richards, 1912).

Figure 30: Statue of Venus de Milo (Richards and Richards, 1912)

Another statue of interest is that of Venus de Medici, which is reported to have the most perfect female figure ever proportioned by man. Figure 31 shows the statue of Venus de Medici by Cleomenes whose measurements are reported as follows: height 5 ft 1 in (154.9 cm); bust 34 ½ (87.6 cm): waist 27 ½ (69.8 cm); hips 36 ½ (92.7 cm) (Simons, 1933).

Figure 31: Stature of Venus de Medici by Cleomenes (Simons 1933)

According to the measurements reported by Richards and Richards (1912), Venus de Milo was 160 cm in height, compared to Venus de Medici whose height was reported to be approximately 155 cm (Simons, 1933).

The ideal female body proportions which are thought to reflect the prevailing cultural view of female beauty at different times throughout history, and at the present time, have been reviewed. The following section addresses the development of various processes for clothing the human female body, one of which relates to the historical practice known as draping or modelling which had its origins far back in early history.

Draping and modelling

The oldest method of pattern designing according to Hillhouse and Mansfield (1948) is that of draping fabric to the human body. Armstrong (1987) defines draping as a form of sculpture, requiring the skilful use of the hands to mould the fabric to a model or dress stand. Draping is sometimes referred to as modelling (Stanley, 1972), or French modelling (Seligman, 1996) or sculpting with fabric (Jenkyn Jones, 2005). This technique was devised prior to the development of pattern cutting/making systems. It enabled the dressmaker in particular to produce close fitting highly complex designs which were the fashion until the early 1900s (Seligman, 1996). It is of interest to note that draping was also used by some of the early tailors as well as the dressmakers as a precursor to pattern cutting, and continues to be used to the present day by some couturiers, designers and professional dressmakers. The technique entails fitting and pinning fabric to a dress stand, fit model, or client to obtain a particular fashion style. Alternatively, fabric is pinned and fitted to make a *toile* for a design, or to obtain a 2-dimensional shape which can be then used to produce master blocks often referred to as slopers, or foundation patterns (Pepin, 1942; Stanley, 1972; Jaffe and Relis, 1973).

Gamber (1995) referred to draping as the ‘Pin to the form method’ which is shown in Figure 32, taken from an 18th century publication titled The Book of English Trades. The illustration depicts a dressmaker using the pin to the form technique, involving pinning paper or inexpensive fabric on the client’s body to obtain a pattern, which was subsequently cut out as a lining and refitted on the client.

Figure 32: Pin-to-the-form technique in The Book of English Trades (1827) (modified from Gamber, 1995 p 461)

The early dressmakers faced numerous disadvantages in comparison to their male counterparts, in acquiring technical knowledge and skills needed for cutting and making female garments. A major disadvantage for the dressmaker was limited access to drafting systems, as these were in most cases developed by tailors for the male tailoring trade in the early 1800s. Gamber (1995) notes for example, that dressmakers were denied access to 'male' skills which included the ability to draft patterns that could be modified to meet the needs of individual clients. An example of this is described in Zakim (1998) who cites Kidwell (1979) in that of 84 US patents issued for drafting systems prior to 1860, only four were related to women's garments.

A review of the literature indicates the importance placed on draping as shown by several master tailors and dressmakers, who strongly advise in their publications that knowledge and skills in draping and modelling should be obtained prior to the application of any pattern cutting system (Morris, 1940s; Pepin, 1942; Kunick, 1967). The authors above also stated that only when the novice tailor had acquired the necessary skills to drape the body with fabric and achieve an aesthetically pleasing result, should he or she proceed to the next step, which was to master the intricacies of garment cutting or pattern making systems. It could be argued on the other hand that the benefit of learning to drape prior to drafting will depend on the system of drafting and measurements used for that drafting process. This issue will be discussed further in the following section.

History of pattern engineering systems

The term 'system' defined by Hulme in Kunick (1967), denotes something that is based on sound reasoning, is able to be demonstrated, and has outcomes that are reliable, verifiable and replicable. In this literature review the term 'system of pattern engineering' will encompass terms such as: garment cutting, pattern cutting, pattern making, pattern drafting, patterning, the geometry of cutting and systems of cutting.

Various systems of pattern engineering have been developed over the centuries. However sources of information regarding these systems prior to the 1800s are limited. The earliest documented work on pattern cutting has been traced to Spain sometime during 1580, followed by publications in France in 1789, England in 1789 and in America 1809 (Seligman, 1996). The early authors of pattern cutting systems which began to emerge in the early 1800s were not without variety in their approach. Many writers formulated and published their own system which incorporated unique features. Some of the systems devised by the tailors and writers in this period include the following: Direct Measurement System, by Hearn in 1818; The Breast Measurement System, by Edward Minister in 1820; The Shoulder Measure System, by Otis Madison in1827 and by Thomas Oliver in

1845 (Poole 1927; Seligman, 1996); La Simplicite (Folding) Systeme, (Monahan, 1912) and The Proportionate Measure System, (Wampen, 1853, Wampen, 1864).

Other works associated with pattern cutting systems mainly published in the early 1900s include: *L' Art du Tailleur: Application de la Geometrie, a la coupe de L' Habillement*, (Compaing, 1828 in Aldrich, 2007); Drafting and Pattern Designing (The Woman's Institute, 1924); The Science of Pattern Construction for Garment Makers (Poole, 1927) and Ladies Garment Cutting and Making (Morris, early 1940s).

Additional types of systems have been referred to by Aldrich (2007) in the literature as 'Divisional' systems and 'Combination' systems, and by Kidwell (1979) as 'Proportional, or Hybrid, or based on Direct-Measure' principles. For a more detailed review, Seligman (1996) and Kidwell (1979) provide a comprehensive list of references in relation to pattern cutting systems.

Many of the earlier exponents of pattern engineering systems were of the view that garment cutting was both an art and a science (Wampen, 1864; Poole, 1920; Morris, 1940s; Kidwell, 1979). Monahan (1912) also stated that cutting is both a science and an art and asserted that for it to be effective constant thought, reasoning and the continual employment of technical skills is required. This view was also supported by Poole (1927) who described the art of cutting as a highly scientific endeavour. To illustrate his argument, Poole referred to current and earlier tailoring practices by comparing the thinking man of the time with the illiterate man of folklore, whom Poole believed had failed to use analytical reasoning.

Measure of a man

In earlier periods some cutters made use of notched parchment paper or leather to obtain a record of each client's dimensions. Each cutter had his own particular way of marking his measure, often by using his own hieroglyphics, which would have been difficult to interpret by another cutter. These measures were stored and retrieved when next required for the same customer. This practice enabled a bright apprentice to take the 'measure of a man' without the skills of reading and writing or the use of numbers (Kidwell, 1979; Zakim, 1998).

It could be argued, therefore, that a degree of 'illiteracy' may have been the driving force behind the resourcefulness shown by the early cutter and tailor. The use of notched parchment paper indicates that a considerable amount of thought had been given to finding solutions to overcome the barriers that illiteracy had imposed. The above is one example of the many techniques used by the early tailors before the arrival of the inch tape (Seligman, 1996).

With the emergence of the numerous documented and published cutting and pattern systems which evolved after the 15th century, it was generally the case that the methods and procedures associated with each were often very different (Poole, 1927; Kidwell, 1979; Aldrich, 2007). Faced with a myriad of choices, tailors reportedly sought the ideal system, despite the probability that a system created by one person can never completely satisfy the needs of another (Kunick, 1967). Another feature of some of the systems was that different sets of body measurements were required for each. This resulted in a lack of consistency between many of the systems in existence at any one time. Kunick also states that such inconsistencies were inevitable as there were no established standards of sizing. Moreover, he claims that as measurements used in cutting systems were obtained largely by trial and error, and since there was a lack of reliable data, this led to a preference for the proportionate drafting system and its continued use. Kunick also notes that measurements derived from the calculated proportionate system of drafting were hypothetical, as there had been no scientific surveys conducted in the UK prior to 1957 to confirm their validity. Therefore whilst the proportionate system continued to be popular, it had no reliable foundation. Despite this drawback Gamber (1995), notes that some proponents of proportionate systems claimed that these systems were able to fit many figure types ranging from ‘Venus de Milo to a Baboon monkey’.

Another reason put forward for the increased popularity of the proportionate measurement system is that it is based primarily on two main measurements, those of height and width, making it more acceptable due to what was perceived to be the unreliability of the tape measure (Wampen, 1853; Wampen, 1864; Poole, 1927; New South Wales TAFE School of Fashion, 1977).

Kidwell (1979) notes that all **but** the professional custom tailors relied on proportionable scales – a practice of obtaining all dimensions of a garment from one body measurement according to set rules of proportions. An example of this may be likened to the calculated proportionate system used by Wampen (1853) and the Pattern Making Metric S.I Method (New South Wales TAFE School of Fashion, 1977). In contrast, the professional custom tailors reportedly abhorred this practice and instead followed the principle of taking direct measurements on the body in the belief that when nature intervenes the figure is not proportional (Queen and Lapsley, 1809, in Kidwell, 1979). Custom tailors prided themselves on their ability to provide superior fitting garments, and for this reason may have opted to use the direct measurement system which enabled them to cater for human variation and individual characteristics of their clients (Kidwell, 1979; Zakim, 1998). It is interesting to note that as far back as 1933, a large volume of female garments produced using proportionate measurement systems required alterations that retailers claimed were far too costly, accounting for a large percentage of the annual turnover of women's apparel, which at that time amounted to millions of dollars. The retailers put forward the view that the number and the cost of alterations could be considerably reduced if a thorough study of misses and women's measurements were conducted (Simons, 1933).

As noted previously, the traditional manual method for obtaining clients' measurements, by tailors in the late 1700s and early 1800s, had been to use parchment paper or leather strips which contained each tailor's own hieroglyphic markings (Wampen, 1853). This practice eventually changed once the convenience of the inch tape and the tailors square was realised and both instruments came to be accepted by some tailors as a practical alternative. According to Seligman (1996), Giles cites a report by Atkinson, in which he states that he was the first person to use the inch measure and the tailors square. Atkinson also claims that the concept of applying a scale of inches to a tape, then subsequently to a wooden square, came about from a coincidence associated with instructions for measuring a foot with a tape to which a scale of inches was then applied. However, the use of the tape continued to be restricted by some tailors to as few measurements as possible as they distrusted the accuracy of measurements obtained in this manner.

Philosophy of the proportionate system

The philosophy of the proportionate system is based on the conviction that the human body conforms to rules of proportions. Poole (1927), notes that Dr Henry Wampen, a German Professor of mathematics and art exponent, played a major role in the development of a proportionate system of pattern cutting for the clothing trade. Poole (1920), states that the scientific formulation and approaches to systematic garment cutting can be attributed more to Dr Henry Wampen than to any other person, and that he should be acclaimed as one of the most influential and innovative contributors to systematic cutting for the clothing industry.

Various authors have reported that Wampen was approached by his tailor in the early 1800s to devise a scientific pattern cutting system for the tailoring trade (Carlstrom, 1905; Poole, 1927; Hard's Year Book for the Clothing industry, 1954; Kidwell, 1979; Seligman, 1996). Wampen's professed passion for art and his mathematical training were both strongly influential in the philosophy underlying his pattern cutting systems. He believed that the ideal human body form was one which portrayed a number of qualities, the foremost of which was proportionality. Like the neo-classicists he linked ideal proportions, with beauty, harmony, and symmetry.

Carlstrom (1905) suggested that Wampen was unique, in that he brought to his writings a fervent conviction that the ideal human form as portrayed in classical Greek and Roman Art was based on exact laws of proportions and symmetry. To this effect, Wampen (1864) postulated that artefacts from Grecian antiquity, the Egyptian and Assyrian eras and the classic Greco-Roman periods showed without doubt that artists of those times had a knowledge of 'geometrical science' (based on measurements of height and breadth) and had applied the laws which define the harmonious proportions of the human form. The pose of the male figure used to illustrate Wampen's theory strongly suggests the link with ancient Greco-Roman sculpture Figure 33).

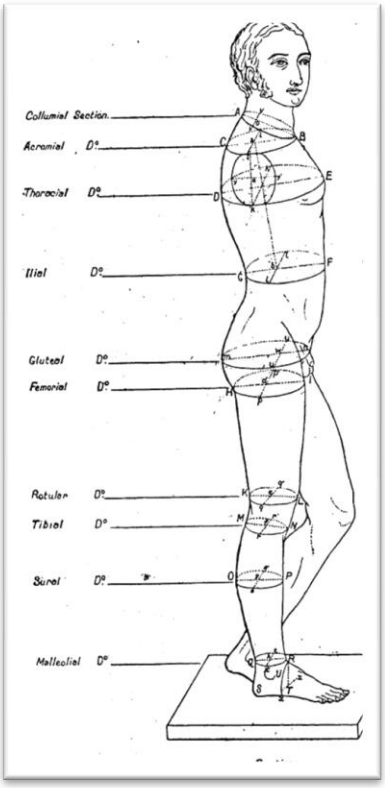


Figure 33 Wampen's model showing the link between Greco-Roman art and the early canons of proportions (Wampen, 1864)

Wampen's dedication and unshakeable belief in a theory of proportions based on the canons of artists from the classical eras, namely Polyclete (Polyclitus) whom he refers to in his text (Wampen, 1864) led to the publication of several highly technical and scientifically complex publications for both art and cutting design students (Kidwell, 1979; Seligman, 1996; Aldrich, 2007).

Wampen's major contribution to tailoring was to introduce and link three sciences: anatomy, anthropometry, and mathematics. Wampen particularly emphasised anatomy and anthropometry in his instructions. Wampen's philosophy was based on the conviction that students of cutting and design required a sound knowledge of the 'inward formation' of the human body in order to have an understanding of the external form. He also believed that nature should be observed closely in order to understand what he saw to be the fixed laws of proportionality which determine the development of shape and form in different species, particularly the human species (Wampen, 1853).

Wampen (1853) had a very strong bias towards describing the human body in terms of geometrically derived shapes, which he applied to specific sections of the body. Figure 34 illustrates Wampen's application of geometrical concepts in which he uses planes, triangles, and ellipses to show how to calculate proportionate relationships between sections of the body. He identified three types of human body forms on the basis of height and breadth, which he referred to as (i) proportionate, (ii) slender, and (iii) broad. Wampen's ideas on body proportions extended to the point of describing figures that did not fit within his perceived ideal as being absurd and even abnormal. For example, in relation to a man's height he considered the normal height to be 5'4", the greatest height to be 6'6", and the smallest to be 4'6". Wampen also labelled a person over 6'6" as a giant, and one under 4' as a dwarf (Wampen, 1853).

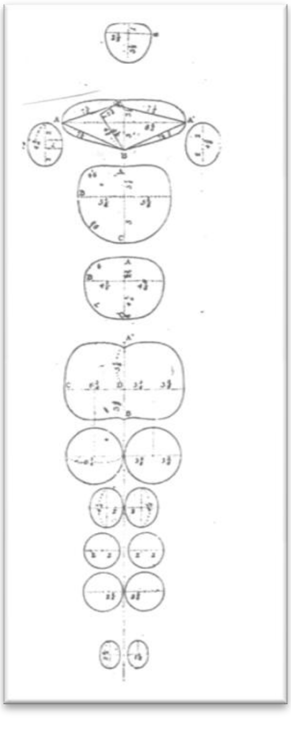
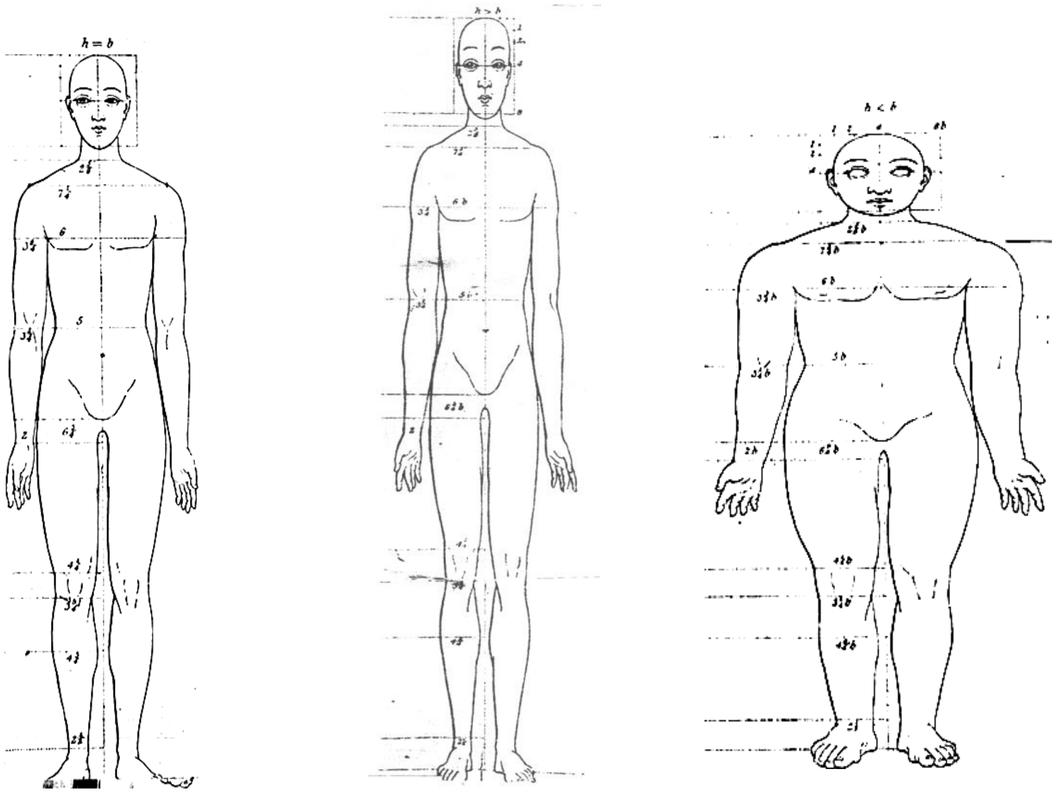


Figure 34: Wampen's application of geometrical concepts (Wampen, 1853)

It is interesting to note that Wampen provides two methods for identifying the proportionate human body form. The first of these which he called 'The Proportion Measure' specified criteria for proportionality consisting of a height to breadth ratio of 64:19 for males and a ratio of 64:16 for females, with the second number of each ratio representing one half of the thoracic circumference (Wampen, 1853). The technique involved folding a tape, or strip of parchment paper in two directions. The first series of folds represented the height (h) and the second the breadth (b) according to a set number of folds based on a precise ratio of height to breadth. To check if the criteria for proportionality were met, the resulting height unit had to equal the breadth unit. In this case the figure was deemed to a proportionate body form (h=b); if the height unit was greater than the breadth unit, the figure was deemed to be of a slender body form (h>b) and if height unit was less than the breadth unit the figure was deemed to be a broad body form (h<b).

Wampen's second method for identifying proportionality was a pre-determined series of proportional measures, which included a breast measure (from a small size of 10½ inches to a large size of 25 inches) as well as ground height, and total height across the range. Although Wampen (1853), referred his readers to Plate 1 in his text, he also provided numerical examples to illustrate what constituted the proportionate, slender and broad body forms. As a matter of interest, the researcher found that the examples did not correspond to the figure forms that they were meant to represent. For a more a more detailed explanation of the process, refer to Wampen (1853).

Figure 35 illustrates Wampen's three body forms of; proportionate, slender and broad. Wampen states that the slender and the broad form are presented in an exaggerated form, and also emphasises that this was necessary so as to make a strong impression on students, and that human figures of these types are not found in real life.



Proportionate Slender Broad

Figure 35: Wampen's illustration of three body forms: Proportionate, Slender and Broad (Wampen, 1863)

As noted above, Wampen used height and breadth to ascertain if a figure was proportionate. In relation to the human female body form, he gave instructions for taking a bust measure, but it is interesting to note that the bust measure was not used to ascertain proportionality. In its place, Wampen used half the breast measure which is half the thoracic circumference and should be taken around the thorax, over the lower angle of the scapula, through the fovea axillaris, [sic] (close under the arm) and above the breast, then to the middle of the sternum. He described the method for taking the bust measure as similar to the breast measurement except that in the front of the body it is taken over the mammilla ([sic]) (the most prominent part of the breast) (Wampen, 1864).

The choice to ignore the bust measurement in testing for proportionality raises the question of how a figure can be deemed proportional while ignoring the fact that the bust measurement could be greater than breast measurement in some body forms by as much as 5 to 20 cm. It is possible that Wampen chose to present his system for pattern cutting as simply as possible, and this is borne out by his emphasis on instructions for the male body, with few modifications for the female body. It should also be noted, that reference has been made to the complexity of Wampen's Systems. Poole (1920), states that Wampen's systems were ahead of the times but were too obtuse and mathematical and only a few, other than his pupils were able to master his instructions. Aldrich (2007) refers to Wampen's use of graduated tapes which allowed for the incorporation of different heights and breadths, but noted that this process was too complicated to be understood by many tailors.

Wampen's philosophy and his system for calculating measurements based on human body proportions have been reviewed above. His philosophy and influence on pattern cutting systems from the early 1800s is of relevance to this study because Wampen's input in particular continues to be followed and modified by many advocates of the proportionate system to the present day.

Philosophy of the direct measurement system

The philosophy of a direct measurement system differs greatly from that of a proportionate system. As the name implies, all measurements are taken directly on the body and these specified key characteristics are far greater in number than those designated by a proportionate system. The strength of a direct measurement system lies in its underlying philosophy which is based on the belief that measurements taken on the body, and utilised in the drafting process provide a conceptual framework for analytical reasoning and problem solving, and lead to a deeper understanding of the drafting process. It also provides a direct link between the location on the body where the actual measurements are taken, and the application of those measurements to the construction lines of the draft (Berry and Hennes, 2008). More importantly, the direct measurement system is markedly superior to the proportionate system, in its ability to distinguish and incorporate individual aspects of human variation, particularly figure types which lie outside the criteria which define standard proportions (Kidwell, 1979; Zakim, 1998).

Historically, it has been accepted by many, that taking direct measurements is a process that is fraught with difficulties (Simons, 1933; Bye et al., 2006). For example, it has been argued that accurate measurements on the figure are difficult to take (New South Wales TAFE School of

Fashion, 1977). Additionally, there have been many reports of an entrenched mistrust of the tape measure (Poole, 1927; Morris, 1940's; Kunick, 1967; Kidwell, 1979). It has been noted moreover, that measurement-taking techniques are arbitrary, and are subject to technical error in the absence of reliable and valid specifications. There was no standardisation of measurement-taking procedures prior to the publication of ISO 8559 (International Organisation for Standardisation (ISO), 1989). To complicate the issue further, the literature shows that for many decades it was common practice for measurements to be taken over customer's outer clothing by tailors and dressmakers (Wampen, 1853; Devere, 1866; Monahan, 1912; Poole, 1927; Simons, 1933; Aldrich, 2007). This practice of measuring the body over outer clothing meant that specific body locations were obscured. Moreover the location of landmarks was often left to guesswork by the measurer (Aldrich, 2007). Other factors which have influenced the aversion for taking direct measurements are: imprecise specifications, (Winks, 1997), a lack of knowledge and technical skills (Berry and Hennes 2008), and a lack of confidence in using the tape measure (Kunick, 1967; Kidwell, 1979), all of which contributed to the preference for using a proportionate system of drafting.

Taking into consideration all of the above, it may be argued, that the ability to minimise technical error when taking measurements can be effectively addressed if a scientific process as proposed by Taylor (1949) is implemented. Taylor's definition of a scientific process is one that is based on accuracy and verifiability in particular, but which should equally be built on knowledge obtained from observations that are explicit and relevant. Applications of these principles particularly verifiability, and relevant and explicit observations, may enable many of the difficulties outlined above to be reduced substantially.

As stated previously, one of the aims of this thesis is to compare and evaluate two pattern drafting systems. The systems chosen were (i) a calculated proportionate system – The Metric S.I. Method (New South Wales TAFE School of Fashion, 1977) hereinafter referred to as MSI and (ii) a direct measurement system – The Fashion Design System (Berry and Hennes, 2008) hereinafter referred to as FDS. It is of interest to note that the former of these systems appears to have originated from the early works of Dr Henry Wampen.

Metric S.I Method (MSI)

MSI is a clear example of a pattern cutting/making system that has direct links to Wampen's work, which includes the assumption of human body proportionality and the relationship between height and width factors and their role in pattern construction. For example the human body forms illustrated in the MSI New South Wales TAFE School of Fashion (1977) manual have been directly attributed to Wampen, as shown in Figure 36. The average height and build figure type equates to Wampen's concept of a 'Normal' figure in relation to height and width factors.

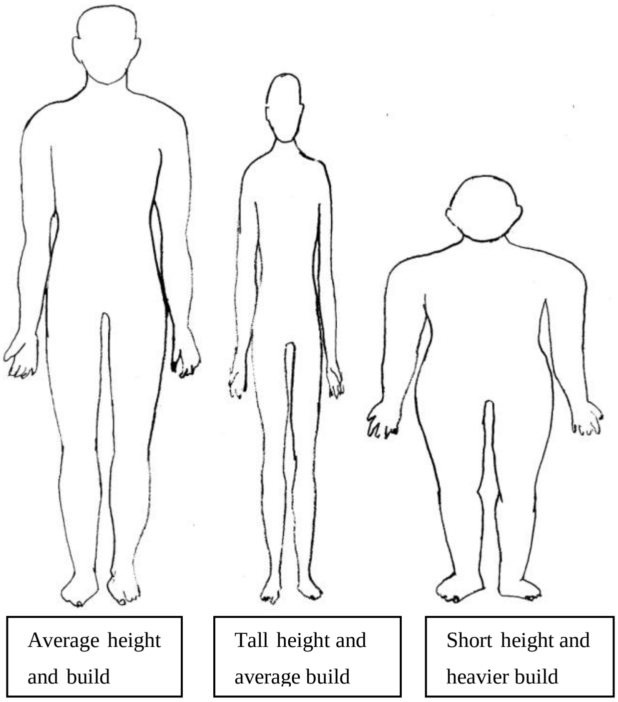


Figure 36: Wampen's human body forms (MSI) (modified from New South Wales TAFE School of Fashion, 1977)

In regard to Figure 36, there are several points of interest. The first of these is that the MSI Average height and build is described as representing Wampen's interpretation of the 'Normal' figure which shows height and width factors in a particular relationship. The MSI manual also states that satisfactory results are achieved by utilising the eight head height theory for back length, hip depth and underarm level when constructing patterns for this figure type. The 'Tall' height and average build is an example in which the height is greater than the width factor and represents a thin build. The short height and heavier build denotes the 'Fat' figure in which the width factor is greater than the height (New South Wales TAFE School of Fashion, 1977). It is interesting to note that each body form (in Figure 36) is represented in a specific Table of Standard Measurements. However there is an additional table titled "Shorter Height and Lighter Build" which bears no relationship to Wampen's three figure types.

The body form denoted as MSI Average height and build corresponds to the Table for Average Height and Build (Table 2).

Table 2: Table of Standard Measurements for Average Height and Build. (Height 158 cm-176 cm) (modified from New South Wales TAFE School of Fashion, 1977)

Height	158	160	162	164	166	168	170	172	173	174	175	176
Bust	80+8	84+8	88+8	92+8	96+8	100+8	104+8	110+8	116+8	122+8	128+8	134+8
Waist	59+2	63+2	67+2	71+2	75+2	79+2	84+2	88+2	95+2	102+2	109+2	116+2
***C.B**	39.5	40	40.5	41	41.5	42	42.5	43	43.25	43.5	43.75	44
Hip	85+5	89+5	93+5	97+5	101+5	105+5	108+5	113+5	119+5	125+5	131+5	137+5
***N - W**	69.8	70.4	71	71.6	72.2	72.8	73.4	74	74.3	74.6	74.9	75.2

***C.B (Length of back) * N - W (Neck to Wrist)**

The body form denoted as Tall height and average build (Figure 36) is closest to the Table for Taller Height and Average Build (Table 3).

Table 3: Table of Standard Measurements for Taller Height and Average Build (170 cm-178 cm) (modified from New South Wales TAFE School of Fashion, 1977)

Height	170	171	172	173	174	175	176	177	178
Bust	80+8	84+8	88+8	92+8	96+8	100+8	104+8	110+8	116+8
Waist	58+2	62+2	66+2	70+2	74+2	78+2	83+2	87+2	94+2
***C.B**	42.5	42.75	43	43.25	43.5	43.75	44	44.25	44.50
Hip	85+5	89+5	93+5	97+5	101+5	105+5	109+5	113+5	119+5
***N - W**	79.4	79.7	80	80.3	80.6	80.9	81.	81.5	81.8

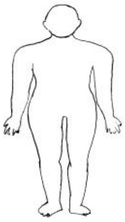
***C.B (Length of back) * N - W (Neck to Wrist)**

The body form denoted as Short height and heavier build (Figure 36) corresponds to the Table for Shorter Height and Heavier Build (Table 4).

Table: 4 Table of Standard measurements for Shorter Height and Heavier Build (152 cm-160 cm) (modified from New South Wales TAFE School of Fashion, 1977)

Height	152	153	154	155	156	157	157	159	160
Bust	84+8	88+8	92+8	96+8	102+8	108+8	114+8	120+8	126+8
Waist	66+2	70+2	74=2	78+2	85+2	92+2	99+2	106+2	112+2
***C.B**	38	38.25	38.50	38.75	39	39.25	39.50	39.75	40
Hip	90+5	94+5	98+5	102+5	108+5	114+5	120+5	126+5	132+5
***N - W**	66	67.3	67.6	67.9	68.2	68.5	68.8	68.1	69.4

***C.B (Length of back) * N-W (Neck to Wrist)**



A further point of interest relates to the acknowledged difficulty in obtaining a satisfactory underarm level measurement for MSI Tall build and MSI Short and Heavy build. It is stated in the MSI manual that the eight head height principle used to obtain the underarm level, which is ⅛ of height or ½ centre back length for the average proportionate figure, cannot be applied satisfactorily when constructing patterns for these two figure types. On the contrary, for MSI Tall build and MSI Short and Heavy build it is stated that a proportion of the bust area as well as a proportion of total height needs to be taken into account. The two different formulae for calculating the under arm level are described in Table 5. The method on the left, illustrates the use of the eight head height theory, and the method on the right shows the modified formula based on width and height for the ‘Short and heavy build’ and ‘Tall build’. It is interesting to compare the variation in the results obtained when calculating the underarm level measurement according to each formula.

Table 5: Proportions and calculation of under arm level based on height, or width and height (modified from New South Wales TAFE School of Fashion, 1977)

Proportion based on height principle (cm) **Formula: ⅛ of height or ½ back length (cm)**	**Proportion based on width and height principle (cm)** **Formula: (1/10 of bust) + (2/10 of back length) +3 (cm)**
Short and heavy build:	**Short and heavy build**:
Bust 84	Bust 84
Back length 38	Back length 38
Under arm level=19	8.4+7.6+3=19 Under arm level=19
Bust 102	Bust 102
Centre back length 39	Centre back length 39
Under arm level=19.5cm	10.2=7.8+3=21 Under arm level=21 cm
Bust 126	Bust 126
Back length 40	Back length 40
Under arm level=20cm	12.6+8+3=23.6 Under arm level=23.6 cm
Tall build	**Tall build**
Bust 80	Bust 80
Back length 42.5	Back length 42.5
Under arm level=21.2cm	8.0+8.4+3=19.4 Under arm level +19.4 cm
Tall build	**Tall build**
Bust 92	Bust 92
Back length 43	Back length 43
Under arm level=21.5	9.2+8.6+3=20.8 Under arm level 20.8 cm
Tall build	**Tall build**
Bust 116	Bust 116
Back length 44.25	Back length 44.25
Under arm level=22.12	11.6+8.8+3=23.4 Under arm level=23.4

Another aspect of the MSI method is the limited number of measurements taken directly on the body. These are: Body height, Bust, Waist, Hip, and Neck to wrist. It should be noted also that all width measurements are obtained by deductional calculations from the bust measurement, and all length measurements are calculated from the total body height. The height measurement is taken from the top of the head to the floor without shoes (Figure 37). It is apparent that the total height obtained in this manner does not take into account the anterior or posterior body contours or postural irregularities such as lordosis and kyphosis. In some instances this may affect length measurements such as, centre back which is calculated by taking one quarter of the total height. Another length measurement which may be affected is the centre front, which is calculated from the back length plus an extra allowance required for bust development.

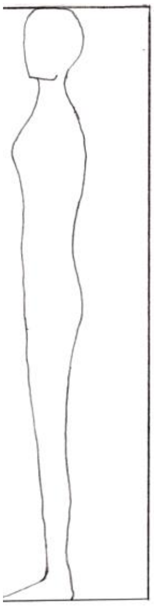


Figure 37: Method for measuring total height (modified from New South Wales TAFE School of Fashion, 1977)

The reliance on calculated measurements based on an assumption of a fixed relationship between height and width factors is questionable. The method of measuring the total height as a vertical line as opposed to measuring the body contours may provide only a close approximation of actual body dimensions. It is interesting to note that the method for taking the total height used by MSI is the same anthropometric process used by ISO 8559 (International Organisation for Standardization, 1989).

Figure 38 illustrates another height dimension referred to as cervical height, which is taken according to the method and procedure documented in ISO 8559 (International Organisation for Standardization, 1989). The measurement is taken from the 7th cervical vertebra and follows the rear contour of the spinal column to the hip level from where it falls vertically to the ground. It can be seen from the illustration, that the method for taking the cervical height clearly follows the upper body contours and thus provides an accurate representation of this region of the body. It is interesting that the importance of accuracy in taking direct measurements was also emphasized by Wampen (1853) who, despite his preference for calculating measurements based on height and width proportions, emphasised the importance of taking direct measurements accurately. As a matter of interest it is also noted that cervical height as described above (International Organisation for Standardization, 1989) is also referred to by Wampen who used the term ground height as opposed to cervical height.

Wampen's instruction for obtaining ground height was that the person to be measured stands upright, the tape is placed on 7th vertebra 'as exactly as it can be located through the clothing' the tape is led to the greatest depression above the sacrum, (which Wampen claims would be the natural length of the back), then to the heel of the boot, or sole of the foot.

Figure 38:Method of measuring height and cervical height (modified from International Organisation for Standardization, 1989)

The philosophies underlying both the proportionate and direct measurement systems have been addressed. The justification for relying on calculated deductional measurements on the basis that direct measurements taken on the human body are difficult to obtain accurately has been noted. The direct measurement system described in the following section however, acknowledges that scientific principles of anthropometry are essential for minimising technical errors when taking measurements and employs these methods accordingly.

Fashion Design System

The Fashion Design System (FDS) uses a direct measurement approach consisting of manually derived measurements obtained directly from an anthropometric survey of the Australian female population in which five figure type categories were identified (Berry 2001). The five figure type categories from Berry (2001) were marginally enhanced and colour coded for presentation in an educational textbook titled - The Fashion Design System (Berry and Hennes, 2008) as shown in Figure 39. In that publication, FDS utilises the five figure type categories with specifications for drafting a master block for each of the figure types. It is notable that each draft relates specifically to shape and the system does not incorporate a range of sizes within each shape category. The FDS system can be used for both the couturier as well as ready to wear garments. In the latter case Industry may use a shape category and apply its own size increments for grading patterns for its target market.

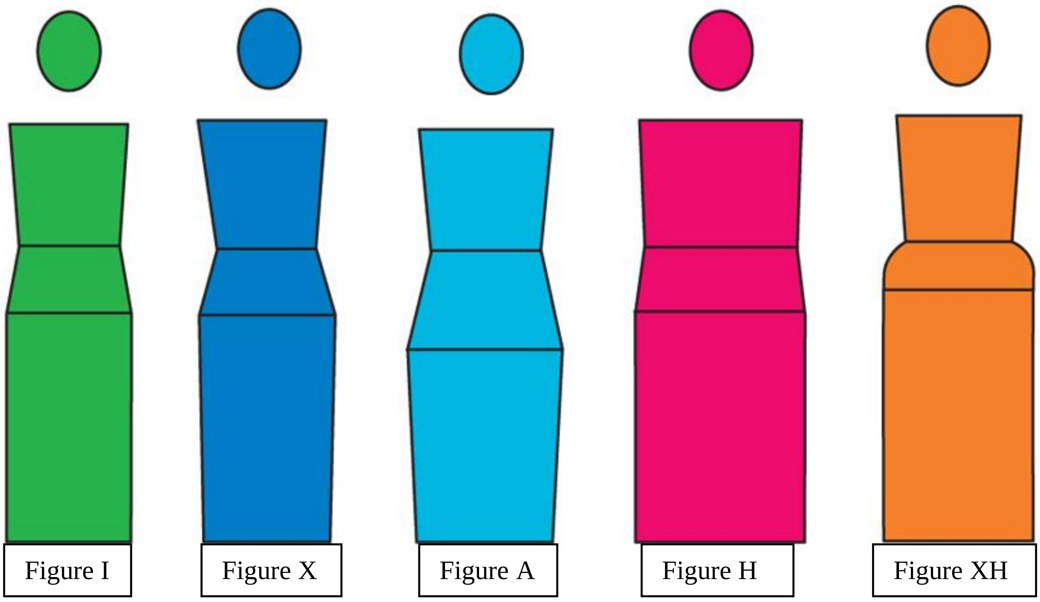


Figure 39: Five figure types (Berry and Hennes, (2008)

The benefits of the FDS system relate to the fact that it is able to address variation in human morphological characteristics of the female body. It is unique in that the instructions are transferable and cater for many varieties of the human female figure shape. The female body is not labelled with classifications such as those used by Wampen (1863) namely: proportionate, disproportionate, and abnormal or the categories labelled in MSI as normal, fat or broad. In contrast, while the FDS caters for figure types that are outside the range of average proportions, they are not given any negative or disparaging descriptions. As stated previously, the dimensions, measurements, specifications and construction lines of the draft are all interrelated, which leads to a greater understanding of the total pattern engineering process. This comprehensive approach and emphasis on anthropometric principles provides a conceptual framework for analytical reasoning and problem solving in many of the areas associated with pattern engineering and garment fitting. The application of anthropometric principles is now a worldwide phenomenon and numerous ways in which anthropometry has been applied will now be reviewed.

Anthropometric surveys

Anthropometric based research has been conducted over the centuries to obtain data for a wide range of fields which include:- anthropology (Henneberg and Ulijaszek, 2010), psychiatry (Kretschmer,1936), psychology (Sheldon et al., 1970), social sciences (Quetelet 1842 in Diamond 1969), human biology (Boyd, 1980), sports science (Norton and Olds, 1996) and organisations which include The World Health Organisation (2006), and Governmental agencies such as the Australian Bureau of Statistics (2009). Other areas in which anthropometric studies have been applied include; assessment of nutritional status, (National Health and Nutrition Examination Survey, 1988), ergonomics and workplace safety and design (Bridger, 1995), human engineering (Hertzberg, 1972) and the provision of data for clothing size standards (American Society for Testing and Materials, 1995; Australian Standards, 1959; Australian Standards, 1997).

Large scale anthropometric surveys were conducted primarily by the armed forces in the past. Gordon and Friedl (1994) cite Ordronaux (1863) as evidence that anthropometric studies in America date back to the civil war. Military studies were used to obtain data in relation to stature, weight and body mass index (BMI) of personnel and for the identification of health issues such as tuberculosis for use in the selection process of recruits for the armed forces. Surveys of the armed forces for the 21st century were carried out not only for selection and health issues but also a wide range of applications such as, retention, physical performance, effective use of military workstations, protective clothing, military hardware and clothing sizes (Hertzberg, 1972).

Military surveys however, are limited in that they are population specific and therefore the data cannot be extrapolated to the civilian population in general (International Organisation for Standardisation, 1991). Gordon and Friedl, (1994) compiled a list of traditional surveys by the American military (as shown in Table 6) which give an indication of the ongoing need for current data relating to various military personnel over a 120 year period from 1861 to 1988.

