EVALUATING GARMENT SIZING AND FIT FOR PETITE WOMEN USING 3D BODY SCANNED ANTHROPOMETRIC DATA

by

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DEDICATION

To my late father, Dr Ramosedi Lucas Phasha, you always believed in me and taught me the importance of education.

Dad, I made it!

Ke lebogile go menagane Hlabirwa a' Dimo (Thank you).

You were the wind beneath my wings. Your legacy lives on!

DECLARATION

Name: Masejeng Marion Phasha

Student number: 54178924

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I declare that

"Evaluating garment sizing and fit for petite women using 3D body scanned anthropometric data"

is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE

November 2017

DATE

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CERTIFICATE FOR ENGLISH LANGUAGE EDITING

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I have corrected the language and I am of opinion that this document is suitable for submission.

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SUMMARY

Research suggests that there is a plethora of information on the size and shape of the average and plus sized women in South Africa (Winks, 1990; Pandarum, 2009; Muthambi, 2012; Afolayan & Mastamet-Mason, 2013 and Makhanya, 2015). However, there is very little information on petite women's body shapes, their body measurements and their shopping behaviour, especially in South Africa, for manufacturing ready-to-wear garments.

The purpose of this petite women study was to investigate the shapes and sizes of a sample of petite South African women and develop size charts for the upper and lower body dimensions.

This study used a mixed-method; purposive, non-probability sampling method to achieve the objectives of the study. A (TC)² NX16 3D full body scanner and an Adam's® medical scale were used to collect the body measurement data of 200 petite South African women, aged between 20-54 years with an average height range of 157cm, residing in Gauteng (Pretoria and Johannesburg). Other data collection instruments included a demographic questionnaire to collect the subjects' demographic information such as, age, height, weight, etc.; and the psychographic questionnaire to gather the petite subjects' demographics as well as their perceptions and preferences on currently available ready-to-wear shirt and trouser garments.

Of the 200 subjects that were initially recruited, based on the petite women's body height that ranged from 5' 4" (163 cm) and below, the most prevalent body shape profile that emerged from the dataset, was the pear body shape which was evident in 180 of the 3D full body scanned petite women subjects. Therefore, the anthropometric data for these 180 subjects was used in the development of the experimental upper and lower body dimensions size charts and as the basis for the fit test garments developed in this study. The collected data was analysed and interpreted in Microsoft Excel and the IBM SPSS Statistics 24 (2016) software package, using principal component analysis (PCA) to produce the experimental size charts for the upper and lower body dimensions necessary for creating prototype shirt and trouser garments. Regression analysis was used to establish the primary and secondary body dimensions for the development of the size charts and for determining the size ranges. The experimental upper and lower body dimensions size charts were developed for sizes ranging from size 6/30 to size 26/50. Subsequently, the accuracy of the size charts developed in this study was evaluated by a panel of experts who analysed the fit of the prototype shirt and trouser garments, manufactured using measurements for a size 10/34 size range from the size chart, on a sample of the petite subjects. The fit of these garments was also compared with the fit of garments manufactured using the 3D full body scanned measurements of a size 10/34 petite tailoring mannequin, that is currently commercially available for use in the production of garments for petite women in South Africa.

The shirt and trouser prototype garments developed using the size 10/34 upper and lower body dimensions size chart measurements had, overall, a better quality of fit than the garments made to fit the current, commercially available, size 10/34 mannequin. These findings thereby confirmed that the data extracted from the (TC)^2 NX16 3D full body scanner and the size charts subsequently developed using the data, has the potential to provide better/improved fit in garments for petite South African women than data hitherto published.

From the evidence of this study, it is recommended that the South African garment manufacturing industry needs to revise the current sizing system for petite women to accommodate the body dimensions and shape variations that currently prevail amongst consumers. The South African garment manufacturers and retailers also need to familiarise themselves with the needs, challenges and preferences of the petite consumers' target market that purchase ready-to-wear shirt and trouser garments in South Africa.

Keywords: Petite women, 3D body scanner, pear body shape, garment sizing and fit, principal component analysis, body dimensions, size charts, shirt garments, trouser garments, fit test evaluations.

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CHAPTER 1

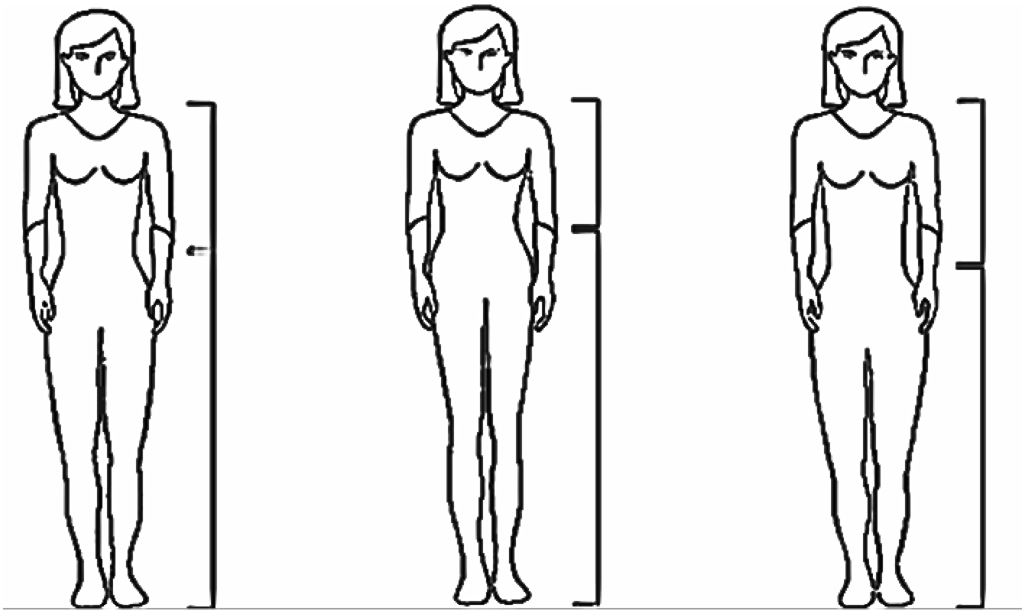
OVERVIEW OF THE STUDY

1.1 INTRODUCTION AND BACKGROUND TO THE STUDY

The first known and recorded study on petite women's garment sizing, according to Kim *et al.* (2016:48-49) was published in the United States in "*Women's Measurements for Garment production and Pattern Construction*", a publication by O'Brien and Shelton in 1941. The authors divided the women's body measurements into three categories, namely: short, regular and tall; however, the United States' "*Women's Measurements for Garment production and Pattern Construction*" apparel government publications used the word "*short*" to classify petite measurements, at that time. In 1971, the National Bureau of Standards published the PS 42-70 standard that defined a petite woman as being shorter than the average woman, but having similar girth and width measurements as that of average women. Thereafter, in 1995, the American Society for Testing and Materials (ASTM) international issued ASTM D5585 Standard Table of Body Measurements for "*Adult Female Misses Figure Type*", replacing the National Bureau of Standards. Subsequently, in 2013, the ASTM International standard developed the currently used ASTM D7878 sizing standard for Misses petite women.