Table 6: Anthropometric surveys of US military populations (modified from Gordon and Friedl, 1994)

Reference	Survey -year	Population	Sample size
Gould (1869)	1861-1865	**Volunteers**	1 232 256
Baxter (1875)	1863-1865	Draftees	501 068
Davenport and Love (1921)	1971 [sic]-1918	Draftees	1 961 692
Davenport and Love (1921)	1919	Separatees	103 909
Newman and White (1951)	1946	Army Men	105 062
Randall and Munro (1949)	1946	Army Women	8 859
Hertzberg et al., (1954)	1950	Air Force Flyers	4 063
Gifford et al., (1965)	1964	Navy Flyers	1 549
White and Churchill (1971)	1966	Army Men	6 682
White and Churchill (1978)	1966	Marines	2 008
Grunhofer and Kroh (1975)	1967	Air Force Flyers	2 420
Clauser et al.,(1972)	1968	Air Force Women	1 905
Churchill et al., (1971)	1970	Army Aviators	1 482
Churchill et al., (1977	1977	Army Women	1 331
Gordon et al., (1989)	1988	Army Men	5 506
Gordon et al., (1989)	1988	Army Women	3 491

Similar lists have been compiled by Robinette (1997) which also include studies of civilian populations, several of which have been carried out in countries other than the USA. Robinette notes that her lists of selected studies illustrate the frequency and well documented reliance on anthropometric data and she describes also the wide range of applications, for which this type of data are required. Such areas described by Robinette include: clothing and equipment systems, automobiles and work spaces, occupational safety and health, and human growth and development'. It is of interest to note that in the lists compiled by Robinette (Table 7) that far fewer female studies were conducted in the time period reviewed, even in the area of military personnel.

Table 7: Selected anthropometric surveys: Adult males and adult females (modified from Robinette, 1997)

Reference	Survey -year	Population	Location
Hertzberg et al., (1954)	1950	Air Flyers	USA
White (1961)	1959	Army Aviators	USA
Hertzberg et al.,(1960)	1959-1960	Military Personnel	Italy, Turkey and Greece
Snow and Snyder (1965)	1960-1961	Air Traffic controllers	USA
Stoudt et al.,(1965)	1962	**Civilian**	USA
White (1964)	1963	Military Personnel	Vietnam
Gifford et al., (1965)	1964	Navy Aviators	USA
Hart et al., (1967)	1965	Military	Korea
Kennedy (1986)	1965	Air Force Personnel	USA
White and Churchill (1966)	1966	Army Personnel	USA
Kennedy 198 [sic]	1967	Air force Aviators	USA
Grunhofer and Kroh (1975)	1968	Air Force Personnel	West Germany
Dobbins and Kindick (1972)	1965-1970	Military Personnel	Latin American Countries
Jurgens et al., (1972)	1970-1971	Military	West Germany
Churchill et al., (1971)	1970	Army Aviators	USA
Bolton et al., (1973)	1970-1971	Air Force Aircrew	UK
Yokobori (1972)	1971	Air Force	Japan
Anonymous	1973	Military	France
Gooderson (1982)	1972-1975	Army Personnel	UK
Martin (1975)	1973-1974	Law Enforcement Officers	USA
McCann et al., (1975)	1974	Military Personnel	Canada
Yanagisawa (1974)	1974	**Civilian**	Japan
Gooderson (1982)	1976	Transport Corpsmen	UK
Stewart (1985)	1985	Military Aircrew	Canada
Brekelmans et al., (1986)	1985	Military	The Netherlands
Gordon et al., (1989)	1988	Army Personnel	USA
Hooper et al., (1991)	1986-1990	Navy Personnel	UK
Ignazi (1992)	1990-1991	Military Personnel	France
Jones et al., (1993)	1992	**Civilian**	UK

Selected anthropometric surveys: Adult females (modified from Robinette, 1997)

Reference	Survey -year	Population	Location
O'Brien and Shelton (1941)	1940	**Civilians**	USA
Randall et al., (1946)	1942	Army Pilots and Air Force Nurses	USA
Randall and Munro (1949)	1946	Army Separatees	USA
Sittig and Freudenthal (1951)	1951	**Civilians**	The Netherlands
Kemsley (1957)	1951	**Civilians**	UK
Stoudt et al., (1965)	1962	**Civilians**	USA
Clauser et al., (1970)	1968	Air Force Personnel	USA
Yanagisawa (1974)	1974	**Civilians**	Japan
Churchill et al., (1977)	1977	Army Personnel	USA
Gordon et al., (1989)	1988	Army Personnel	USA
Mellian et al., (1990)	1988	Navy personnel	USA
Jones et al., (1993)	1992	**Civilians**	UK

Anthropometric surveys of the civilian female population

As noted above, very few comprehensive anthropometric surveys of the female civilian population have been conducted over the past century. From the point of view of this study, data of the female population are essential, particularly for the design and production of female garments. Numerous contributory factors can be put forward as possible causes of such an omission. For example, traditional methods of data collection used manual devices such as tape measures, callipers, or an anthropometer. Use of such devices required extensive training in applied anthropometry for a team of anthropometers to ensure that accurate and consistent data were obtained (O'Brien and Shelton, 1941; Board of Trade UK, 1957). As a result, traditional surveys were time consuming, costly, and labour intensive (Jones et al., 1989). Given the lack of survey data, it is of interest to note that Australia was reported to be the first country to carry out a large scale anthropometric survey of the female population.

Australian anthropometric clothing survey: 1926-1928

The Australian company, Berlei, a Sydney based manufacturing firm, conducted a survey in Australia from 1926-1928 to ascertain the size and shape of Australian women for the production of Berlei foundation garments. In the absence of other published data, Dr Lancaster, from the School of Public Health, was invited by the directors of Berlei to prepare the data for publication, as there had been several requests from manufacturers for access to the Berlei data. Some 5,000 women participated in the survey in which 26 measurements were taken. Measurements were taken with the subjects wearing a bathing costume. The age group of the subjects ranged between 15 and 65 years. Although attempts were made to survey a representative sample of the Australian population, in the main, a more athletic figure type was represented, (due to the fact that the survey was conducted at sea side resorts and factories), additionally, the ages of the majority of subjects were between 15 and 24 years (Lancaster, 1957).

American anthropometric clothing survey: 1939-1940

A second large anthropometric survey of the female population was performed in America between 1939 and 1940. This study was conducted by the Bureau of Home Economics funded by The State Work Projects Administration, and published by United States Department of Agriculture. At the time of the survey no other scientific study of body measurements for the construction of women's clothing had ever been carried out for this purpose in America. The primary aim was to provide data for the garment and pattern industry to enable them to develop a system of sizes, for the production of garments, as well as to improve the fit of garments. Prior to this time, measurements, used for the design and production of female garments were obtained by trial and error by individual manufactures with little or no consultation between them (O'Brien and Shelton, 1941).

Subjects in the American study were residents and visitors from Arkansas, California, Illinois, Maryland, New Jersey, North Carolina, Pennsylvania and the District of Columbia. Some 14,698 women 18 years of age and older participated in the study in which 54 measurements were taken of each subject. The authors acknowledged the lack of representativeness of the sample due to the selection procedures and biases toward white urban employed females. Foreign born women were under-represented, as were the home-maker and too few were from outlying areas (O'Brien and Shelton, 1941).

Landmarks were placed on the subjects at skeletal points and other specific locations such as waist. The landmarks were marked with a small + using a skin pencil. Measurements were taken over pant and bra (as shown in Figure 40). If the subject normally wore a foundation garment she was then remeasured at the bust girth, waist girth, abdominal extension, and lower hip girth (O'Brien and Shelton, 1941).

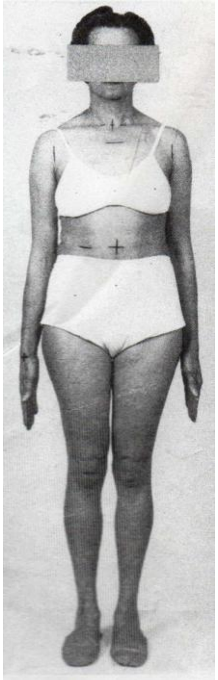


Figure: 40 Subject wearing measuring garments showing landmarks placed on front of body (O'Brien and Shelton, 1941).

United Kingdom anthropometric clothing survey: 1957

The earliest undertaking of a large anthropometric survey in the UK dates back to 1951 but was not completed and published until 1957 by The Board of Trade. As with America, no large scientific study of British women had been conducted previously in that country, other than a national survey of height and weight conducted in 1943 (Kemsley, 1950). The data from this survey replaced the measurements then in use which, according to Kunick (1967), had been obtained from imprecise measurement procedures that were questionable, together with measurements obtained through trial and error. According to Kemsley, there was no authoritative data available, at that time. Therefore individual manufacturers had to assume responsibility for their own data. The 1951-1957 survey was commissioned to ascertain data to improve the fit of female garments and to build a sizing system. Approximately 5000 British women aged between 18 to 70 years took part in the study. Thirty seven measurements were taken on each subject, wearing foundation garments. Smaller sub-samples were also conducted during the first six weeks of the survey. These included measurements taken over a variety of foundation garments, and taken without foundation garments. Landmarks were placed on the body following the procedure outlined by O'Brien and Shelton (1941) using a skin pencil at pre-determined sites (as shown in Figure 41) (Board of Trade UK, 1957).

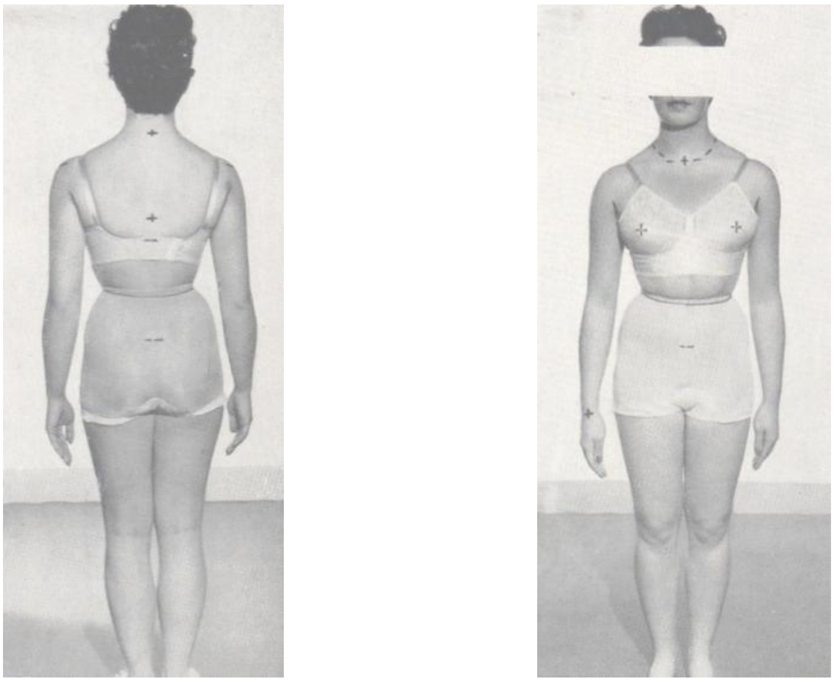


Figure 41: Subject wearing foundation garments, showing landmarks on front and back of body (Board of Trade, 1957)

The Real Australian Woman: Berlei revisited 2000

To compare the changes in women’s body size and shape since the initial Berlei survey in the 1920’s, the University of Newcastle was commissioned by Berlei Pty Ltd (parent company of Hestia Pty Ltd) through SPIN Communications, to carry out a new survey for this purpose. The study consisted of 450 female participants. The age group of participants ranged between 25 and 39 years, and consisted of 150 individuals from three locations in Australia which comprised Newcastle-(New South Wales), Melbourne-(Victoria), and Brisbane-(Queensland). The measurements included: height (standing and sitting), weight, waist circumference, hip circumference and over and under bust circumference. Each participant completed a questionnaire which covered demographics, health, fitness and body image, clothes and shopping, values, and breast cancer. The measurements were taken over the participant’s light weight layer of indoor clothing without a bra. The study found that women in 1999/2000 compared to the 1920s were 3cm taller and 4.5 kg heavier; and that the waist and hip measurements had increased 3.5cm, and the average bust had increased approx 6cm. BMI was 24.4 compared to 23.5 in the 1920s which was just within the healthy range (20-25). It was felt that the there was no recognisable change in the overall shape as waist and hip had increased by the same amount. However it was reported that there may also have been some additional changes in the bust region of many participants due to the increase of 6 cm in average bust measurement (Patterson and Brown, 2000).

Anthropometric clothing survey: Berry 2001

A pilot study conducted by Berry (2001) investigated the size and shape of a representative sample of South Australian women. Some 170 women, aged from 18 to 82 years from various socio-economic backgrounds, whose average height and body weight matched Australian Bureau of Statistics data for South Australian women, participated in the survey. The measuring garment consisted of a close fitting cotton stretch vest which was available in a variety of sizes. Each participant selected the appropriate size and wore the vest over her own pant and bra. Thirty eight body measurements which included height and weight were taken after each participant was photographed morphometrically from an anterior, lateral, and posterior aspect. A small platform was placed behind a portable wire grid consisting of 100 x 100mm squares. Markers indicating the position for the feet were placed 50 mm apart on the platform which was positioned centrally and close to the grid (as shown in Figures 42a; 42b; and 42c).

The anterior aspect was photographed first. The participant stood on the platform with feet touching the markers and with weight distributed evenly on both feet. The centre of the body was aligned (where possible) to the centre of the vertical gridline. The head was held in the Frankfurt plane. The second photograph was taken of the posterior aspect. The participant faced the backdrop and assumed the same posture as for the anterior aspect. The head was held in the Frankfurt plane. The third photograph was taken laterally. This time the participant stood on the platform with the lateral aspect of the body in line with a vertical gridline.

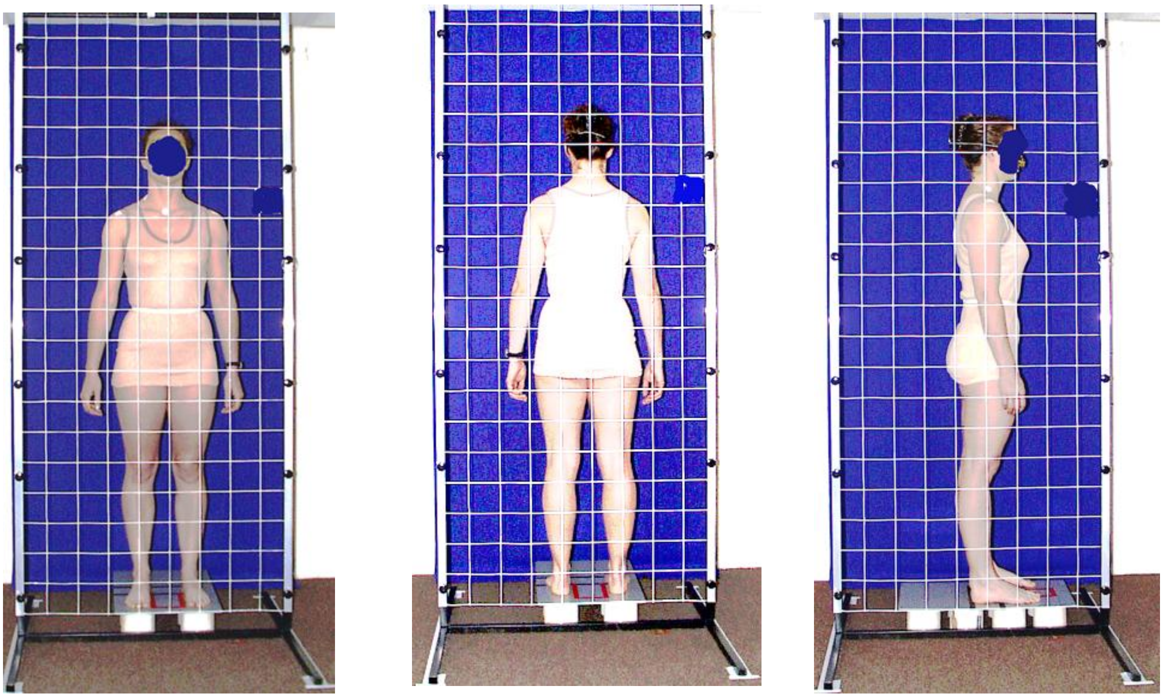


Figure 42a; 42b; and 42c Participant from anterior, posterior and lateral aspect (Berry, 2001)

The results of the Berry (2001) study, when compared with earlier findings of the 1926-28 Berlei study, found a notable difference in weight amounting to as much as 6 kg, and a modest difference in average height of around 11mm. The average Body Mass Index for the group was calculated to be 24.7, which falls just within the upper limit of the healthy range, and concurs with the findings reported above by Patterson and Brown (2000). Of relevance to the present study was the reported identification of five female body types for which basic anthropometric body dimensions were tabulated.

National size and shape survey of Australia: KINANTHREPORT 2003

In a joint venture co-funded by the Wood Jones Chair of Anthropological Anatomy at the University of Adelaide, and Sharp Dummies, together with the support of several clothing manufacturers, a National Size and Shape Survey of Australia women was conducted between, 2002 - 2003. The aim of the survey was to obtain industry-relevant human biological data for the purpose of devising a range of measurement charts, and body forms, which were most representative of the population (Henneberg and Veitch, 2003). The survey was conducted by a team of volunteers from several Australian Universities which included: University of Western Australia, Australian National University, Royal Melbourne Institute of Technology, University of Western Sydney, University of Queensland, and several Technical and Further Education (TAFE) colleges. The study consisted of 1320 females and 88 males, who were recruited as a result of wide-ranging publicity. The measurements were taken at craft fairs held in each of the capital cities of Australia. Participants were measured wearing their own light clothing which consisted mainly of T-shirts and shorts. A trace was taken of the shoulder to obtain a basic shape of this body region. Sixty dimensions were taken, which included height, length and width of body segments, circumferences of trunk, head, and limbs as well as skinfold measurements.

The findings of this study when compared with those of the 1926-1928 Berlei study reported that; body height increased 1.5%, and body weight increased 15%. In comparison with Australian Bureau of Statistics (1995) data of 5000 women, the participants were 10 mm taller but were approximately 6 kg heavier. It is interesting to note that Henneberg and Veitch (2003) drew attention to changes in body shape particularly weight, relative to height, which alter the proportions between certain body characteristics. This implies that a particular relationship between certain body dimensions which may exist for some body types is not found in all body configurations.

Anthropometric clothing survey: Rip Curl 2003

This study was undertaken by Rip Curl to improve the fit of their surf wear designs. The study was conducted between early December 2002 and late January 2003. The purpose was to obtain anthropometric data of young Australian females. There were approximately 2108 participants, aged between 11 and 24 years. Four locations in three states were chosen for the study, which comprised Surfers Paradise, Queensland; Manly, New South Wales; Melbourne, Victoria; and Torquay, Victoria. The measuring garment consisted of a hip length sleeveless stretch top, which was worn over the participants' undergarment or swimwear. Forty-five body dimensions plus weight were measured according to International Organisation for Standardisation (1989) and the company's requirements. As a result of the study a set of standards was developed (Henneberg and Berry, 2003). It is noted that as a preliminary to the survey, an anthropometric team was trained to take a set of pre-determined body dimensions in accordance with the company's goals and objectives. In addition, landmarks consisting of self-adhesive stickers were placed on the body of each participant at specific locations relevant to skeletal structures and anatomical points (Henneberg and Berry, 2002).

The review of the foregoing anthropometric studies has focussed on a selection of traditional clothing surveys of the female body for the garment industry. In recent years there have been major technological advances in the field of anthropometry which have also had an important bearing on the garment manufacturing industry. These advances include high technology using sophisticated equipment such as 3-D body scanners, which many believe will revolutionise the entire process of garment production (Robinette, 1997; Fralix, 2001) and medical research (Treleaven and Wells, 2007). A review of selected 3-D body scanning applications will be presented in the following section.

History of 3-D imaging and 3-D body scanning

Three dimensional images of the human face and body are not just a 21st century phenomenon. Rioux and Jones (1997) cite Newhall (1958) who reported a photo sculpture process developed by Francois Willeme in 1860. The technique involved the use of 24 encircling cameras to simultaneously photograph the human body. The photographs were then used with the aid of a pantograph to sculpt a body shape in clay. The process was adopted by Paris, London and New York studios, between 1863 and 1867. The practice was eventually discontinued however, as it was uneconomical and found to be no better than traditional sculpting methods. Jones and Rioux also report that with advances in computerisation and camera technology, the interest in three dimensional images of the human body was revived in the 1980's when Cyberware developed a 360 degree rotating laser profile system (Addleman and Addleman, 1985 in Advisory Group for Aerospace Research and Development, 1997). Additionally Rioux and Jones (1997) cite Grindon (1989) who reported that Vision 3D in France also pioneered work similar to that of the earlier work of Willeme, which used a multi camera light projection system.

Over the past two decades it has been noted in the literature that 3-D body scanning technology has made a major contribution and played a significant role in research and development in a variety of fields, which include: ergonomics, orthotics and prosthetics design, plastic/cosmetic surgery, obesity studies and clothing studies (Jones and Rioux, 1997; Ashdown, 2007; Bougourd, 2007; Treleaven and Wells, 2007).

Treleaven and Wells (2007) also state that there are many benefits for the medical profession resulting from advances in technology of 3-D surface body scanning such as high quality digital detailed information about human body size and shape, and the implications for health and disease. They state that 3-D scanning can be non- intrusive, easy to use, suitable for scanning large groups and identifying multiple medical conditions simultaneously. The authors claim that it may in the future replace the traditional BMI used currently to assess nutritional factors associated with underweight, overweight and obesity since the BMI is unable to distinguish between fat and lean tissue.

The rapid development and advances in 3-D body scanning now enables accurate data of many body regions to be extracted. It allows for indexing, transmission, retrieval, and analysis of human variability throughout growth to adulthood (Robinette, 1997). Moreover 3-D body scanning has extended anthropometry by providing 3-D geometry and morphology of the external size and shape of the human body (Jones and Rioux, 1997). Major advances of 3-D scanning have facilitated large scientific clothing surveys of the military and/or civilian populations in several countries, which include United Kingdom (Bougourd, 2005), the United States ([TC]^2, 2004), The Netherlands and Italy (Robinette and Daanen, 2003) Germany, Sweden, France, and Japan, (Kirchdorfer and Rupp, 2004), and China (D'Apuzzo, 2007).

Traditional measurements and 3-D scanning

According to Jones and Rioux (1997) continuing progress in 3-D scanning technology may in the future minimise and/or replace manual data collection completely. Robinette (1997) on the other hand puts forward the view that traditional methods of anthropometry may never become totally obsolete and that 3-D scanning is not designed to replace traditional anthropometry which has been in use for several centuries and is well-established with an abundance of data already collected that can be easily retrieved. Robinette argues moreover, that tape measures are inexpensive, readily available, and have been in use for tailoring purposes for many years. In situations where only a small number of measurements are required, such as at recruiting stations, or for mail orders, these can be obtained quickly and efficiently, whereas extracting data from a full body scan would be costly and time consuming. Another point put forward by Robinette, is that whilst 3D technology may in the future replace the tape measure, further development of that technology is necessary before the tape measure is finally abandoned.

Robinette also acknowledged at the time of writing that 3-D anthropometry may address some issues better than traditional anthropometry. These she identified as; ambiguous body contours, the body segment orientation, the spatial relationship between the body and clothing worn, and the differences which invariably occur when taking measurements manually (Robinette, 1997). Robinette describes 3-D anthropometry as an additional tool to manual anthropometry, and maintains there are still some measurements such as waist, hip, chest, and circumferences that only traditional anthropometry can obtain accurately.

The Loughborough anthropometric 3-D shadow scanner 1989

The Loughborough University conducted several traditional anthropometric surveys of British babies and infants, boys and girls from birth to 16 years of age and British men and women 16 years to 65 years of age on behalf of Marks and Spencer and a syndicate of clothing manufacturers. The number of subjects surveyed ranged between 4,500 and 6,500. Due to the large number of subjects it was determined that further studies of such large groups conducted manually were not feasible due to the cost, time involved, and labour intensiveness. It was therefore decided that alternative methods for obtaining and collating data were essential. A collaborative decision by the syndicate led to research into the need for an automated system that would have the capability of measuring the human body accurately and quickly as well as identifying the external size and shape of the human body for use in the garment manufacturing industry. As a result of the research, The Loughborough Anthropometric 3-D Shadow Scanner was developed with the intention of establishing a data base of body shapes derived from sample populations (Jones et al., 1989).

CAESAR 3-D anthropometric survey 2002

Civilian American and European Surface Anthropometry Resource (CAESAR) conducted a survey of civilian populations of three North Atlantic Treaty Organization (NATO) countries, comprising the USA, the Netherlands and Italy. Whilst NATO has a long history of anthropometric surveys of the military population, CAESAR, was the first NATO survey to use 3-D body scanning of the civilian population. At the time the CAESAR group were planning to implement the survey, two other committees, comprising the Society of Automotive Engineers and the American Society of Testing and Materials, were also planning to conduct traditional anthropometric surveys. This resulted in the three groups joining together under the umbrella of CAESAR (Robinette and Daanen, 2003).

The three NATO countries were chosen because of (i) the diverse population of the US (ii) the tall population of the Netherlands and (iii) the short population of Italy. The survey was conducted by the US Air Force, and contractors which included; Syntronics Inc, D'Appolonia in Italy, and a consortium of companies associated with Society of Automotive Engineers, (Robinette and Daanen, 2003).
The total number of subjects surveyed in the three countries was 4,426. The breakdown consisted of, North America 1,255 females and 1,120 males, Netherlands 691 females and 564 males, Italy 386 females and 410 males. The age groups of the participants ranged from 18 to 65 years. The

garments worn for scanning were cotton biker shorts for both males and females, and a sports bra for women. A knit cap was worn to cover the hair (Robinette et al., 2002). Figure 43 illustrates sitting positions of subjects being scanned. Figure 44 illustrates standing posture and foot placement guides on the scanner platform for correct body stance used for CAESAR body scan**.**

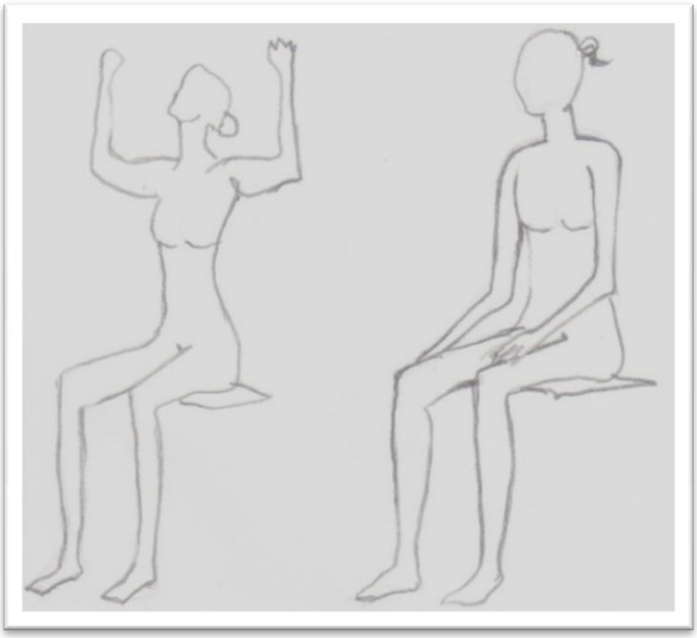


Figure 43: Sitting posture (modified from Robinette et al., 2002)

Figure 44 illustrates the standing posture, and foot placement guides on the scanner platform for the correct body stance used for CAESAR body scan**.**

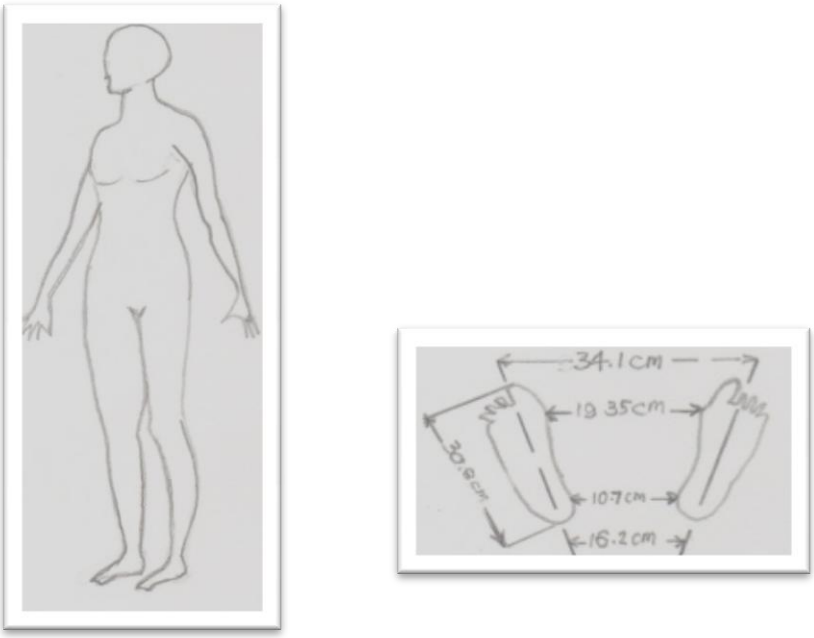


Figure 44: Standing posture with foot guides (modified from Robinette et al., 2002)

Lessons learned from CAESAR

Before the survey commenced, the authors of the report noted that all procedures relating to the application of the scanning process were discussed at regular intervals to obtain feedback from the participating partners. It was noted that the feedback helped to identify key requirements for the survey, which comprised the following: to include both a sitting and standing posture, to have subjects wear a specifically designed scanning garment over their own undergarments, to develop an effective method for identifying landmarks, to test for the most appropriate garment colour, and to specify the division of labour within the measuring team.

Another important recommendation from the pre-survey planning group was the inclusion of 40 traditional measurements. These were to be taken with tape measures and callipers, to supplement the 59 point to point, or point to surface measurements taken from the scan. The reason given for inclusion of manual measurements was that software for emulating measurements normally taken with a tape measure, such as circumferences and arcs, that track body contours had been found repeatedly to be unreliable as reported by Robinette and Daanen (2003) who also cite the following in this regard; Daanen and Brunsman (1998), Paquette et al., (2000), and Bradtmiller and Gross (1999). An additional consideration for the inclusion of traditional measurements was that these have been used for many years and it may be many more years before all users have access to a 3-D scanner which has the ability to locate body landmarks (Robinette and Daanen, 2003). In addition to the above recommendations, several processes were identified on conclusion of the survey as factors which should be addressed prior to undertaking a similar study in the future. These factors included the need to use scanners with comparable capabilities in terms of scan quality and scope, landmark identification, data export and automatic measurement extraction software, particularly when surveys are carried out at multiple sites. It can be seen that scanners may differ significantly in their capabilities and this aspect will be addressed in more detail later in the section on 3-D scanning limitations.

Size UK 2001

Size UK was a large civilian survey conducted in the United Kingdom in 2001. The survey was conducted from a 3-D research centre, set up and jointly funded by the UK Government together with some twenty leading clothing companies, and included leading academics and several universities. Of the ten scanner companies initially invited to provide scanners for use in the Size UK survey, a short list of seven was subsequently considered by an assessment group comprising the Ministry of Defence, London College of Fashion, and De Montfort University. The [TC]^2 Scanner was the final choice based on its ability to automatically extract all but 8 of the required 140 measurements. These measurements had been identified together with fifty body landmarks relevant to product development for the clothing industry, by the London School of Fashion in collaboration with the consortium partners (Bougourd, 2005).

The UK sizing survey involved 3-D whole body scans of approximately 11,000 subjects including women, men and children. The 3-D body scans were taken of each subject in a seated and standing position (Figure 45).

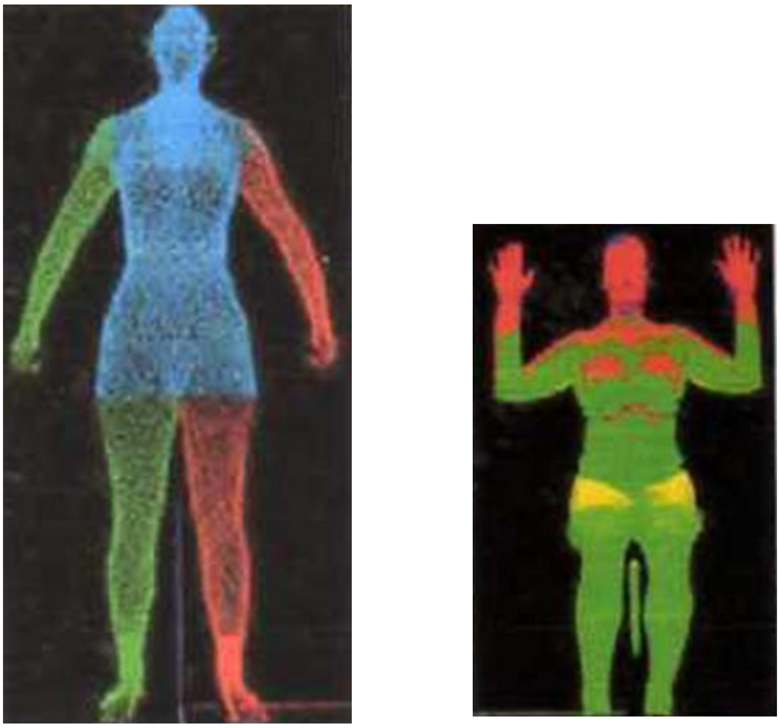


Figure 45: Standing and seated positions of a subject in Size UK study (Bougourd, 2005) (reproduced with permission from Size UK and J Bougourd December 2010)

[TC]2 developed a software program to automatically extract 130 measurements required from each subject (Treleaven and Wells, 2007). Bougourd (2005) cites two main reasons for the inclusion of some additional manual measurements in this study. These were (i) limitations of the scanner's size extraction software and (ii) difficulties that scanners have with hair. The manual measurements, plus height and weight, included; head girth, head arc, over bust, armhole girth, centre back neck to elbow, centre back neck to wrist, hand girth, and hand length (Bougourd, 2005). Figure 46 illustrates the scan resulting from the automatic measurement extraction process.

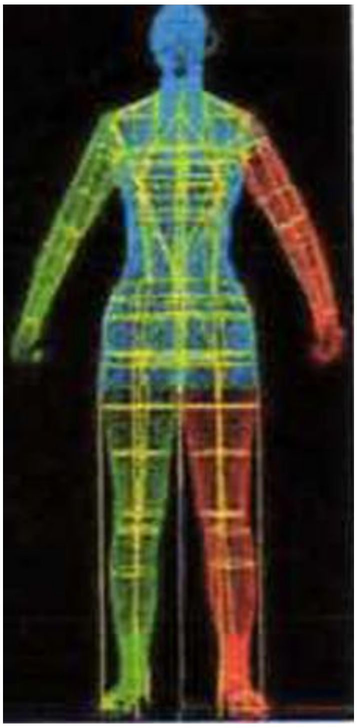


Figure 46: Size UK scan, illustrating automatic measurement extraction (Bougourd, 2005) (reproduced with permission from Size UK and J Bougourd December 2010)

Findings from Size UK study

One of the most significant results of the Size UK study was the capturing and identification of current female body shapes. Of equal interest was the finding that females on average have grown taller, larger and heavier. The data showed increases of four centimetres in the areas of: height, bust, and hips, and more extraordinarily, a major increase of 14 cm in the average waist measurement of the female body! In her summary of the above, Bougourd notes that this major increase in the waist measurement of females, has resulted in a straighter and less curvaceous figure than was the case in the 1950s (Kemsley, 1957 in Bougourd, 2005). Bougourd concludes that research of this nature would not have been possible without the advances in body scanning in the three years preceding the study, the cost savings resulting from advanced information technology and the forty member partnership of Government, industry and educational institutions.

Another large scale civilian survey referred to as Size USA, was conducted by the Textile Clothing Corporation [TC]^{2,} (a not-for-profit US sewn products industry organisation) on behalf of various sponsors and supported by a grant from USA Department of Commerce. The purpose of the survey was to measure body dimensions of a representative sample of the US population ([TC]^{2} 2004). The number of subjects surveyed was approximately 12,000 which included males and females between 18 to 66+ years of age. The sampling strategy was modelled on distributions of height and weight as determined by National Health and Nutrition Examination Surveys 1988–1994 ([TC]^{2} personal communication). The survey commenced in 2002 and was completed in 2003. The aim of the survey was to obtain a set of 100-200 body measurements from which additional measurements and shape information may be extracted from the scan data as required by sponsors. On completion of the survey, yearly group meetings were conducted by Size USA User Group, at which comments and findings relating to the various uses made of the Size USA data were presented ([TC]^{2}, 2004; [TC]^{2} ,2005; [TC]^{2} ,2006).

Size USA user group meeting 2005

The first Group Meeting in 2005 ([TC]^{2}, 2005) included a report by Jockey (an international company specialising in undergarments) that Size USA data had enabled the group to develop undergarments with far better comfort and fit. In a re-launch of a re-designed line of bras which focused on improved size, shape and proportions as a result of the Size USA data, Jockey asserted that their customer base had increased to around 92% of their target market. Another group member, J C Penny, reported that the old industry saying that 'if it measures right it must fit right' is…wrong! J C Penny argued that it was equally as important to 'fit a person's shape as it was to fit a person's size'. This became apparent after they conducted an in-house survey of 67 participants, which identified 43% as being pear shaped, 33% as apple or diamond shaped, and 19% as a rectangle shape.

Archetype Solutions supported J C Penny's findings in relation to the impact of shape on fit. They stressed the point that the fit of garments is a major problem for retailers due to varying and different body shapes, and emphasized that in order to address the issue of fit it was necessary for retailers to take shape into account. It was also noted that with a group of customers all categorised as the same size on the basis of specific body dimensions, the majority may not fit into that size due to their unique body shapes ([TC]², 2005).

To illustrate this point [TC]² ,(2004) shows laser scans of four women with similar bust, waist, and hip measurements, but with very different body shapes and questions how such different body shapes can fit into the same size garment, (Figure 47).

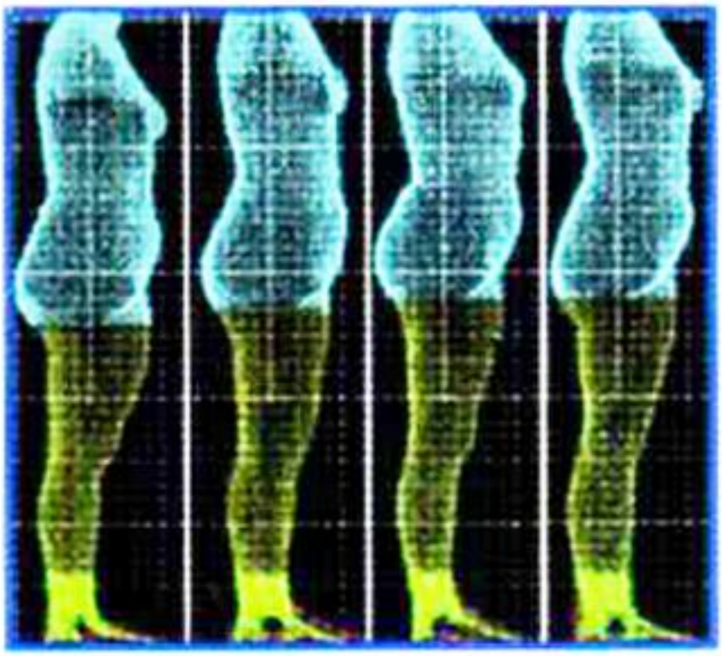


Figure 47: Comparison of scan images showing women with similar bust, waist and hip measurement but with significantly different body shapes ([TC] ², (2004), (reproduced with permission`([TC] ² December 2010)

Academics also made presentations at the 2005 Group Meeting. Susan Ashdown (Cornell University) stated that 3-D scanning technology has had a major impact on the apparel industry and can be likened to the introduction of the sewing machine in the 19th century. Other academics including Lenda Jo Connell and Pam Ulrich (Auburn University) made particular reference to their focus on the tweens market and noted that the same shape does not fit all and more importantly one size does not fit all. Karla Simmons (University of Missouri) noted that Size USA data has been invaluable source for gathering data by students. Finally, Su-Jeong Hwang-Shin and Cindy Istook (North Carolina State University) reported that they found curious differences when they compared and contrasted body measurements between people of different age and ethnicity. Istook also drew attention to the disparity in The American Society for Testing and Materials (ASTM) Standards on sizing and suggested that industry involvement with the ASTM review panel is necessary, to bring about much needed improvements to the current standards.