A petite woman has been defined differently by various authors and researchers. In South Africa, Defty (1988:16), Winks (1990:74), and Bailey (2010:3) defined a petite woman as women who are short in body stature resulting in shorter body length measurements. Crenna's (1990) study defines a petite woman by their body weight coupled with a short height. Boston's (1992) study suggests that the division of body dimensions from the bust to the waist and the waist to the hip can be used as a guideline to differentiate petite women from the average woman, whom Chun (2014:275) classifies as a regular sized woman with a body frame that is neither tall or short, nor large or thin. Furthermore, Bello's (1994) study included narrow shoulders and a reduced waistline to crotch length to define petite women.

An article in Alterations Needed (2010) states that petite body proportions may vary, being either evenly proportioned to having a long torso and short legs or a short torso and long legs (see the different female body proportions in Figure 1.1).



Long torso/ Short legs   Short torso/ long legs   Evenly proportioned

Figure 1.1: Figures of different female body proportions from Alterations Needed (2010).

However, Defty (1988:16), Winks (1990:74), Boston (1992), Rayner (1997:1), Yoo *et al.* (1999:220), Barona-McRoberts (2005:10), Townsel (2005:1), Petite Resource (2007), Williams (2007), Bailey (2010:1), Kgarza (2013), Simplicity (2013), Lee (2014), and Taylor (2014) suggest that petite women's garments are manufactured principally with an emphasis on the body height measurements, which are from 5'4" (163 cm) and below. Knowles' (2005:35, 37, 40) study classified two types of petite women, the junior petite woman, having a typical height measurement of 5'1" (156 cm), and the misses' petite woman, having a maximum height measurement of 5'2" (158 cm). The junior petite women have a small body frame, a short torso and short sleeves; whilst the misses' petite women are said to be shorter than the average women who have a more matured body frame. Nonetheless, Kim's (1993) study supports the studies mentioned above, and argue that petite woman requires their own sizing categories for ready-to-wear garments, as petite women are differently proportioned in comparison to the average woman.

This is endorsed by Rasband and Liechty's (2006:24) study who maintain that body proportions must also be used, together with body height measurements to distinguish petite women from the average women.

To date, Defty (1988) who published a size chart for short (petite) women for patternmaking purposes; Winks (1990), and Bailey (2010) are the only known South African studies to have reported on petite women. These studies collected body measurements manually, by tape-measure, for women whose body heights ranged from 156 cm to 161 cm (Defty, 1988: 16-18), 156 cm to 163 cm with a mean of 160 cm, (Winks, 1990:74-76) and 160 cm and below (Bailey, 2010:3), respectively. Consequently, this study used body height as the principle recruitment criteria for the petite women subjects for this study.

Bye *et al.* (2006:66) suggest that ready-to-wear garments are mostly manufactured using the apparel industry's standard-sized body measurements and the most common size category for the average consumer. Bye *et al.* (2006:66) further mention that the industry standards vary per country and are defined according to an ideal body shape that appears to be balanced in upper and lower body proportions. However, Strydom and De Klerk (2006:81), Pisut and Connell (2007:370), and Petrova and Ashdown (2008:320) state that a single garment of a specific size is unlikely to have the same level of fit on two different individuals because of their varied body shapes and proportions, as most women do not conform to an ideal body shape (Rasband & Liechty, 2006:23; Keiser & Garner, 2008:352).

Ready-to-wear garments are defined as garments that are mass-produced in predetermined body size measurements with the purpose of being sold in stores (Zakaria & Gupta, 2014:3). Most customers today primarily purchase mass-produced ready-to-wear garments and these garments are mainly sized according to the retailer's or manufacturer's apparel sizing systems, based on their target markets (Bye *et al*., 2006:66; Chun, 2007:220-221; Petrova, 2007:64). Therefore, to improve the quality of ready-to-wear garment fit for different individuals, body measurements together with body proportions/dimensions, i.e. body shapes should be considered when developing garment-sizing systems (Strydom & De Klerk, 2006:81).

1.2 PROBLEM STATEMENT

The aforementioned dearth of relevant information for petite women's body sizes and the confusion that currently exists in the apparel industry as to the definition of a petite woman prompted this study.

Anecdotal experience by the author is that South African petite women experience significant garment fit issues. This is endorsed, to some extent, by previous studies conducted by South African researchers, such as Bailey (2010:6) who stated that most petite women often purchase their ready-to-wear garments in the children's department, whilst others find that they have to alter the ready-to-wear garments to achieve a better fit. Barona-McRoberts (2005:21) and Apeagyei (2008:4) further state that vanity sizing promoted by garment manufacturers who place a smaller size label on a garment with larger measurements to satisfy, but ultimately confuse customers, has also contributed immensely to garment fit problems that consumers are faced with today. Hence, the purpose of this study was to gain some insight into the garment fit issues experienced by South African petite women to determine to what extent sizing and fit is a problem.

1.3 RESEARCH QUESTIONS AND OBJECTIVES

This study aimed to address the following:

1.3.1. To what extent are South African petite women satisfied with the sizing and fit of ready-to-wear of shirt and trouser garments currently offered in retail stores in South Africa?

1.3.2. How relevant are the size charts previously established by Defty (1988:17-18), Winks (1990:74-76), and Bailey (2010:23) for the manufacturing of garments for petite South African women?

1.3.3. How does the fit of garments generated from the size charts produced from 3D full body scanned data of South African petite women compare with the fit from the scanned data for a petite tailoring mannequin currently used commercially in the manufacturing of garments for petite South African women?

To answer these questions, the following objectives were formulated:

- **Objective 1:** To perform 3D full body scans of 200 petite women subjects residing in Gauteng (Pretoria and Johannesburg), South Africa, and analyse their body measurements and body shapes from the generated data.
- **Objective 2:** To develop experimental upper and lower body dimension size charts from the 3D full body scanned subjects' measurements for the most prevalent body shape of the subjects arising in this study.
- **Objective 3:** To compare the collected 3D full body scanned subjects' upper and lower body dimensions size chart measurements derived from this study with previously published size charts for petite women by Defty (1988:17-18), Winks (1990:74-76), and Bailey (2010:23), and the 3D full body scanned petite tailoring mannequin's measurements.
- **Objective 4:** To investigate the petite women subjects' perceptions of their body shapes and proportions, together with their shirt (upper body) and trouser (lower body) garment fit evaluations and purchasing behaviour. This was done to evaluate the satisfaction with, and challenges faced by the petite consumers when purchasing currently available ready-to-wear shirt and trouser garments.
- **Objective 5:** To assess the accuracy of the measurements in the experimental upper and lower body size charts developed for this study compared with the mannequin's measurements, and thereby determining which of the two sets of measurements provided better fitting garments. This was done by evaluating the fit of prototype shirt and trouser garments manufactured from basic pattern blocks using the 3D full body scanned petite women subjects' data from the developed experimental size charts and the 3D full body scanned mannequin measurements.

1.4 SIGNIFICANCE OF THE STUDY

The information gathered from the study is intended to be published and made available for the South African apparel industry to improve the fit of South African petite women's ready-to-wear garments. Within the scope and size of the study, it is also anticipated that the outcomes of the study will make the South African apparel industry aware of the sizing and fit concerns that South African petite women are experiencing to date.

1.5 RESEARCH DESIGN AND METHODOLOGY

This study used a mixed-method, purposive sampling, non-probability sampling method to achieve the objectives of the study (Maree, 2007:76). The use of mixed-method research in a study, according to Maree (2007:262) improves the significance of a study and strengthens legitimacy in the objectives of the study. The above-mentioned sampling methods are further explained in section 3.2.

Taking into consideration the literature background and the objectives of the study discussed in the afore-mentioned sections, the following conceptual framework for this study, adapted from Ashdown (2007: xix) is presented in Figure 1.2. This will serve as a proposed structure that will guide the perceptual study on garment sizing and fit for petite female consumers in South Africa. The conceptual framework highlights the most important concepts of the study and it also displays how each concept may ultimately be related to or has an influence on one another. Furthermore, the conceptual framework permits that all aspects that the study proposes to generate are considered and emphasised when concluding the findings and suggesting recommendations at the end of the study.

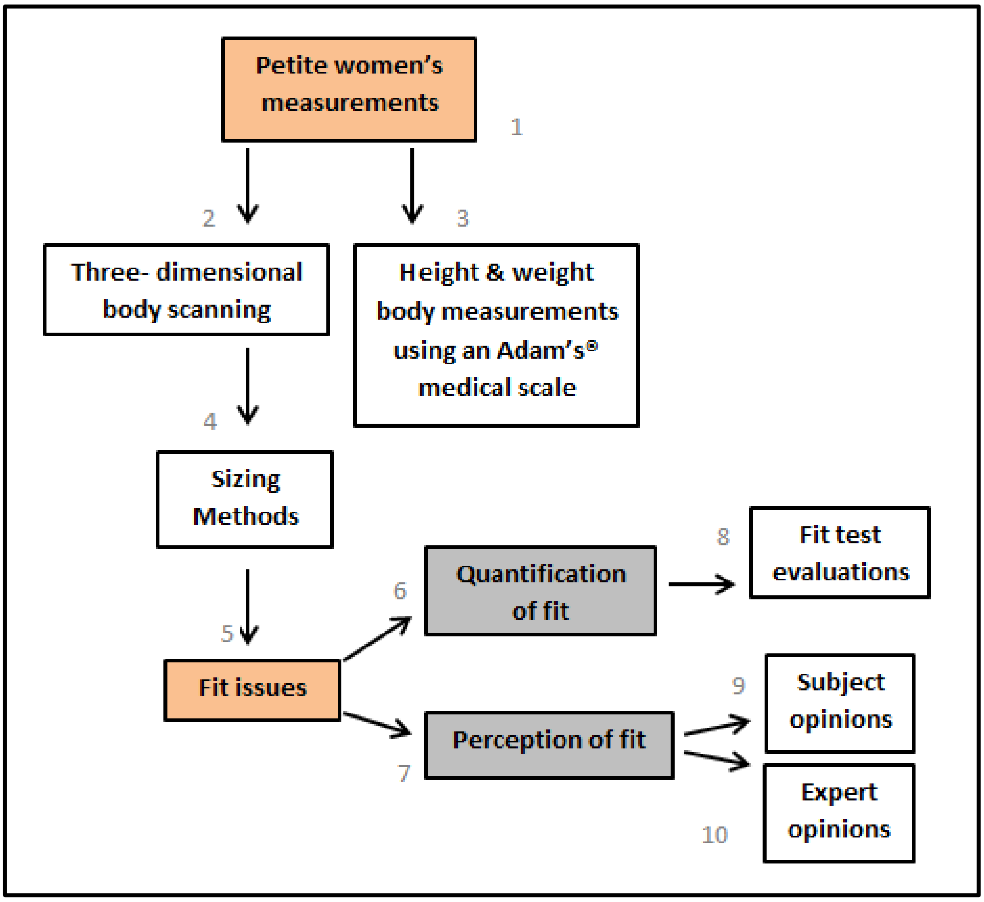


Figure 1.2: An adapted conceptual framework showing the relationship between the parameters used to determine sizing methods and to evaluate garment fit for this study.

The conceptual framework devised for this study adapted the population measures from Ashdown's study as the petite women's measurements and focused on fit issues. The numbers as indicated in Figure 1.2 are used below to explain the flow of the conceptual framework for this study.

The above conceptual framework suggests the collection of the petite women's body measurements (**1**) as a starting point for accurate and up-to-date garment sizing and fit. Since female body shapes and body proportions differ and may have an influence on their body measurements this is a critical step. Hereby, challenging garment manufacturers and designers when developing patterns and creating well-fitting garments to fit various body shape profiles existing in a population. A $(TC)^2$ NX16 3D full body scanner (**2**) and an Adam's® medical scale (**3**) was used to collect the anthropometric data for the 200 petite women subjects sampled in this study.

The 3D full body scanner have the advantage of detecting different body shapes from the scanned data (Apeagyei, 2010:58; Connell *et al.*, 2006:81). Data collected using 3D full body scanners is collected in a short period of time, reliable, more accurate, repeatable and non-intrusive (Yu, 2004:164; Pandarum & Yu, 2015:187). 3D full body scanners can also measure body landmarks, such as the crotch area (Pandarum, 2009:4; Kouchi, 2014:67). The data collection process included the procedure as defined in ISO 20685 (2010) for reducing errors in 3D scanning to ensure comparability of body measurements. The Adam's® medical scale was used to collect the height and weight measurements since they could not be extracted by the 3D full body scanner.