Size USA user group meeting 2006

The ([TC]^2 2006) User Group Meeting included a presentation relating to bust analysis given by a manufacturer of women's bras. The analysis resulted from a survey in which scan data of 1400 females from the manufacturer's customer base across the US, were supplemented with scan data of 4000 women from Size USA. Termed 'Victoria's Secret Bust Shape Analysis' technical designers reported that irrespective of a female's size and shape, their geographic location, their age or ethnic background, breasts come in four distinct shapes. Of particular interest to this study is the conclusion that the four different bust shapes will not fit the same bra regardless of size. These findings are of interest, as the position and shape of the bust are important aspects in relation to garment cutting and garment fitting, as has been noted previously (Figure 27). Subsequent [TC]^2- User Group meetings have reported a growing list of different applications for the Size USA data. For a more detailed coverage the reader is referred to the [TC]^2 website.

Scanner variation

A further study of interest is that of the comparison of the Hamamatsu with Vitus Smart 3D body scanner data, which found that there was lack of agreement between measurements obtained using the different scanners, as well as between scanned measurements and manual measurements (Daniell, 2007). The study which was conducted during 2005 in South Australia, comprised thirteen females and seventeen males who were measured manually, according to protocols described in 2001 by the International Society for the Advancement of Kinanthropometry (Daniell, 2007), then scanned by two different 3-D whole body scanners after being landmarked using the same sites marked for manual measurements. Participants wore form fitting underwear and a swim cap to minimise the effect of hair on head girth. Thirteen manual measurements were taken, consisting of, five girth, four length and four breadth measurements. Participants adopted the standard scanning pose to reduce the possibility of missing data and to facilitate measurement extraction. Participants were told to breathe naturally while being scanned and to avoid tensing their muscles. Results showed that scanned measurements were larger than manual measurements in eight cases out of twelve for the Vitus Smart scanner, and ten cases out of thirteen for the Hamamatsu scanner, and that overall the errors were smaller for the Hamamatsu pathway when compared to the Vitus Smart pathway. The whole-of-process error using Structural Equation Modelling (SEM) for the Vitus Smart pathway was reported as 5.7 - 6.0mm and for the Hamamatsu pathway the whole-of-process error SEM was 4.8mm.

Daniell suggested that compression caused by callipers may account for the instances where scan derived measurements were larger. Another possible factor was that participants may have been at different stages of a shallow breathing cycle during the scanning process, whereas, manual measurement of the waist girth for example is taken at the end of a normal expiration. Postural sway was also suggested as a cause of measurement error which can result from the arms being slightly abducted in the standard scanning pose. It is of interest to note that consideration was given to the reliability of the physical location of landmarks, and it was reported that an average inter-tester error rate of 2.9 mm, which had been established in an earlier reliability study, was accounted for in the data from both scanners.

Comparison of 3-D with manual measurements

The above study points to a continuing debate as to the accuracy of some measurements obtained by the 3-D body scanning process when compared to manual measurements (Daanen and Reffeltrath, 2007). It has been noted that in some cases the manual process uses a technique of 'palpating' the skin in order to identify underlying key skeletal points from which certain measurements need to be taken (Daniell, 2007). One example is the practice of 'palpating the iliac spine bone' (sic) as a reference point for circumference measurements (Daanen and Reffeltrath, 2007). While this procedure is beyond the capabilities of 3-D scanners (which do not touch the body), it has also been pointed out that bony points are not able to be visually located on a 3-D scan in many cases (Daniell, 2007).

A study by Brooke-Wavell et al., (1994) compared manual measurements with 3-D scan-derived measurements, and found that outcomes from both processes were generally similar, although small but statistically significant differences were found for dimensions such as bust circumference, neck and waist depth, waist height and waist width. Reasons put forward for the differences, included the possibility that measurements were not taken at the same locations on the body due to the acknowledged difficulty in identifying some of the landmarks. Other reasons for discrepancies between manual and scan measurements were attributed to, difficulty in keeping the tape measure completely horizontal, and the effect of the body stocking worn during the scan which often stood off the skin, and may have caused the scan measurement to be larger than the manual measurement, as the instruments used to obtain manual measurements are required to touch the skin. An overall finding in this study was that repeatability of the 3-D measurements taken from the scans was no better than the repeatability obtained from traditional anthropometric measurements.

Advantages of 3-D whole body scanning

Despite some areas of concern which have been noted above, there are also many advantages in using the hi-technology of 3-D body scanning for obtaining data. Although 3-D body scanning was developed primarily for the clothing industry, it is ideally suited for many medical applications in clinical practice, and epidemiological surveys (Treleaven and Wells, 2007; Wells et al., 2007b). Bye et al., (2006) also note that 3-D body scanning is fast, non invasive, in most instances data are easily retrieved, scans are able to identify body shape, and also provide a permanent record that can be accessed for future reference and analysis. Another important advantage is that large scale surveys can to be conducted quickly and efficiently (Robinette, 1997; Bougourd, 2005). Jones and Rioux (1997) add also that 3-D body scanning enables the study of 3-D geometry and morphology of the exterior human body, and they list other positive features which include: acquisition, indexing transmission, archiving, retrieval, and analysis of body size, shape, and surface together with their variability throughout growth and development. Park et al., (2004) note, however, that data acquisition, translation, storage, analysis and extraction have not been adequately standardised.

Limitations of 3-D whole body scanning

In addition to a lack of standardisation, Bye et al., (2006) cite Treleaven (2003) who is reported as describing extreme variation in both hardware and software components of 3-D scanners in terms of poor quality, and inconsistent data and in some cases missing regions of the body in the scans. Daanen and Reffeltrath (2007) report that 3-D scan-derived circumferences often differ markedly from manually measured circumferences. Another concern in relation to circumference measures is that 3-D scans highlight the irregularities in body contours (lumps) whereas the tape measure spans even moderate variations in body contours of this type (Robinette, 1997). Park et al., (2004) have also drawn attention to the lack of specification of processes and tasks. Other studies have pointed to the difficulty in locating or identifying landmarks on 3-D scans (Brooke-Wavell et al., 1994; Daniell, 2007), or to the fact that different landmarks and measurements are used by different scanners, making comparisons between studies unfeasible (Honey and Olds, 2007). The latter authors also point out that measurement procedures and definitions specific to 3-D scanning are vitally necessary. A further limitation noted is the high cost of the hardware and the time needed for digitations of large body areas while the body needs to remain immobile, since body movement generates errors (D'Apuzzo, 2007). Despite the limitations noted above, it is probable that steps have already have been taken to remedy most, if not all of these limitations in view of the unquestionable benefits and future possibilities associated with continued advances in 3-D body scanning technology.

Manual and 3-D Scan: bust circumference study

It is interesting to note in a paper reported by [TC]^2 (2002), that a comparison between measurements of the bust circumference of five female subjects taken manually and the same measurement taken by a 3-D scan found that the scanned measurement was consistently larger. In the re-test part of the study, the anthropometers viewed a 3-D representation of how the scanner measured each subject. After viewing the scan, the anthropometers were then given the opportunity to re-measure the subjects. While this reduced the difference between the scan-derived and manual measurements, several errors were identified with respect to how the manual measurements were taken.

One major cause of error was reported to be the inability of the anthropometers to keep the tape position parallel to the floor at the back of the body. [TC]^2 **(**2002) reported that a tape drop of only 1 to 2 inches can result in a significant manual error. It was noted also that a further cause of error was the compression of the soft tissue on the bust circumference to keep the tape in position. Although the study stated that each anthropometrist was an experienced measurer, one may question if the instructions given to them were clearly understood and able to be replicated according to given specifications. It could be argued that the degree of standardisation in place and the level of training that each anthropometrist is given prior to any experimental research are questionable. The following section will focus on various instructions for taking the bust measurement, and inconsistencies that exist in the literature in this regard.

Anthropometry: bust variations

A comparison of established standards for taking manual measurements shows ambiguous definitions in many instances. One such example is that of the bust circumference. Australian Standard (1959), and Australian Standard (1972) state that the bust circumference should be measured horizontally at the level of the maximum bust girth. However, Australian Standard (1975), states the bust circumference should be measured during normal breathing with tape measure passed over the shoulder blades, under the armpits and across the bust prominences. In view of the different descriptions for taking the bust measurements as set out in the above two standards, a study was undertaken by Berry (1976) of eighty female participants who were measured according to the two different bust descriptions. The results showed marked differences between the measurements obtained by each method. This finding will be discussed later in this review.

The definition of taking the bust circumference in the Australian Standard (1997) is identical to that of the International Organisation for Standardisation (1989) which states that the bust girth is taken at the maximum horizontal girth, measured during normal breathing with the tape-measure passed over the shoulder blades (*scapulae)*, under the armpits (*axillae)*, and across the nipples. Despite identical wording, however, it is noted that that the illustration on the right from Australian Standard (1997) shows the tape measure sloping downward towards the rear of the body and not under the armpit (axillae), (Figure 48).

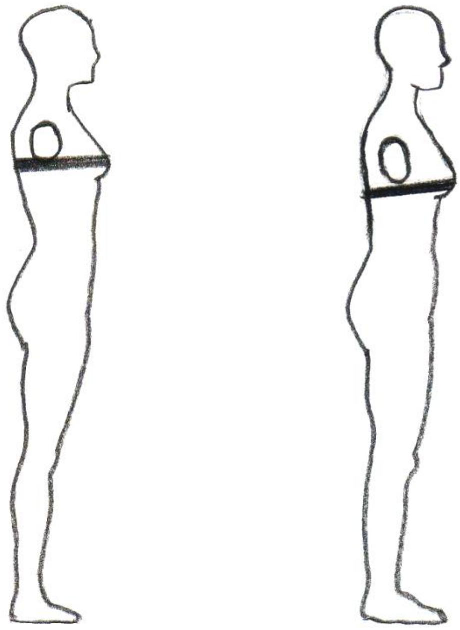


Figure 48: Illustration of bust girth (modified from International Organisation for Standardisation, 1989) (on left) and (modified from Australian Standard, 1997 (on right)

Another example for comparison of taking the bust girth is the definition in the American Society for Testing and Materials (1994), which is given as the circumference of the body over the fullest part of the breast and parallel to the floor. In contrast, the American Society for Testing and Materials, (2007), gives the chest/bust girth definition as, the horizontal circumference around the body under the arms and across the fullest part of bust apex including the lower portion of the shoulder blades.

A further variation in taking the bust girth is given by O' Brien and Shelton (1941) who state that the tape is passed around the **chest** so that the upper edge of the tape is at the level of the maximum girth with the anterior and posterior arcs of the girth in the same horizontal plane (Figure 49).

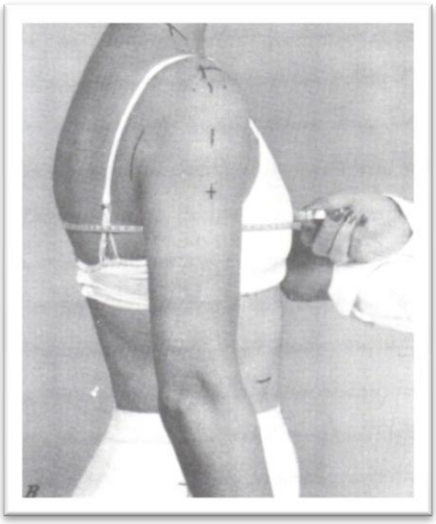


Figure 49: Photograph demonstrating bust girth measurement procedure (O'Brien and Shelton, 1941)

Board of Trade UK (1957), on the other hand states that the tape passes under subject's right arm and is taken around the bust so that upper border of the tape is at the level of the bust girth indicated by the landmarks. It is interesting to note the emphasis placed on the tape measure being kept in a horizontal plane at the level of the maximum bust girth. However, it was also stated that if the subject's bust prominence is low, for example nearer to the waist line, this is not always possible. In such cases it is recommended that the posterior arc is held in position on the lowest point of the shoulder blade and the tape sloped down to the bust prominence, (Figure 50). As a point of interest Kunick (1967) used the same photograph and similar instructions as Board of Trade UK (1957).

Kunick also stated that in the case of subjects who were low busted, the tape measure was positioned on the lowest point of the shoulder blade then sloped down to the fullest part of the bust. It is notable that Kunick asserts that the tape measure cannot be held horizontally or parallel to the floor in the case of females with a low bust prominence.

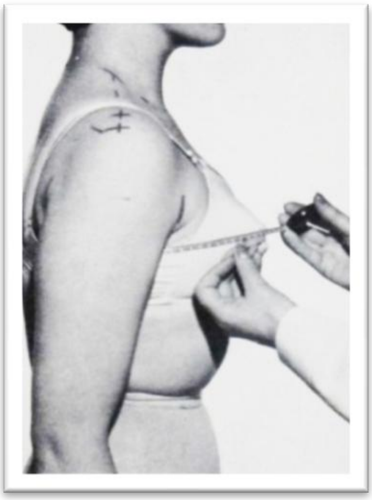


Figure 50: Photograph demonstrating bust girth measurement procedure (Board of Trade, 1957)

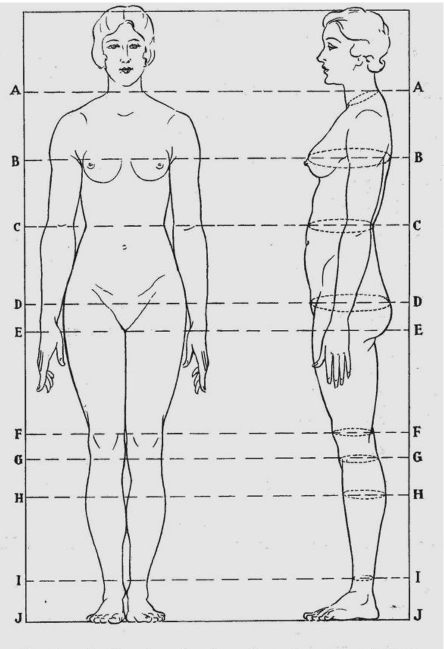
The following procedure for taking the bust measurement described by Berry (2001) notes that tape measure was placed horizontally around the body over the fullest part of the bust with the tape measure parallel to the floor, (Figure 51).

Figure 51: Photograph demonstrating bust girth measurement procedure (Berry, 2001)

Using a [TC] ^{2} 3-D body scanner, Simmons defines the process for obtaining the bust circumference as the horizontal circumference taken across the bust points at the fullest part of the chest. It is of interest that Simmons makes a distinction between American Society for Testing and Materials

(2007) and the [TC]^{2} (1999) definition (in Simmons 2002), noting that American Society for Testing and Materials defines the bust measurement as being parallel to the floor, whereas in her study she states the bust measurement was taken as parallel as possible. Simmons claims that when taking the bust measurement manually, the tape measure is ‘usually’ not held exactly parallel, therefore she attempted to approximate the usual manual measurement process.

Simons (1933) described a different method for obtaining the bust circumference, which involved taking the chest circumference and adding 3 inches (7.6 cm). Simons noted that this method was used by certain designers at the end of the 1800s and in the early 1900s. It can be seen from Figure 52 for example, that the chest measurement appears to be taken parallel to the ground high under the armpit (*axillae*) across the chest (above the bust nipple). Simons also made the point that many circumference measurements varied considerably from one discipline to another, as they were not taken at the same points of the body as the measurements taken by tailors and cutters.



Front and side view showing where the circumference measurements are taken. A is the neck; B, the chest; C, the waist; D, the hips; E, the thigh; F, the knee; G, below knee; H, calf, and I, ankle.

Figure 52: Front and side view of proportions of female figure and the position of measurement taken on the female body (Simons, 1933)

As a point of interest Wampen (1864) used the chest measurement of the human female body as the basis for his test of proportionality together with the height measurement, and **not** the bust measurement. Wampen also claimed that when his conditions for proportionality were met, the chest (breadth measurement) was all that was required for the calculation of other body dimensions. It is acknowledged that the bust and the chest (or breast) measurements are taken differently, and used for different purposes, as noted by Simons, (1933) and Wampen, (1864). It is therefore critical that there is an explicit understanding, not only of the actual position on the body where the bust or chest measurements are taken, but also the practical application and utilisation of these measurements in the pattern engineering and the fitting process.

The following descriptions for taking the chest measurement are included here for comparative purposes. These provide other examples of the ambiguity surounding the many variables associated with instructions given by various reputable sources on how to obtain the same measurement anthropmetrically.

The first method illustrated in Figure 53 for taking the chest girth was taken from the International Organisation for Standardisation (1989). The instruction for taking the **chest girth** states that the maximum horizontal girth is measured by passing the tape measure over the shoulder blades (scapulae), under the armpits (axillae), and across the **chest nipples.** It is interesting to note that this description is identical to that for obtaining the **bust** measurement (as shown in Figure 48).

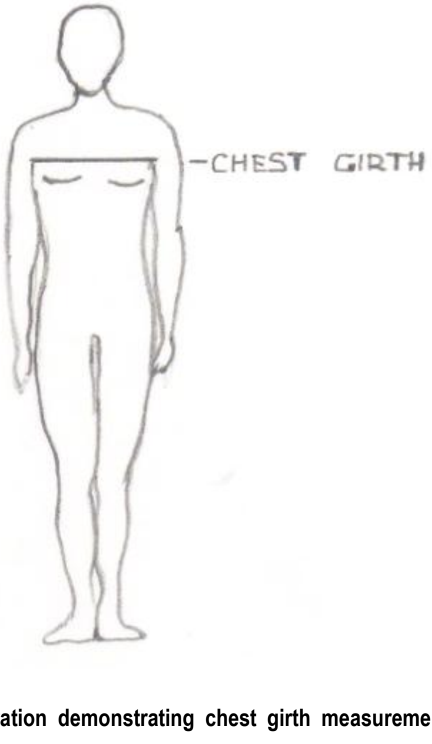


Figure 53: Illustration demonstrating chest girth measurement procedure (modified from International Organisation for Standardisation, (1989)

The second and third methods were taken from American Standards published in 1994 and 2007 (American Society for Testing and Materials, 2007). The 1994 example is shown in Figure 54a with the definition of the **chest girth** given as the circumference of the body over the shoulder blades, under the arms, and across the upper chest. The 2007 example shown in 54b refers to **upper chest,** defined as the horizontal circumference around the body taken under the arms and above the fullest part of the chest/bust including the lower portion of the shoulder blades.

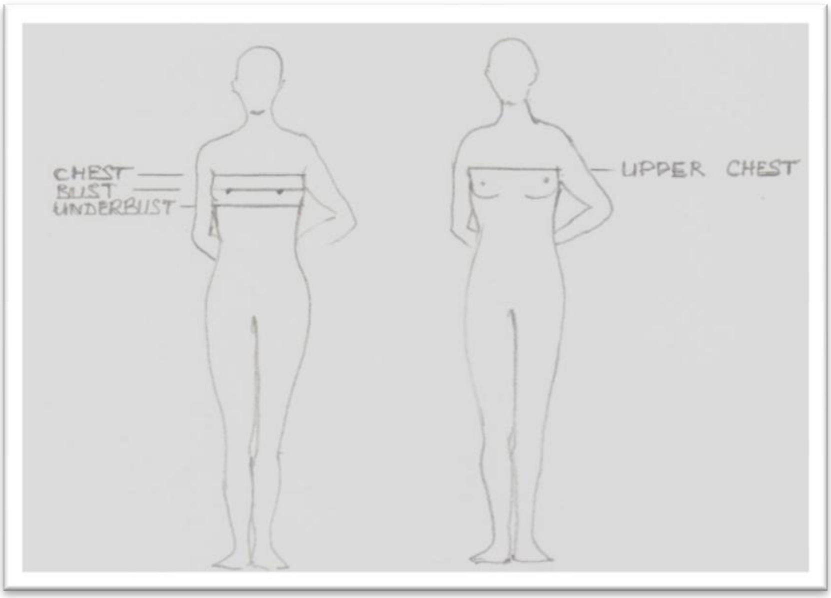


Figure 54a (left): Chest girth measurement procedure and Figure 54b (right): Upperchest girth measurement procedure (modified from American Society for Testing and Materials, (1994 and 2007)

The fourth method is from Berry (2001), which states that the tape measure is placed horizontally around the torso, over the trunk, high up under the armpit, across the top of the bust and around the back (as shown in Figure 55).

Figure 55: Photograph demonstrating chest girth measurement procedure (Berry, 2001)

An analysis of the four descriptions above raises an issue for anatomical consideration. In some instances the tape is placed well above the nipple, high up under the armpit, whereas in others, the instructions state that the tape measure is to be passed across the chest nipples (?) under the *axillae* and over the shoulder blades. It would seem in the latter case that there is an assumption that the bust prominence is in line with the *axillae*. In reality, it is arguable that in most cases, only the younger female with firm small breasts would meet that criterion, or in instances where a bra or corsetry has altered the natural bust position.

A selection of instructions for taking the bust and chest girth have been described. It can be seen that there are many variations in the method and procedures documented for taking these two measurements. Serious questions remain regarding the ambiguities associated with (i) the position of the bust prominence in relation to the lower part of the shoulder blades, (ii) the measurement procedure and use of body landmarks such as axillae and scapulae and (iii) which are the most appropriate descriptions for taking the bust and chest measurements?

In view of these anomalies, the question arises as to whether the variations found in the descriptions for taking these measurements may equally apply to other body dimensions? Given the disparity between the instructions as outlined above, one may question if, and to what degree specifications were written and tested prior to being implemented? It could be argued that the measurement process is highly complex and that until (if ever) there is industry agreement on standardised procedures for taking measurements, this issue will remain complex. Moreover, unless scientific principles are adhered to, the accuracy of any measurement taken manually or by 3-D scanning may always be open to question

As has been stated previously, the size and position of the bust plays a major role in pattern engineering, and garment fitting. The female bodice draft from the 1860's as illustrated in Figure 56 shows a pattern with a high full bust, narrow back and a small waist line indicative of that era. In this instance the dictates of fashion influenced the bust position through the wearing of undergarments, such as corsetry or bras which lifted the bust to place a high emphasis on the décolletage. The female bodice draft in Figure 56 is a clear example of the fullest part of the bust being in line with the *axillae*.

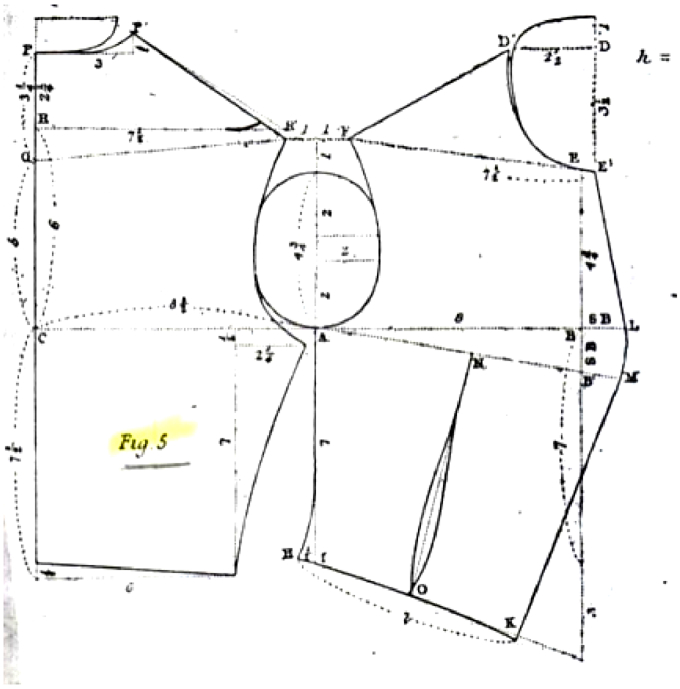


Figure 56: Female Bodice Draft from the 1860s (Wampen, 1864)

Garment industry: past present and future

The garment industry over the centuries has been through many revolutionary changes, particularly in relation to an original emphasis on the early, highly skilled artisan/tailor and the multi skilled craft person. These changes include the dissemination of specialist skills to a wide range of personnel within an organisation, which occurred with the emergence of mass production in the garment industry. Methods and procedures for the production of garments have also evolved over the past several centuries due to an exponential growth of knowledge and skills, and more importantly, the increasing impact of technological advances in the field of computerisation.

Since its inception, the design and production of clothing has incorporated many different processes. At the present time the success of a range or the production of an individual garment depends on the successful integration of different yet interdependent processes (Anderson, 2005). Throughout such diverse yet interrelated processes, a fundamental consideration is the achievement of the successful fit of an individual garment, or a range of garments (Winks, 1997).

Tailor / Dressmaker

The earliest history of cutting dates back to the 15th century in Spain, 17th century in France, 18th century in England and 19th century in America (Seligman, 1996). The term 'tailor' was derived from the old French word *tailleur* which translates literally into 'one that cuts', whereas the professional dressmaker in America and the continent was often referred to as a *modiste* (Gamber, 1995) and in the UK as a mantua maker (based on a garment called a mantua which became popular in England in the 18th century) or seamstress (Kidwell, 1979). Another earlier term associated with dressmaker was that of a needle woman (Groves, 1966 in Aldrich, 2007). The seamstress and needle woman who sewed the seams of garments with needle and thread, together with their male equivalent sempters or seamsters, required less knowledge and training, and were generally considered to be relatively unskilled in comparison to the tailor, the modiste, and the mantua maker (Kidwell, 1979).

In the mid 17th century the distinction between the skill of cutting and the labour of sewing became institutionalized in France by the passing of laws which restricted cutting to tailors only. At a later stage of the 17th century a separate guild was created for women in France which allowed them to produce a wider range of garments, and this change in custom was followed about the same time in England. By the 18th century the dressmaker-mantua maker had acquired the advanced skills that enabled them to cut more complex feminine garments (Kidwell, 1979).

Tailoring

Tailors were often referred to as artisans, who were highly revered and respected in the community and who worked meticulously and individually with the client to produce custom made garments according to each individual body form (Poole, 1920; Anderson, 2005). In its earliest days of development, tailoring was a labour intensive industry in which most processes were undertaken by one person who, of necessity, was required to have a diverse range of skills. This included; taking measurements, making the pattern, cutting fabric (in some cases directly onto cloth), preparing the garment for fitting, fitting the garment, making alterations (if necessary), and then applying the finishing processes (Kunick, 1967). Custom made clothing was generally only affordable by the wealthy, due to the high cost of producing an individualised garment (Dorner, 1974).

To assist early tailors and professional dressmakers in the course of their work, a variety of drafting and measuring tools were used, as shown in Figure 57 (Monahan, 1912) and Figure 58 (Devere, 1866).

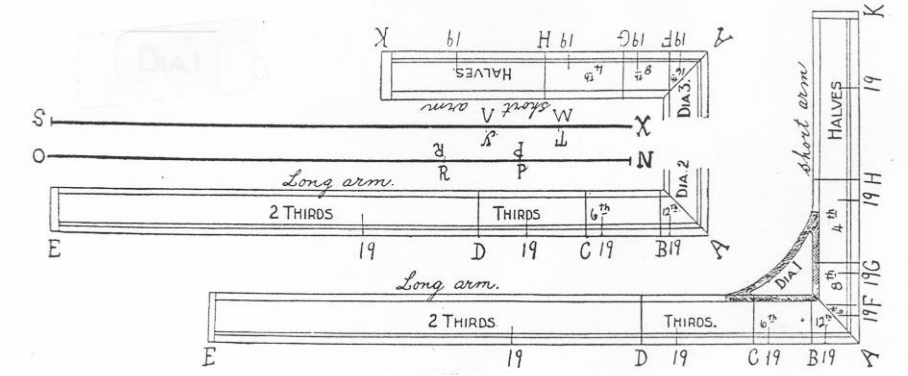


Figure 57: Drafting tools (Monahan, 1912)

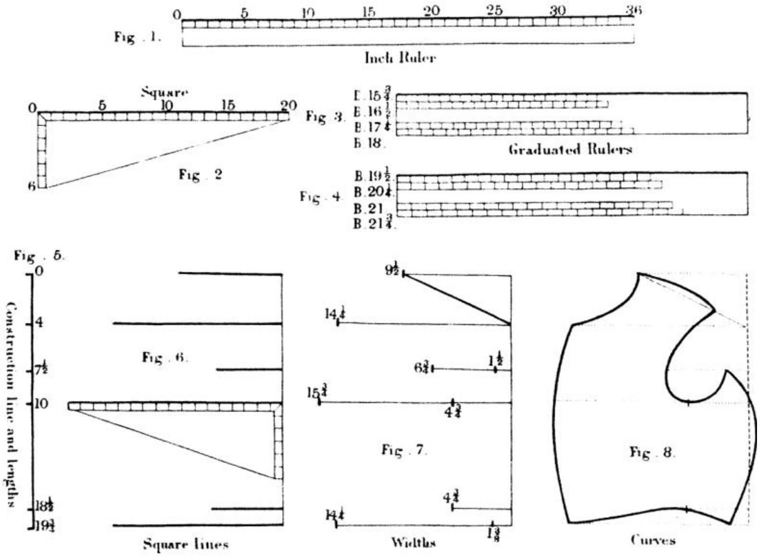


Figure 58 – Drafting and measuring tools (Devere, 1866)

Dressmaking

Dressmaking in the early 19th century in America was largely a nameless occupation carried out by disadvantaged women working in restricted circumstances, who relied on personal recommendations to keep themselves in business Kidwell (1979). At that time, the majority of women had few opportunities to be as well-educated as men, and were thought not to have the intellectual capabilities to integrate and absorb as much knowledge as their male counterparts and could only contemplate occupations such as that of a cook, laundress, household servant or seamstress (Kidwell, 1979). Those who chose to become seamstresses, and dressmakers, generally lacked the skills to cut, make and fit the complex stylish garments of that period (Kidwell, 1979; Fernandez, 2004). Dressmaker/machinists employed in factories in France during the mid 1800s, however, were afforded a higher status; many were acknowledged to be skilled artisans and highly proficient in their trade and these stood out from other unskilled factory workers at that time (Wyatt, 2009).

To assist the seamstress, dressmaker and home sewer to master the increasingly complicated styles that were the fashion between 1830s to the 1890s, various so-called drafting systems (tools) were developed during that period (Kidwell, 1979; Gamber, 1995). Gamber notes that these consisted mainly of highly specialised devices designed either by tailors, or enterprising men with very limited practical knowledge of the clothing industry. Some of the devices included: the Mc Dowell Garment Drafting Machine (as shown in Figure 59); various Perforated Proportional Systems; The Buddington Dress Cutting Machine; and a number of Conformator systems (Kidwell, 1979; Gamber, 1995).

Figure 59: Mc Dowell garment drafting machine and instruction book, (reproduced with permission from Collection: Powerhouse Museum, Sydney. Photo: Sotha Bourn)

Arguably the most elaborate of the drafting tools was the McDowell Garment Drafting Machine. Specified measurements were taken on the customer; the machine was then adjusted to reflect the customer's measurements, the pattern was then obtained by tracing around adjusted plates on the outline provided by the tool. Initially, the tool was designed to produce one style of garment. However, latter modifications extended the use of the tool to include closer fitting garments which conformed to changing fashion trends. This machine became obsolete with the introduction of the paper pattern industry as well as the continuing changes in the designs of that era (Kidwell, 1979; Powerhouse Museum, 2010).

Aldrich (2003 in Aldrich, 2007) also refers to the use of drafting aids, templates and cutting machines in England, but notes that many of the machines produced designs that were based on proportionate measurements, and therefore would only fit bodies that were proportionate in form. Aldrich also notes that as the templates were geared for a personal fit and were design specific, they became obsolete with new fashion trends.

As referred to above, one of the Conformator systems of interest was that of Wickersham's 'Pattern Marker', which comprised a conforming tool that was placed on a person and adjusted to conform to the body shape. This contraption was described by Kidwell as having the appearance of a 'Medieval Torture Machine'. The Pattern Marker device consisted of thin metal strips of tin, brass, or copper corresponding to the seam of a dress bodice, which were studded with pointed prongs and strapped to half of the body with rubber bands. Once positioned correctly, paper or lining fabric was pressed onto the prongs, with the result that the perforations outlined the seam position on the paper or lining fabric (Kidwell, 1979). A notable consequence of the appearance of the first generation drafting systems described above, was that the principles on which they were based provided the framework for the sizing systems needed for the paper pattern industry and for the women's ready to wear clothing industry which followed (Aldrich, 2007; Zakim, 1998).

Paper pattern industry

From the beginning of the 19th century, publications devoted to fashion, dressmaking and tailoring had begun to appear in France, Britain, and America. By the second half of the 19th century, there was a massive increase in the numbers of drafting systems, magazines, trade periodicals, and journals as the publishing industry began to flourish, side by side with the development of commercial paper patterns (Seligman, 1996; Aldrich, 2007). It would appear, that the commercialisation of the paper pattern industry originated in France with the publication of periodicals, from which paper patterns could be purchased by readers via mail order. Seligman (1996) expressed the view that the French *Journal des Demoiselles* that began publication in 1833 was the first to introduce and include small diagrams of ladies fashions as a supplement. Seligman also refers to the advertising of French patterns, imported for sale in England by Madame Folet in 1837, and the Beetons borrowing from the French tradition with their publication of patterns, and a mail order service in the *Englishwoman's Domestic Magazine* in the early 1860s.

Aldrich (2007) states that a great expansion of the commercial paper pattern industry occurred in America in the 1860s, with companies such as Butterick, and McCall, and Weldon's in England, producing commercial patterns using proportional systems and graded by graduation. Schofield (2007) also notes that mass produced commercial paper patterns in the 1860s, were created using proportional dressmaker's systems.

The availability of paper patterns that could be ordered and sent through the mail had a major impact on both the professional and the home dressmaker, as it provided a means of accessing current fashion styles, in a variety of sizes, as well as in many cases, cutting and assembly procedures. Figure 60 shows an example of a free paper pattern from *Weldon's Ladies Journal,* (1921) showing the style, cutting out procedure, and assembly techniques.

Figure 60: Example of 1921 paper pattern from (*Weldon's Ladies Journal,* 1921)

Industrial Revolution / Mechanisation

The industrial revolution which began in the mid 18th century in Britain and several years later in America had a major impact on economic growth and social development (Boyd, 1980; Tanner, 1981). The textile industry was the first to become mechanised with the opening of a cotton spinning mill, which used a machine known as a water frame, powered by water. Other technological advances such as steam powered machinery and mechanical looms, together with urbanization and the development of the factory system, combined to replace the home, and then the small workshops, as the principal place of work (Lambert, 2010). All of these factors contributed to a change in emphasis from the skilled-based creation of custom made garments, to the mass production of apparel, in which many elements such as style and fit could not be achieved or had to be sacrificed on the basis of cost or convenience (Jenkyn Jones, 2005).

Mass production of ready-to-wear clothing went hand in hand with the rise in commerce and industry in Britain, and the need for suitable clothes for the thousands of people entering newly emerging occupations such as banking, insurance and public administration (Lee, 1979, in Aldrich, 2007). The American Civil War was also a factor in the rise of mass production in that country due to the urgent need for the production of over a million uniforms for army conscripts (Kidwell, 1979; Green, 1997, in Aldrich, 2007). Large volumes of cheap clothes were produced initially by hundreds of women machinists, using pre cut garments that were pieced and bundled together and sent to their homes for sewing (Jenkyn Jones, 2005). At a later stage, small factories and workshops overseen by a contractor or 'sweater' (Zakim, 1998), were set up to save time, reduce costs of delivery and collection, as well as to maintain the quality of garments (Jenkyn Jones, 2005). The overriding factor which contributed enormously to the mass production of clothing, however, was the invention of the sewing machine (Bellis, 2008; Forsdyke, 2008).

History of sewing machines

According to Cole (2005), sewing machines were originally invented for production lines in garment factories to enable uniform mass production, but the beneficial impact of the sewing machine was felt as much in the home as in the workplace. Fernandez (2004), notes that for most of the 18th century and into the early 19th century, nearly all Anglo-American women sewed for themselves and their families, regardless of their social position, and only the more prosperous women employed professional clothiers to make their dresses for special occasions. It is claimed that the sewing machine, together with the paper pattern industry, provided the means for women sewing in the home to make fashionable and stylish garments, develop new skills, and gain confidence and self esteem (Fernandez, 2004; Seligman, 1996; Aldrich, 2007).

According to various authors, there were many attempts in Britain, Europe, and America to invent and patent sewing machines. Some of 18th and 19th century inventions documented in the literature are described below. Charles Weisenthal, a German immigrant patented a needle for mechanical sewing in London in 1755, despite the fact there was no machine to operate the needle at the time (Askaroff, 2008; Museum of American Heritage (MOAH), 2010).

Thomas Saint, an English cabinet maker, invented a machine for the purpose of sewing leather and canvas in London in 1790 (Askaroff, 2008; Forsdyke, 2008), as illustrated in Figure 61.

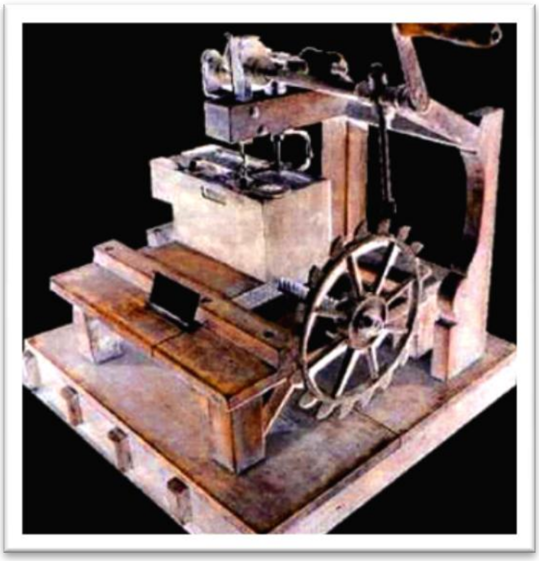


Figure 61: Illustration of a replica of a sewing machine invented in 1790 by Thomas Saint in London (modified from Askaroff, 2008).

Thomas Stone and James Henderson patented two inventions in France in 1804 which attempted to emulate hand sewing (Askaroff, 2008; Bellis, 2008). Balthasar Krem invented an automatic machine in Germany in 1810 for sewing caps and hats (Bellis, 2008; Forsdyke, 2008; Askaroff, 2008).

Josef Madersperger, an Austrian tailor, produced a series of machines in 1814, none of which were notably successful (Bellis, 2008; Forsdyke, 2008; Askaroff, 2008). John Knowles and his partner John Adams Doge invented a machine in Vermont USA in 1818 that was only able to stitch a few inches at a time before malfunctioning (Bellis, 2008; Forsdyke, 2008).

Barthelemy Thimonnier, a French tailor, patented the first successful sewing machine in Paris in 1830. By 1841 Thimonnier had been given a contract by the French Government and had eighty machines for sewing army uniforms in his garment factory. Figure 62 shows an illustration of the Thimonnier sewing machine which was made predominantly of wood (Bellis, 2008; Museum of American Heritage 2010).

Figure 62: The predominantly wooden sewing machine invented by Thimonnier in France in 1830 (modified from Askaroff, (2008)

It is of interest to note, that there was great resistance from Parisian tailors who felt threatened that the success of the new machines, would make hand sewing obsolete, and put craftsmen tailors out of work (Forsdyke, 2008). Eventually, enraged tailors fearing for their employment, burnt down Thimonnier's garment factory, destroyed all his sewing machines and caused him to flee for his life.

In 1834, Walter Hunt developed the first sewing machine that worked in America, with the drawback that the machine could only stitch small sections at a time. Hunt did not patent the machine, as his daughter persuaded him that 'impoverished seamstresses' would become unemployed as a result (Museum of American Heritage, 2010). Twenty years later Hunt patented an improved model, but by then it was too late as many other workable sewing machines had already entered the market (Askaroff, 2008).