The 3D scanned subjects' body shapes were classified using the scanner manufacturer's proprietary body shape identification software. Thereafter, every subject's body shape was visually reviewed (using the 3D-point cloud surface images generated from the subject's 3D full body scans) by a panel of clothing/fashion experts to verify the body shape classification identified by the $(TC)^2$ NX16 3D full body scanner software. The IBM SPSS Statistics 24, (2016) software package and Microsoft Excel were used to analyse and interpret the data collected in this study.

Experimental upper and lower body dimensions size charts were developed from the 3D full body scanned measurements of the 180 pear shaped petite subjects, as identified by the scanner shape software and verified by the panel's visual assessment. The measurements were thereafter compared to the manual tape-measurement data derived from Defty's (1988:17-18), Winks' (1990:74-76), and Bailey's (2010:23) size charts for South African petite women. This was further compared with the data collected from a 3D full body scan of a size 10/34 petite tailoring mannequin developed by a well-known mannequin company in South Africa. The mannequin was produced for a large-scale retailer, from data supplied by the retailer gathered from their target market in 2003, which is still in use today (Millam, 2016).

The decision to use the petite tailoring mannequins' measurements was because these are the only currently acceptable "*true values*" measurements since there are no other petite 3D scanned anthropometric data measurements in South Africa with which to compare the 3D full body scanned data of the subjects collected during this study. Subsequently, prototype shirt and trouser garment pattern blocks were developed from both the 3D full body scans of the 180 pear shaped petite subjects' measurements and the scanned mannequin data. These were used to manufacture prototype shirt and trouser garments.

Most garment manufacturers in developing countries, including South Africa, do not adhere to standardised sizing methods (**4**) when manufacturing their garments. This promotes fit issues (**5**), due to varying sizes among the manufacturers or within the same manufacturer (Loker *et al*., 2005:2; Pisut & Connell, 2007:368; Mgwali, 2014). This results in consumers being dissatisfied. Irrespective of the above-mentioned factors, this study explored two influences of fit to minimise garment sizing and fit problems for petite women in South Africa, namely, the quantification of fit (**6**) and the perception of fit (**7**). The quantification of fit were calculations of the subjects' 3D full body scanned measurements and that of using the Adam's® medical scale measurements, to develop the upper and lower body size charts. Thereafter measurements were established for a garment size range to use for constructing the prototype shirt and trouser garments as proposed in this study for fit test (**8**) evaluations. The perception of fit (in this petite study) included the subject's opinions (**9**) and expert opinions (**10**). The subjects' opinions consisted of the subjects' perceptions, experiences and challenges with their ready-to-wear shirt and trouser garments currently available in retail stores.

A demographic and psychographic questionnaire in the form of open ended and closed questions, Likert and semantic differential scales were used to collect the data from the psychographic questionnaire. Included also was a photographic question on the subjects' self-perceived body shapes adapted from Liddelow (2016). As the study seeks to explore the petite female challenges and experiences with ready-to-wear shirt and trouser garments currently offered in retail stores for South African petite consumers.

The conceptual framework further suggests that another important evaluative dimension relevant to this study is the expert opinion on garment sizing and fit. The expert opinions included analysis and classifications of the subjects' body shapes, along with the evaluations of the fit of the prototype garments produced from this study, only for the 10/34 size range.

Human fit models or dress form tailoring mannequins are used by the fashion industry to establish the fit and drape of a given garment style on the body, based on an industry established base size as determined by their target markets (Alexander *et al*., 2005:56; Bougourd, 2007:130-131; Kadolph, 2008:91; Song *et al*., 2010:264; Joseph-Armstrong, 2014:35,38). This study used both the live human fit model (the selected subjects) and a petite mannequin to test the quality of fit of the prototype shirt and trouser garments manufactured in this study. The quality of the garment fit of the prototype shirt and trouser garments on a sample of petite women subjects was analysed and evaluated by a panel of clothing lecturers within the Department of Life and Consumer Sciences at UNISA, to determine the accuracy and limitations of the experimental size charts and the mannequins' measurements. The fitting standards for evaluating the fit of the prototype garments, from this study, was adapted from studies by Stamper *et al.* (2005), Liechty *et al.* (2010:54) and Marshall *et al.* (2012).

Furthermore, the conceptual framework proposes that the petite female consumers who experience fit problems in their shirt and trouser garments contributed by their body measurements, shapes and proportions may influence garment sizing and can be a factor in providing garment manufacturers and retailers with practical solutions to improve garment fit for petite female consumers in South Africa. Consequently, the development of the size charts for the upper and lower body dimensions when applying the concepts (1-6) from the conceptual framework shows that the concepts will ultimately promote and serve to understand petite women's measurements and sizing systems. The concepts (7-10) will promote a better understanding of the consumer's challenges and experiences with shirt and trouser garment sizing and fit. This further provides information and contribution to female petite garment manufacturers and retailers in South Africa.

The data collected in this study is intended for use by the apparel retail and manufacturing sectors, in the hope of minimising dissatisfaction among the petite consumers in South Africa who still have challenges in finding a satisfactory fit in ready-to-wear shirt and trouser garments.

1.6 DEFINITIONS

Anthropometric measurements/data: A collection of varying human body measurements, proportions, size and weight, grouping them in a range of sizes (Bougourd, 2007:19; Gupta, 2014:38; Zakaria, 2014:95).

Basic garment: A simple designed garment with few pattern pieces usually used for evaluating garment fit (Liechty *et al.,* 2010:9-10).

Body dimension size chart: A table of upper and lower body dimension's data, consisting of 3D scanned body measurements established for a range of garment sizes.

Body proportions: The length of body sections based on how they relate to each other e.g.: an individual can have a short torso and long legs or a long torso and short legs or an evenly proportioned body (Palmer & Alto, 2005:58; *Alterations Needed*, 2010).

Body shape: A distribution of muscle and fat formed around a human's body structure (Rasband & Liechty, 2006:19).

Garment drape: The effect of how a fabric hangs or falls on a human body, controlled by the fabric's weight and the body silhouette (Liechty *et al.,* 2010:31).

Garment fit: The relationship between the size of a body silhouette and the size of a garment (Chen, 2007:132).

Garment sizing: A range of categorised dimensions used to classify manufactured garments (Petrova, 2007:61).

Ideal body shape: A description of a balanced, well-proportioned body (Bye *et al.,* 2006:66; Zwane & Magagula, 2007:283; Mastamet-Mason, 2008:58; Liechty *et al.,* 2010: 82).

Pattern: A template draft of garment pieces constructed on a paperboard or cardboard that can be traced onto a fabric, cut out and assembled (Liechty *et al.,* 2010:11-12; Aldrich, 2015:13).