In 1844, Elias Howe, credited as producing the first workable sewing machine in America, patented several components of his sewing machine in the United States, which incorporated ideas very similar to those of Hunt. Howe was forced to travel to England to promote his machine but this was unsuccessful. On his return to the US he found that many new sewing machine manufacturers had started using his patented ideas, particularly in relation to the needle, which had a long grove in it to prevent the thread snapping and unravelling (Askaroff, 2008; Bellis, 2008; Museum of American Heritage, 2010).

Askaroff (2008) notes, that one of the manufacturers who had adopted Howe's lockstitch mechanism was Isaac Singer. However, singerco*,* (2010) states that Isaac Singer was the first to mass produce a commercially viable sewing machine in the US in 1851, after obtaining the first lockstitch sewing patent. Other sources note that Singer patented the first rigid-arm sewing machine and invented a foot treadle in place of the hand crank (Museum of American Heritage, 2010) and it was stated that Singer's greatest skill lay in his ability to adapt other inventor's ideas (Askaroff, 2008).

According to Bellis (2008), on discovering that his machine patent had been infringed by various machine manufacturers, including Singer, Elias Howe sued the infringers and won the legal battle in 1854. As a result, Singer had to pay a royalty to Howe whereas other machine manufacturers had to pay a licence fee. Both Howe and Singer became very wealthy. The Singer manufacturing company went on to become the world's largest by 1855 (Askaroff, 2008; Bellis, 2008; Museum of American Heritage, 2010), and in the same year, after commencing overseas expansion in Paris, the Singer Company became the world's first international company (singerco, 2010). Figure 63 shows a selection of the early model singer machines.

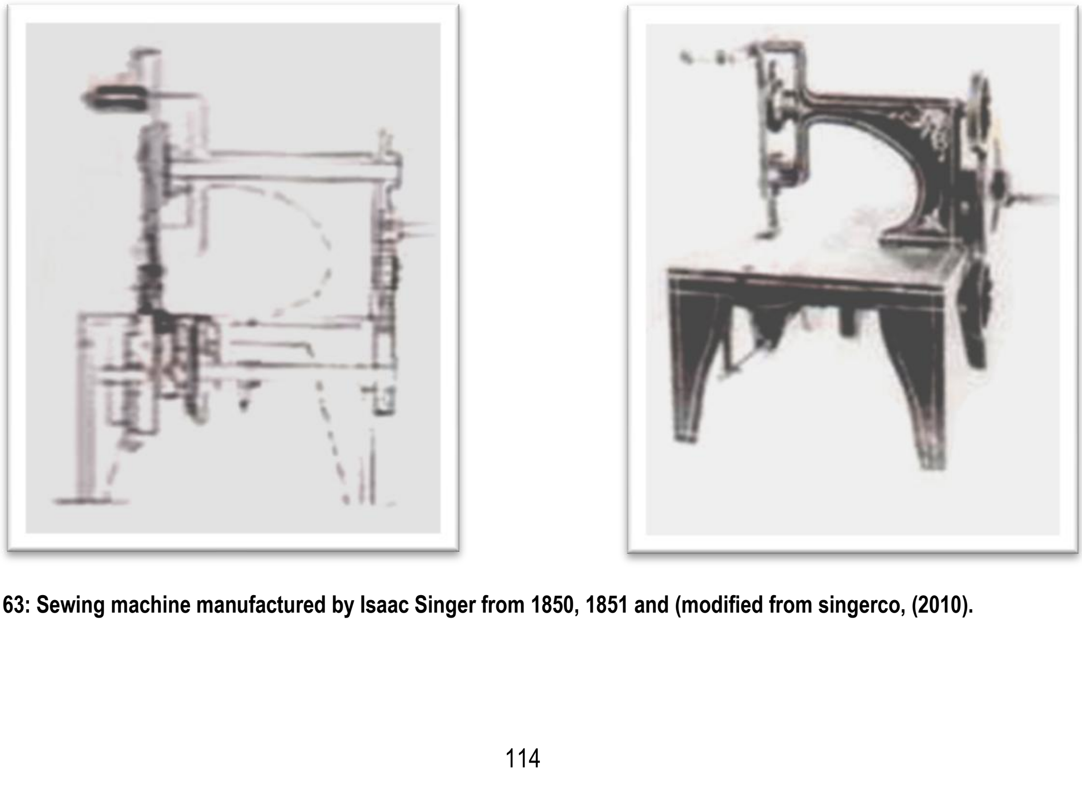


Figure 63: Sewing machine manufactured by Isaac Singer from 1850, 1851 and (modified from singerco, (2010).

The advent of the sewing machine on the development of the garment industry was profound (Kidwell, 1979, Ashdown, 1997). From a positive perspective it provided an opportunity for the home sewer to produce garments more quickly without labour-intensive hand stitching (Cole, 2005) and become self employed (Fernandez, 2004). An article published in the Victorian press claimed that the sewing machine was the greatest invention in the history of the world to that date, because it had freed more women from the 'drudgery of manual labour' than any other invention (Askaroff, 2008). The professional dressmakers and tailors also benefited from the invention of the sewing machine as it reduced the tedium and monotony of repetitive and time consuming hand sewing, while greatly reducing the time required to complete a garment (Museum of American Heritage, 2010). Another undoubted benefit according to a Cheltenham dressmaker was that the health of her machinists improved considerably (Seligman, 1996). With the introduction of the electric sewing machine in 1921, Jenkyn Jones, (2005) notes that the evenness of the finish was so much better, that anything homemade was seen to be inferior for the first time.

From a negative perspective, the numerous changes that occurred primarily within the larger workshops and garment factories with the introduction of the sewing machine had the greatest impact, although most were not permanent (Wyatt, 2009). Such changes in workshops and factories included impersonal management, loss of independence, harsh working conditions, and low wages which characterised the early years for many female workers in particular, despite continual increases in production (Museum of American Heritage, 2010). In this regard it has been noted, that as clothing was able to be produced ten times faster than by hand stitching, fewer stitchers/seamstresses were needed to produce the same output. This resulted in a dramatic decline in the number of the female employees. Wages were also kept low due to the large number of unemployed stitchers/seamstresses (Maginnis, 1996).

Since most stitchers were female and received only half the wages of males, few if any could afford to buy a sewing machine and set up a small business on their own. Many itinerant dressmakers were also forced to find another way to make their living. Enterprising housewives who could afford to purchase a sewing machine took advantage of its greater efficiency and began to take in sewing, to earn extra money (Fernandez, 2004). As demand for ready-to-wear women's clothing grew, so too did the numbers of female machinists employed in the garment factories. However, it was not until the beginning of the 20th century that mass-production of women's clothing in America began to exceed the combined output of the dressmakers, tailors, and clothiers (Scranton, 1994 in Aldrich, 2007).

Mass production of ready-to-wear garments

As noted previously, mass production of ready to wear garments commenced in the mid 1800s in Britain, America and on the Continent. In the earliest stages of mass production with the setting up of factories, the immediate and major considerations were: (i) what measurements to use, (ii) what sizes to make, and (iii) how to label the garments (Winks, 1997). Data for the manufacture of male and female clothing had to be obtained from a variety of sources, including tailors' drafts of simple garments such as breeches, and from tables of proportionate measurements published by tailors and dressmakers with the gradual improvement in literacy skills (Aldrich, 2007).

The measurements for mass produced garments for men in the US were largely obtained from army conscripts who were measured for uniforms as a result of the occurrence of the American Civil War and the Crimean War. The need for up to one million uniforms to be produced quickly, and the early recognition of certain linked patterns in chest, waist and leg measurements led to the establishment of a single set of sizes which was subsequently applied to civilian menswear (Kidwell, 1979; Scranton, 1994 in Aldrich, 2007).

On the other hand, available published data of the female population in the same period were almost non-existent. In most cases, the first ready-to-wear garments for women supplied by clothiers and wholesalers were based on proportional systems of pattern cutting, which did not take into account either the variation in the relative proportions of the bust and waist measurements in different sized women, or the three dimensional change in breast shape that occurs in larger sizes (Aldrich, 2007). Schofield (2007) cites Cooklin (1990) who notes that many of the first fitted ready-to-wear garments for women were based on the incorrect assumption that there was a fixed proportional relationship between circumferences and lengths, which resulted in clothing that fit very few and required substantial alteration to obtain a reasonable fit. It has been noted by Aldrich that Tables and Size Charts of proportionate measurements utilised by the clothiers, resulted in numerous garments of unreliable fit. With the expansion of some drapery and tailoring establishments into department stores, there was increasing demand for garments that could be fitted quickly, as in the case of mourning clothes. Due to the vast number of alterations required for ready to wear garments, department stores found that additional workrooms with experienced dressmakers were essential to make the necessary adjustments to obtain a reasonable fit for their customers (Aldrich, 2003 in Aldrich, 2007).

Mass production of women’s clothing developed slowly, largely as a result of the very detailed and close fitted fashions of the mid to late 1800s (Kidwell 1979). Artificial body shape changes also resulted from more women wearing corsets which had become cheaper and more flexible (Aldrich, 2007) which exacerbated the problem of making garments that would fit a reasonable number of customers. For several decades clothiers faced the problem of being unsure of how to size garments to fit a range of unnatural body shapes which changed frequently according to the dictates of fashion.

Zakim (1998) notes, that as mass production increased, a growing percentage of drafting systems were developed using principles of proportionality. This meant that a minimum number of measurements were taken on the customer and the rest calculated by means of a set of scales or tables. Zakim suggests that proportionality became the basis of mass production because it was the logical means for extrapolating sizes in the absence of any direct measurement data. However, the ‘fit’ of the garments was dependent upon how closely the wearer matched the system developer’s concept of proportionality (Gamber, 1995).

It has been noted that the earliest ready-made clothing often fitted poorly because manufacturers used arbitrary sizing systems based on inaccurate body data or no body data at all. This resulted not only in additional costs for alterations, but also in a large volume of returned merchandise. An added problem was that garments of varying dimensions were labelled the same size by different manufacturers (Museum of American Heritage, 2010).

With the expansion of the ready-to-wear industry, the complex issue of establishing standard clothing sizes to cater for the wide variety of shapes and sizes of people in a population and provide a reasonable fit, needed to be addressed (Winks, 1997; Ashdown, 2007). However, the arbitrary labelling of garments by different manufacturers continued through to the 1940s. O’Brien and Shelton (1941) commented that garments labelled the same size but made by different manufacturers can vary markedly and rarely fit without alterations. This comment was followed in 1951 by the UK Clothing Industry Development Council expressing its concern about the losses in labour and materials, specifically in relation to the scale of alterations required for ladies clothing, which it attributed to an absence of reliable sizing systems and standardized measurement procedures (Board of Trade UK, 1957).

What measurements to use and what size to make?

The issue of what size to make and what measurements to use **continues** to be an ongoing worldwide dilemma. Sizing systems are complex and vary considerably, in nomenclature, as well as measurements, as has been noted by Winks (1997), who compared national and international size designations for women's outerwear as shown in Table 8.

Table 8: Comparison of international and national size designations for women's outerwear (cm) (modified from Winks, 1997)

Member country	Size designation	Height #	Bust #	Waist #	Hips #
Australia	14	160-170	90	70	95
Bulgaria	81	164	92	69.9	96
Czechoslovakia	3AA45*	166	90	68	98
Denmark	40	-	90	72	98
Finland	C40	161-166	92	70	98
France	42n	-	93	60-72	101
Germany	40	164	92	72.5	98
Hungary	164/90/94**	164	90	68	94
Iran	38	-	90	66	96
Ireland	12	158-168	-	-	91-95
Israel	40	165-167.5	92	70.5	100
Japan	92/99	-	92	69	99
New Zealand	14	157-165	92	72	97
Poland	164/92/96	164	92	-	96
South Africa	92/96/164**	165	92	72	96
Spain	46+2 (L)	167	92	67	96
Sweden	C40	163-170	90	-	98
Switzerland	40	-	92-95	69-72	98-100
UK	14	160-170	90-94	-	95-99
USA	14	165	93	70	98
USSR	164/92/96**	164	92	-	96
Yugoslavia	40	162	92	72	100

#Actual or nearest measurement
*Designation includes waist listed before hips
**Actual designation method not given

The ongoing sizing issue continues to confront designers, manufacturers, retailers, educational institutions, and consumers as well as fashion graduates who wish to pursue a career in the garment industry. Fashions houses use data that have been derived either from their own market research, which is focused on specific target markets, or from designers' experience, or market observation (American Standard for Testing and Materials, 1995; Winks, 1997). Numerous commercially driven anthropometric surveys have also been conducted by a consortium of partners made up of industry, Government and academic institutions over the past decade (Robinette et al., 2002; [TC] ^{2}, 2004;

Bougourd, 2005). In many instances the data from such studies are only available at a high cost to interested parties. An overriding factor which contributes to the fit and sizing issue in Australia is that there has never been a scientific survey conducted of the Australian population for the purpose of establishing clothing size standards for the female population.

History of Australian clothing size standards for women

Clothing size standards in Australia were initially prepared to provide a classification of women's body measurements for the purpose of sizing ready to wear garments for women (Australian Standard, 1959). The first standard was prepared at the request of the Apparel Manufacturers Association of NSW in 1957 in conjunction with garment manufactures and the retail industry. The request was to prepare a draft document for: (i) a classification of body measurements and (ii) a size coding scheme for women's clothing. As a result, Australian Standard L9-1959 was published and documented in 1959 as the Australian Standard Body Measurements for The Sizing of Woman's Ready-To-Wear Apparel (outerwear and Underwear) (Australian Standard, 1959).

It is of interest to note that the Standard Australia Committee on Women's Wear at that time expressed the view that there was a need for a comprehensive anthropometric survey of the Australian population. Some members noted, however, that such a survey would be time consuming and expensive. The committee felt, after a comparison by Dr H O Lancaster from The School of Public Health and Tropical Medicine Sydney, that existing data from a US Commercial Clothing Standard TS-5200A, published as CS 252-58 showed striking similarities to data from an Australian survey, conducted by Berlei (a manufacturer of women's undergarments) between 1926 and 1928. The committee noted in the preface (Australian Standard, 1959) that there was sufficient evidence of similarities between the Berlei data and the US data to justify the publication of Australian Standard L9 and that this standard could be reviewed at a later time after a period of use. It is notable that the initial Australian Standard L9 1959 was not based on an anthropometric survey of the Australian population.

Subsequent reviews and revisions were carried out between 1970 and 1997. The 1970 revision was based on a 'self reporting' survey conducted late in 1969 by the Standards Association with the assistance of the Australian Women's Weekly Magazine. The survey consisted of body measurements of 11,455 women which included; bust, waist, hip, height and age. This was a self reported survey and not conducted by trained personnel. As a consequence of the survey findings, a new size coding scheme, L9 1970 was introduced (Australian Standard, 1970). It was noted that the size coding was similar to the numerical system of the UK and USA. It was felt that the system would simplify the import of garments from the UK and USA and would assist all sections of the clothing industry in Australia as a simple scheme to designate the size of women's clothing.

In 1972 there was a revision of the 1970 standard that resulted in its replacement with the AS 1344-1972. The purpose of the revision was for conversion of the L9 1970 standard to metric units. This conversion consisted of incremental steps of 5 cm on the bust, waist and hip, and it was noted that the conversion would not change the existing sizes (Australian Standard, 1972). In 1975 another revision was undertaken and replaced AS 1344-1972. This standard was completed by the inclusion of foundation garments. An additional chart was incorporated into the code giving actual body measurements, which represented the control dimensions for foundation garments that covered the upper body.

The most recently published standard AS 1344-1997, superseded AS 1344-1975. This revision reaffirmed the information contained in the previous edition, as there had not been any survey data produced in the interim. It was stated that the committee deplored the practice of altering size codes, to show a lower size label for measurements meant to be applied to one, or even two sizes higher, according to the standard tables. The committee also noted that this practice results in a lack of confidence by consumers about the fit of garments and reduces the effectiveness of a size code system (Australian Standard, 1975). Vanity sizing is the term often used to denote a garment labelled a size or two smaller than the control measurements applicable to the size code. Honey and Olds (2007) refer to vanity sizing as a strategy to gain a competitive advantage. Bougourd (2007) suggests that in some instances vanity sizing is used as a marketing tool to flatter prospective consumers. While the contentiousness and complexity of vanity sizing is acknowledged, the issue lies outside the objectives of this thesis.

Of interest to this study, however, is the statement by the committee that the relationship of bust to waist to hip has changed over time, and the suggestion that manufacturers include this information on garment labels, as well as the size code where appropriate (Australian Standard, 1997). Subsequently in 2003, the most recently published Australian Standard (1997), was withdrawn, and as at the present time no other Clothing Size Standard designated for the Women's Ready-To-Wear Apparel has been issued, despite the fact that the International Organisation for Standardisation (1991), recommends that clothing surveys should ideally be updated every 10 years to keep abreast of the current size and shape of the population.

Sizing dilemma

Withdrawal of Australian Standard (1997) reflects the widespread dissatisfaction with its usefulness as a guide for the sizing of women's garments. One of the fundamental issues is that the measurements in Australian Standard (1997) did not reflect the average size and shape of the Australian female population. It has been argued moreover, that the Australian Size Coding Scheme for women has been outdated for some considerable time. The literature suggests for example that there is, and has been for many decades, a major dilemma in the sizing of women's clothing in Australia (Sew Trade, 1990; *Ragtrader,* 1998; Hornet, 2004; Patterson and Brown, 2000; Berry, 2001; Honey and Olds, 2007; Australian Safety Compensation Council, 2009). Industry bodies in the area of clothing and textiles, including, The Council of Textile and Fashion Industries of Australia (TFIA) (2009), and the Fashion Technicians Association Australia (FTAA) (2009), have long recognised that the problem is attributable to outdated data in relation to the size and shape of the Australian population, and have presented submissions and lobbied the Federal Government in this respect.

Numerous criticisms and recommendations have also been made through various media sources in relation to consumer confusion and frustration when buying clothes. The Standards Association of Australia is well aware of the issues in relation to outdated standards and the effect these are having on consumers. The *Ragtrader* (1998) reported that Frank Whitford from Sportsgirl/Sportscraft Group stated that the sizing debate has been a continuing problem for the last hundred years. In the same issue Jack Moncrieff (Standards Association of Australia) noted that Australian Standard, 1997 was outdated and that little had changed since 1975*.* Ann Howes (Standards Association of Australia) also in the same issue stated, that whilst Australian Standard 1997, was relatively outdated, having something was better than having nothing. Howes also noted the increasing trend of manufacturers to label clothes one or even two sizes lower, and that many large retailers and chain stores were using their own sizing tables.

Hornett (2004), summarised various key points raised at the first National Sizing Forum initiated by Standards Association of Australia. One of the points was that the current sizing problems may be attributed to inadequate clothing size standards based on anthropometric data collected over 70 years ago. Another point raised by industry related to the various ways to obtain comprehensive body measurements of the Australian population, with the ultimate aim of creating a revised Australian Standard. A further point discussed, was that size discrepancies are so great that they vary as much as two sizes, between adjacent retail outlets in the same shopping centre, leading to consumer frustration and distrust of the size codes of the brands in question.

It is apparent that the Australian clothing manufacturing industry, and retailers, as well as educational institutions, have had to work with standards that were outdated and not representative of the Australian population. It is interesting that the Department of Innovation, Industry, Science and Research (2008), reports that the Textile Clothing and Footwear (TCF) industries in Australia can have a promising future, and suggests that to achieve this they will need to manufacture products that are of high quality, and uniquely different in design from their competitors. A recommendation was also made that the long overdue Australian National Sizing Standard for clothing and footwear should be developed. The recommendation is based on the fact that to produce high quality garments that fit a large majority of the population, one of the fundamental requirements are current data that reflect the size and shape of the target population in order to ensure a competitive and sustainable advantage.

Clothing size standards: a worldwide issue

The historical development of clothing size standards has followed a similar difficult path worldwide. Holzman (1996) quotes Goldsberry, who noted that US clothing size standards are based on studies conducted in the 1940s, and that women's shapes, over recent decades have changed dramatically. In the same paper, Ashdown is quoted as saying that the then current standards do not reflect the size and shape of the population. Simmons et al., (2004a) also note that the US clothing standard is based on 60 year old data that are far from basic human proportional truths, and do not conform to the current shapes of American females. More recently, American Society for Testing and Materials (1995 Reapproved 2001) acknowledged that the measurements in the current standard were originally developed from an anthropometric survey by O'Brien and Shelton (1941), and advised that they have since been upgraded using data from designers' experience and market observations, and cross checked with available data bases, rather than from a new national anthropometric survey. Labat (2007) also refers to American Society for Testing and Materials (2001) and asserts that the revision consisted of a shift in size comprising the increase by one grade interval of the bust girth and affirms that the revision was an upgrade only, as the bust girth was increased by one grade interval per size code for all figure types.

In the UK, it was not until after World War II that any action was taken to devise a clothing size standard. A study was initiated by the Joint Clothing Council in 1951 and the responsibility for completion of the work was assumed in 1953 by the UK Board of Trade and published in 1957 (Board of Trade UK, 1957). Aldrich (2007), notes that a set schedule of code sizing was established by the British Standards Institution in 1953, but was not successful with manufacturers who preferred their own size charts which they developed for their own target markets. In view of the lack of interest by manufacturers, another standard was introduced (British Standard Institution, 1963). However, according to Aldrich (2007), the 1963 standard became obsolete in 1965 due to the change to metrication and was replaced in 1974 with a modified version. Once again, the standard was replaced in 1982, with information taken from two International Standards published by the International Organisation for Standardisation (British Standard Institution, 1982). For further information on the development of clothing standards not only in Britain, but internationally, the reader is referred to Winks (1997).

Despite documented changes to clothing size standards both nationally and internationally over the past 60 years, it is generally the case that the various revisions were rarely based on anthropometric research (Winks, 1997). As a result, the revised data do not accurately reflect the changes in size and shape of a population, particularly with respect to the overweight / obesity epidemic referred to previously in this thesis. Consequently, standards have become of little value to many design houses and manufacturers, who for various reasons have continued to implement their own sizing systems to meet their specific client group or niche market (Ashdown, 2007) and retain their ‘signature fit’ (Petrova, 2007). Chun, (2007) also notes that the resulting lack of standardisation of sizing has created ongoing confusion in the marketplace for both retailers and consumers. Simmons et al., (2004a) argue similarly that industries’ implementing their own sizing systems does not address the problem of obtaining a uniform sizing system that will fit the variety of human female morphological shapes that currently exist. Simmons et al., (2004b) note that most sizing systems are based on the illusion of human proportionality. Moreover, the point is stressed that body shapes and body proportions are far different today from those of several decades ago. Holzman (1996) refers to Ashdown and Paal who assert that humans do not grow proportionately and these authors also suggest that population morphology should be considered in relation to sizing as human body size and shape does not increase at even intervals.

The assumption of proportionality relies on the notion that an average sized individual will be average in all dimensions (McConville, 1978). This concept of an average sized individual has been the subject of discussion in the literature for some considerable time, (Hertzberg, 1972; Bridger, 1995). Hertzberg claimed, that designing to fit the ‘average man’ is a serious design flaw and that the notion of an average person is a fallacy as it ignores the reality that no one is average in all regards. According to Daniels and Churchill (1952, in McConville, 1978) the so-called 'average man does not exist'. In their study of the concept of the average man, it was found that of 4,000 plus subjects, only 1000 were of average height; only 300 were of average chest circumference; of these only 143 had an average sleeve length. They concluded that the concept of the average man was an illusion, and a misleading basis for design practice. They suggested that a more valid approach is to use the range of variability in body dimensions.

The illusion of an 'average person' has recently been referred to once again in a media release by Gibbs (2011) who reported comments by Dr Kathleen Robinette, an anthropological researcher and anthropometrist, in her keynote address titled "Who is Average?" Robinette put forward the view that the so-called average female does not exist and is a myth from the past, and notes that a widespread industry practice at the present time is for companies to engage a fit model who is representative of their target group and use the fit model's body dimensions as the base size for their product lines. Robinette attributes the reliance on the average body dimensions of the fit model to the ongoing issues relating to ill fitting garments, and equates this to 'poor guess work' in the area of garment sizing, as some people may be average in dimensions such as body height, but no one is average in all dimensions.

It is interesting to note that a focus on body dimensions and body proportions is not new. Simons (1933) compared proportional measurements used by prominent designers from the late 1800s to the early 1900s. Table 9 shows the measurements for sizes 32 to 36 which have been converted to centimetres for this study. Simons argued that one of the reasons for the variation in measurements was related to the fashion styles of that period.

Table 9: Comparison of designers' measurements in cm from late 1880s to early 1900s (Simons, 1933 p2)

Size	**32**	**36**	**32**	**36**	**32**	**36**
Designer	Bust	Bust	Waist	Waist	Hip	Hip
G. Englewan	81.3	91.4	59.7	63.5	94.0	104.1
*Ladies system	91.4	96.5	73.7	78.4	94.0	101.6
S. Shorr	89.0	99.1	55.9	63.5	91.4	101.6
D.E.Ryan	81.3	91.4	62.2	66.1	89.0	104.1
Vincent	81.3	91.4	57.2	60.9	96.5	106.8

Simons noted that the variation in the waist and hip measurement was unquestionably related to the styles of the period, as some measurements were in use before 1900, when it was fashionable for women to have a small waist and large hips. To illustrate this point, Figure 64 from Simons (1933) shows two superimposed morphological shapes illustrated by solid lines and dotted lines. The dotted line shows the decrease in the waist and the increase in the hips of the female of the 1890s, compared to the female of the 1930s.

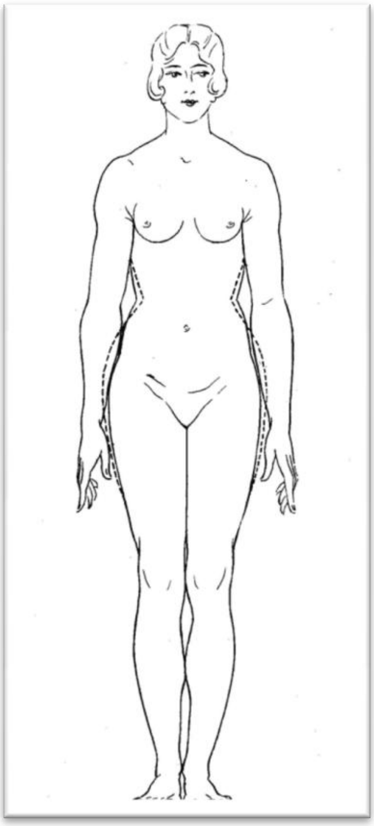


Figure 64: Illustration of morphological shapes of the 1890 period and the 1930's (Simons 1933)

A further indication of differences in body dimensions of bust, waist and hip for the design and production of female garments between 1910 and 2001 is shown in Table 10. These measurments were obtained from various published sources such as anthropometric surveys for clothing size standards, or tailoring and dressmaking publications.

Table 10: Comparison of data from 1910-2001 of bust, waist and hip (average bust size 91.4 cm)

Reference	Year	Country	Bust	Waist	Hip	Height	Source
Vincent (in Hard's 1954)	1910	UK	91.4	66.0	101.6		Tailor
The Woman's Institute	1924	USA	91.4	71.1	99.0		Dressmaker
Poole	1927	UK	91.4	61.0	101.6		Tailor
Morris	1940's	UK	91.4	68.5	101.6		Tailor
O' Brien and Shelton	1941	USA	90.9	73.66	98.8	162.5	Survey
Lapick	1948	USA	92.7	71.1	95.2	165.1	Tailor
Delafera (in Hard's 1954)	1950	UK	91.4	71.1	99.1		Tailor
Board of Trade	1957	UK	91.4	66.8	96.5	160.0	Survey
Kunick	1967	UK	91.4	68.5	96.5	162.5	Survey
Standard Australia	1997	Aust	90.0	70.0	95.0	164.0	Standards
American Society for Testing and Materials	2001	USA	91.4	71.1	97.8	166.4	Standards

The complexity associated with sizing systems is also found in commercial paper patterns. A comparison of American and European size charts in a 1998 publication shows the differences in nomenclature, size increments, and the variations in waist and hip associated with a similar bust measurement. Table 11 shows the comparison of paper patterns from McCalls, Simplicity, and Vogue/Butterick with the European company Burda (Palmer and Alto, 1998).

Table: 11 Commercial pattern size chart comparison of USA and Europe (modified from Palmer and Alto, 1998)

American size charts (cm) (Mccalls, Simplicity, and Vogue/Butterick)

Size	6	8	10	12	14	16	18	20	22	24	26w	28w	30w	32w	34w
*Bust	78	80	83	87	92	97	102	107	112	117	122	127	132	137	142
*Waist	58	61	64	67	71	76	81	87	94	99	105	112	118	124	130
*Hip	83	85	88	92	97	102	107	112	117	122	127	132	137	142	147

*Bust increase from size 12 to 34w is 5cm
*Waist increase from size 12 to 34w varies between 4cm to 7cm
*Hip increase from size 12 to 34w is 5cm

European size chart (Burda)

Size	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
*Bust	76	80	84	88	92	96	100	104	110	116	122	128	134	140	146
*Waist	58	62	66	70	74	78	82	86	92	98	104	110	116	122	128
*Hip	82	86	90	94	98	102	106	110	116	122	128	134	140	146	152

*Bust increase from size 34 to 46 is 4cm
*Waist increase from size 32 to 50 is 4cm and from size 50 to size 60 is 6cm
*Hip increase from size 32 to 46 is 4cm and from size 46 to 60 is 6cm

The lack of clothing size standards is also a major issue for education and training. For example, clothing size standards in the past were considered an essential component and guide for students in various areas of clothing and fashion studies. In some institutions, the 'Clothing Size Standards' were considered to be 'The Bible'. Such standards provided the foundation for students to design and present fashion ranges to meet industry criteria. Due to the withdrawal of the latest Australian Standard, (1997) in 2007, educational training institutions and entrepreneurial fashion graduates now have to rely on their own resources through trial and error, or purchase data at a considerable cost. With no clothing size standards or reliable population data available it is not surprising that there continues to be a reliance on a proportionate system approach to pattern engineering. Kunick (1967) believed that a lack of reliable data was responsible for the continued use of this system, as minimal measurements are required.

Using a proportionate system approach to pattern engineering, however, may have serious disadvantages in that human variation and individual characteristics cannot be easily catered for. Another factor relating to human variation that creates major challenges in the engineering and construction of properly fitting garments is body posture, which is addressed in the following section.

Posture: Garment Fit

A significant factor for the successful design and production of female garments is the role body posture plays in the final analysis of the overall appearance, fit, and comfort. Historically, skilled couturiers, tailors and dressmakers were trained to identify human variation in size, shape, and posture (Poole, 1927; Hard's Yearbook for the Clothing Industry, 1954; Bye et al., 2006). This training enabled them to disguise figure irregularities and achieve a high quality and aesthetically pleasing garment. The ready to wear industry on the other hand, caters for the masses within a competitive environment, where economics is a major factor. Sizing systems used for the production of ready to wear garments are based on an 'average size': therefore postural variation is given little or no consideration. Ashdown (2007) asserts that not only are there numerous sizes and proportions within the human female population, but the added element of posture also has a major impact on the fit of clothing.

Simons (1933), defined posture according to the clothing trade as the 'attitude or exterior delineation' of the body which is generally determined by the curvature of the spine. Simons classified postural variations as: stooped with head forward; or sway-backed with an erect figure; and also drew attention to the variations in the slope of the shoulder and neck position. Bye et al., (2006) have also made the point that a process needs to be developed for measuring variations in posture such as back curvature, hip position and bust shape, in a form that can be applied to the pattern engineering process.

Hard's Year Book for the Clothing Industry (1954), states that posture affects both size and shape of certain body dimensions and therefore plays an important role in garment fit. Hard's also describes numerous figure types such as: stooped; erect; round backed; pigeon chested; and various stances such as head forward or slouched; and shoulder positions such as square and sloping, almost all of which relate to posture. Norris (1998) cites Kendall et al., (1993) who state that a standing posture can be assessed using a plumb line that is positioned laterally. In an ideal posture the plumb line should pass just 'forward of the mid-line of the knee, through the greater trochanter, bodies of the lumbar vertebrae, shoulder joint, bodies of the cervical vertebrae, and the lobe of the ear. Reference is also made to the vertical alignment of the anterior superior iliac spine and pubic bone being parallel to the plum line (Figure 65a).

Figure 65a: Ideal standing posture (modified from Norris 1998).

It is interesting to note the similarity between the erect anatomical presentation of Norris, (1998) in Figure 65a, and the body posture of the female figure from Richards and Richards (1912), in Figure 65b. Richards and Richards (1912) described the posture as one that is 'poised and graceful, with the head upright, a straight abdomen, curved back, and well rounded hips set backwards'. Both authors make the point that this is the ideal stance. However from a realistic point of view, the present day posture of the average adult female falls well short of this ideal.

Figure 65b: Ideal stance from Richards and Richards (1912)

Postural deficiencies from an anatomical viewpoint relate to deviations from the normal curvature of the spinal column. Three main spinal deviations that affect the fit of female garments in particular are: kyphosis, lordosis, and scoliosis.

These three spinal abnormalities have been defined as follows: kyphosis, an exaggeration of the thoracic curve of the vertebral column, often referred to as hunch-back; lordosis, exaggerated forward or inward curvature of the lumbar spine, sometimes referred to as sway-back; and scoliosis, lateral bending of the vertebral column usually in the thoracic region and the most common of the abnormal curves (Tortora and Grabowski, 1996) as shown in Figure 66 (Imwold et al., 2007).

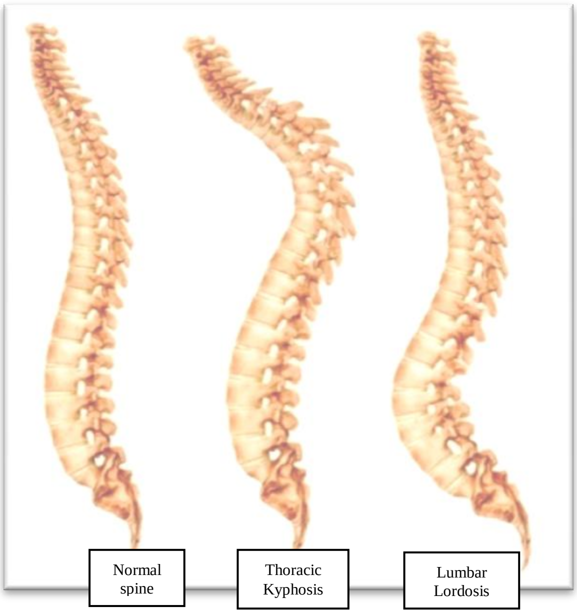


Figure: 66 Comparison of normal spine, thoracic kyphosis, and lumber lordosis (modified from Imwold et al., 2007)

Barker (2002), see Figure 67 shows deviations from the normal curve of the spine such as: A, sway back; B, flat back; C, lordosis; and D, kyphosis. These postural variations will inevitably affect the fit and balance of female garments.

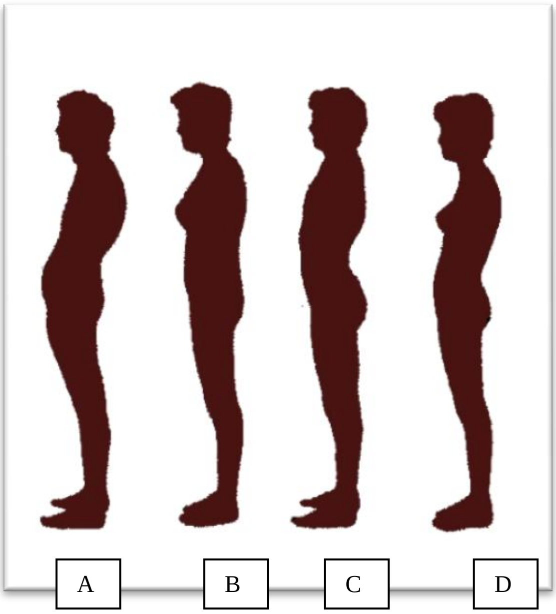


Figure 67: Postural imbalances: A, sway back; B, flat back; C, lordosis; and D, kyphosis (modified from Barker, 2002)

As noted above, Bye et al., (2006) have drawn attention to the skill of the earlier tailors in disguising postural imbalances and other figure faults. These skills comprised knowledge of the human body form in all its variations, and knowledge of how to drape fabric on the body to achieve the best possible result in terms of garment fit and balance. At the present time, it is arguable that the posture of many women is less than ideal, and a far cry from that of women during the corsetry era when the term 'strait laced' meant just that, and deportment was part of a young female's education. Poor posture may well be an unsuspected contributor to ill fitting garments.

It should not be overlooked, however, that the fit preferences of women also play a major role in the resulting impression of whether or not a garment fits well. Bougourd (2007) notes for example that there are marked differences in fit preferences between cultures. In this regard it is generally accepted that French women prefer more closely fitting garments, while women from other Mediterranean regions often prefer a more relaxed and looser fit.

This concludes the literature review section of this study. As has been noted, many topics addressed in this review have implications for pattern engineering and the successful production of adult female garments, particularly in relation to comfort and fit. It is acknowledged that there is an abundance of published literature in relation to the above topics, some of which were beyond the scope of this study and would benefit from greater in-depth investigation and analysis. In the author's view, the introduction of 3-D body scanning together with an increasing expansion of digital computerisation also calls for further research. The following section presents the methods and materials relating to the stated aims of this study.

Chapter 2: Materials and Method

Introduction

The aim of the present research required the testing and analysis of two block drafting systems. The first system which is based on proportionality and uses minimal direct measurements is referred to hereinafter as a Calculated Proportionate system. The second system which is based on shape, and uses measurements which have been taken directly on the body is referred to herein after as a Direct Measurement System.

The two systems chosen for the study are as follows:

1 Calculated proportionate system: The Metric S.I. Method (N.S.W TAFE School of Fashion, 1977) hereinafter referred to as (MSI)

2 Direct measurement system: The Fashion Design System (Berry and Hennes, 2008) hereinafter referred to as (FDS)

Ethics approval

Ethics approval was not necessary as the testing procedure followed that of a conventional method used in the product development section of an industry, or of a dressmaker. Because of the sensitive nature of fitting the garments on participants, due care was taken to avoid any embarrassment by referring to size, shape or any other figure irregularities of the participant.

Units of measurements

In the fields of scientific research and reporting, the standard unit of measure is the millimetre (mm). Within the garment industry, however, the conventional unit of measure is the centimetre (cm) particularly when drafting or grading patterns. In this thesis the international unit of the millimetre will be utilised for statistical analyses and all reporting other than that concerned directly with the garment industry convention.

Equipment

- A standard 15 mm fibreglass tape measure
- Standard dressmaking pins
- Sleeveless, closely-fitting thigh-length cotton vests
- Medium weight calico for dress toile
- A 580mm dress zip
- Portable metal stand 2100 mm high x 9000 mm wide with a grid of 100 mm squares positioned behind a wooden platform 100 mm high X 700 mm wide
- 2.3 metre length of fabric as back drop for the portable stand
- Adjustable tripod for camera stability
- Olympus digital camera with two media smart cards and a floppy disk adaptor
- PC computer for photograph generation
- Full length mirror
- Checklist for garment adjustment
- Checklist of tolerances for acceptability
- Questionnaire sheets for subject feedback
- L-Square ruler for drafting
- Self adhesive stickers for land marks
- A right angled ruler, suitable for simultaneous placement on the subject's vertex and an adjacent wall, used to measure the subject's height in conjunction with metal tape measure 15 mm wide and 50 mm long
- Subject number allocation cards numbered 1-10

Subjects

The volunteers who participated in the study are referred to hereinafter as subjects. The subjects were from a diverse range of occupations. The age group categories were 18-29, 30-39, 40-49, 50-59, 60-69, and 70-75 years.

Subject selection

The subjects were selected according to the criterion that they conformed to shape categories defined by five figure types documented in research conducted by Berry (2001). The selection criterion was based on shape as opposed to a size category: shape being the fundamental basis for analysis in this study. The five figure types have been shown previously in Figure 4 of this thesis.