Petite: A small framed woman with a less than average height (Bello, 1994 and Trulypetite, 2007). Petite is based on height, not the weight of a person (Williams-Dahlman & Shelton, 2004:2).

Size labels: Labels placed on garments, providing information on body measurements for body sizes that the particular garment is designed to fit (Kinley, 2010:401).

Sizing standards: Documents published and developed by authority within an agreement of principles of an organisation (La Bat, 2007:88).

Sizing system: A principle used for establishing size ranges for clothing sizing requirements in a population (Petrova, 2007:57).

Three-Dimensional (3D) body scanner: Scanning device, using different light methods to scan a subject and different systems to extract the scanned data (Connell *et al.,* 2006:81; Petrova & Ashdown, 2008:227; Pandarum, 2009:8,11; Apeagyei, 2010:60; Ka Wai YIP, 2013:13-14).

Vanity sizing: A marketing tool used by manufacturers to sell their garments by placing a smaller size label on a garment with larger measurements to satisfy consumers who want to feel slim (Alexander *et al.,* 2005:56; Pisut & Connell, 2007:368; Apeagyei, 2008:4).

1.7 ACRONYMS

ASTM: American Society for Testing and Materials

BMI: Body mass index

CAESAR: The Civilian American and European Surface Anthropometry Research

ISO: International Organisation for Standardisation

SABS: South African Bureau of Standards

SANS: South African National Standards

NPD: National Purchase Diary

$(TC)^2$: Textile/Clothing Technology Corporation

UNISA: University of South Africa

USA: United States of America

1.8 OUTLINE OF THE DISSERTATION

Chapter 1: Introduction

The introductory chapter presents a brief overview of the study by presenting the background, the motivation, and reasoning behind petite women's garment sizing and fit, the objectives of the study, the methodology, definition of terms and acronyms used in this study.

Chapter 2: Literature review

Chapter 2 presents the relevant literature relating to the study's purpose by reviewing literature relating to previous studies of petite women's body height, shapes and dimensions, anthropometric measurements, garment fit, fitting models, garment sizing systems, ready-to-wear garments and garment styles used in this study. A review of contemporary literature on 3D full body scanners and garment patterns is also presented in Chapter 2.

Chapter 3: Research Methodology

Chapter 3 describes the methodology used in the study. Detailed research methods, sampling and data measurement instruments are provided, and broad explanations are given on how the data was collected and analysed. Measures employed to enhance the quality of the data, in terms of its validity, reliability and ethical considerations are also discussed.

Chapter 4: Data analysis and interpretation

Chapter 4 initially describes the classification of the 3D body shapes of the petite women in this study to determine the predominant body shape. It then presents the data analysis, interpretation and the different steps used to create the experimental upper and lower body dimensions size charts, using the analysed body measurement data for 180 of the subjects with pear body shape profiles, from their 3D full body scans.

This chapter also compares the 3D full body scanned subject's upper and lower body size chart measurements derived from this study with those previously published in size charts for petite women by Defty (1988:17-18), Winks (1990:74-76), and Bailey (2010:23), and the 3D scanned petite tailoring mannequin's measurements. Furthermore, the subject's self-perceptions of their body shapes and body proportions, together with their shopping and purchasing behaviour regarding their shirt and trouser garments extracted from the psychographic questionnaire were analysed and interpreted in this chapter.

Chapter 5: Developing the basic pattern blocks, constructing the garments and the selected subject's fit test evaluations

Chapter 5 describes how the size 10/34 size range obtained from the developed experimental upper and lower body dimensions size charts and the measurements of the size 10/34 3D full body scanned mannequin was used to manually draft basic shirt and trouser pattern blocks.

Furthermore, this chapter describes how the prototype garments were produced from the drafted shirt and trouser pattern blocks. The quality of the fit attained from the garments produced was evaluated and are presented in the latter part of this chapter.

Chapter 6: Conclusion, implications, limitations and recommendations for further research

Chapter 6 summarises the results obtained from the study and presents conclusions in relation to the research questions posed and objectives set. In addition, the implication of the findings, the limitations, and shortcomings of the study are discussed and recommendations for further research are proposed.

The referencing techniques used in this study follow the Harvard method adopted by the Department of Consumer Science at the University of South Africa (UNISA). British English is used throughout this dissertation. For further references, appendices are provided.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Barona-McRoberts (2005:28) state that petite women have different body dimensions from the average women and that manufacturers rarely consider their body dimensions when manufacturing petite garments. This results in petite women having difficulties in finding garments that fit properly in relation to their diverse body dimensions. The South African apparel industry has a well-established sector consisting of highly competitive garment retailers and manufacturers, as well as formal and informal traders that supply to diverse consumers in different ethnic groups (Kahn, 2008:1). Despite this vibrancy, there is still a lack of knowledge on realistic South African female body shapes and sizes (Kasambala 2013:42). According to Bailey (2010:9) the South African apparel industry has paid little attention to petite women's clothing. An article in a national newspaper by Kahn (2008), Kasambala *et al.* (2015:98), and Pandarum and Yu (2015:192) highlight the fact that there has never been an extensive body shape and sizing study conducted on the South African population to date. The SABS has not published a ready-to-wear apparel sizing standard for South African women (Muthambi, 2012:18). As a result, the South African garment manufacturers and retailers rely on garment sizing charts that are out-dated when designing and manufacturing ready-to-wear garments for South African consumers (Strydom, 2006:217; Zwane & Magagula, 2007:283; Kahn, 2008; Ola-Afolayan & Mastamet-Mason, 2013:202-203; Mbandazayo *et al.,* 2014; Pandarum & Yu, 2015:192).

In South Africa, the only known studies conducted for petite women are those of Defty (1988:17-18), Winks (1990:74-76), and Bailey (2010:23), all of which used manually, dress-makers tape measured, anthropometric data. Defty (1988:17-18) used the measurements of women without shoes, based on their width and the body height measurement of 153 cm to develop a size chart for "*short*"/petite women. Winks' (1990:74-76) study identified body size distribution measurements of three female ethnic groups, whites, blacks and coloureds and defined a mean body height measurement of 160 cm for petite women. Bailey's (2010:22) study, which is the most recent, collected data from 60 students from the Cape Peninsula University of Technology and the University of Cape Town, to evaluate their clothing perceptions and confidence in women's clothing. The findings from Bailey's study revealed that all the subjects in the study were unhappy with the ready-to-wear petite women's garments sold in retail stores and that they felt that they were not adequately accommodated in terms of well-fitting garments.

The next sections begin by defining petite women and conceptualising garment, body dimensions and body shapes, together with factors that influence garment sizing and fit for petite women.