Pre-selection was carried out by visual observation on the part of the researcher. To confirm that each subject fitted into the appropriate figure type category, the bust circumference of each was taken over a closely fitted cotton vest worn over the subject's own bra. Waist and hip circumferences of each subject were also taken as an additional reference points for the analysis of the outcomes of the fitting process.

To prevent distortion of natural body contours subjects had been advised previously to avoid wearing controlled fitting underwear. All but two volunteers met the criterion of close conformity to one of the five figure types. Of the ten subjects selected, two were representative of Figure Type-I, two of Figure Type-X, two of Figure Type-A, two of Figure Type-H and two of Figure Type-XH. For recording purposes each subject was allocated a number from one to ten (1-10).

Drafting and specifications of dress toiles for MSI and FDS

A two piece fitted dress *toile* consisting of a bodice with a set-in sleeve and a skirt was constructed in compliance with the pattern specifications of the two drafting systems, resulting in five MSI *toiles* labelled **A-Garments** and five FDS *toiles* labelled **B-Garments**. Specific body dimensions were required for the construction of A-Garments and B-Garments. According to MSI, only five key characteristics were stipulated for the drafting process. From these five key characteristics fourteen additional width and length measurements were derived by proportional calculations for the drafting and construction of the A-Garments. The five key characteristics used for MSI drafts are listed in Table 12.

Table 12: Key characteristics stipulated for MSI Garment-A (New South Wales TAFE School of Fashion, 1977)

Characteristics
Height
Bust circumference
Waist circumference
Lower hip circumference
Neck to wrist

The illustrations in Figure 71 identify the body locations associated with the five key MSI characteristics required for the A-Garments (New South Wales TAFE School of Fashion, 1977).

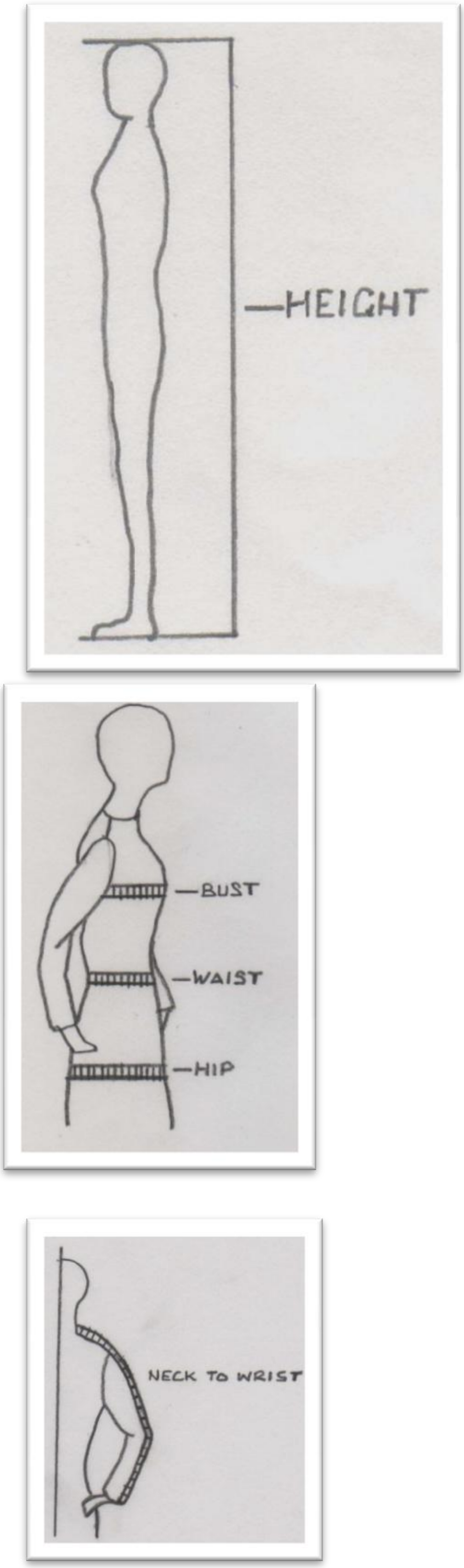


Figure 71: Body locations associated with key characteristics of MSI (modified from New South Wales TAFE School of Fashion, 1977)

In contrast to the A-Garments, eighteen characteristics were required for the B-Garments. The eighteen characteristics were selected from thirty six characteristics which had been obtained in an anthropometric survey in which actual (direct) measurements had been taken of each participant (Berry 2001), and subsequently utilised in the 'The Fashion Design System' (Berry and Hennes 2008). The eighteen characteristics are listed in Table 13.

Table: 13 Key characteristics required for FDS Garment-B (Berry and Hennes, 2008)

No	Characteristics
1	Neck circumference
2	Bust circumference
3	Waist circumference
4	Armhole circumference
5	Across chest
6	Centre front length
7	Shoulder length
8	Bust separation
9	Across back
10	Centre back length
11	Side front neck to bust point
12	Upper arm circumference
13	Outside sleeve length
14	Upper hip circumference
15	Height of upper hip
16	Lower hip circumference
17	Height of lower hip
18	Skirt length

The illustrations in Figure 72 show the eighteen characteristics required for drafting and construction of the B-Garments

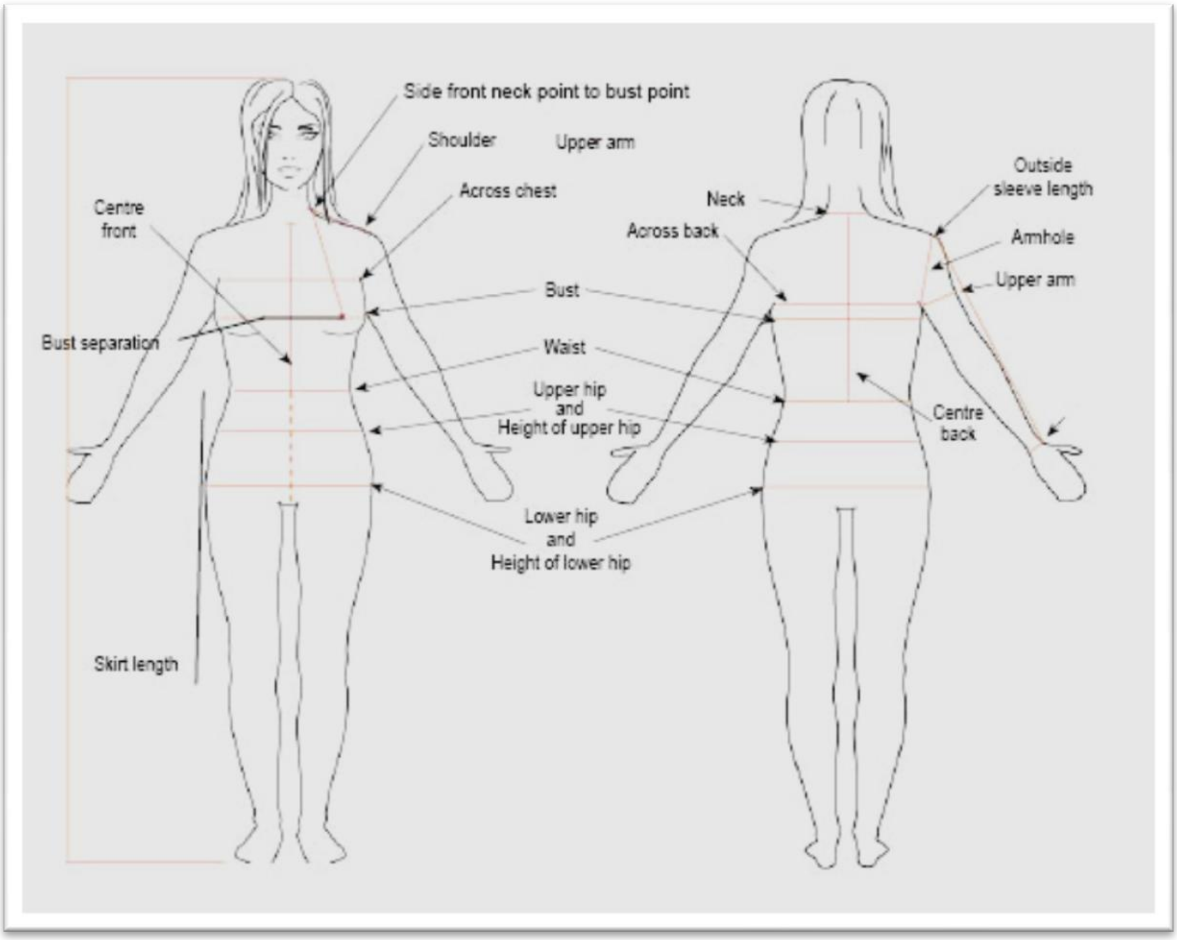


Figure 72: Body locations associated with eighteen key characteristics from FDS (Berry and Hennes, (2008)

Selection of dimensions for drafting the A-Garments

Before the calculation and drafting process could be initiated, it was necessary to select a set of measurements from one of the four MSI Tables of Standard Measurements (New South Wales TAFE School of Fashion, 1977 p19-20) that came closest to the specific set of measurements representing the average dimensions for each of the five figure type categories documented by Berry and Hennes (2008).

A sub-set of five FDS characteristics identical to the five key characteristics of MSI is shown in Table 14. These characteristics were selected from the eighteen FDS characteristics, for matching purposes to ensure that the five figure types would be catered for equally by both of the drafting systems.

Table 14: Sub-set of characteristics, of the five figure type categories (cm) (Berry and Hennes, 2008)

Characteristics	FDS Fig-A	FDS Fig-I	FDS Fig-X	FDS Fig-X/H	FDS Fig-H
Height	163.6	161.4	162.6	162.8	160.8
Bust	90.3	91.0	97.0	101.0	107.6
Waist	72.2	72.7	78.0	82.8	92.4
Hip	98.5	93.5	100.6	104.2	111.7
*Neck to wrist	N/A	N/A	N/A	N/A	N/A

*The Neck-to waist- characteristic in FDS is not used therefore it is not applicable (N/A).

On examination of the four MSI Standard Tables of Body Measurements, the table titled 'Table of Standard Measurements for Average Height and Build' as shown in Table 15 below, was selected, as it was the only table of the four which covered a comparable height range to those of the five figures types in FDS. The height range in FDS was 160.8 cm to 163.6 cm (Table 14) whereas the height range for MSI was 158 cm to 176 cm (Table 15). The range for the FDS shape categories is smaller than that of the MSI system. This further emphasises differences in shape and not in size.

Table 15: MSI, Table of standard measurements for average height and build (cm) (New South Wales TAFE School of Fashion, 1977)

Height	158.0	160 0	162.0	164.0	166.0	168.0	170.0	172.0	173.0	174.0	175.0	176.0
Bust	80.0	84.0	88.0	92.0	96.0	100.0	104.0	110.0	116.0	122.0	128.0	134.0
Waist	59.0	63.0	67.0	71.0	75.0	79.0	84.0	88.0	95.0	102.0	109	116.0
*C.B	39.5	40.0	40.5	41.0	41.5	42.0	42.5	43.0	43.25	43.5	43.75	44.0
Hip	85.0	89.0	93.0	97.0	101.0	105.0	109.0	113.0	119.0	125.0	131.0	137.0
Neck-wrist	69.8	70.4	71.0	71.6	72.2	72.8	73.4	74.0	74.3	74.6	74.9	75.2

***Centre back length (C.B length =¼ Height)**

It can be seen in Table 15 (MSI) that the height range greatly exceeds that of Table 14 (FDS). It was therefore necessary to construct an adjusted table with height increments of 1 cm instead of 2 cm and follow the same degree of increment for each of the other four characteristics. The bust measurement was also critical, as the MSI drafting system required that all width measurements were calculated from the bust measurement. The above process was necessary to align MSI data-sets more closely to the FDS data-sets without contravening the parameters set within the MSI system as shown in Table 16.

Table 16: Adjusted MSI standard table for average height and build (cm) (bust and height increments highlighted)

Height	160.0	**161.0**	162.0	**163.0**	164.0	**165.0**	166.0	**167.0**	168.0	**169.0**	170.0	**171.0**	172.0
Bust	84.0	**86.0**	88.0	**90.0**	92.0	**94.0**	96.0	**98.0**	100.0	**102.0**	104.0	**107.0**	110.0
Waist	63.0	**65.0**	67.0	**69.0**	71.0	**73.0**	75.0	**77.0**	79.0	**81.5**	84.0	**86.0**	88.0
C.B/L	40.0	**40.2**	40.5	**40.7**	41	**41.2**	41.5	**41.7**	42	**42.2**	42.5	**42.7**	43
Hip	89.0	**91.0**	93.0	**95.0**	97.0	**99.0**	101.0	**103.0**	105.0	**107.0**	109.0	**111.0**	113.0
Neck/wrist	70.4	**70.7**	71.0	**71.3**	71.6	**71.9**	72.2	**72.5**	72.8	**73.1**	73.4	**73.7**	74.0

Table 17 shows the adjusted MSI data set that conformed most closely to the FDS data-set on the basis of height and bust measurements as shown in Table 14. The data-set in Table 17 was used for drafting and construction of master blocks for the A-Garments.

Table 17: Adjusted MSI data-sets which conform most closely to FDS figure type categories (cm).

Characteristics	**MSI Fig-A**	**MSI Fig-I**	**MSI Fig-X**	**MSI Fig-X/H**	**MSI Fig-H**
Height	163.0	164.0	166.0	168.0	171.0
Bust	90.0	92.0	96.0	100.0	107.0
Waist	69.0	71.0	75.0	79.0	86.0
Hip	95.0	97.0	101.0	105.0	111.0
Neck to wrist	71.3	71.6	72.2	72.8	73.7

Table 18 is identical to Table 14 and shown here for comparison purposes to illustrate the degree of similarity between the key dimensions of MSI and sub-set of FDS.

Table 18: Sub-sets of FDS characteristics selected for comparison with MSI (cm)

Characteristics	**FDS Fig-A**	**FDS Fig-I**	**FDS Fig-X**	**FDS Fig-X/H**	**FDS Fig-H**
Height	163.6	161.4	162.6	162.8	160.8
Bust	90.3	91.0	97.0	101.0	107.6
Waist	72.2	72.7	78.0	82.8	92.4
Hip	98.5	93.5	100.6	104.2	111.7
Neck to wrist	N/A	N/A	N/A	N/A	N/A

Neck-to wrist characteristic in FDS is not used therefore it is not applicable (N/A).

Ease allowance

An extra allowance referred to as ease (tolerance) of 8 cm was added to the bust, 2 cm to the waist, and 5 cm to the hip for the A- Garments in compliance with the MSI specification and instructions. Ease allowance added to the B- Garments consisted of 8 cm to the bust, waist, and hip according to FDS specifications and instructions.

Specifications for drafting the A-Garments

The five characteristics in Table 17 provided the base from which all other required measurements were calculated for drafting the master blocks for the A-Garments. The bust measurement was used to determine width measurements of across back, armhole width, and front bust width, according to the prescribed MSI formulae. The relative proportions of these three dimensions, when added together, constituted ½ of the bust measurement. As the armhole width remained constant at one tenth of the bust plus 1 cm for all figure types, any variation in the front bust width required reciprocal variation in the across back width. Length measurements of centre back equalled ¼ of height; under arm level (side length) and hip depth equalled ⅛ of height; and front length equalled ¼ of height plus 3.5cm.

The five A-Garment *toiles* were then drafted in accordance with the pattern drafting system as set out in MSI manual for each of the five figure type categories. Figure 73 shows a completed draft with construction lines and darts.

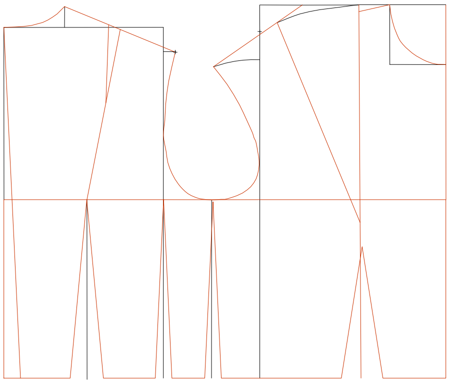


Figure 73: Construction of a master block bodice according to MSI system for an A-Garment

Specifications for drafting the B-Garment

Specifications for drafting the master blocks for the B-Garment for each of the five figure type categories were extracted from FDS. These specifications provided all data necessary to draft the master blocks for B-Garment in compliance with the FDS instructions. Figure 74 shows a completed draft for a B-Garment with construction lines and darts.

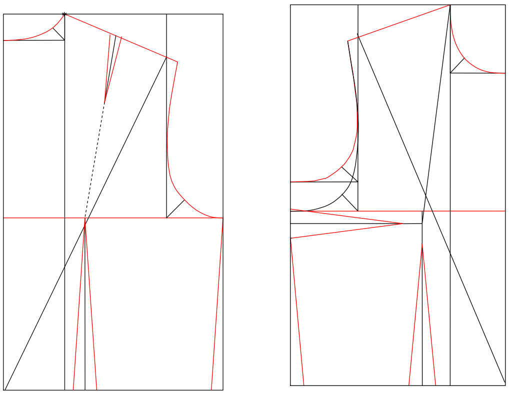


Figure 74: Construction of a master block bodice according to FDS system for a B-Garment

On completion of all the construction blocks, final master blocks were made of the bodice, skirt and sleeve for all figure type categories using the MSI system and the FDS system. The blocks of the A-Garments were superimposed on those of the B-Garments in each of the figure type categories and were then photographed for a visual comparison and analysis.

Toile construction

Ten *toiles* were constructed, five from patterns made for the A-Garments, and five from patterns made for the B-Garments (one being for each of the specified figure type categories). To ensure impartiality during the fitting procedure, the *toiles* were labelled on the outside only with the figure type designation of Figure I; Figure X; Figure A; Figure X/H; or Figure H. The inside of each *toile* was labelled A-Garment or–B-Garment. Balance lines were drawn on the outside of the *toiles* at; centre front, (centre back had a seam to allow for back opening), front and back bust line, front and back lower hipline, centre of sleeve and upper arm line. The *toiles* were machine stitched ensuring that the correct seam allowance was taken on all garments. A zip was machined into the centre back. The necklines of all *toiles* were faced to avoid stretching. Sleeve and skirt hems were overlocked. The garment was pressed ready for fitting.

Garment adjustment checklist

Individual garment adjustment checklists were prepared for the experimenters use (Table 19).

Table 19: (S 1) Check list for garment adjustment (mm)

No	Characteristic	Garment A (mm)	Garment B (mm)
	Front Torso		
1	Shoulder		
2	Neck		
3	Across chest		
4	Centre front length		
5	Side neck to B.P		
6	Front armhole		
7	Bust separation		
8	Front bust		
9	Front waist		
10	Front upper hip		
11	Front lower hip		
12	Waist to lower		
	Back torso		
13	Back neck		
14	Across back		
15	Back bust		
16	Back waist		
17	Back upper hip		
18	Back upper		
19	Centre back length		
20	Back armhole		
21	Skirt dart length		
	Upper limbs		
22	Sleeve length		
23	Sleevehead height		
24	Upper arm		
25	Elbow		
26	Wrist		

A fit acceptability scale was devised as follows:

1 Ideal fit (no change required n/c)

2 Acceptable fit

3 Poor fit

4 Unacceptable fit

Tolerance range for fit acceptability

A specific range of plus (+) or minus (-) tolerance (mm) was determined for each garment characteristic. The tolerances which expressed the degree of fit of each garment characteristic are shown together with the associated ratings (Table 20).

Table 20: Tolerance range for acceptability of garment fit (mm)

No	Characteristics	**Ideal** Rating (1)	**Acceptable** Rating (2)	**Poor** Rating (3)	**Unacceptable** Rating (4)
	Front Torso				
1	Shoulder	n/c	±4	±6	±8
2	Neck	n/c	±4	±6	±8
3	Across chest	n/c	±10	±20	±25
4	Centre front length	n/c	±7	±12	±15
5	Side neck to B P	n/c	±5	±10	±20
6	Front armhole	n/c	±13	±16	±20
7	Bust separation	n/c	±5	±8	±12
8	Front bust	n/c	±10	±20	±40
9	Front waist	n/c	±10	±20	±40
10	Front upper hip	n/c	±10	±20	±40
11	Front lower hip	n/c	±10	±20	±40
12	Waist to Lower hip	n/c	±5	±10	±20
	Back Torso				
13	Back neck	n/c	±6	±9	±12
14	Across back	n/c	±10	±20	±25
15	Back bust	n/c	±10	±20	±40
16	Back waist	n/c	±10	±20	±40
17	Back upper hip	n/c	±10	±20	±40
18	Back lower hip	n/c	±10	±20	±40
19	Centre back length	n/c	±7	±12	±15
20	Back armhole	n/c	±13	±16	±20
21	Skirt dart length	n/c	±5	±10	±20
	Upper limbs				
22	Sleeve length	n/c	±10	±15	±20
23	Sleevehead height	n/c	±5	±7	+-/10
24	Upper arm	n/c	±10	±17	±40
25	Elbow	n/c	±10	±17	±25
26	Wrist	n/c	±10	±17	±25

n/c denotes no changes were required

Questionnaire design

A blind test questionnaire was prepared to provide feedback in relation to the fit and comfort of both garments (Table 21).

Table 21: Questionnaire for testing fit and comfit of the A-Garments and B-Garments

No	Question	Garment-A	Garment-B
Q-1	Is garment A comfortable		
Q-2	Is garment B comfortable		
Q-3	Does garment A restrict movement		
Q-4	Does garment B restrict movement		
Q-5	Which garment feels better A or B		
Q-6	Looking in the mirror which garment do you think looks better		
Q-7	Which garment would you buy		
Q-8	What reason would you buy either garment		

An experimenter tally sheet of subjects' responses to the blind test questionnaire was prepared for recording purposes (Figure 22).

Table 22: Experimenter tally sheet of subjects' responses to the blind test questionnaire

No	Question	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Q-1	Is garment A comfortable										
Q-2	Is garment B comfortable										
Q-3	Does garment A restrict movement										
Q-4	Does garment B restrict movement										
Q-5	Which garment feels better A or B										
Q-6	Looking in the mirror which garment do you think looks better										
Q-7	Which garment would you buy										
Q-8	What reason would you buy either garment										

Fitting and photographic procedure

The order for trying on Garment-A and Garment-B was not randomized in order to simplify the photographic referencing. However, subjects were not aware which toile constituted Garment-A and Garment- B.

1 The subject put on the first garment appropriate for her figure type
2 The subject was then photographed standing a wooden platform in front of a metal grid; three photographs were taken from the anterior, posterior, and lateral aspect prior to fitting
3 The garment was visually assessed for overall appearance
4 The garment was pinned in, if it was too loose or if the garment was too tight, the zip was left open
5 After fitting the first garment the subject was re-photographed from the same three aspects as above
6 The subject then put on the second garment appropriate for her figure type and points 2-5 were repeated
7 On completion of the fitting and photographing of the two garments, subjects completed the questionnaire
8 After the subject had completed all parts of the testing procedure the experimenter recorded all fitting adjustments in mm on the subject's numbered check list
9 The above process was repeated for each subject at various appointed times

The photographic procedure was undertaken to enable a visual assessment of the fit, fall, and balance of the garments. The lateral view was included to identify postural imbalance such as; lordosis; kyphosis; posterior pelvic tilt or anterior pelvic tilt, as these imbalances may affect the fit and/or fall of the garment. The six photographs of each subject taken from an anterior, posterior and lateral aspect are shown in the order that these were taken in Plates 1 to 120.

Subject: 1 – Garment-A – Figure Type I

Bust circumference 910 mm – Waist 715 mm – Hip circumference 950 mm

Plates 1, 2, 3: Subject-1 – Garment-A – Figure Type-I (before fitting).

Plates 4, 5, 6: – Subject 1 – Garment-A – Figure Type I (after fitting)

Subject: 1 – Garment-B – Figure Type-I

Plates-7, 8 ,9: – Subject 1 – Garment-B – Figure Type-I (before fitting)

Plates-10, 11, 12: – Subject 1 – Garment-B – Figure Type-I (after fitting)

Subject: 2 – Garment-A – Figure Type I

Bust circumference 880 mm – Waist 720 mm – Hip circumference 960 mm

Plates-13, 14, 15: – Subject 1 – Garment-A – Figure Type I (before fitting)

Plates-16, 17,18: – Subject 2 – Garment-A – Figure Type I (after fitting)

Subject: 2 – Garment-B – Figure Type I

Plates-19, 20, 21: – Subject 2 – Garment-B – Figure Type I (before fitting)

P-19

P-20

P-21

Plates-22, 23, 24: – Subject 2 – Garment-B – Figure Type I (after fitting)

P-22

P-23

P-24

Subject: 3 – Garment A – Figure Type XH

Bust circumference 1040 mm – Waist 820 mm – Hip circumference 1100 mm

Plates-25, 26, 27: – Subject 3 – Garment-A – Figure Type XH (before fitting)

Plates-28, 29, 30: – Subject 3 – Garment-A – Figure Type XH (after fitting)

Subject: 3 – Garment-B – Figure Type XH

Plates-31, 32, 33: – Subject 3 – Garment-B – Figure Type XH (before fitting)

P-31

P-32

P-33

Plates-34, 35, 36: – Subject 3 – Garment-B – Figure Type XH (after fitting)

P-34

P-35

P-36

Subject: 4 – Garment-A – Figure Type H

Bust circumference 1090 mm – Waist 1000 mm – Hip circumference 1150 mm

Plates-37, 38, 39: – Subject 4 – Garment-A – Figure Type H (before fitting).

P-37

P-38

P-39

Plates-40, 41, 42: – Subject 4 – Garment-A – Figure Type H (after fitting)

P-40

P-41

P-42

Subject: 4 – Garment-B – Figure Type H

Plates-43, 44, 45: – Subject 4 – Garment-B – Figure Type H (before fitting)

P-43

P-44

P-45

Plates-46, 47, 48: – Subject 4 – Garment-B – Figure Type H (after fitting)

P-46

P-47

P-48

Subject: 5 – Garment-A – Figure Type H

Bust circumference 1090 mm – Waist 980 mm – Hip circumference 1110 mm

Plates-49, 50, 51: – Subject 5 – Garment-A – Figure Type H (before fitting)

Plates-52, 53, 54: – Subject 5 – Garment-A – Figure Type H (after fitting)

Subject: 5 – Garment-B – Figure Type H

Plates-55, 56, 57: – Subject 5 – Garment-B – Figure Type H (before fitting)

Plates-58, 59, 60: – Subject 5 – Garment-B – Figure Type H (after fitting)

Subject: 6 Garment-A Figure Type XH

Bust circumference 1010 mm – Waist 790 mm – Hip circumference – 1060 mm

Plates-61, 62, 63: – Subject 6 – Garment-A – Figure Type XH (before fitting)

Plates-64, 65, 66: – Subject 6 – Garment-A, Figure Type XH (after fitting)

Subject: 6 – Garment-B – Figure Type XH

Plates-67, 68, 69: – Subject 6 – Garment-B – Figure Type XH (before fitting)

P-67

P-68

P-69

Plates-70, 71, 72: – Subject 6 – Garment-B – Figure Type XH (after fitting)

P-70

P-71

P-72

Subject: 7 – Garment-A – Figure Type X

Bust circumference 970 mm – Waist 790 mm – Hip circumference 1070 mm

Plate 73, 74, 75: – Subject 7 – Garment-A – Figure Type X (before fitting)

P-73

P-74

P-75

Plate: 76, 77, 78: – Subject-7 – Garment-A – Figure Type X (after fitting)

P-76

P-77

P-78

Subject: 7 – Garment-B – Figure Type X

Plate 79, 80, 81: – Subject 7 – Garment-B – Figure Type X (before fitting)

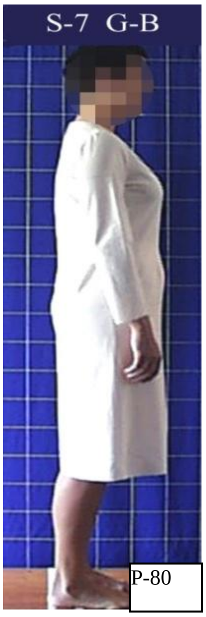


Plate 82, 83, 84: – Subject 7 – Garment-B – Figure Type X (after fitting)

Subject: 8 – Garment-A – Figure Type X

Bust circumference 990mm Waist 830mm Hip circumference 1030mm

Plate 85, 86, 87: Subject 8 – Garment-A – Figure Type X (before fitting)

Plates 88,89,90: – Subject 8 – Garment-A – Figure Type X (after fitting)

Subject: 8 – Garment-B – Figure Type X

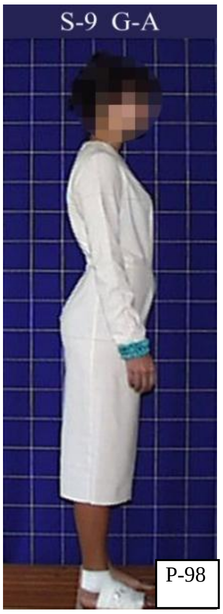
Plates-91, 92, 93: – Subject 8 – Garment-B – Figure Type X (before fitting)

Plates 94, 95, 96: – Subject 8 – Garment-B – Figure Type X (after fitting)

Subject: 9 – Garment-A – Figure Type A

Bust circumference 880 mm – Waist 700 mm – Hip circumference 990 mm

Plates 97, 98, 99: – Subject 9 – Garment-A – Figure Type A (before fitting)



Plates 100, 101, 102: – Subject 9 – Garment-A – Figure Type A (after fitting)

Subject: 9 – Garment-B – Figure Type A

Plates-103, 104, 105: – Subject 9 – Garment-B – Figure Type A (before fitting)

Plates- 106,107, 108: – Subject 9 – Garment-B – Figure Type A (after fitting)

Subject: 10 – Garment-A – Figure Type A

Bust circumference 860 mm – Waist 720 mm – Hip circumference 1010 mm

Plates-109, 110, 111: – Subject 10 – Garment-A – Figure Type A (before fitting)

P-109

P-110

P-111

Plates-112, 113, 114: – Subject 10 – Garment-A – Figure Type A (after fitting)

P-112

P-113

P-114

Subject: 10 – Garment-B – Figure Type A

Plates-115, 116, 117: – Subject 10 – Garment-B – Figure Type A (before fitting)

Plates-118, 119, 120: – Subject 10-Garment-B – Figure Type A (after fitting)

Subjective test

On conclusion of the fitting process, each subject completed (verbally) a subjective blind test in relation to garment comfort and fit in the form of a questionnaire (Table 21). Responses were recorded by the experimenter on the tally sheet (Table 22).

Objective test

The objective test analysis focused on specific regions of the body such as front torso, back torso, and upper limbs, and provided the basis for statistical analysis of the fitting procedure required for each figure type and garment category. Garment adjustments for each characteristic were recorded, on the subject's individual checklist (Table 19). The tolerance rating chart (Table 20) determined the fit acceptability rating of each garment characteristic.

Statistical method

Chi-squared was calculated from contingency tables. The sign test took the form:

$$X^2 = \frac{([+] - [-])^2}{[+] + [-]} \qquad \text{with 1 degree of freedom}$$

[+] refers to number of positive events, [-] refers to number of negative events

The cut off value for $p = 0.05 = 3.81$

Chapter 3: Results

This chapter presents findings of statistical analyses in relation to objective tests and analysis of subjective tests designed to provide insights into the stated aims of the study. The results focus on three regions of the body. These comprise: front torso, back torso and upper limbs. Data relating to specific characteristics of the three regions were critically assessed in relation to five female figure types and the fit of garments constructed according to two different pattern engineering systems.

To test for overall differences in the degree of fit of A-Garments and B-Garments ratings for all subjects on each of the 26 garment characteristics were combined under each of the four rating categories of **Ideal**, **Satisfactory**, **Poor** and **Unacceptable** and were compared using Chi Squared test. Results showed significant differences between ratings, with **Ideal** ratings being significantly greater in number for the B-Garments [$\chi^2 = 16.82$, *df* 1, $p<0.005$] and **Unacceptable** ratings being significantly greater in number for the A-Garments [$\chi^2 = 37.69$, *df* 1, $p <0.005$] (Table 23).

Table 23 Summary of results of Chi Squared tests comparing Fit Ratings for Garment-A and Fit Ratings for Garment-B

Ratings	Garment –A	Garment –B	B/A Ratio	Chi-squared
1 = Ideal	77	137	1.78	16.82*
2 = Acceptable	45	51	1.13	0.38
3 = Poor	56	52	0.93	0.14
4 = Unacceptable	82	20	0.24	37.69*
Total	260	260		

*P<0.005

To investigate further into where the differences might lie in terms of key garment characteristics, summed positive ratings [1&2] and summed negative ratings [3&4] for each of 26 body garment characteristics were compared by Sign Test. Of the 26 characteristics tested, five produced a significantly good fit at the 0.005 probability level for the A-Garments, and seven characteristics produced a significantly poor to unacceptable fit. Conversely, results for the B-Garments showed that of the 26 characteristics tested, 10 produced a significantly good fit and no characteristic was significantly poor or unacceptable. A summary of these results is presented in Table 24.

Table 24: Summary Table of significant differences between the frequency of Positive and Negative Ratings of Garment A and Garment B across 26 Characteristics. Fit goodness refers to what percentage of wearers rated Garment-A or Garment-B as fitting well (1+2 rating)

Characteristic	Garment	Positive Ratings 1+2	Negative Rating 3+4	*Sign Test Result	Goodness of Fit	B/A Ratio
Shoulder	A	4	6		40	1.5
	B	6	4		60	
Neck	A	3	7		30	3.0
	B	9	1	4.9	90	
Across chest	A	7	3		70	1.4
	B	10	0	8.1	100	
Centre front length	A	6	4		60	1.0
	B	6	4		60	
Side neck to B.P	A	6	4		60	0.8
	B	5	5		50	
Front armhole	A	8	2		80	1.3
	B	10	0	8.1	100	
Bust separation	A	8	2		80	1.3
	B	10	0	8.1	100	
Front bust	A	0	10	_*8.1_	0	
	B	7	3		70	
Front waist	A	1	9	_*4.9_	10	4.0
	B	4	6		40	
Front upper hip	A	3	7		30	2.0
	B	6	4		60	
Front lower hip	A	4	6		40	1.5
	B	6	4		60	
Waist to lower hip	A	0	10	_*8.1_	0	
	B	10	0	8.1	100	
Back neck	A	9	1	4.9	90	1.1
	B	10	0	8.1	100	
Across back	A	1	9	_*4.9_	10	8.0
	B	8	2		80	
Back bust	A	0	10	_*8.1_	0	
	B	3	7		30	
Back waist	A	1	9	_*4.9_	10	2.0
	B	2	8		20	
Back upper hip	A	3	7		30	1.3
	B	4	6		40	
Back lower hip	A	3	7		30	1.7
	B	5	5		50	
Centre back length	A	5	5		50	1.0
	B	5	5		50	
Back armhole	A	9	1	4.9	90	1.1
	B	10	0	8.1	100	
Skirt dart length	A	7	3		70	1.1
	B	8	2		80	
Sleeve length	A	6	4		60	1.0
	B	6	4		60	
Sleevehead height	A	10	0	8.1	100	1.0
	B	10	0	8.1	100	
Upper arm	A	1	9	_*4.9_	10	8.0
	B	8	2		80	
Elbow	A	9	1	4.9	90	1.1
	B	10	0	8.1	100	
Wrist	A	9	1	4.9	90	1.1
	B	10	0	8.1	100	

*Sign Test results in italics indicate a significantly poor fit

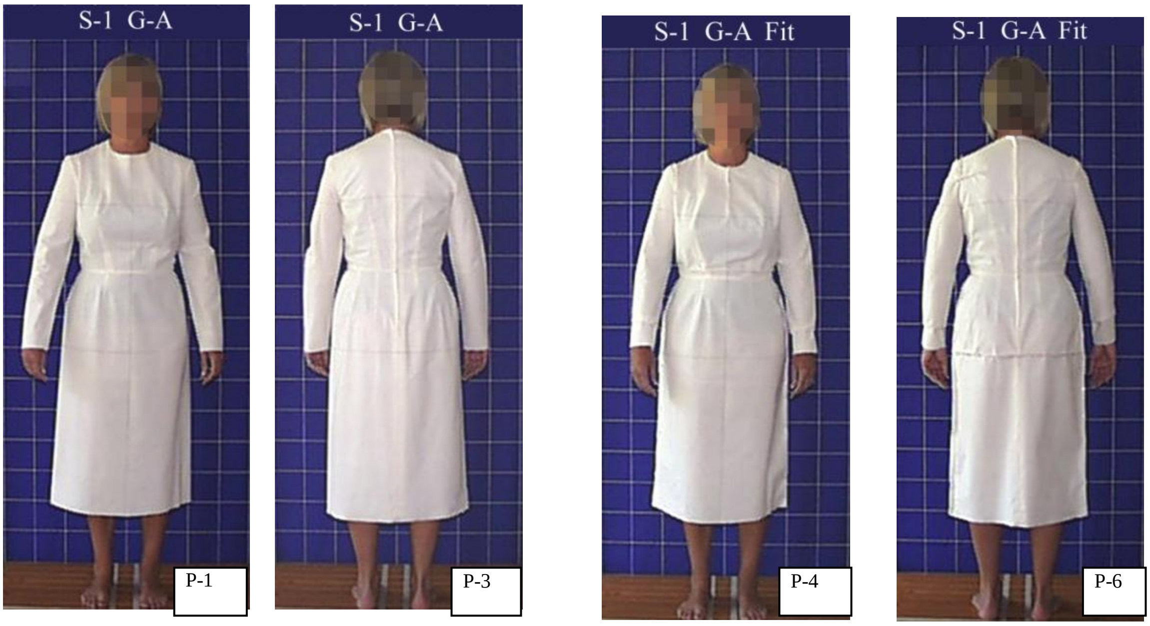
Photographic analysis

A visual assessment was carried out using photographs of each subject before and after fitting. Measurement adjustments were rated according to the predetermined tolerance range for acceptability of garment fit (in millimetres) as shown in Table 20.

A description of the acceptability of fit of each garment prior to adjustment was recorded. The pinned adjustments are shown in the photographs labelled 'Fit' in the plates on the right.

Analysis of Subject 1

Plates 1, 3, 4, 6: - Subject 1 Figure Type-I - Garment-A before and after fitting



Plates 7, 9, 10, 12: - Subject 1 Figure Type-I - Garment-B before and after fitting

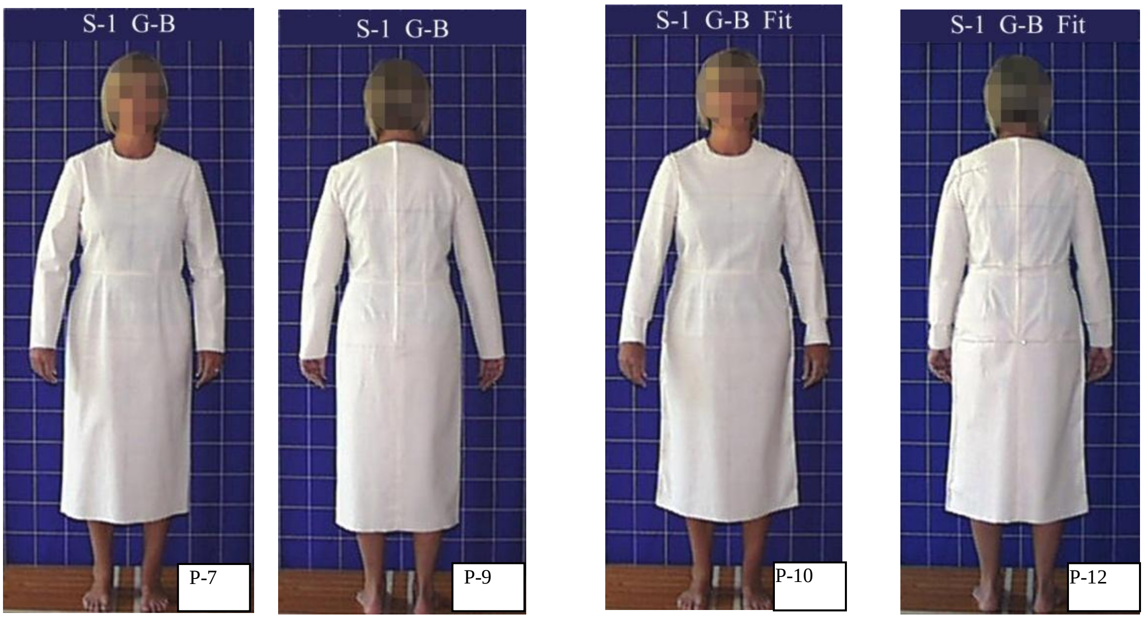


Table 25: Subject 1: Garment characteristic list with fit adjustments and associated ratings (mm).