2.2 DEFENITION OF A PETITE WOMAN

Petite women have been classified by various international and national researchers, (Winks, 1990:74-76; Boston, 1992; Rayner, 1997:1; Defty,1988:16-18; Yoo *et al.,* 1999:220; Knowles, 2005:35,37,40; Townsel, 2005:1; Barona-McRoberts, 2005:10; Petite Resource, 2007; Williams, 2007; Bailey, 2010:1; Kgarza, 2013; Simplicity, 2013; Lee, 2014; Taylor, 2014) by their body height, measuring from 5' 4" (163 cm) and below with proportionally smaller body dimensions (Crenna, 1990; Rayner, 1997:1).

Kim *et al.* (2016:49,52) compared the 2013, ASTM standard D7878 for the Misses petite women, with the ASTM D5585, a sizing standard developed in 1995 for the adult female Misses average, regular sized women. The average women's data consisted of a height measurement taller than 5' 4" (163 cm) to 5' 8" (173 cm). This comparison noted that petite women can be identified as having a body stature that is 3 inches shorter, a back-waist length that is ¾ inches shorter, a 2 inches shorter leg length and an arm length that is 17/8 inches shorter than regular sized women. Kim *et al.* (2016:49) further defined petite women's circumferences by a waist girth that was smaller by ½ an inch and a shoulder width that was ½ an inch smaller than the average women's sizes, whilst the balance of the girth and length measurements remained the same as those in the two standards.

2.3 WOMEN'S BODY DIMENSIONS AND SHAPES

2.3.1 Classification of women's body shapes and body dimensions, inclusive of the petite women

According to Schofield *et al.* (2006:148) an individual's body shape changes with age and varies (Paquet, 2014:125) by country (Nkambule, 2010:22) which may also affect the fit of garments. Nutritional diet, lifestyle and body weight are among the factors that have an influence on an individual's body shape (Howarton & Lee, 2010:220). Garment manufacturers usually use an ideal body shape as a base-pattern size for manufacturing ready-to-wear garments (Loker *et al.,* 2005:1). The ideal body is defined as having an evenly balanced upper and lower torso, a slightly narrow waist, average bust and buttocks curves that balance each other, a flat abdomen, together with lean arms and legs (Bye *et al.,* 2006:66; Zwane & Magagula, 2007:283; Mastamet-Mason, 2008:58; Liechty *et al.,* 2010: 82). Rasband and Liechty (2006:23) stated that only a limited number of people can be classified as having an ideal body shape.

According to Park *et al.* (2009:374), most female consumers that do not have a body shape that is particular to an apparel retailer's target market, might experience problems with the fit of garments sold in retail stores. The apparel industry is said to have predetermined standard garment sizing systems to manufacture ready-to-wear garments, using the most common size category, for their target markets. Furthermore, Vuruskan and Bulgun's (2011:46) study found that two individuals with the same body measurements would experience different levels of garment fit because their individual body shapes and dimensions may vary. Therefore, identifying and classifying the most commonly represented body shapes in a population is beneficial for garment manufacturers, as this will provide guidelines on how to manufacture better fitting garments for many consumers in the different garment size categories (Vuruskan & Bulgun, 2011:46-47). Vuruskan and Bulgun (2011:46-47) and Pandarum and Yu (2015:192) suggest that geometrical figures and terminologies are often used to indicate an individual's body shape. For example, the triangular, inverted triangular, rectangle, oval, hourglass, bottom hourglass, top hourglass, spoon and diamond which may also be represented by the letters (A, V, H, O, X) or fruits (such as pear and apple). These figure terminologies could affect garment fit if the consumer does not understand what they mean since they are usually used as information communicated to represent various body shapes.

Female body shapes vary greatly when compared to men and are expressed in various types and proportions (Bougourd, 2007:120; Rasband & Liechty, 2006:19); which, until the 1980s, were studied and categorised using traditional anthropometry and then, subsequently, using 3D full body scanners. According to Apeagyei (2010:58) and Connell *et al.* (2006:81), the advantage of collecting data using a 3D full body scanner is that it can detect the different body shapes from the scanned data. However, prior to 3D full body scanners, for body shape classification, female body shapes were identified and categorised through visual observations of the front and side view of photographic images of the body and by drop values. Drop values are the relationship between fundamental body parts; such as the bust, waist and hips, which were used to differentiate body shapes (Petrova & Ashdown, 2008:230; Bougourd, 2007:120; Chen, 2007:8). Various researchers including Rasband and Liechty (2006) and Liddelow (2011) have used rating scales in their studies from photographs and images.

However, Simmons *et al.* (2004a,b), and Connell *et al.* (2006) used a 3D body scanner to classify the commonly known body shapes and defined variations in figure types from 3D scan data. The researchers found that most of the women's physical features did not conform to the description of an ideal body shape. Simmons *et al.'s* (2004a) Female Figure Identification Technique (FFIT©) for Apparel study suggest that aside from the "ideal" body shape, there are nine different body shapes viz. the hourglass, bottom hourglass, top hourglass, rectangle, oval, diamond, triangular, spoon and inverted triangular (see Figure 2.1). Simmons *et al.* (2004b) developed the Female Figure Identification Technique (FFIT©) for Apparel software to analyse 3D body scanned data and identified the nine different shapes from a convenience sample of 253 women based on their body measurements, relative body proportions and the different shapes occurring within the scanned data. The body measurements for shape identification in Simmons *et al.'s* (2004b) research were the bust, waist, hips, high hips, abdomen and stomach circumferences to analyse ratios and differences of the body measurements.

Limits in the above-mentioned body circumferences were defined to categorise different body shapes.

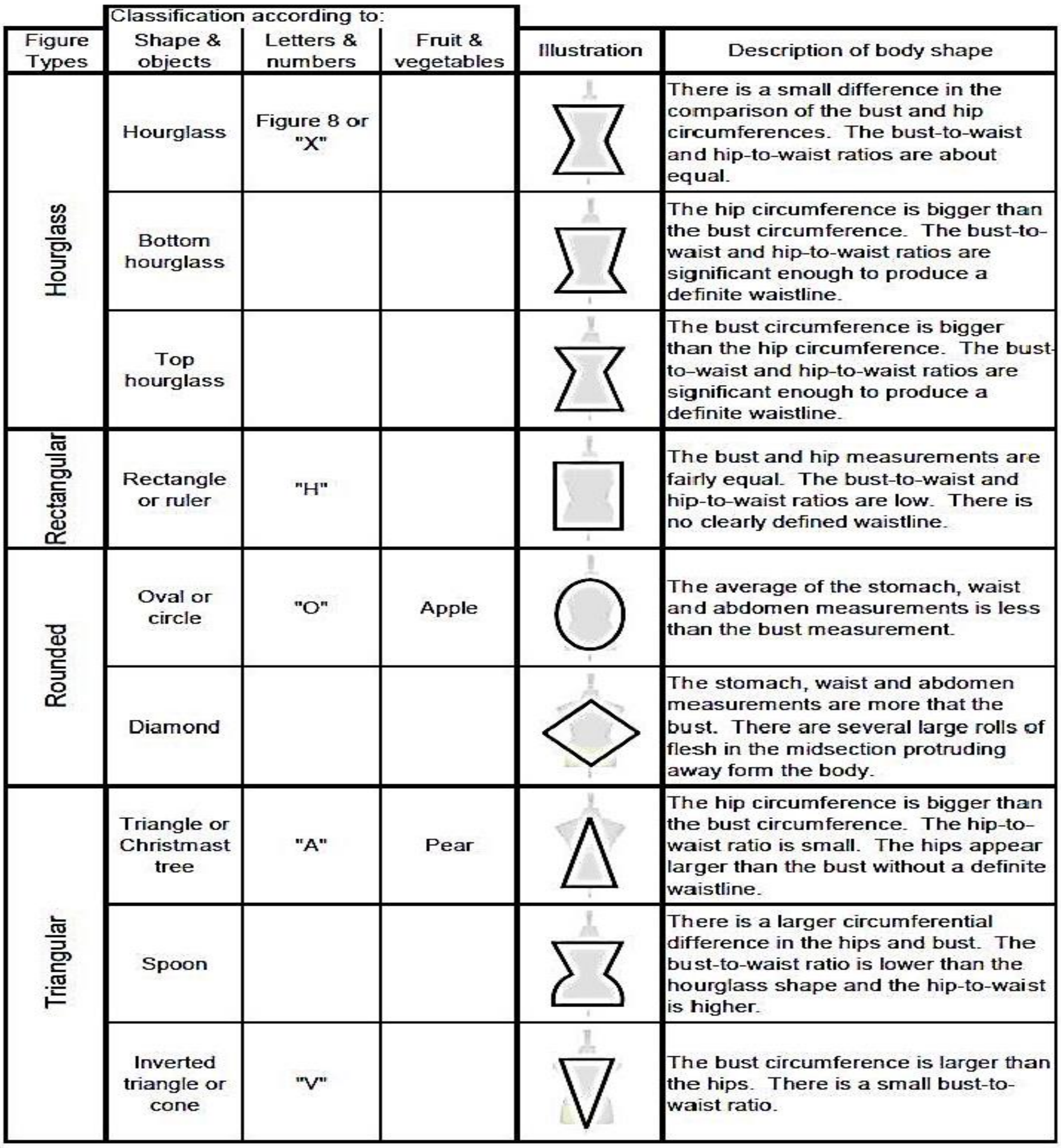


Figure Types	Classification according to:			Illustration	Description of body shape
	Shape & objects	Letters & numbers	Fruit & vegetables		
Hourglass	Hourglass	Figure 8 or "X"			There is a small difference in the comparison of the bust and hip circumferences. The bust-to-waist and hip-to-waist ratios are about equal.
	Bottom hourglass				The hip circumference is bigger than the bust circumference. The bust-to-waist and hip-to-waist ratios are significant enough to produce a definite waistline.
	Top hourglass				The bust circumference is bigger than the hip circumference. The bust-to-waist and hip-to-waist ratios are significant enough to produce a definite waistline.
Rectangular	Rectangle or ruler	"H"			The bust and hip measurements are fairly equal. The bust-to-waist and hip-to-waist ratios are low. There is no clearly defined waistline.
Rounded	Oval or circle	"O"	Apple		The average of the stomach, waist and abdomen measurements is less than the bust measurement.
	Diamond				The stomach, waist and abdomen measurements are more that the bust. There are several large rolls of flesh in the midsection protruding away form the body.
Triangular	Triangle or Christmast tree	"A"	Pear		The hip circumference is bigger than the bust circumference. The hip-to-waist ratio is small. The hips appear larger than the bust without a definite waistline.
	Spoon				There is a larger circumferential difference in the hips and bust. The bust-to-waist ratio is lower than the hourglass shape and the hip-to-waist is higher.
	Inverted triangle or cone	"V"			The bust circumference is larger than the hips. There is a small bust-to-waist ratio.

Figure 2.1: Female Figure Identification Technique (FFIT©) for Apparel (Simmons *et al.*, 2004b)

The findings from Simmons et al.'s (2004b) FFIT© software study revealed that the overall percentage accuracy of the FFIT© software provided better results in classifying seven of the nine shape groups as compared to a discriminant function that was developed from using body shapes obtained from the visual analysis of the training data. Devarajan *et al.'s* (2004:1,13) study to validate the FFIT© software showed that the software was designed in a manner that it looks at one person's body shape at a time before moving to the next person and the percentage of accuracy from the validation was found to be approximately 90%.

Connell *et al.* (2006) developed the Body Shape Assessment Scale (BSAS©) software to evaluate physical characteristics from the front and side views of 3D scanned bodies. The body scans were derived from a sample of 42 women between the ages of 20 and 55. The researchers also assessed and reviewed existing body scales, and thereafter combined the existing body scales with their results to develop nine modified scales to evaluate the body shapes. The BSAS© comprised four categories of viz. Body Build, Body Shape, Hip Shape and Shoulder Slope from the frontal view and five categories viz. Torso Contour, Bust Shape, Buttocks Prominence, Back Curve and Posture from the side view. The Body Shape category generated four prominent frontal body shapes which included the rectangular, hourglass, pear and inverted triangular body shapes (see Figure 2.2).