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	-4	2	-4	2
2	Neck	+8	3	n/c	1
3	Across chest	+20	3	+8	2
4	Centre front length	+10	3	-10	3
5	Side neck to B P	n/c	1	n/c	1
6	Front armhole	n/c	1	n/c	1
7	Bust separation	n/c	1	n/c	1
8	Front bust	-40	4	n/c	1
9	Front waist	-40	4	n/c	1
10	Front upper hip	+10	2	+10	2
11	Front lower hip	+10	2	+10	2
12	Waist to lower hip	+30	4	n/c	1
	Back Torso				
13	Back neck	n/c	1	n/c	1
14	Across back	-20	3	n/c	1
15	Back bust	-40	4	n/c	1
16	Back waist	-40	4	+10	2
17	Back upper hip	+10	2	+10	2
18	Back lower hip	+10	2	+10	2
19	Centre back length	+5	2	+10	2
20	Back armhole	+10	2	+10	2
21	Skirt dart length	+10	2	+10	2
	Upper limbs				
22	Sleeve length	+10	2	+10	2
23	Sleevehead height	-5	2	-5	2
24	Upper arm	-20	3	n/c	1
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 1: Garment-A (Plates 1 and 3)

This garment shows excess fullness in neck and across chest area; front and back of bust and waist are unacceptably tight; the fit of the across back and upper arm is rated as poor due to degree of tightness in this area; the centre front length is too long; the waist to lower hip is unacceptable due to excess length (P 1-3). Other areas requiring little or no change and rated as acceptable or ideal are shown in the table above.

Subject 1: Garment-B (Plates 7 and 9)

This garment shows a reasonable fit in all but one area, this being the centre front length which is rated as poor as it is marginally short.

Both Garments A and B show an excess fullness around the lower hip regions.

Analysis of Subject 2

Plates 13, 15, 16, 18: – Subject 2 Figure Type–I – Garment-A before and after fitting

Plates 19, 21, 22, 24: - Subject 2 Figure Type-I - Garment-B before and after fitting

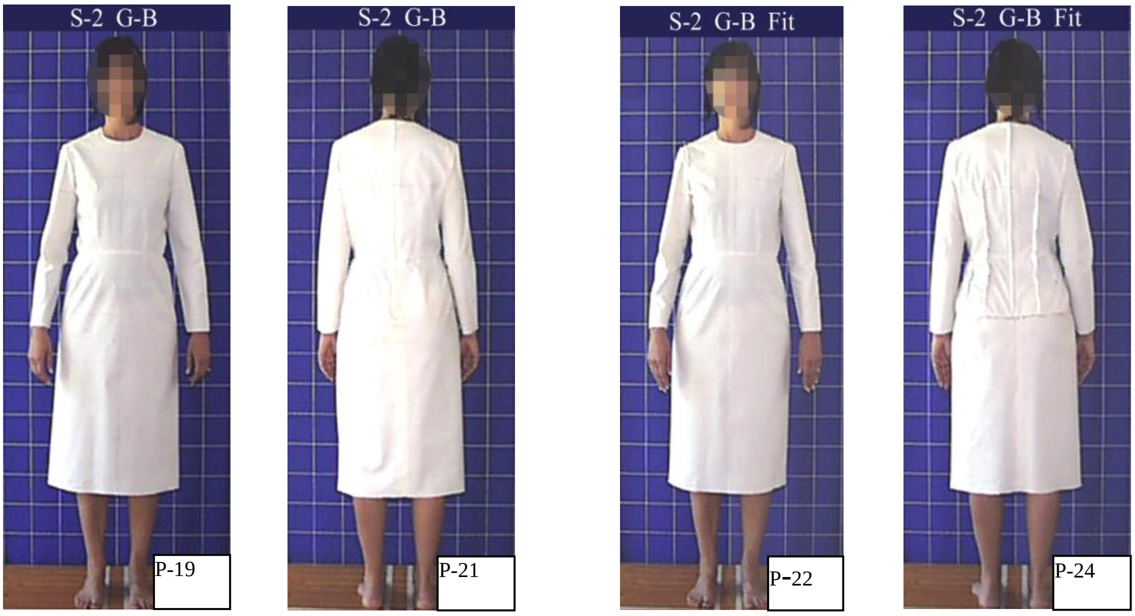


Table 26 Subject 2: Garment characteristic list with fit adjustments and associated ratings.

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	+4	2	+4	2
2	Neck	+5	2	n/c	1
3	Across chest	+20	3	n/c	1
4	Centre front length	n/c	1	n/c	1
5	Side neck to B P	-20	4	n/c	1
6	Front armhole	n/c	1	n/c	1
7	Bust separation	n/c	1	n/c	1
8	Front bust	+30	4	n/c	1
9	Front waist	+20	3	n/c	1
10	Front upper hip	+10	2	+10	2
11	Front lower hip	+20	2	+10	2
12	Waist to lower hip	+30	4	n/c	1
	Back Torso				
13	Back neck	n/c	1	n/c	1
14	Across back	-20	3	n/c	1
15	Back bust	-20	3	+20	3
16	Back waist	-20	3	+20	3
17	Back upper hip	-10	2	-10	2
18	Back lower hip	n/c	1	n/c	1
19	Centre back length	n/c	1	n/c	1
20	Back armhole	n/c	1	n/c	1
21	Skirt dart length	n/c	1	n/c	1
	Upper limbs				
22	Sleeve length	-20	4	-20	4
23	Sleevehead height	n/c	1	n/c	1
24	Upper arm	-15	3	+15	3
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 2: Garment-A (Plates 13 and 15)

This garment shows excess fullness in the across chest area, and in the front bust and front waist area. There is tightness in the back bust, across back and back waist. The lateral view emphasises tightness of the garment in these regions and highlights a pronounced lordotic lumbar curve (P-14). The waist to lower hip is unacceptable due to excess length; the sleeve length is short; the sleeve in the upper arm is tight.

Subject 2: Garment-B (Plates 19 and 21)

The overall fit of this garment is acceptable, despite the fact that the fit is loose rather than firm, the length of sleeve is short and the sleeve in the upper arm is loose. The lordotic lumbar curve is less pronounced.

Analysis of Subject 3

Plates 25, 27, 28, 30: - Subject 3 Figure Type-XH - Garment-A before and after fitting

P-25

P-27

P-28

P-30

Plates 31, 33, 34, 36: - Subject 3 Figure Type-XH - Garment-B before and after fitting

P-31

P-33

P-34

P-36

Table 27: Subject 3: Garment characteristic list with fit adjustments and associated ratings.

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	+8	4	=8	4
2	Neck	n/c	1	n/c	1
3	Across chest	n/c	1	-6	2
4	Centre front *length*	-10	3	-10	3
5	Side neck to B P	-5	2	-10	3
6	Front armhole	-10	2	-10	2
7	Bust separation	n/c	1	n/c	1
8	Front bust	-40	4	-20	3
9	Front waist	-40	4	-20	3
10	Front upper hip	-40	4	-10	2
11	Front lower hip	-40	4	-20	3
12	Waist to lower hip	-30	4	n/c	1
	Back Torso				
13	Back neck	-5	2	-5	2
14	Across back	-20	3	-10	2
15	Back bust	-40	4	-20	3
16	Back waist	-60	4	-30	4
17	Back upper hip	-40	4	-20	3
18	Back lower hip	-40	4	-20	3
19	Centre back length	-5	2	-5	2
20	Back armhole	-20	4	-10	2
21	Skirt dart length	n/c	1	n/c	1
	Upper limbs				
22	Sleeve length	+10	2	+10	2
23	Sleevehead height	-5	2	-5	2
24	Upper arm	-30	4	n/c	1
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 3: Garment-A (Plates 25 and 27)

This garment shows an unacceptable fit due to tightness in the front and back bust, waist, upper hip and lower hip. There is extreme tightness in the across back, the back armhole, back waist, and the upper arm. The centre front length is marginally short, and shoulder length is marginally long.

Subject 3: Garment-B (Plates 31 and 33)

This garment shows a poor fit due to tightness in the front and back bust and front waist, however the back waist is unacceptable due to extreme tightness. The back and front lower hips are both tight. The centre front length is marginally short, and shoulder length is marginally long.

Analysis of Subject 4

Plates 37, 39, 40, 42: - Subject 4 Figure Type-H - Garment-A before and after fitting

P-37

P-39

P-40

P-42

Plates: 43, 45, 46, 48: - Subject 4 Figure Type-H - Garment-B before and after fitting

P-43

P-45

P-46

P-48

Table 28 Subject 4: Garment characteristic list with fit adjustments and associated ratings

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	+5	3	+5	3
2	Neck	n/c	1	n/c	1
3	Across chest	-10	2	n/c	1
4	Centre front length	n/c	1	n/c	1
5	Side neck to B P	n/c	1	n/c	1
6	Front armhole	-5	2	-5	2
7	Bust separation	n/c	1	n/c	1
8	Front bust	-40	4	-20	3
9	Front waist	-40	4	-20	3
10	Front upper hip	-40	4	-20	3
11	Front lower hip	-40	4	-10	2
12	Waist to lower hip	+30	4	n/c	1
	Back Torso				
13	Back neck	-5	2	-5	2
14	Across back	-40	4	-15	3
15	Back bust	-60	4	-20	3
16	Back waist	-70	4	-20	3
17	Back upper hip	-40	4	-20	3
18	Back lower hip	-30	4	n/c	1
19	Centre back length	+20	4	+20	4
20	Back armhole	-5	2	-5	2
21	Skirt dart length	n/c	1	n/c	1
	Upper limbs		1		
22	Sleeve length	n/c	1	n/c	1
23	Sleevehead height	n/c	1	n/c	1
24	Upper arm	-40	4	-10	2
25	Elbow	-30	4	n/c	1
26	Wrist	-30	4	n/c	1

n/c denotes no changes were required

Subject 4: Garment-A (Plates 49 and 51)

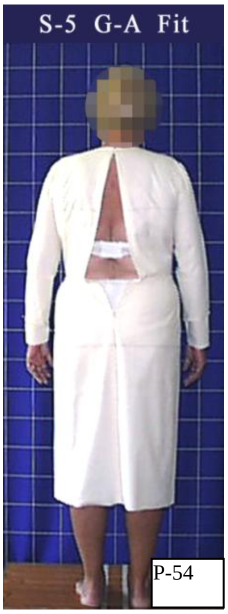
This garment shows an unacceptable fit due to tightness in the front and back bust, waist, upper hip and lower hip; there is extreme tightness in the across back, the upper arm, elbow, and wrist. The shoulder length is marginally long. Waist to lower hip is unacceptable due to excess length.

Subject 4: Garment-B (Plates 43 and 45)

This garment shows a poor fit due to tightness in the front and back bust, front and back waist , front and back upper hip.

Analysis of Subject 5

Plates 49, 51, 52, 54: - Subject 5 Figure Type-H - Garment-A before and after fitting



Plates 55, 57, 58, 60: - Subject 5 Figure Type-H - Garment B before and after fitting

Table 29: Subject 5: Garment characteristic list with fit adjustments and associated ratings

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	-15	4	n/c	1
2	Neck	+5	2	+5	2
3	Across chest	+10	2	n/c	1
4	Centre front length	-10	2	+10	2
5	Side neck to B P	n/c	1	n/c	1
6	Front armhole	-20	4	n/c	1
7	Bust separation	n/c	1	n/c	1
8	Front bust	-40	4	-10	2
9	Front waist	-40	4	-20	3
10	Front upper hip	-40	4	-10	2
11	Front lower hip	-20	3	-10	2
12	Waist to lower hip	-30	4	n/c	1
	Back Torso				
13	Back neck	-10	4	-5	2
14	Across back	-60	4	-20	3
15	Back bust	-60	4	-20	3
16	Back waist	-80	4	-50	4
17	Back upper hip	-40	4	-20	3
18	Back lower hip	-30	4	-20	3
19	Centre back length	n/c	1	n/c	1
20	Back armhole	-10	2	n/c	1
21	Skirt dart length	n/c	1	n/c	1
	Upper limbs				
22	Sleeve length	+20	4	+20	4
23	Sleevehead height	-5	2	-5	2
24	Upper arm	-40	4	-15	3
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 5: Garment-A (Plates 49 and 51)

This garment shows an unacceptable fit due to tightness in the front and back bust, front and back waist, front and back upper hip, back lower hip, and waist to lower hip, across back, and front armhole. The upper arm is too tight and sleeve length is too long. The shoulder length is marginally long.

Subject 5: Garment-B (Plates 55, and 57)

This garment shows an unacceptable fit in the back waist and sleeve length. There is a poor fit in the front waist, across back back bust, back upper hip and lower hip and in the upper arm area.

Analysis of Subject: 6

Plates 61, 63, 64, 66: - Subject 6 Figure Type-XH - Garment-A before and after fitting

Plates 67, 69, 70, 72: - Subject 6 Figure Type-XH - Garment-B before and after fitting

Table 30: Subject 6: Garment characteristic list with fit adjustments and associated ratings

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	+6	3	+6	3
2	Neck	+5	2	+5	2
3	Across chest	+5	2	n/c	1
4	Centre front length	-7	2	-7	2
5	Side neck to B P	n/c	1	n/c	1
6	Front armhole	n/c	1	+10	2
7	Bust separation	-20	4	n/c	1
8	Front bust	-20	3	n/c	1
9	Front waist	-20	3	+20	3
10	Front upper hip	-10	2	+10	2
11	Front lower hip	n/c	1	+10	2
12	Waist to lower hip	+30	4	n/c	1
	Back Torso				
13	Back neck	n/c	1	n/c	1
14	Across back	-20	3	n/c	1
15	Back bust	-20	3	n/c	1
16	Back waist	-20	3	+20	3
17	Back upper hip	+10	2	+10	2
18	Back lower hip	+20	3	n/c	1
19	Centre back length	+15	4	+15	4
20	Back armhole	n/c	1	n/c	1
21	Skirt dart length	-20	4	n/c	1
	Upper limbs				
22	Sleeve length	+20	4	+20	4
23	Sleevehead height	n/c	1	n/c	1
24	Upper arm	-20	4	n/c	1
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 6: Garment-A (Plates 61 and 63)

This garment shows an unacceptable fit in the area of upper arm due to tightness and sleeve length and waist to lower hip which are too long. It shows a poor fit in the area of front and back bust and front and back waist due to tightness, and back lower hip is too long.

Subject 6: Garment-A (Plates 6 and 69)

This garment is acceptable to ideal in all areas apart from front and back waist which are poor, and sleeve length which is unacceptable as it is too long

Analysis of Subject: 7

Plates 73, 75, 76, 78: - Subject 7 Figure Type-X - Garment-A before and after fitting

Plates 79, 81, 82, 84: - Subject 7 Figure Type-X - Garment-B before and after fitting

Table 31: Subject 7: Garment characteristic list with fit adjustments and associated ratings

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	-5	3	n/c	1
2	Neck	n/c	1	n/c	1
3	Across chest	n/c	1	n/c	1
4	Centre front length	-15	4	-15	4
5	Side neck to B P	n/c	1	-12	4
6	Front armhole	n/c	1	-10	2
7	Bust separation	n/c	1	n/c	1
8	Front bust	-20	3	n/c	1
9	Front waist	-20	3	n/c	1
10	Front upper hip	-20	3	-20	3
11	Front lower hip	-20	3	-20	3
12	Waist to lower hip	+20	4	n/c	1
	Back Torso				
13	Back neck	n/c	1	n/c	1
14	Across back	-20	3	n/c	1
15	Back bust	-20	3	+20	3
16	Back waist	-30	4	+40	4
17	Back upper hip	-20	3	-20	3
18	Back lower hip	-20	3	-20	3
19	Centre back length	-10	3	n/c	1
20	Back armhole	n/c	1	n/c	1
21	Skirt dart length	n/c	1	+20	4
	Upper limbs				
22	Sleeve length	-30	4	-30	4
23	Sleevehead height	-5	2	n/c	1
24	Upper arm	-20	4	n/c	1
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 7: Garment-A (Plates 73 and 75)

This garment shows unacceptable fit at back waist and upper arm due to tightness in these areas. Waist to lower hip is also unacceptable as it is too long, and the sleeve length is too short. Front and back bust are poor due to tightness, front and back upper and lower hip are tight, front waist is tight.

Subject 7: Garment-B (Plates 79 and 81)

This garment shows an unacceptable fit at back waist due to excess fullness, the sleeve length is too short, the back bust is poor due to excess fullness, and the front and back upper and lower hip are poor due to tightness

Analysis of Subject 8

Plates 85, 87, 88, 90: - Subject 8 Figure Type-X - Garment-A before and after fitting

P-85

P-87

P-88

P-90

Plates 91, 93, 94, 96: - Subject 8 Figure Type-X - Garment-B before and after fitting

P-91

P-93

P-94

P-96

Table 32: Subject 8: Garment characteristic list with fit adjustments and associated ratings

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	+6	3	+6	3
2	Neck	n/c	1	n/c	1
3	Across chest	-10	2	n/c	1
4	Centre front length	n/c	1	-10	3
5	Side neck to B P	+20	4	-20	4
6	Front armhole	-15	3	+10	2
7	Bust separation	n/c	1	n/c	1
8	Front bust	-30	4	n/c	1
9	Front waist	-20	3	n/c	1
10	Front upper hip	-20	3	n/c	1
11	Front lower hip	-10	2	n/c	1
12	Waist to lower hip	+30	4	n/c	1
	Back Torso				
13	Back neck	n/c	1	n/c	1
14	Across back	-20	3	n/c	1
15	Back bust	-30	4	n/c	1
16	Back waist	-30	4	n/c	1
17	Back upper hip	-20	3	n/c	1
18	Back lower hip	-10	2	n/c	1
19	Centre back length	n/c	1	+15	4
20	Back armhole	-10	2	+10	2
21	Skirt dart length	n/c	1	n/c	1
	Upper limbs				
22	Sleeve length	-10	2	-10	2
23	Sleevehead height	-5	2	-5	2
24	Upper arm	-20	4	n/c	1
25	Elbow	-10	2	-10	2
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 8: Garment-A (Plates 85 and 87)

This garment shows an unacceptable front and back bodice due to tightness in the bust region, and the front and back waist. The upper arm is also unacceptable due to tightness, and waist to lower hip is too long. Front and back upperhip, front waist, across back and front armhole are poor due to tightness.

Subject 8: Garment-B (Plates 91 and 93)

This garment shows an acceptable to ideal fit in all but four minor characteristics.

Analysis of Subject 9

Plates 97, 99, 100, 102: - Subject 9 Figure Type-A - Garment-A before and after fitting

P-97

P-99

P-100

P-102

Plates 103, 105, 106, 108: Subject 9 Figure Type-A Garment-B before and after fitting

P-103

P-105

P-106

P-108

Table 33 Subject 9: Garment characteristic list with fit adjustments and associated ratings

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	n/c	1	n/c	1
2	Neck	+5	2	+5	2
3	Across chest	+20	3	n/c	1
4	Centre front length	n/c	1	n/c	1
5	Side neck to B P	-15	4	-15	4
6	Front armhole	n/c	1	n/c	1
7	Bust separation	n/c	1	n/c	1
8	Front bust	+30	4	+20	3
9	Front waist	-20	3	+20	3
10	Front upper hip	-20	3	+20	3
11	Front lower hip	-30	4	+20	3
12	Waist to lower hip	+30	4	n/c	1
	Back Torso				
13	Back neck	n/c	1	n/c	1
14	Across back	-20	3	n/c	1
15	Back bust	+20	3	+20	3
16	Back waist	-30	4	+40	4
17	Back upper hip	-20	3	+20	3
18	Back lower hip	-30	4	+20	3
19	Centre back length	+10	3	+20	3
20	Back armhole	n/c	1	n/c	1
21	Skirt dart length	+20	4	+20	4
	Upper limbs				
22	Sleeve length	+10	2	+10	2
23	Sleevehead height	-5	2	-5	2
24	Upper arm	-10	2	n/c	1
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 9: Garment A (Plates 97 and 99)

This garment shows an unacceptable fit in the front and back lower hip, and back waist due to tightness; the waist to lower hip is too long and front bust is unacceptable due to excess fabric. Front and back upper hip, and across back are poor due to tightness; back bust and across chest are poor due to excess fabric.

Subject 9: Garment B (Plates 103 and 105)

This garment shows that the back waist is unacceptable, and a poor fit at front and back bust, front waist, front and back upper and lower hip.

Analysis of Subject 10

Plates 109, 111, 112, 114: - Subject 10 Figure Type-A – Garment-A before and after fitting

109

111

112

114

Plates 115, 117, 118, 120: - Subject 10 Figure Type-A - Garment-B before and after fitting

P-115

P-117

P-118

P-120

Table 34 Subject 10: Garment characteristic list with fit adjustments and associated ratings

No	Characteristic	Garment A ±	Rating	Garment B ±	Rating
	Front Torso				
1	Shoulder	n/c	1	n/c	1
2	Neck	+5	2	+5	2
3	Across chest	+20	3	n/c	1
4	Centre front length	n/c	1	n/c	1
5	Side neck to B P	-15	4	+10	3
6	Front armhole	n/c	1	n/c	1
7	Bust separation	+20	3	n/c	1
8	Front bust	+30	4	n/c	1
9	Front waist	-10	2	+20	3
10	Front upper hip	-30	4	+20	3
11	Front lower hip	-20	3	+20	3
12	Waist to lower hip	+30	4	n/c	1
	Back Torso				
13	Back neck	n/c	1	n/c	1
14	Across back	n/c	1	n/c	1
15	Back bust	+20	3	+30	4
16	Back waist	+10	2	+30	4
17	Back upper hip	-30	4	+20	3
18	Back lower hip	-30	4	+20	3
19	Centre back length	+10	3	+10	3
20	Back armhole	n/c	1	n/c	1
21	Skirt dart length	+10	3	n/c	1
	Upper limbs				
22	Sleeve length	+10	2	+10	2
23	Sleevehead height	n/c	1	n/c	1
24	Upper arm	-20	4	n/c	1
25	Elbow	n/c	1	n/c	1
26	Wrist	n/c	1	n/c	1

n/c denotes no changes were required

Subject 10: Garment A (Plates 109 and 111)

This garment shows an unacceptable fit due to tightness in front and back upper hip, back lower hip, and upper arm, and unacceptable in the front bust and waist to lower hip due to excess. There is a poor fit due to excess in the across chest, and back bust, and tightness in the front lower hip

Subject 10: Garment B (Plates 115 and 117)

This garment shows an unacceptable fit due to excess in the back bust and back waist and poor fit due to excess in the front and back lower hips and front waist.

Responses by subjects to the questionnaire regarding the fit and wearability of the A-Garments compared to the B-Garments are shown in Table 35. This was a blind test as subjects were not aware which of the two toiles represented the A-Garment, and which represented the B-Garment. Subjects' verbal responses to the questionnaire which asked for their opinions about the first garment and the second garment were recorded immediately after the second garment had been removed, following the fit adjustments.

Table 35: Subjective blind test by questionnaire results for Garments-A and B (Subjects (S) 1-10)

No	**Question**	**S-1**	**S-2**	**S-3**	**S-4**	**S-5**	**S-6**	**S-7**	**S-8**	**S-9**	**S-10**
Q-1	Is the garment A comfortable	No	No	No	No	No	No	No	No	No	No
Q-2	Is garment B comfortable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q-3	Does garment A restrict movement	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q-4	Does garment B restrict movement	No	No	No	No	No	No	No	No	No	No
Q5	Which garment feels better A or B	B	B	B	B	B	**A**	B	B	B	**A**
Q-6	Looking in the mirror which garment do you think looks better	B	B	B	B	B	**A**	B	B	*T—**A** *B—B	**A**
Q-7	Which garment would you buy	B	B	B	B	B	**A**	B	B	B	**A**
Q-8	For what reason would you buy either garment	**	**	**	**	**	**	**	**	**	**

*Q-6 T= top section of garment A B=bottom section of garment B

**Q-8 See Table 36

Each subject's free response to question 8 as to the reason she would purchase either the A-Garment or the B-Garment, is shown in Table 36.

Table 36: Question 8 (**): For what reason would you buy either garment?

Subject	Answer
S-1	B not as structured. Not tight under bust, smoother line.
S-2	B more comfortable look. Garment A, restricted movement across back and arms.
S-3	B comfort, look, feel. Garment A, felt restricted and showed up body imperfections
S-4	B comfort and fit – Garment A, restrictive, unable to move, very tight, too sculptured
S-5	B generally a better fit.
S-6	A although garment was tight liked a firmer fit
S-7	B is comfortable Garment A, restricted movement
S-8	B for comfort, look and fit
S-9	B as it is more comfortable, however, would need adjustments.
S-10	A as it shows up the figure

Characteristics for which B-Garments received a greater number of positive ratings than A-Garments, and for which the A-Garments were rated equal to or better than B-Garments are shown in Table 37 and Table 38.

Table 37: Characteristics for which B-Garments have a greater number of positive ratings than A-Garments

No	**Characteristic**	No of B ratings	No of A ratings
1	Shoulder	6	4
2	Neck	9	3
3	Across chest	10	7
6	Front armhole	10	8
7	Bust separation	10	8
8	Front bust	7	0
9	Front waist	4	1
10	Front upper hip	6	3
11	Front lower hip	6	4
12	Waist to lower hip	10	0
13	Back neck	10	9
14	Across back	8	1
15	Back bust	3	0
16	Back waist	2	1
17	Back upper hip	4	3
18	Back lower hip	5	3
20	Back armhole	10	9
21	Skirt dart length	8	7
24	Upper arm	8	1

Table 38: Characteristics for which A-Garments are rated equal to, or better than B-Garments

No	**Characteristic**	No of A ratings	No of B ratings
4	Centre front length	6	6
5	Side neck to B.P	6	5
19	Centre back length	5	5
22	Sleeve length	6	6
23	Sleevehead height	10	10

To compare key measurements which contribute to the degree of tightness or looseness at specified points on the test garment and vary according to (a) figure type category, and (b) the different requirements of the MSI and FDS Systems, bar graphs were prepared. The areas of greatest contrast (in measurement terms) between the A-Garments and B-Garments within each figure type category were those of the across back, and upper arm and these differences are shown in Figures 75 and 76.

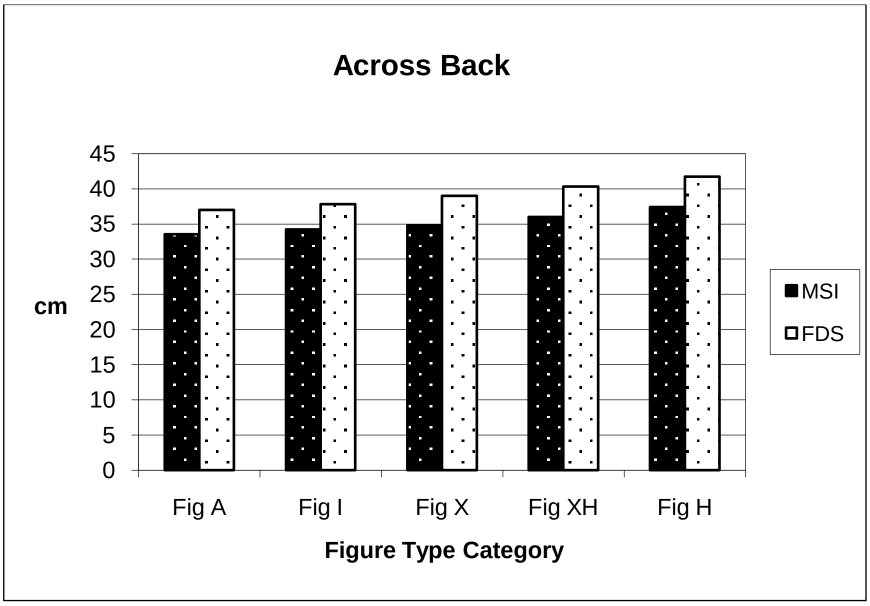


Figure: 75 Comparison of direct and calculated measurements for Across Back

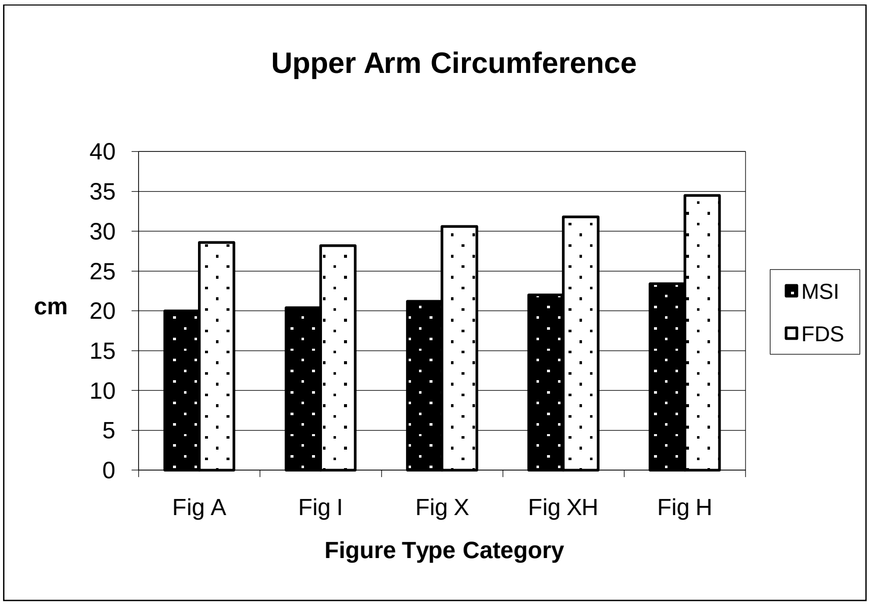


Figure: 76 Comparison of direct and calculated measurements for Upper Arm Circumference

To show the degree of similarity between the bust circumference measurements used in the construction of the MSI and FDS dress toiles for each of the five figure types, a bar graph as shown in Figure 77 was used.

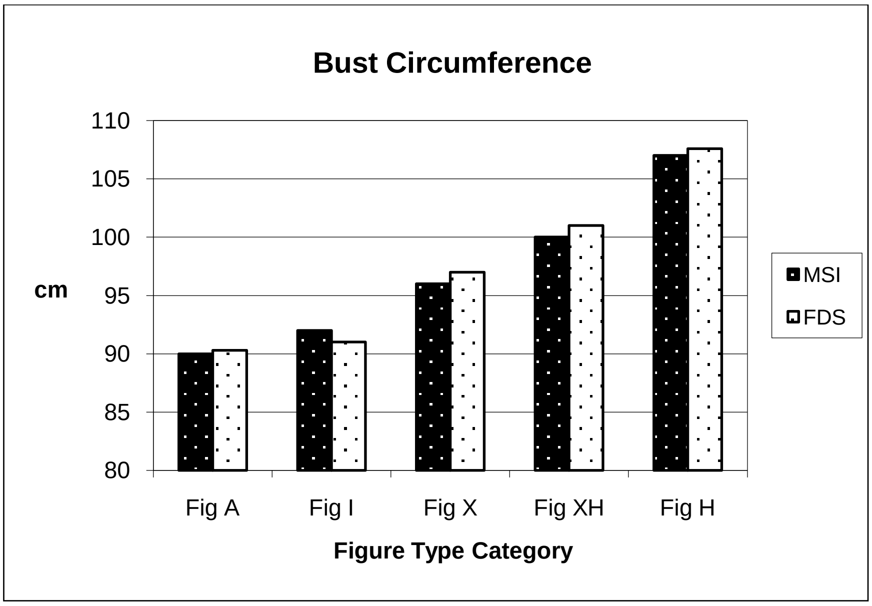


Figure 77: Bar graph for similarity of bust circumference

To show the degree of similarity between the waist circumference measurements used in the construction of the MSI and FDS dress toiles for each of the five figure types, a bar graph as shown in Figure 78 was used.

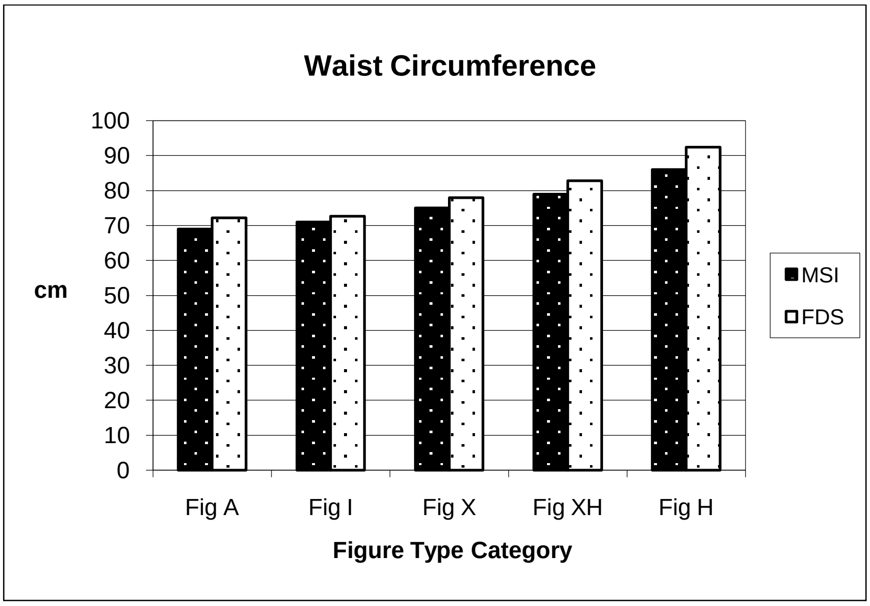


Figure 78: Bar graph showing differences of waist circumference

A comparison of the pattern engineering systems used to develop the five master blocks engineered for A-Garments- and B-Garments-was conducted to investigate further the tightness of fit particularly in the upper torso regions and upper limbs, in terms of the shape of the patterns derived from each system. An analysis of the final master blocks used for the dress toiles was made after the master blocks were drawn, superimposed and photographed as shown in Plates 121 to 126. The A-Garment is represented by the dotted line in each plate.

Plates 121 to 125 show a trend of marked differences in the patterns for the A-Garments and the B-Garments across all figure types with minor variations in the lower torso areas. The back pattern of each A-Garment (dotted line) on the side seam area, is considerably smaller in the across back, bustline, waistline and lower hip. On the other hand, the front patterns on the side seam show each A-Garment to be larger than its B-Garment counterpart. The A-Garments have an extremely large shoulder dart, whereas the B-Garments have a relatively smaller bust dart radiating from the side seam. The upper arm line of each A-Garment is also smaller than that for each B-Garment. The waist to hip line is lower in each A-Garment than in each B-Garment. This contributed to the excessive length of the back skirt waist darts in the A-Garment.

Plate 121: Comparison of master blocks for Garment-A and Garment-B (Figure Type-A)

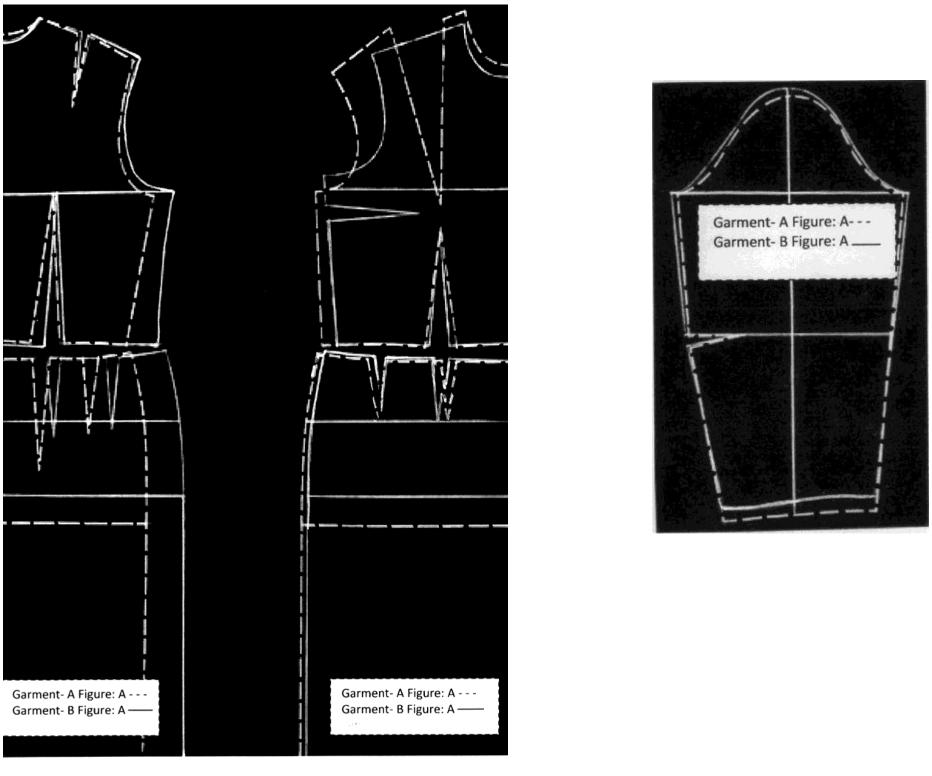


Plate 122: Comparison of master blocks for Garment-and Garment-B (Figure Type-I)

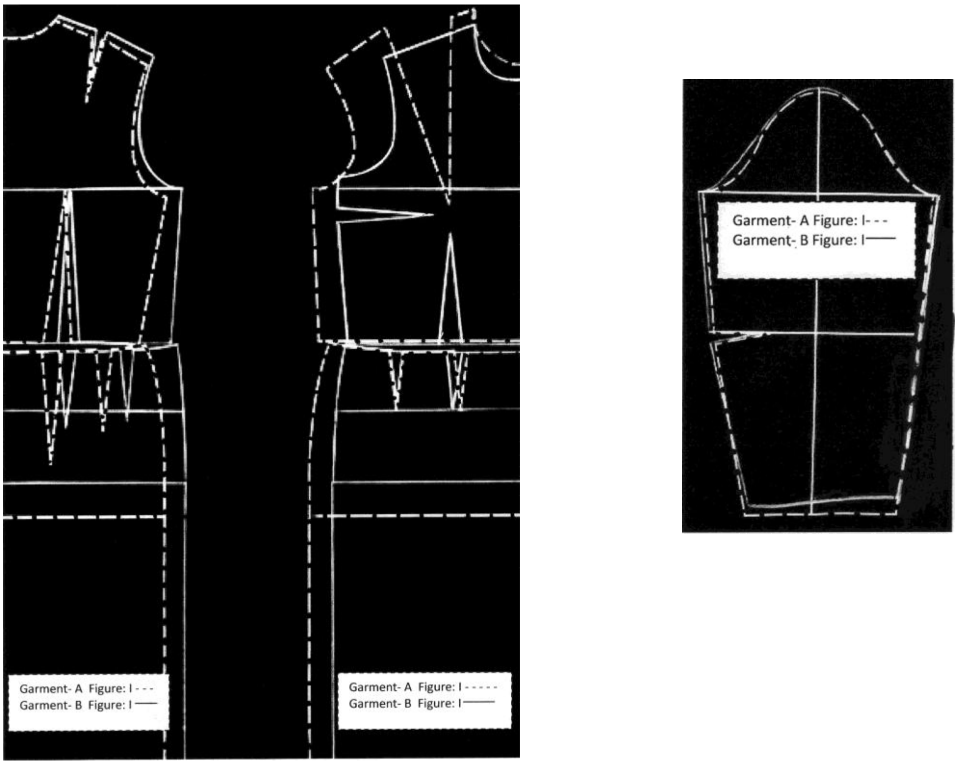


Plate 123: Comparison of master blocks for Garment-A and Garment-B (Figure Type-X)

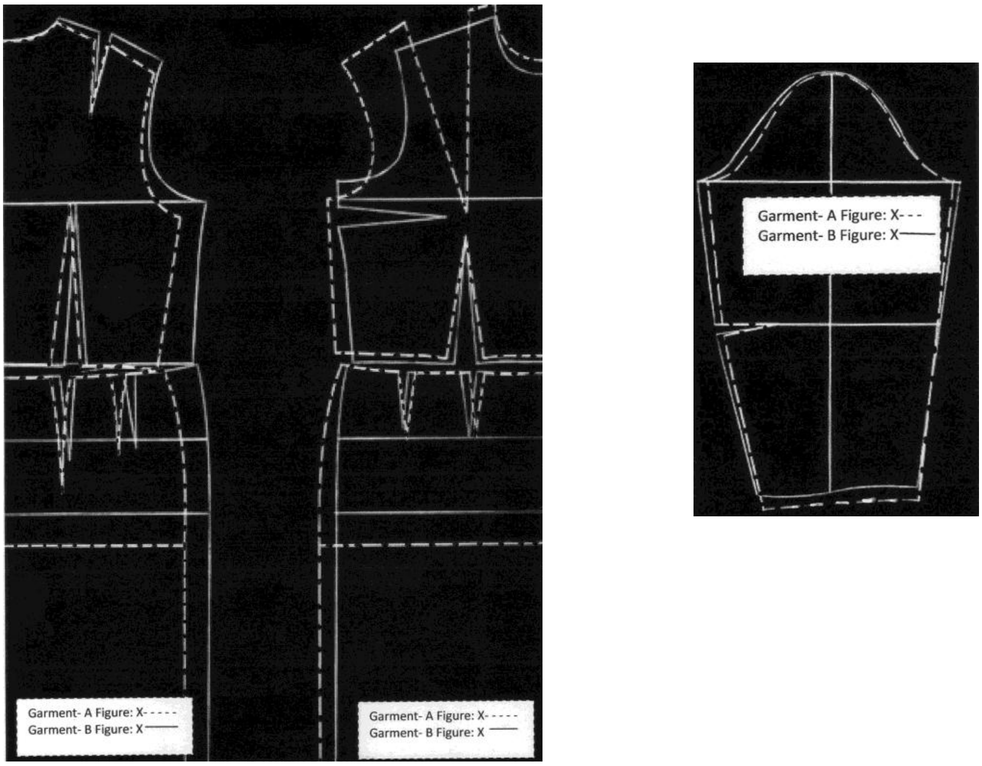


Plate 124: Comparison of master blocks for Garment-A and Garment-B (Figure Type-XH)

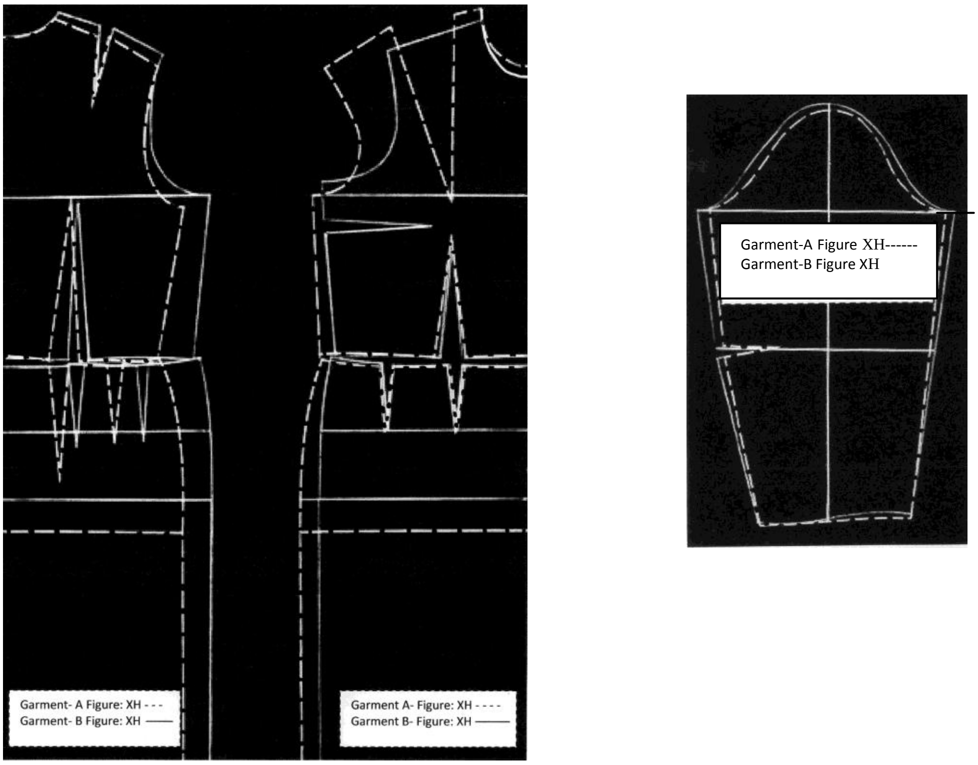
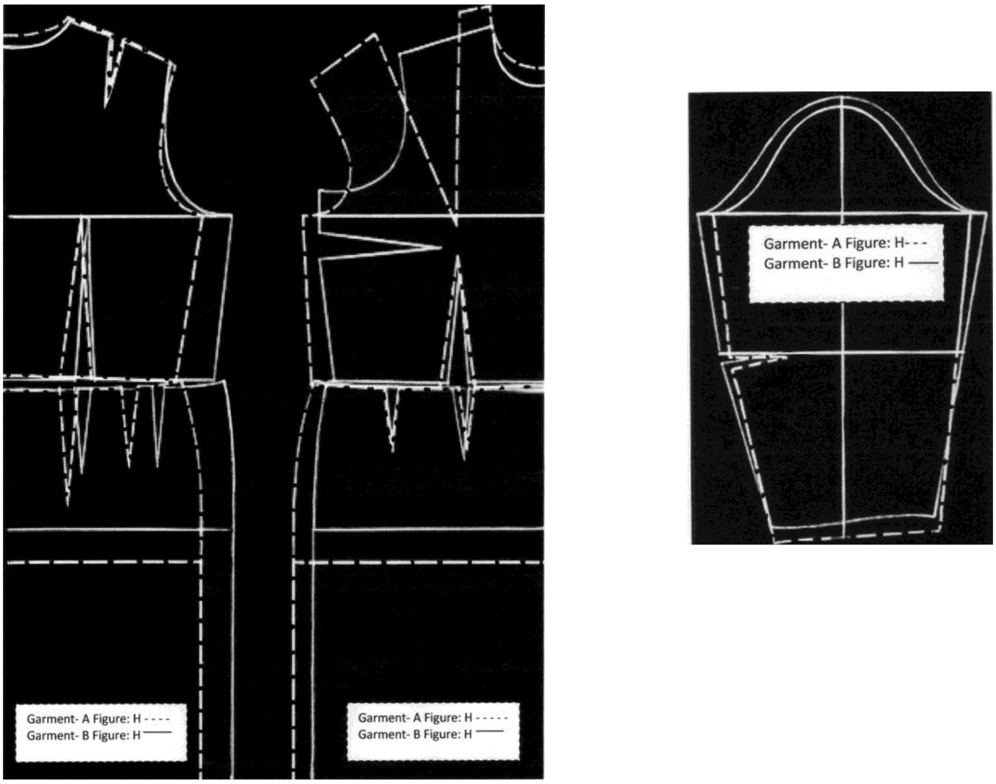


Plate 125: Comparison of master blocks for Garment-A and Garment-B (Figure Type-H)



To further evaluate the fit of an A-Garment and a B-Garment on a static body form, the *toiles* constructed for Figure Type I were compared by placing them in turn on a size 14 dress stand which has a bust measurement identical to that of Figure Type I, (of 91 cm). The A-Garment displayed noticeable excess fullness in the upper torso, particularly in the neck, across chest and midriff regions. The B-Garment presented a smoother and cleaner fit in these regions. The waistline of the A-Garment was perceptibly smaller than that of the B-Garment.

Figure: 79 **Dress stand assessment of A-Garment (left) and B-Garment (right)**

Chapter 4: Discussion

Differences in external morphological characteristics of the human female body in relation to the design, production and fit of female garments, were examined using two contrasting pattern engineering systems as a measuring tool. Of particular interest was the impact of changes in body size and shape which have occurred in the period since the development of pattern engineering systems for the construction of garments which had their beginnings in the mid 17th century.

Statistical analyses of the differences in the overall fit of garments made from the two contrasting pattern engineering systems for five different figure types showed that the B-Garment fit ratings were significantly better than the A-Garment fit ratings. A key finding was the difference in negative fit ratings between the two garment types, in that the A-Garments recorded four times more unacceptable fit ratings than the B-Garments.

Visual assessment of the photographs showed clear differences in the overall appearance and fit of A-Garments and B-Garments. One reason for the marked variation in fit between the A-Garments and the B-Garments may be due to the measurements used for each system, which were chosen to comply with the underlying philosophy of each system, and were not the subject's personal measurements. In the FDS system, the basis for drafting the pattern was to use the average body dimensions of five different figure types which had been derived from anthropometric survey data - a critical variation being that the figure types were identified and categorised according to shape (Berry 2001). In contrast, the A-Garment measurements were calculated by formulae which assume fixed proportionate relationships between body dimensions, and take no account of the fact that changes in body size result in changed proportions (Holzman, 1996; Simmons, 2004a; Bye et al., 2006).

It is notable that the regions on the A- Garments which showed a statistically significant poor fit were front bust, back bust, front waist, back waist, across back, waist to lower hip and upper arm. The poor fit appears to have been influenced by compliance with the MSI charts, and the application of calculated proportional measurements according to the MSI formulae. It is open to question therefore whether these charts reflect the current size and shape of the female population.

Excess tightness, restricted movement and discomfort in the across back, back bust, and back waist regions of the upper torso and the upper arm of the A-Garments- were reported by all subjects. One could conclude therefore that the poor fit of the A-Garments in these regions was due to the calculated proportional measurements being too small. For example, the across back measurement used for the MSI system is calculated from the bust circumference, and in the present study the across back was approximately 4 cm less for each body type than the anthropometrically based across back measurement used for each body type in FDS. Narrow across back measurements have been an issue for many decades and are highlighted in ‘A study of measurements used in the size coding scheme for women’s clothing’ (Berry, 1977). That study compared clothing size standards from Australia, New Zealand and two different standards from France, with a survey of eighty females. It was found that the across back measurement in the Australian Standard at that time was 3 to 5 cm smaller than both the surveyed females and the other standards.

It is of interest to note that the recently withdrawn Australian Standard AS 1344 (1997) showed an across back measurement of only 33 cm for a bust measurement of 90 cm. In comparison, the more current FDS data specifies an across back measurement of 37-38 cm for a bust size of 90 cm (Berry, 2001) based on anthropometric survey data. The data are almost identical to the across back measurement in the D5585-95 Standard from the American Society for Testing and Materials, (1995). In the case of excess tightness reported in the across back and upper arm areas, bar-graphs comparing these measurements have also demonstrated the marked differences between MSI (calculated proportional measurements) and FDS (anthropometric data).

One source of the marked differences between the MSI and FDS measurements may have been the bust circumference, as the bust measurement is the basis for the calculation of all other width measurements used in the MSI master blocks. However, a bar-graph of the specified bust dimensions for each of the five figure types showed that there were minimal differences between MSI and FDS bust circumferences. As both sets of the A-Garment and B-Garment *toiles* were constructed using virtually the same bust measurements for each figure type, it can be argued therefore that the relatively poor fit of the A-Garments was caused by the formulae specified in MSI system for the standard bodice drafts.

This argument is strengthened by the fact that the front upper torso of both garments also shows significantly different results in the front neck, and across chest regions. These results have indicated that the front neck and across chest of the A-Garments showed a much higher negative rating than did the B-Garments, due to excess fullness in the neck and upper chest regions. This fullness could be attributable once again, to the use of the bust measurement to proportionately calculate the front neck and the shoulder dart value. The bust circumference is also responsible for the calculated proportions of the across back width, armhole width and front bust width. The fact that the distributions of these three measurements take place on the bust construction line may also have contributed to the tightness of the back upper torso regions.

It is of interest to note that the MSI system uses a proportionally greater front bust width measurement than back bust width measurement when bust sizes are over 100cm. The rationale put forward is that the front bust width is increased and the across back width is proportionately decreased because the body frame does not usually develop to the same degree as the bust (New South Wales TAFE School of Fashion, 1977). There appears to be an assumption that a larger bust circumference is due primarily to an increase in breast tissue, and is not accompanied by an increase in adipose tissue particularly in the subscapular region of the back. One might question whether this compensation exacerbated the fitting problems in the back torso which were evident in the present study. It seems likely that the small across back with the larger front bust, combined with the large front shoulder dart may well have been based on the original shape of women's bodies in the era when garment styles were designed to portray a small waist with a tight fitting back bodice and prominent up-lifted bust (Kidwell, 1979; Seligman, 1996; Palmer and Alto, 1998; Jenkyn Jones, 2005).

A bar-graph comparing the waist dimension of the five figure types shows that there were some differences between the MSI and the FDS measurements in this area of the pattern drafts, and it is probable these differences contributed to variations in fit between the two garment types, particularly in the waist area. In this instance the fitting issue may be also be attributed to the assumption of proportionality inherent in MSI system. Attention is drawn to the MSI Tables of Standard Body Dimensions (New South Wales TAFE School of Fashion, 1977) which clearly demonstrate the assumption that the relationships between certain human body dimensions are constant for most figure types.

The A-Garment and B-Garment toiles photographed on a dress form (Figure 79) confirmed the earlier findings of noticeable excess fullness in the front neck, across chest and midriff regions of the A-Garment (Plates 1 and 13). A dress form, however, although a valuable tool for testing *toiles* and assessing the fit and appearance of a garment, is limited in that it cannot assess essential aspects such as movement and comfort. Subjects' responses to the questionnaire confirmed the statistical and visual assessment tests of comparative fit of the two garment types, and gave a comprehensive endorsement of the B-Garments in terms of comfort and relative ease of movement. There were also some areas of disagreement. Interestingly, the two subjects who disagreed with the majority in their responses to three questions relating to appearance were consistent in stating a preference for a very close tightly fitting garment. These subjects reported that the A-Garments 'felt' better, looked better and stated they would buy them, despite their earlier comments that the garments were tight and uncomfortable. This finding highlights the fact that fit preferences of women of similar size and shape can vary markedly.

Additionally, fit preferences are known to vary according to an individual's self image and perception and can also vary according to material, garment type, a given situation and activity level (Bye et al., 2006, Ashdown and De Long, 1995, in Branson and Nam, 2007). It is also notable that the closeness of fit of master blocks for each design house is the prerogative of that design house and that different market groups and cultures often prefer different degrees of fit (Ashdown, 2007).

In view of the fact that the bust measurements used for each system were relatively similar in each figure type category, the experimenter questioned the marked differences in the variation of the fit of A-Garments and B Garments across all figure types. In an attempt to find an explanation for these differences in the fit, full scale master block patterns of each figure type were superimposed and then compared and analysed.

The analysis of the superimposed patterns showed clearly the areas of differences between the two systems. The upper torso, lower torso and limbs were all noticeably different. In the A-Garments, the shape of the shoulder and chest regions differed markedly from the B-Garments. The large dart value (width) of the shoulder dart in the A-Garments is reminiscent of fashion trends which were prevalent in the era when the proportionate based pattern engineering systems originated as they provided the desired shapely fit for that period (Wampen, 1853; Simons, 1933). A similar link may be made with the fashion trends of the 1950s and 1960s when bras were engineered to present a pointed and prominent shaped bust (Hard's Year Book for the Clothing Industry, 1954). The B-Garments on the other hand, used a smaller dart value which radiated from the side seam, and showed a markedly cleaner shape and fit in the shoulder and chest region. It is probable that the size of a dart (dart value) plays a significant role in the shaping and fitting of a garment. Also the exact direction and length of the dart may have an impact on fit. However, it is an accepted industry adage that a large dart provides more shaping regardless of its position. In this study the size of the MSI dart appears to have had a major impact on the fit of the A-Garments. An additional factor which contributed to the differences in fit between both garment types, is that the FDS system uses an actual across chest measurement obtained anthropometrically and not one derived from a calculation based on the bust measurement as is required by the MSI pattern engineering process.

The photographs of the superimposed master blocks also confirmed the significant differences found between the across back, back bust, back waist, back hip and waist to hip. As stated previously, areas associated with the upper torso of A-Garments in particular, were excessively tight and restricted movement. In some cases, the zip at the back of the *toile* had to be left open, in order to establish the margin of measurement error and apply an appropriate rating.

The analysis of the photographs of the superimposed sleeve blocks showed that for all garments, the upper arm of the A-Garment toiles was smaller. It is of interest to note that the upper arm measurement for the sleeve is derived from twice the armhole width of the pattern and not a direct measurement obtained anthropometrically. The armhole width measurement of the pattern was calculated from the bust measurement. The analysis of the superimposed patterns confirmed the finding of significant statistical differences between Garments-A and B on this dimension. These differences are also apparent in the bar-graph comparison of FDS and MSI upper arm measurement.

For this study, woven fabric was used for the construction of the toiles, as opposed to a stretch or knitted fabric. Historically, the traditional method for testing master block patterns was to use muslin, or a similar inexpensive fabric such as calico (Gamber, 1995; Seligman, 1996; Aldrich, 2007). The fabric chosen for testing the toiles in this study was a woven, stable soft calico. The purpose for choosing calico was that it would produce a more reliable result in the fit analysis in relation to comfort and wearability, as it did not have stretch properties and was stable.

The findings have shown that there are significant differences in fit between the A-Garments and B-Garments. The B-Garments were superior on almost every characteristic, and it appears that this may be due to the differences in measurements and formulae used to construct the patterns, as well as well as the differences in the engineering process used for each system. A major reason for the differences in the measurements can be attributed to the source of the data - one set of which were calculated according to a formula based on a theory of body proportionality (MSI), the other set obtained by anthropometric survey (FDS).

It could be argued that the application of the assumption of body proportionality in relation to pattern engineering may need to be reviewed as a result of the findings of this study. The calculated proportionate system devised in the mid 1800s was originally developed for master tailors who made garments for individual clients. At that time extra fabric was allowed to make fit adjustments and enabled the tailor to achieve a superior fit, regardless of the accuracy or otherwise, of predetermined scales of proportions, when these were utilised. An inherent distrust of the tape measure and lack of current data, were a major reason for its popularity in the 20th century (Kunick, 1967) and its continued use in the 21st century. However, this thesis has shown that such an approach does not appear to have taken into account changes in human female morphological proportions over time (Ashdown, 2007).

It can be seen that there is an undeniable need for the clothing industry to recognise limitations of pattern systems which rely largely on calculated proportions and therefore fall short in addressing morphological changes in the human female size and shape. The calculated proportionate system was based on theories of fixed proportions put forward by great artists, painters, sculptors, and mathematicians (Fletcher, 1883; Huntley, 1970; Smith and Wheeler, 1988; Lawlor, 2000). Theories of proportion of an ideal body were applied to an inanimate object such as a sculpture or a painting to produce magnificent objects of art which have been admired for many centuries (Morris, 1940's, Boyd, 1980, Tanner, 1981). In contrast, the art of clothing the human body is far more complex, in that the physiology of the human body involves movement, (Bye et al., 2006) and dimensions of the human body rarely conform to the ideal (Schott, 1992; Vegter and Hage 2000).

Given the length of time that calculated proportionate systems for pattern engineering have been in use, the question arises as to the validity of their associated tables of body proportions, in view of the morphological changes of the human female body over the past century. The validity of any tables of proportion devised in the past century may have implications for both the ready to wear and made to measure industry in the present century. The suggestion is made therefore, that validation of the notion of fixed proportions of the human body is essential if the calculated proportionate system of pattern engineering is to be used successfully in the future. This would require current scientific survey data of the population to be tested in terms of the validity and reliability of such concepts that had their beginnings with the notion of an ideal or proportionate body (Fletcher, 1883; Carlstrom, 1905; Simons 1933; Poole, 1927).

This study has highlighted various theories, philosophies and schools of thought, and touched on a copious amount of material relating to a wide range of related topics. It is acknowledged that there are many other related topics which were beyond the scope of this study but warrant further investigation as to their role in relation to the fit and comfort of female garments. Such topics may include: garment balance, body posture and stance, (Simons, 1933; Hard's Year Book for the Clothing Industry, 1954; Kendall et al., 1993 in Norris, 1998; Bye et al., 2006; Ashdown, 2007), waist tilt (Armstrong, 1987; Veitch et al., 2007), as well as anterior and posterior tilt.

It has been suggested that waist tilt is a shape variable, influenced by tightness in the hip and waist regions, and that it can affect the evenness of a garment hemline (Veitch et al., 2007). Veitch et al. provided an example of (shape variables) of the lateral view of two garments worn by the same model, one being a 'ready to wear' garment, the other a garment made from the 'actual' measurements of the model, which included a waist tilt measurement (Appendix 4). The latter garment required no adjustments, whereas the ready to wear garment displayed an uneven hemline and excess tightness in the upper torso region.

It is interesting to compare the Veitch et al. examples with two specific garment examples produced in this study. In the case of the A-Garment (MSI) a similar approach was followed using predetermined ready to wear data. In the case of the B-Garment (FDS) the direct measurement system was used.

There is a striking similarity between the ready to wear garment in the Veitch et al. example, (Appendix 4) and the MSI garment worn by Subject 5 in Plate 50 of this study, which also shows excess tightness in the upper torso region, and an uneven waistline and hemline. The uneven hemline of the 'ready to wear' garment (Veitch et al., 2007), however, is much more pronounced than the uneven hemline of the (MSI) garment worn by Subject 5 (Plate 50). It is also interesting to note, that once the back zip on Subject 5 (Plate 54), was released and left open to midway between the upper and lower hipline, the excess fullness from C7 to the waistline improved considerably, allowing the waistline to return to its natural position, which resulted in a straighter hemline.

A comparison of Subject 5, Plate 50 (MSI system) with Subject 5, Plate 56, (FDS system) showed that the FDS (B-Garment) demonstrated a better outcome in terms of fit and garment balance. Although it is recognised that there was a difference in garment balance and fit between the A-Garment and B-Garment, it is of interest to note, however, that neither system applied the waist tilt principle. A question remains as to what effect different pattern engineering systems may have on the waist tilt aspect *per se.*

As noted previously, there are various pattern engineering systems used by the industry and training institutions at the present time. Some industries and training institutions place great importance on in-depth knowledge and skills in relation to the fundamental aspects of block making (Poole, 1920; Kunick, 1967). In other areas of the industry, however, the norm is to place a greater emphasis on design components, and utilise pre-prepared blocks to design and produce garments, and then adjust these pre-prepared blocks for individual use. It is questionable whether fashion and design graduates are being disadvantaged with the latter approach, as many industries expect fashion and design graduates to be capable of producing master blocks as a matter of course. An example of employer expectations in this area has been reported from the UK. According to *The Guardian* (2008), tailor, designer and teacher, Imtaz Khaliq states that fashion and textile graduates are coming out of universities and art colleges lacking the ability to draft a bodice block from scratch. Imtaz Khaliq claims that it is *sine qua non* for anyone embarking on a career in fashion and textiles. The writer agrees that training in the area of block making is of paramount importance, particularly due to the continual changes reported in relation to the size and shape of the population. Such changes which are occurring nationally and internationally will require trained personnel with the knowledge and skills to cope with the challenge of producing new blocks periodically, that reflect the recurring changes in human female morphology (National Health and Medical Research Council, 1997; Winks, 1997; Loesch et al., 2000; Swinburne et al., 2004; Australian Bureau of Statistics, 2009).

It would seem that the art and craft, as well as technical skills of block making have been somewhat sacrificed to convenience. This may well be due to the lack of availability of reliable data, time constraints, lack of knowledge and skills, and/or the complexities of some pattern engineering systems. As noted above, the skill of block making first hand has been replaced in some institutions with established pre-prepared blocks for students' use. In the opinion of this writer this is a critical omission, as such a skill should be placed at the forefront of training programs for the 21st century. Students deserve to be working with tools that reflect an ongoing commitment to initiative, innovation and excellence.

Knowledge and skills in block making will become even more essential with the continuing development of new technologies and software advances that are providing mechanisms to generate master blocks, patterns designs and 3-D data analysis, as well as the emerging 3-D shape analysis. It cannot be emphasised too strongly that one of the dangers of technological advances is the risk of a corresponding loss of traditional skills and a failure to conserve intellectual resources – a critical point to which other authors have also drawn attention (Bye et al., 2007, p.76).

The vast complexities related to the design and production of clothing, are undeniable (Holzman, 1996; Winks, 1997; LaBat, 2007). Designers, manufacturers, and retailers use their own size charts, and have similar sized garments labelled up to two to three sizes smaller. This down-sizing or vanity sizing, (Winks, 1997; Chun, 2007; Honey and Olds, 2007) often has a psychological effect on the consumer. For example, many consumers choose to buy a garment that is labelled a size smaller than their actual size and in some instances consumers will not buy a garment that is labelled larger than they perceive themselves to be (Hornett, 2004; Sea Elements, 2010; Waterlily, 2010).

The challenges facing the clothing production industry in Australia have placed it at a competitive disadvantage nationally and globally, as noted in the TCF industries review of 2008. The report particularly acknowledges an inability to compete with China on low cost items, but states that the TCF industries 'have a promising future providing they deliver products that are differentiated from those of their competitors by their uniqueness, product quality and design and branding'. The three most noteworthy TCF recommendations relevant to this study are: (5) to build innovative capability at the level of the enterprise and workplace, (10) to develop a long overdue Australian National Sizing Standard, and (13) to provide support to TCF firms to meet their needs for training and skills development (Department of Innovation Industry Science and Research, 2008 p.1).

The implementation of recommendations 10 and 13 in particular would significantly enhance the capability of graduates and industry to produce aesthetically pleasing and well fitting garments that would cater for human variation in relation to the morphological size and shape of the female population at the present time, as well as any secular changes which may occur in the future. An added bonus might well be an image boost for an industry that in the past, has not been given the professional recognition that it deserves (Poole 1920).

Chapter 5: Conclusions

This thesis has examined the implications for the production of female garments resulting from changes in human female morphology which have occurred since the development of pattern engineering systems in the mid 17th century. The process involved comparison of two contrasting pattern engineering system which differed radically in their philosophical approach, specifications and procedures. The results showed clearly that a significantly different outcome was obtained between the two systems, and that a system of pattern engineering will deliver a better outcome when it is not tied to the notion of body proportionality and associated formulae.

It is concluded therefore that although human morphological characteristics such as the size and shape of the human female body have changed considerably over the past century, clothing size standards and many pattern engineering systems may not reflect these changes, despite the fact that the link between female shape and pattern engineering systems is indisputable.

Schofield, who has drawn attention to the limitations of proportional based pattern engineering systems, asserts that assumptions of proportionality and ideal proportions are “antiquated” and counterproductive to producing clothing that will fit populations characterised by a rich diversity in ‘dimensions, shapes and proportions’. Schofield also argues that only measurement data from real people can produce garments that fit real people of the 21st century (Schofield, 2007).

Shape is the key component and connective element of anthropometry, morphology, pattern engineering and garment fit. Simmons et al., (2004a; 2004b) assert that shape has now been identified as a critical factor in the production of female garments for the mass production industry, couturier, professional dressmaker, student and aspiring fashion designer. The writer supports this assertion and strongly believes that ‘**Shape’** should be taken into consideration, not only in the production of female garments, but also in the development of sizing systems, to ensure that secular changes and secular trends in human female morphology are adequately addressed.

This study recommends the implementation of creative, innovative educational training programs that incorporate a scientific approach using basic elements of: anatomy, morphology, anthropometry and applied anthropometry, particularly in view of the predicted continual changes in human female morphology and the increasing technological advances of computerisation and digital technological for the clothing industry. The inclusion of these sciences combined with the design and the creative art of pattern engineering would provide future graduates and industry with the foundations for a more comprehensive insight into the entire design and pattern engineering process. Training and education in the application of scientific principles in conjunction with the creative aspects of design, pattern engineering, and fit analysis will provide additional essential tools to assist with analytical reasoning, problem solving, and decision making. The adoption and implementation of these recommendations at an educational and training level would play a major role in building an innovative and sustainable garment industry.

Bibliography

Advisory Group for Aerospace Research and Development. (1997). *Surface anthropometry: review of technologies*. AGARD Advisory Report 3293-D*.* Neuilly-Sur-Seine, France: North Atlantic Treaty Organisation.

Aldrich W. (2007). History of sizing systems and ready-to-wear garments. In: Ashdown SP, editor. *Sizing in Clothing*. Cambridge: UK: Woodhead Publishing Ltd. p 1-56.

Allport GW. (1937). Personality – A psychological interpretation. London: Constable & Company Ltd.

American Society for Testing and Materials. (1994). Designation: D 5219 – 94d. Standard terminology relating to body dimensions for apparel sizing*.* Philadelphia Pennsylvania: American Society for Testing and Materials.

American Society for Testing and Materials. (1995 Reapproved 2001). Designation D 5585-95 Standard table of body measurements for adult female misses figure type sizes 2-20. West Conshohocken,

American Society for Testing, and Materials. (2004). Designation: D 6960 – 04. Standard table of body measurements relating to women's plus size figure type sizes *14W-32W*. West Conshohocken, Pennsylvania: American Society for Testing and Materials.

American Society for Testing and Materials. (2007). Designation: D 5219 – 07a. Standard terminology relating to body dimensions for apparel sizing*.* West Conshohocken, Pennsylvania: American Society for Testing and Materials.

Anderson K. (2005). Pattern making: past to present. Retrieved 3rd May 2010. http://www.techexchange.com/library/patternmaking.html .

Armstrong HJ. (1987). *Pattern making for fashion design*. New York: Harper & Row, Publishers.

Ashdown SP. editor. (2007). *Sizing in clothing*. Cambridge, UK: Woodhead Publishing Ltd. p xvii-xix.

Askaroff AI. (2008). A brief history of the sewing machine. Retrieved 14thMay 2008. http://www.sewalot.com/sewing_machine_history.htm.

Australian Bureau of Statistics. (1995). How Australians measure up. Document Number 4359.0. Canberra: Australian Government Printing Office.

Australian Bureau of Statistics. (2009). National health survey: Summary of results 2007-2008 Document Number 4364.0. Retrieved 3rd March 2010 http://www.abs.gov.au/ausststs/abs@.nsf/mf/4364.0/.

Australian Safety Compensation Council. (2009). Sizing up Australia: How contemporary is [sic] the anthropometric data Australian designers use. Review commissioned by Office of Australian Safety Compensation Council. Barton, ACT: Australian Government Printing Office.

Australian Standard. (1959). *Australian standard body measurements for sizing of women's ready-to-wear apparel* (outerwear and underwear). Sydney: The Standards Association of Australia.

Australian Standard. (1970). *Size coding scheme for women's clothing: (underwear and outerwear*). Sydney: The Standards Association of Australia.

Australian Standard. (1972). *Size coding scheme for women's clothing: (underwear and outerwear).* Sydney: The Standards Association of Australia.

Australian Standard. (1975). *Size coding scheme for women's clothing: (underwear, outerwear and foundation garments)*. Sydney: The Standards Association of Australia.

Australian Standard. (1997). *Size coding scheme for women's clothing: (underwear, outerwear and foundation garments)*. Sydney: Standards Association of Australia.

Banfield MA. (2000). The posture theory*.* Adelaide: The author.

Barker R. (2002). Postural types and body shapes. *Healthwise Newsletter* No 35: The author.

Beals RL. and Hoijer H. (1961). *An introduction to anthropology.* New York: The Macmillan Company.

Beedee. (1926). An interesting experiment. *The Australian Women's Mirror*. September 28th 1926.

Beirne P. (1987). Adolphe Quetelet and the origins of positivist criminology. American Journal of Sociology 92 (5): 1140-1169.

Bellis M. (2008). Industrial revolution - timeline of textile machinery. Retrieved 14th June 2010. http://inventors.about.com/library/inventors/blindustrialrevolutiontextiles.htm.

Benardot D. (2006). *Advanced sports nutrition.* Champaign USA: Human Kinetics.

Berkowitz RI. Fujioka K. Daniels SR. Hoppin AG. Owen S. et el., (2006). Effects of sibutramine treatment in obese adolescents-A randomised trial. *Annals of Internal Medicine* 145 (2): 81-89.

Berlei Review. (1926). In house article published July 1926. Sydney: Berlei Limited.

Berlei. (1928). Research department report. April 17th 1928. Sydney: Berlei Limited.

Berry KM. (1976). *A study of measurements used in the size coding scheme for women's clothing*. Submitted to Department of Technical and Further Education, Torrens College of Advanced Education, Adelaide, South Australia, in partial fulfilment of a Diploma in Teaching (Technical).

Berry KM. (2001). The changing size and shape of Australian women. Thesis presented to The University of Adelaide Australia in fulfilment of Master of Medical Science Degree.

Berry KM. and Henneberg M. (1998). Australian fashion body ideal is far from reality. Paper presented at the *Challenge the body culture conference proceedings*. Brisbane, Queensland: University of Technology Publications and Printing Unit.

Berry KM. and Hennes LF. (2008). *The fashion design system: Pattern engineering for the 21st century*. Nambour Qld: Queensland Complete Printing Services.

Blumenkrantz M. (1998). Obesity: The world's oldest metabolic disorder. *Obesity and Health – An overview.* Retrieved 2nd July 1998 http://www.quantumhcp.com/obesity.htm

Board of Trade UK. (1957). *Women's measurements and sizes: A study sponsored by The Joint Clothing Council Limited*. London: Her Majesty's Stationery Office.

Body Image and Advertising. (2008). Eating disorders. Retrieved 11th May 2010. http://www.healthyplace.com/eating-disorders/main/eating-disorders-body-image-and

Bogin B. (2006). Commentary: Proportion not the cause of beauty but of health? *Int. J. Epidemiology*. doi: 10.1093/ije/dy1230, Advance Access published October 30th 2006.

Bogin B. Smith P. Orden AB. Varela Silva MI. and Louky J. (2002). Rapid change in height and body proportions of Maya American children. *American Journal of Human Biology*. 14 (6): 753-761.

Bouchard C. and Perusse L. (1993). Genetic aspects of obesity. In: Williams CL and Kimm SYS. editors. Prevention and treatment of childhood obesity. *Annals of the New York Academy of Sciences* Vol 699 (October 29):26-36.

Boucher F. (1967). *A History of Costume in the West.* London: Thames and Hudson.

Bougourd J. (2005). Measuring and shaping a nation: SizeUK 5th Istanbul textile conference: Recent advances in innovation and enterprise in textile and clothing.

Bougourd J. (2007). Sizing systems fit models and target markets. In: Ashdown SP, editor. *Sizing in Clothing*. Cambridge: UK: Woodhead Publishing Ltd. p 108-151.

Boyd ED. (1980). *Origins of the study of human growth*. Savara D. and Schilke J. editors. University of Oregon Health Sciences Centre.

Branson DH. and Nam J. (2007). Materials and sizing. In: Ashdown SP. editor. *Sizing in Clothing.* Cambridge UK: Woodhead Publishing Ltd. p 264-276.

Bridger RS. (1995). *Introduction to Ergonomics.* Singapore: Mc Graw - Hill International Editions.

British Standard Institution. (1963). *Size Coding Scheme for Women's Outerwear*. London: British Standard Institution.

British Standard Institution. (1982). *Size designation of women's wear*. London: British Standard Institution.

Brooke-Wavell K. Jones PRM. and West GM.(1994). Reliability and repeatability of 3-D Body (LASS) measurements compared to anthropometry. *Annals of Human Biology* 21 (6):571-577.

Buist A. (2000). The recognition and management of eating disorders. *Australian Family Physician,* April 2000 29 (4): 328-332.

Burley FR. (1926). An ambitious project. In: *Berlei Review* July 7th 1926 Sydney: Berlei Ltd.

Bye E. Labat KL. and Delong MR. (2006). Analysis of body measurement systems for apparel. *Clothing and Textiles Research Journal* 24: 66-79.

Cabot S. and Cooper D. (1997). *The Body Shaping Diet*. Werombi, New South Wales Australia: Women's Health Advisory Service.

Carlstrom JA. (1905). *Neo-Classicism in architecture and cutting.* Excerpt from The Cutter and Tailor. Retrieved 2009. www.cutterandtailor.com/forum/index.php?showtopic=437

Carter JEL. and Honeyman Heath B. (1990). Somatotyping – development and applications. Cambridge UK: Cambridge University Press.

Casanovas G. (2001). *The Iceman.* Retrieved 16th October 2001. www.american.edu/ted/iceman.htm.

Chun J. (2007). Communication of sizing and fit. In: Ashdown SP. editor. *Sizing in Clothing*. Cambridge UK: Woodhead Publishing Ltd. p 220-245.

Clauser C. Tebbetts I. Bradtmiller B. Mc Conville J. and Gordon CC. (1988). Measurer's handbook: US army anthropometric survey 1987-1988. United States Army Natick, Massachusetts: Science and Advanced Technology Directorate.

Cole A. (2005). A Brief history of sewing machines, *EzineArticles*. Retrieved 14th May 2008. http://ezinearticles.com/?A-brief-History-of-S-Machines&id=73917

Cosgrave B. (2000). *The complete history of costume and fashion.* Great Britain: Hamlyn.Couper S. (2008). When and wear: the prehistory of clothing. *Australian National Reporter* Winter Edition. Canberra: Australian National University.

Couper S. (2008). When and wear: the prehistory of clothing. The Australian National Reporter (winter edition). Canberra Australia: Australian National University

Crawley AE. (1912). Dress - In: Johnson KKP. Tontore SJ. and Eicher JB. editors. (2003). *Fashion foundations.* Oxford: Oxford International Publishers Limited. p 21-27.

Daanen HAM. and Reffeltrath PA. (2007). Function, fit and sizing. In: Ashdown SP. editor. *Sizing in Clothing.* Cambridge UK: Woodhead. p 202-219.

Daily Mail (2006). Are size zero models too thin for the catwalk? Retrieved 17th May 2010. http://www.dailymail.co.uk/femail/article-405600/Are-size-zero-models-catwalk.html#ixzzOo9Ydp5Ds

Daily Mail (2007). In support of the bigger woman, Marks & Spencer's J-cup revolution. Retrieved 1st April 2010. http://www.dailymail.co.uk/news/article-493915/In-support-bigger-woman-Marks--Spence

Damon A. (1963). The utility of NATO anthropometric data. In: *Anthropometric survey of Turkey, Greece and Italy.* Advisory Group for Aeronautical Research and Development North Atlantic Treaty Organisation: Pergamon Press. Chapter 6.

Daniell N. (2007). A comparison of the accuracy of the Vitus Smart® and Hamamatsu Body Line® 3D whole-body scanners, In: Marfell-Jones M. and Olds T. editors. Kinanthropometry X: *proceedings of the 10th International Society for Advancement of Kinanthropometry Conference, Held in Conjunction with the 13th Commonwealth International Sport Conference*. Abingdon UK: Routledge. Chapter 4.

D'Apuzzo N. (2007). 3D body scanning technology for fashion and apparel industry. In: Beraldin J. Remondino F and. Shortis MR. editors. Videometrics IX Proceedings of SPIE-IS&T Electronic Imaging. San Jose, California: SPIE Vol 6491A.

DeBrohun J. (2001). Power dressing in ancient Greece and Rome. *History Today* 51 (2):18-25.

de Onis M. and Habicht JP. (1996). Anthropometric reference data for international use: Recommendations from a WHO Expert Committee. *American Journal of Clinical Nutrition* 64**:** 650-8.

Department of Human Services. (2008). In: *National Preventative Health Services Technical Paper 1,* Canberra Australia: Australian Government Printing Service.

Department of Innovation, Industry, Science and Research. (2008). *Report Outlines Promising Future for TCF Industries*. Australian Government Media Release 19/09/2008. Retrieved 20th October 2008.http://www.innovation.gov.au/tcfreview/Pages/REPORTOUTLINESPROMISINGFUTU

Devere L. (1866). *The Handbook of Practical Cutting on the Centre Point System*. Revised in 1986 by Shep RL editor. Mendocino CA. USA: R. L. Shep.

Diamond S. (1969). Introduction. In: Quetelet Lambert AJ. *A Treatise on Man and the Development of his Faculties.* (A facsimiles reproduction of the English translation of 1842 with an introduction by Solomon Diamond). Gainesville, Florida: Scholar's Facsimiles and Reprints. p. V.

Donohoe M. (2006). *Beauty and body modification*. Retrieved 9th February 2008. http://www.medscape.com/viewarticle/529442_2

Dorner J. (1974). *Fashion: The changing shape of fashion through the years*. London: Octopus Books Ltd.

Drummond S. (2000). Address the weighty problem of obesity. *Practice Nurse* (August 11), 20 (3): 146.

Drury. E. editor. (1999). Fashions of the past. London: Collins & Brown Limited.

Eknoyan. G. (2007). *Adolphe Quetelet* (*1796-1874*) *– the average man and indices of obesity.* Oxford: University Press. The Author

Ewing E. (1978). History of 20th century fashion. London: B.T. Batsford Ltd.

Fagan BM. editor. (2004). *The Seventy Great Inventions of the Ancient World*. London: Thames and Hudson Ltd.

Falbo C. (2005). The Golden Ratio- A contrary viewpoint. *The College Mathematics Journal* 36 (2): 123-134.

Fashion Technicians Association Australia. (2009).*Technically Speaking*. Fashion Technicians Association Australia Newsletter. Volume 1.

Fernandez N. (2004). Innovations for home dressmaking and the popularization of stylish dress. *The Journal of American Culture* 17: 23-33.

Fisher A. (2010). Why are British women's breasts getting bigger? The Observer 16th May 2010 Retrieved 19th May 2010. http://www.guardian.co.uk/lifeandstyle/2010/may/16/womens-breasts-are-getting-bigger.

Fletcher R. (1883). *Human proportion in art and anthropometry.* Lecture delivered at The National Museum Washington D.C. Cambridge USA: Moses King Publisher.

Forsdyke G. (2008). A brief history of the sewing machine. Retrieved 14th May 2008. http://www.ismacs.net/smhistory.html .

Foss YJ. (2009). Vitamin D deficiency is the cause of common obesity. *Medical Hypotheses* 72)3): 314-321.

Fralix MT. (2001). From mass production to mass customisation. *Journal of Textile and Apparel, Technology and Management* 1 (2):1-7.

Friedman JM. and Halaas JL. (1998). Leptin and the regulation of body weight in mammals. *Nature* 395:763-770.

Fullagar R. (2004). Lousy Clothes. *Nature Australia* 28 (1): 18-19.

Gadzik J. (2006). How much should I weigh? — Quetelet's equation, upper weight limits, and BMI prime. *Connecticut Medicine*. 70 (2): 81-88.

Gamber. W. (1995). Reduced to science: gender, technology, and power in the American dress making trade 1860-1910. *Technology and Culture*. 36 (3): 455-482

Garn S M. and Giles E. (1995). Earnest Albert Hooton - Biographical memoirs. *National Academy of Sciences.* Retrieved 15th March 2003. http://stills.nap.edu/html/biomems/ehooton.html

Gibb J. (2011). No such size as average. *Otago University News.* Retrieved 9th February 2011. http://www.odt.co.nz/campus/university-otago/147046/no-such-size-average

Gilligan I. (2007). Clothing and farming origins: The evidence. *Bulletin of the Indo-Pacific PreHistory Association* 27: 12-21.

Gordon C. and Friedl K. (1994). Anthropometry in the US armed forces. In: Ulijaszek SJ. and Mascie-Taylor CGN. editors. *Anthropometry: The individual and the population*. New York Press Syndicate of the University of Cambridge: Cambridge University Press. p 178-210.

Gordon CC. and Greiner TM. (1993). Biocultural influences in the analysis of secular trends. In: *Race, Ethnicity, and Applied Bioanthropology* Vol 13**.** Arlington VA: National Association for the Practice of Anthropology.

Gordon-Larsen P. Zemel BS. and Johnston FE. (1997). Secular changes in stature, weight, fatness, overweight, and obesity in Urban African American adolescents from the mid 1950's to the mid –1990's. *American Journal of Human Biology* 9: 675-688.

Gosline A. (2009). Ancient beads imply culture older than we thought. *Science* 312:1785.
Gough ELG. (1963). *Principles of garment cutting*. Sydney: Angas & Robertson Ltd.

Hard's Year Book for the Clothing Industry. (1954). *Assessing female figure proportions*. London UK: Hard's Publication. p 208-220

Hamilton Hill M. and Bucknell PA. (1969). *The evolution of fashion*. London: BT Batsford Ltd.

Henneberg M. (1992). 'Continuing human evolution: Bodies, brains and the role of variability'. *Trans Royal Society South. Africa.* 48 (Part 1, March)**:**159-182.

Henneberg M. (1997). Human evolution today: Which way next? *Perspectives in Human Biology* 3:1-12.

Henneberg M. (2001). Secular trends in body height: Indicator of general improvement in living conditions or of a change in specific factors? In: Dasgupta P. and. Huaspie R. editors. *Perspectives in Human growth, development and maturation.* Boston: Kluwer Academic Publishers. p 1-90.

Henneberg M. (2001). The gradual eurytopic evolution of humans: Not from Africa alone. In *Proceedings of Conference on Man: Past, Present and Future*. In A Scientific Life. editor Indriati E. BIGRAF Publishing p,41-51

Henneberg M. (2001a). Possible causes of secular trends in body size – Lessons from the Southern Hemisphere. In: Schultz M. Atzwanger K. Brauer G. Christiansen K. Forster J. Greil H. Henke W. Jaeger U. Scheffler C. Schiefenhovel W. Schroder I. Weichmann I. editors. *Homo-unsere Herkunft und Zukunft*. Gottingen: Cuvillier Verlag. p 234-237.

Henneberg M. and Berry KM. (2002). Scientific sizing study: ripcurlgirl anthropometric training program. Adelaide Australia: The University of Adelaide.

Henneberg M. and Berry KM. (2003). Re: Search the body matrix. Draft of final report on the rip curl girl. Adelaide Australia: The University of Adelaide.

Henneberg M. and George BJ. (1995). Possible secular trend in the incidence of an anatomical variant: median artery of the forearm. *American Journal of Physical Anthropology* 96: 329-334.

Henneberg M. and Louw GJ. (1998). Cross-sectional survey of growth of urban and rural "Cape Coloured" schoolchildren: Anthropometry and functional tests. *American Journal of Human Biology* 10: 73-85.

Henneberg M. and Ulijaszek SJ. (2010). Body frame dimensions are related to obesity and fatness: Lean Trunk Size, skinfolds and Body Mass Index. *American Journal of Human Biology* 22 (1): 83-91

Henneberg M. and van den Berg ER. (1990). Test of socioeconomic causation of secular trend: Stature changes among favored and oppressed South Africans are parallel. *American Journal of Physical Anthropology* 83:459-465.

Henneberg M. and Veitch D. (2003). National size and shape survey of Australia. Kinanthreport XVI: 34-39.

Henneberg M. and Veitch D. (2005). Is obesity as measured by body mass index, and waist circumference in adult Australian women 2002 just a result of the lifestyle? J*ournal of Human Ecology* Special Issue 13: 85-89.

Hertzberg HTE. (1972). Engineering anthropology. In: *Human Engineering Guide to Equipment Design* Washington DC: U.S Government printing office. Chapter 11.

Hillhouse MS. and Mansfield EA. (1948). *Dress design: Draping and flat pattern making*. Boston: Houghton Mifflin Company.

Hirschhorn C. (1983). *The Warner Bros. story*. London: Octopus Books.

Holzman DC. (1996). Fewer sizes fit all. *Technology Review* January 1996 p 19-21.

Honey F. and Olds T. (2007). The Standards Australia sizing system: quantifying the mismatch. *Journal of Fashion Marketing and Management* 11 (3): 320-331.

Honeyman Heath B. and Carter JEL. (1967). A modified somatotype method. *American Journal of Physical Anthropology* 27: 57-74.

Hornett G. (2004). Industry unites on sizing. In: *Ragtrader,* 16th January 2004.

Huang TT. Esposito L. Fisher JO. Mennella JA. and Hoelscher DM. (2009). Development perspective on nutrition and obesity from gestation to adolescence. *Prevention of Chronic Disease.* July 6 (3): A94.

Huntley HE. (1970). *The divine proportion: A study in mathematical beauty*. New York: Dover Publications.

Imwold D. Olds M. and Parker J. editors. (2007). *Anatomica-The complete home medical reference.* Sydney Australia: Global Book Publishing Pty Ltd.

International Organisation for Standardisation. (1989). *Garment construction and anthropometric surveys-body dimensions.* Reference No ISO 8559: 1989 (E). Geneva: International Organisation for Standardisation

International Organisation for Standardisation. (1991).*Technical Report* ISO TR 10652. Geneva: International Organisation for Standardisation.

iSculpt. (2008). *Canons of proportions and the ideal*. Retrieved 27/03/2010.
http://isculpt.org/index.php/2008/01/28/title_1

Jaffe H. and Relis N. (1973). *Draping for fashion design*. Virginia USA: Reston Publishing Company Inc.

Janssen I. Powell LH. Kazlauskaite R. and Dugan SA. (2010). Testosterone and visceral fat in midlife women: the study of women's health across the nation fat patterning study. *Obesity* (Silver Spring) March 18 (3): 604-10.

Jenkyn Jones S. (2005). *Fashion design.* London: Laurence King Publishing.

Johanson DC. (2001). Origins of modern humans: Multiregional or out of Africa? *American Institute of Biological Sciences.* www.actionbioscience.org/evolution/**johanson**.html

Johnson KKP. Tontore SJ. and Eicher JB. editors. (2003). *Fashion foundations.* Oxford: Oxford International Publishers Limited.

Jones PRM. and Rioux M. (1997). Three-dimensional surface anthropometry: Applications to the human bod*y. Optics and Laser in Engineering* 28 (2): 89-117.

Jones PRM. West G M. Harris DH. and Read JB. (1989). The Loughborough anthropometric shadow scanner. *Endeavour New Series* 13 (4). Great Britain: Pergamon Press.

Jovanovic R. (2003). *The golden section and the human body* (Translated by D Filipovic). Retrieved 21st March 2010. http://milan.milanovic.org/math/english/golden/golden1.html .

Kaelin A. (2009). *The development and perfection of the human body in Greek sculpture.* http://www.bukisa.com/articles/43320_

Kanagasingam R. (2008). Journey of early man: Africa to America. In: *German memories in Asia* http://www.pr-inside.com/journey-of-the-early-man-africa-r705346.htm

Kemsley WFF. (1950). Weight and height of a population in 1943. *Annals of Eugenics* 15: 161-183

Keys A. Fidanza F. Karvonen MJ. Kimura N. and Taylor HL. (1972). Indices of relative weight and adiposity. *Journal Chronic Disease* 25: 329-343

Kidwell CB. (1979). *Cutting a fashionable fit: Dressmakers' drafting systems in the United States*. Washington: Smithsonian Institution Press.

Kirchdorfer E. and Rupp M. (2004). *Possibilities and capabilities of 3D body- scanning systems for the purpose of risk assessment.* Hohenstein E.V Germany: Department of Clothing Technology Bekleidungsphysiologisches Institut.

Kittler R. Kayser M. and Stoneking M. (2003). Molecular evolution of *pediculus humanus* and the origin of clothing. *Current Biology* 13 (6): 1414-1417.

Komlos J. editor. (1994). *Stature, living standards and economic development: essays in anthropometric history*. Chicago: The University of Chicago Press.

Kretschmer E. (1936). *Physique and character*. London: Keegan Paul, Trench, Trybner & Co Ltd.

Kritzon C. (2006). The Iceman's Belt. Retrieved 16th July 2008. www.primitiveways.com/Iceman.html

Kunick P. (1967). Sizing, pattern construction and grading for women's and children's garments, London: Philip Kunick Ltd.

Kybalova L. Herbenova O. and Lamarova M. (1970). *The pictorial encyclopedia of fashion*. New York: Crown Publishers Inc.

Kyle UG. Bosaeus I. De Lorenzo AD. (2004). Bioelectrical impedance analysis—Part 1: Review of principles and methods, *Clinical Nutrition* 23: 1226-1243.

Labat KA. (2007). Sizing Standardization. In: Ashdown SP. editor. *Sizing in clothing*. Cambridge UK: Woodhead Publishing Ltd. Chapter 3.

Labour Daily. (1926). Sydney 15th July Issue, *Modern method: Science of fitting.* Sydney: Newspaper Publisher.

Lambert T. (2010). The Industrial Revolution. Retrieved 14/06/2010 http://www.localhistories.org/industrial.html

Lancaster HO. (1957). Some anthropometrical values of women in Australia. *Medical Journal of Australia.* 897-900.

Langner L. (1991). *The Importance of wearing clothes.* Los Angeles: Elysium Growth Press.

Lasker GW. (1994). The place of anthropometry in human biology. In: Ulijaszek S J and CGN Mascie-Taylor. editors. *Anthropometry: The individual and the population*. Cambridge UK: Cambridge University Press. p 1-6

Lawlor. R. (2000) *Sacred Geometry*. London: Thames & Hudson.

Lee Jeong Yim. Istook CL. Nam Yun Ja. and Park Sun Mi. (2007). Comparison of body shape between USA and Korean women. *International Journal of Clothing Science and Technology* 19 (5): 374-391.

Leighton J. (1874). *Madre natura versus the moloch of fashion: a social essay,* London: Chatto & Windus.

Leo NP. and Barker SC. (2005). Unravelling the evolution of the head lice and body lice of humans. *Parasitol. Research* 98: 44-47.

Livio M. (2002) *The golden ratio.* London: Headline Book Publishing.

Livshits G. Roset A. Yakovenko K. Trofimov S. and Kobyliansky. E. (2002). Genetics of human body size and shape: body proportions and indices. *Annals of Human Biology* 29 (3): 271-289.

Loesch DZ. Stokes K. and Huggins R M. (2000). Secular trends in body height and weight of Australian children and adolescents. *American Journal of Physical Anthropology* April 111(4):545-557.

Louw GJ. Henneberg M. (1997). Lack of secular trend in adult stature in white South African males born between 1954 and 1975. *Journal of Comparative Human Biology* 48 (1): 54-61.

Lucentini J. (2003). Clothing's lousy origins. *Discover Magazine*. Retrieved 2nd July 2008. http://discovermagazine.com/2003/dec/clothings-lousy-origins

Macnoriute J. (2000). *The secrets of perfection*. Retrieved 24th September 2004. http://www.geocities.com/jumaclt1/prop1en.html/

Maginnis T. (1996). *The Rise of the industrial revolution in the history of fashion and dress.* Retrieved 6th July 2010. http://www.costumes.org/classes/fashiondress/IndustrialRevolution.htm

Maine M D. (2005). Eating disorders and body image distress in women at mid Life. Retrieved 9th February 2008. http://www.medscape.com/viewprogram/4302

Manica A. (2007). New evidence for the origin of modern man. *Nature* 448: 346-348.

Markowsky G. (1992). Misconceptions about the Golden Ratio. *The College Mathematics Journal* January 23 (1) 1-19

Mc Bride JH. (1903). *The life and health of our girls in relation to their future.* California: Carlise.

McCarthy M. (1990). The thin ideal, depression and eating disorders in women. *Behaviour Research and Therapy* 28 (3): 205-215. In: Christopher G Price (1992) New Zealand Print Advertising and the thin ideal for women. Presented for Master's Thesis University of Otago NZ.

McConville JT. (1978). Anthropometry in sizing and design. In: *Anthropometric Source Book*. vol. 1. NASA Reference Publication 1024. Chapter 8. pp VIII–1-23. Washington DC: NASA.

Mc Dowell C. (2000). *Fashion Today*. New York: Phaidon Press.

Mc Phee IM. (2008). *The mathematics of ancient Egypt: The impressive numeral history of an ancient civilisation.* http://math.suite101.com/article.cfm/the_mathematics_of_ancient_egypt

Media Awareness Network. (2010). Beauty and Body Image in the Media. Retrieved 11th May 2010. http://www.media-awareness.ca/english/issues/sterotyping/women_and_girls/women

Melbourne Herald (1927). Unique scientific survey: Taking measurements of Australian women. 21st January 1927. Melbourne: Newspaper Publisher.

Meredith HV. (1976). Findings from Asia, Australia, Europe and North America on secular change in mean height of children, youths, and young adults. *American Journal of Physical Anthropology* 44: 315-326.

Miller C. (2006) *The complete costume history* (Translation of Racinet A. *Le Costume Historique* of 1888. A reproduction of the original work published in Paris). Hohenzollernring Germany: Taschen

Monahan A M. (1912). *La Simplicite (Folding) Systeme*. Sydney Australia: The Author.

Morris FR. (1940's). *Ladies garment cutting and making*. London: The New Era Publishing Co Ltd.

Mosk C. (1996) *Making Health Work* Berkeley: University of California Press.

Mueller W.H. Meininger JC. Liehr P. Chan W. and Chandler P S. (1998). Conicity: A new index of body fat distribution-what does it tell us? *American Journal of Human Biology* 8 (4):489-496.

Museum of American Heritage (2010). *History of the Sewing Machine*. Retrieved 15th July 2010. http://www.moah.org/exhibits/virtual/sewinng.html

Naini F. Cobourne. M. Mc Donald F. and Donaldson. A. (2009). The influence of craniofacial to standing height proportion on perceived attractiveness. *International Journal of Oral and Maxillofacial Surgery* 37 (10): 877-885.

National Health and Medical Research Council. (1997). *Acting on Australia's Weight.* Canberra: Australian Government Printing Service.

National Health and Medical Research Council. (2003). *Dietary Guidelines for Australian Adults*, Canberra: Australian Govt Printing Service.

National Health and Nutrition Examination Survey (1988). *Body measurements (Anthropometry) Survey 111.* Rockfield USA: Westat, Inc.

National Preventative Health Taskforce. (2009). *Australia:* The healthiest country by 2020- National Preventative Health Strategy-the road map for action. Canberra: Commonwealth of Australia. www.health.gov.au/internet/preventativehealth/...nsf/.../tech-obesity-toc

National Strategy on Body Image. (2009). Feedback on the findings from the national strategy on body image online consultations. Canberra: Australian Government Printing Office.

New South Wales TAFE School of Fashion. (1977). *Pattern making- Metric S I method P102*. Sydney NSW: Government Printing Office.

Norris CM. (1998). *Sports injury diagnosis and management*. Butterworth: Heinemann.

Norris H. (1999). *Ancient European costume and fashion*. New York: Dover Publications Inc. Unabridged republication of Costume and fashion, volume one: The evolution of European dress through the earlier ages. 2nd edition originally published 1924. London: JM. Dent and Sons Ltd

Norton T. and Olds T. (1996), *Anthropometrica*. Sydney: University of New South Wales Press.

O'Brien R. and Shelton WC. (1941). *Women's measurements for garment and pattern construction.* Miscellaneous Publication 454. Washington DC: US Department of Agriculture.

O'Connor JJ. and Robertson EF. (1999). Pythagoras of Samos. http://www-history.mcs.st-andrews ac.uk/Biographies/Pythagoras.html.

Ode JJ. Pivarnik JM. Reeves MJ. and Knous JL. (2007). Body mass index as a predictor of percent fat in college athletes and nonathletes. http://www.medscape.com/view article /555017.

Old State House Museum Arkansas. (1994) *Native Americans in Arkansas*. http://www.oldstatehouse.co/educational_programs/classroom/arkansas_news/detail

O'Neil D. (2007). *Archaic homo sapiens culture*. http://anthro.palomar.edu/homo2/mod_homo_3.htm .

Ostwald MJ. (2004). Under siege: The golden mean in architecture. Nexus Network Journal. http://www.nexusjournal.com/Ostwald.html .

Palmer P. and Alto M. (1998). Fit for real people. Portland, Oregon: Palmer/ Pletsch Publishing.

Park S. Nam Y. and Choi K. (2004). Exploratory study for standardization of 3-dimensional body scanning-The verification of accuracy of 3-dimensional scanned data. *Japanese Journal of Ergonomics* 40:122-125.

Parliamentary Library of Australia. (2006). *Overweight and obesity in Australia*. E-Brief: On Line Only, Issued 5th October 2006.

Patterson A. and Brown W. (2000). The real Australian woman. Newcastle NSW: The University of Newcastle Research Institute for Gender and Health.

Peacock J. (1993). *20th Century fashion.* London*:* Thames and Hudson Ltd.

Pepin H. (1942). *Modern Pattern Design*. New York: Funk and Wagnall's Company.

Petrova A. (2007) Creating sizing systems. In: Ashdown SP. editor. *Sizing in clothing*. (Chapter 2) Cambridge. UK: Woodhead Publishing Ltd.

Pi-Sunyer F X. (1994). Obesity trends: waist not want not? *Foods Insight* 1-4 March/ April 1994.
Poole BW. (1920). *The clothing trades industry*. London: Sir Isacc Pitman and Sons Ltd.

Poole BW. (1920). *The science of pattern construction for garment makers*. London: Sir Isaac Pitman and Sons Ltd.

Poole BW. (1927). *The science of pattern construction for garment makers.* London: Sir Isacc Pitman and Sons Ltd.

Power E. (2010). Bra sales jump along with sizes.Herald Sun 31st March 2010. Retrieved March 31, 2010http://www.herald.com.au/news/national/bra-sales-jump-along-with-sizes/story-e6frf71

Powerhouse Museum. (2010). Mc Dowell garment drafting machine and instruction book. Collection: Powerhouse Museum, Sydney.

Ragtrader. (1998). *Solving the Sizing dilemma***.** March 1998. p 6-19.

Richards FC. and Richards ES. (1912). *Ladies' handbook of home treatment*: *The ladies' medical adviser*. Melbourne Australia: Signs Publishing Company.

Randerson J. (2003). Dawn of human race uncovered. *New Scientist.* 11th June 2003.

Rimm AA. Hartz A. and Fischer ME. (1988). A weight shape index for risk of disease in 44,820 women. *Journal of Clinical Epidemiology* 41(5):459-465.

Rioux M. and Jones PRM. (1997). Applications. In: *Advisory Group for Aerospace Research and Development. Advisory Report 329, 3-D Surface Anthropometry: Review of Technologies.* Nueilly-Sur-Seine, France: *Advisory Group for Aerospace Research and Development*. Chapter 11.

Robinette KM. (1997). Chapter 1 (Untitled). In: Robinette K M. Vannier M W. Rioux M and Jones PRM. editors. *Advisory Group for Aerospace Research and Development. Advisory Report 329, 3-D Surface Anthropometry: Review of Technologies.* Nueilly-Sur-Seine, France: Advisory Group for Aerospace Research and Development.

Robinette KM. Blackwell S. Daanen H. Boehmer M. et al. (2002*). Civilian American and European Surface Anthropometry Resource Final Report, Volume 1: Summary AFRL-HE-WP-TR-2002-0169.* Wright Patterson Air Force Base: Civilian American and European Surface Anthropometry Resource Project.

Robinette K. and Daanen H. (2003). *Lessons Learned From CAESAR: A 3D Anthropometric Survey*. (Report XCAFRL). Wright Patterson Air Force Base: Civilian American and European Surface Anthropometry Resource Project. kath.robinette@wpafb.af.mil

Robinson J. (1989). *The fine art of fashion –An illustrated history*. Kensington NSW: Bay Books.

Roche AF. (1979). Secular trends in stature, weight and maturation. *Monographs of the Society for Research in Child Development*. Chapter II Serial No 179, Nos 3-4.

Schofield NA. (2007) Pattern Grading. In: Ashdown SP, editor. *Sizing in Clothing*. Cambridge: UK: Woodhead Publishing Ltd. p 152-201.

Schott GD. (1992). The extent of man from Vitruvius to Marfan. *Lancet* 340 (8834/8835): 1518.

Sea Elements. (2010). Factors affecting size choices made by swimwear customers. Personal communication. Coolum Australia: Sea Elements Management.

Sea Elements. (2011) Swimwear cup size increase. Noosa Heads, Australia: Waterlily Management. Personal communication.

Seligman KL. (1996). *Cutting for all.* Carbondale and Edwardsville Illinois: Southern Illinois University Press.

Sew Trade. (1990). Costing the industry an arm and a leg. Dec/Jan 1989/90. Sydney: Publishing and Production Projects. p 14-15.

Shamuhitdinova L. Chursina V. and Kamilova K. (2009). *Analysis of historical prototypes of the methods of morphological clothing transformation*. http://www.sanat.orexca.com/eng/3-02/design.shtml .

Sheldon WH. (1949) *Varieties of delinquent youth*. New York: Harper and Brothers.

Sheldon WH. Stevens SS. And Tucker WB. (1970*). The varieties of human physique*. Darien Connecticut USA: Hafner Publishing Company.

Simmons K. (2002). Body shape analysis using three-dimensional body scanning technology. Doctoral Thesis. North Carolina State University.

Simmons K. Istook CL. and Devarajan P. (2004a). Female figure identification technique for apparel. Part I: Describing female shapes. *Journal of Textile and Apparel Technology and Management* 4 (1): 1-16.

Simmons K. Istook CL. and Devarajan P. (2004b). Female figure identification technique for apparel, Part II: Development of shape sorting software. *Journal of Textile and Apparel, Technology and Management* 4 (1): 1-15.

Simons H. (1933). *The science of human proportions.* New York: Clothing Designer Co Inc.

singerco. (2010). Sewing Machines from SINGER Australia-(1800-1860). Retrieved 13th July 2010 http://www.singerco.com.au/about-singer/singer-history/history-1800-1860.html

Smith S. and Wheeler L. (1988). *Drawing and painting the figure.* London: Tiger Books International.

Spillman DM. and Everington C. (1989). Somatotypes revisited: Have the media changed our perception of the female body image? *Psychological Reports* 64: 887-890.

Spindler K. (1994). *The man in the ice*. London: Wedenfeld and Nicolson.

Standards Australia Limited. (2003). *Industry asked to measure up in pursuit of Ms Average (2003-08-25)*. Report by Standards Australia Technical Committee. Retrieved 4th December 2009 http://www.standards.org.au/cat.asp?catid=42&contentid=236&News=1

Stanley H. (1972). *Modelling and flat cutting for fashion: from design to pattern*. London: Hutchinson.

Stokes GW. (1997) *CAESAR Measures the U.S and Europe- Anthropometrics with a twist.* August 1997 Report. New York: Standardisation News.

Suchar V. and Rossi C. (1997). The harmonic system in ancient Egyptian architecture: The origin of proportion in western architecture. A joint lecture to the Bath Royal Literary & Scientific Institution 8th December 1997.

Swinburn BA. Caterson I. Seidell JC. and James WPT. (2004). Diet, nutrition and the prevention of excess weight gain and obesity. *Public Health Nutrition* 7 (1A): 123-46.

Tanner JM. (1981). *A history of the study of human growth.* Cambridge Massachusetts: Cambridge University Press.

Tanti N. (2011) Market dictates a greater choice for larger swimwear cup sizes. Australian Swimwear Designer. Personal communication.

Taylor FS. (1949). *Concerning Science*. London: Macdonald and Company.

[TC]$^{2.}$.(2002). A Comparison of body scan measurement reliability and repeatability versus manual measurement with tape measure. Cary NC, USA: Textile Clothing Corporation.

[TC] ^{2}.(2004). Size USA Final report data. Karen Davis [TC]$^{2.}$.Personal communication.

[TC] ^{2}. (2005). Size USA User group meeting. Cary NC, USA: Textile Clothing Corporation. Retrieved 10th May 2010. http://www.techexchange.com/the library/sizeug05.html

[TC]^{2} .(2006). Size USA User group meeting. Cary NC, USA: Textile Clothing Corporation. Retrieved 10th May 2010. http://www.techexchange.com/the library/sizeug06.html

The Council of Textile and Fashion Industries of Australia. (2009). TFIA Response to TCF Review Recommendations. Melbourne, Australia: Textile & Fashion Industries of Australia Limited.

The Guardian. (2008). Are fashion students being stitched up? 18th November 2008.

The Sunday Sun. (1926). Measuring 20,000 women: Is there a definite Australian type? 8th August 1926. Sydney: Newspaper Publisher.

The Woman's Institute. (1924). *Drafting and pattern designing*. Scranton PA. USA: International Educational Publishing Co.

Thorne, AG. And Wolpoff, MH. (1992). The multiregional evolution of humans. *Scientific American* 266:76-83.

Tobias PV. (1985). The negative secular trend. *Journal of Human Evolution* 14: 347-356.

Tobias PV. (1992). New evidence of the absence of a positive secular trend towards increased adult stature in Southern African Negroes. In: Bellwood PS. editor. *Man and his culture –A resurgence.* New Delhi: Books and Books.

Tortora GJ. and Grabowski SR. (1996). *Principles of anatomy and physiology*. New York: Harper Collins.

Treleaven P. and Wells J. (2007). *3D Body scanning and healthcare applications.* London: IEEE Computer Society.

Tucker WB. and Lessa WA. (1940). Man: A constitutional investigation. *The Quarterly Review of Biology* September 15(3): 265-289

Uwaifo GI. and Arioglu E. (2009). Obesity. *eMedicine Endocrinology* Retrieved 01/03/2010 http://emedicine.medscape.cm/article/123702-overview

van Wieringen JC. (1986). Secular growth changes. In: Falkner F. and Tanner JM. editors. *Human growth: A comprehensive treatise*. Vol 3. New York: Plenum Press. Chapter 15.

Vegter F. and Hage JJ. (2000). Clinical anthropometry and canons of the face in historical perspective. *Plastic and Reconstructive Surgery* October 105 (5): 1090-1096.

Veitch D. Veitch L. and Henneberg M. (2007). Sizing for the clothing industry using principal component analysis – an Australian example. *Journal of ASTM International* 4 (3) paper ID: JAI 100824.

Vertinsky P. (2007). Physique as destiny: William H Sheldon, Barbara Honeyman Heath and the struggle for hegemony in the science of somatotyping. *Canadian Bulletin of Medical History* 24: 291-316.

Waterlily. (2010). Consumer choice in swimwear sizing. Noosa Heads, Australia: Waterlily Management. Personal communication.

Waterlily. (2011). Speciality fit cup fittings. Noosa Heads, Australia: Waterlily Management. Personal communication.

Wampen HD. (1853). *Mathematical instruction in constructing models for draping the human figure.* London: Boone Publishers and Booksellers.

Wampen HD. (1864). *Anthropometry or geometry of the human figure.* London: Boone Publishers and Booksellers.

Weekend Designer. (2007). *Pattern drafting by height* posted 15th September 2007. Retrieved 21/03/2010 http://wkdesigner.wordpress.com/2007/09/

Weldon's Ladies Journal. (1921). Australasian Edition. Weldon's Ltd March 1921.
No 500 London: Fashion Publishers.

Wells BWD. (1983). *Body and personality* London: Longman.

Wells JCK. Cole TJ. Bruner D. and Treleaven P. (2007a). Body shape in American and British adults: between-country and inter-ethnic comparisons. *International Journal of Obesity* 1-8 advance online publication. 31 July 2007. doi:10.1038/sj.ijo.0803685.

Wells JCK. Treleaven P. and Cole TJ. (2007b). BMI compared with 3-D dimensional body shape: UK National Sizing Survey. *American Journal Clinical Nutrition* 85: 419-25.

Wilcox RT. (2008). *The Mode in Costume*. New York: Dover Publications Inc.

Winks J. (1997). *Clothing Sizes: International Standardization.* The Textile Institute Manchester. UK: Redwood Books.
Wolanski N. 1978. Secular trend in man: Evidence and factors. *Collegium Anthropologicum* 2: 69-86 [Zagreb, Yugoslavia UDC 577.4:572.5]

Woodford S. (1982). *Greece and Rome.* New York: Cambridge University Press.

World Health Organisation. (2000). *Obesity: preventing and managing the global epidemic.* World Health Organisation Technical Report 894.

World Health Organisation. (2006). *Obesity and Overweight*, World Health Organisation Fact Sheet. No 311 September 2006.

Wyatt, L.T., (2009), *The Industrial Revolution*. Connecticut, USA: Greenwood Press.

Zakim M. (1998). Customizing the industrial revolution: The reinvention of tailoring in the nineteenth century*:* Winterthur Portfolio, 33 (1): 41-58.

Appendix 1

Summary table of differences between Positive and Negative ratings for Garment A and Garment B across 26 Characteristics with Sign test results. Fit goodness refers to what percentage of wearers rated Garment-A or Garment-B as fitting well (1+2 rating)

No	Characteristic	Garment A (1+2)	Garment A (3+4)	Sign test	A sums	Garment B (1+2)	Garment B (3+4)	Sign test	B sums	Garment A fit goodness	Garment B fit goodness	B/A ratio
1	Shoulder	4	6	0.1	10	6	4	0.1	10	40	60	1.5
2	Neck	3	7	0.9	10	9	1	**4.9**	10	30	90	3.0
3	Across chest	7	3	0.9	10	10	0	**8.1**	10	70	100	1.4
4	Centre front length	6	4	0.1	10	6	4	0.1	10	60	60	1.0
5	Side neck to B P	6	4	0.1	10	5	5	0.1	10	60	50	0.8
6	Front armhole	8	2	2.5	10	10	0	**8.1**	10	80	100	1.3
7	Bust separation	8	2	2.5	10	10	0	**8.1**	10	80	100	1.3
8	Front bust	0	10	*8.1*	10	7	3	0.9	10	0	70	
9	Front waist	1	9	*4.9*	10	4	6	0.1	10	10	40	4.0
10	Front upper hip	3	7	0.9	10	6	4	0.1.	10	30	60	2.0
11	Front lower hip	4	6	0.1	10	6	4	0.1	10	40	60	1.5
12	Waist to lower hip	0	10	*8.1*	10	10	0	**8.1**	10	0	100	
13	Back neck	9	1	**4.9**	10	10	0	**8.1**	10	90	100	1.1
14	Across back	1	9	*4.9*	10	8	2	2.5	10	10	80	8.0
15	Back bust	0	10	*8.1*	10	3	7	0.9	10	0	30	
16	Back waist	1	9	*4.9*	10	2	8	2.5	10	10	20	2.0
17	Back upper hip	3	7	0.9	10	4	6	0.1	10	30	40	1.3
18	Back lower hip	3	7	0.9	10	5	5	0.1	10	30	50	1.7
19	Centre back length	5	5	0.1	10	5	5	0.1	10	50	50	1.0
20	Back armhole	9	1	**4.9**	10	10	0	**8.1**	10	90	100	1.1
21	Skirt dart length	7	3	0.9	10	8	2	2.5	10	70	80	1.1
22	Sleeve length	6	4	0.1	10	6	4	0.1	10	60	60	1.0
23	Sleevehead height	10	0	**8.1**	10	10	0	**8.1**	10	100	100	1.0
24	Upper arm	1	9	*4.9*	10	8	2	2.5	10	10	80	8.0
25	Elbow	9	1	**4.9**	10	10	0	**8.1**	10	90	100	1.1
26	Wrist	9	1	**4.9**	10	10	0	**8.1**	10	90	100	1.1
	average(total)									47.3	72.3	
	No. of significantly good characteristics			5				10				
	No. of significantly bad characteristics			7				0 (none)				

Total number of ratings in each rating category for Garment A and Garment B

Ratings	Garment A	Garment B	B/A ratio	Chi-squared
1 = Ideal	77	137	1.78	16.82
2 = Acceptable	45	51	1.13	0.38
3 = Poor	56	52	0.93	0.14
4 = Unacceptable	82	20	0.24	37.69
Total	260	260		Chi-squared = *P*<0.005

Appendix 2

A-Garment Ratings derived from Garment Adjustment Checklist for Subjects (S) 1-10

	Characteristic	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10
1	Shoulder	2	2	4	3	4	3	3	3	1	1
2	Neck	4	3	1	1	3	3	3	1	3	4
3	Across chest	3	3	1	2	2	2	1	2	3	3
4	Centre front length	3	1	3	1	3	2	4	1	1	1
5	Side neck to B P	1	4	2	1	1	1	1	4	4	4
6	Front armhole	1	1	2	2	4	1	1	3	1	1
7	Bust separation	1	1	1	1	1	4	1	1	1	3
8	Front bust	4	4	4	4	4	3	3	4	4	4
9	Front waist	4	3	4	4	4	3	3	3	3	2
10	Front upper hip	2	2	4	4	4	2	3	3	3	4
11	Front lower hip	2	2	4	4	3	1	3	2	4	3
12	Waist to Lower hip	4	4	4	4	4	4	4	4	4	4
13	Back neck	1	1	2	2	4	1	1	1	1	1
1	Across back	3	3	3	4	4	3	3	3	3	1
15	Back bust	4	3	4	4	4	3	3	4	3	3
16	Back waist	4	3	4	4	4	3	4	4	4	2
17	Back upper hip	2	2	4	4	4	2	3	3	3	4
18	Back lower hip	2	1	4	4	4	3	3	2	4	4
19	Centre back length	2	1	2	4	1	4	3	1	3	3
20	Back armhole	2	1	4	2	2	1	1	2	1	1
21	Skirt dart length	2	1	1	1	1	4	1	1	4	3
22	Sleeve length	2	4	2	1	4	4	4	2	2	2
23	Sleevehead height	2	1	2	1	2	1	2	2	2	1
24	Upper arm	3	3	4	4	4	4	4	4	2	4
25	Elbow	1	1	1	4	1	1	1	2	1	1
26	Wrist	1	1	1	4	1	1	1	1	1	1

Appendix 3

B-Garment Ratings derived from Garment Adjustment Checklist for Subjects (S) 1-10

	Characteristic	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10
1	Shoulder	2	2	4	3	1	3	1	3	1	1
2	Neck	1	1	1	1	3	2	1	1	1	1
3	Across chest	2	1	2	1	1	1	1	1	1	1
4	Centre front length	3	1	3	1	2	2	4	3	1	1
5	Side neck to B P	1	1	3	1	1	1	4	4	4	3
6	Front armhole	1	1	2	2	1	2	2	2	1	1
7	Bust separation	1	1	1	1	1	1	1	1	1	1
8	Front bust	1	1	3	3	2	1	1	1	3	1
9	Front waist	1	1	3	3	3	3	1	1	3	3
10	Front upper hip	2	2	2	3	2	2	3	1	3	3
11	Front lower hip	2	2	3	2	2	2	3	1	3	3
12	Waist to Lower hip	1	1	1	1	1	1	1	1	1	1
13	Back neck	1	1	2	2	2	1	1	1	1	1
14	Across back	1	1	2	3	3	1	1	1	1	1
15	Back bust	1	3	3	3	3	1	3	1	3	4
16	Back waist	2	3	4	3	4	3	4	1	4	4
17	Back upper hip	2	2	3	3	3	2	3	1	3	3
18	Back lower hip	2	1	3	1	3	1	3	1	3	3
19	Centre back length	2	1	2	4	1	4	1	4	3	3
20	Back armhole	2	1	2	2	1	1	1	2	1	1
21	Skirt dart length	2	1	1	1	1	1	4	1	4	1
22	Sleeve length	2	4	2	1	4	4	4	2	2	2
23	Sleevehead height	2	1	2	1	2	1	1	2	2	1
24	Upper arm	1	3	1	2	3	1	1	1	1	1
25	Elbow	1	1	1	1	1	1	1	2	1	1
26	Wrist	1	1	1	1	1	1	1	1	1	1

Appendix 4

Photograph of shape variables (ready to wear on left, and made to measure on right) (Veitch et al., 2007) "Reprinted with permission from the *Journal of ASTM International* Vol. 4 (3) copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428"