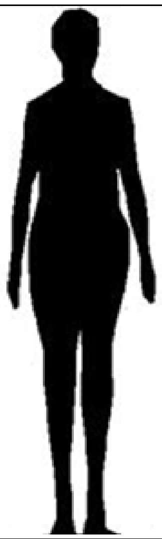
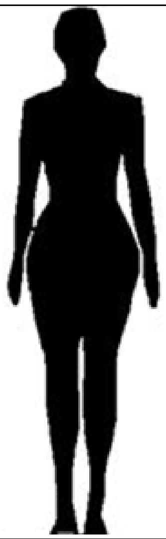
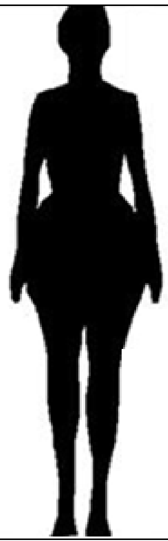
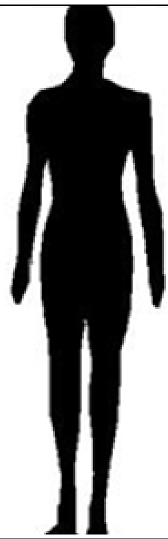
LABEL	R(RECTANGULAR)	H(HOURGLASS)	P(PEAR)	I(INVERTED TRINGLE)
DESRIPTION	SHOULDER AND HIP WIDTH ARE BALANCED WITH LITTLE TO NO WAIST DEFINITION	SHOULDER AND HIP WIDRH ARE BALANCED WITH CLEARLY DEFINED TO VERY SMALL WAIST IN RELATION TO SHOULDER AND WIDTH	HIP AND/OR THIGH WIDTH IS VISUALLY GREATER THAN SHOULDER	SHOULDER WIDTH IS VISUALLY GREATER THAN FULLEST WIDTH AT HIP OR THIGHS
STIMULI				

Figure 2.2: Body Shape Assessment Scale (BSAS©) (Connell *et al*., 2006).

The four body shapes were founded on the following body landmarks: shoulder to shoulder point, the frontal waistline and the widest point between the waist and front crotch line. For validation purposes, a panel of five experts used the BSAS© to evaluate 100 additional body scans. The evaluations permitted the development of BSAS© software that can take measurements of body parts in 3D; the BSAS© software has the capability of measuring body mass index (BMI), body measurements, and weight.

Both Simmons *et al.'s* (2004b) FFIT© and Connell *et al.'s* (2006) BSAS© studies represent the most significant uses of the point cloud data produced by 3D body scanning systems and using algorithms based on 3D form to identify shapes and to evaluate anthropometric body shapes related to the garment fit studies. Similarly, to Connell *et al.*'s (2006) Body Shape Assessment Scale (BSAS©), observational evaluations by Rasband and Liechty (2006), and Liddelow (2011), identified four common female body shapes viz. the hourglass, the triangular, the inverted triangular and the rectangle. The observational methods of Rasband and Liechty's (2006) and Liddelow's (2011) studies additionally identified the oval and the diamond body shapes as part of the common female body shapes. Liddelow's (2011) classification system identified all six common female body shapes whilst other classification systems, by the above-mentioned researchers, had either less or more female body shapes.

Discussed below are the different types of the commonly known female body shape profiles with the representing illustration of every shape.

2.3.1.1 The ideal body shape profile

An ideal body shape is said to be equally proportioned in body weight and dimensions (Zwane & Magagula, 2007:283; Mastamet-Mason, 2008:58; Liechty *et al.*, 2010: 82) as indicated in Figure 2.3. However, Rasband and Liechty (2006:24) further state that a shape with proportionally balanced length and width characteristics consisting of body parts with a fairly rounded bottom and lean thighs is considered as the ideal body shape.

Theoretically, the ideal body proportions can be divided equally into halves, with the elbow and knee measurements dividing the arm and leg into half measurements. The elbows should lie at a level corresponding to the waist, the wrist bone should lie next to the crotch level and finger tips next to the middle of the thigh area.

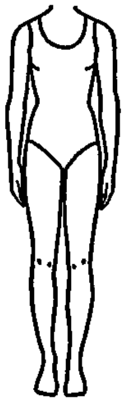


Figure 2.3: An illustration of an ideal body shape (Adapted from Liechty *et al.,* 2010: 81).

2.3.1.2 The hourglass body shape profile

The hourglass body shape consists of similar girth width measurements such as the bust and hip area, the waist area is indented and smaller which makes the top and bottom area appear to be proportionally larger (see Figure 2.4). The bust measurements are between medium to large and the hips appear to be smoothly rounded. The hourglass figure can be divided into two variations, namely, the top-heavy hourglass which describes individuals who have a bust circumference larger than the hips and a bottom heavy hourglass that consist of individuals with a hip circumference that is wider than the bust (Rasband & Liechty, 2006:24, 210; Mastamet-Mason, 2008:72; Liechty *et al.,* 2010:83; Makhanya, 2015:55).

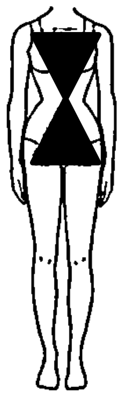


Figure 2.4: An illustration of an hourglass body shape (adapted from Liechty *et al.,* 2010: 81).

2.3.1.3 The triangular or pear body shape profile

The triangular body shape is also referred to as the pear and occasionally as the spoon body shape (Molino, 2007:1; Mastamet-Mason, 2008:64; Sewing & craft alliance, 2008:1; Ola-Afolayan & Mastamet-Mason, 2013:203-204; Kausher & Srivastava, 2016:136). Although, a study by Simmons *et al*., (2004a) identified the pear body shape as being distinctively different from the triangular body shape; the triangular body shape was classified similar to the pear body shape by Molino (2007:1); Mastamet-Mason (2008:64); Sewing and craft alliance (2008:1); Ola-Afolayan and Mastamet-Mason (2013:203-204); Kausher and Srivastava (2016:136), who suggested that both the triangular and pear body shape profiles are characterised by a narrow upper body (shoulders and bust area) and a wider lower body circumference that becomes indented at the waist area and becomes larger towards the hips and buttocks area (see Figure 2.5). Therefore, the triangular and pear body shape profiles were grouped together and referred to as the pear shape profile for the purpose of this petite sizing and fit study. Furthermore, the bust cup size of a pear / triangular shape profile size is usually smaller, and the hips are rounded (Rasband & Liechty, 2006:24; Mastamet-Mason, 2008:64; Liechty *et al.,* 2010:82; Ola-Afolayan & Mastamet-Mason, 2013:203; Makhanya, 2015:56).

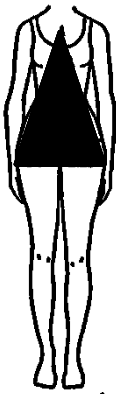


Figure 2.5: An illustration of a triangular/pear body shape (Adapted from Liechty *et al.,* 2010: 81).

2.3.1.4 The inverted triangular body shape

The inverted triangular body shape has more body weight in the upper top area consisting of broad shoulders and a full bust that ranges from medium to large in measurements. The waist, the hips and buttocks are usually small (see Figure 2.6). The location of the rib cage is short with a higher waist and long legs. The hips lie low, having a raised curve that appears to be flat and straight on the side of the body (Rasband & Liechty, 2006:24-25; Mastamet-Mason, 2008:66; Liechty *et al.,* 2010:82; Makhanya, 2015:58).

Figure 2.6: An illustration of an inverted triangular body shape (Adapted from Liechty *et al.,* 2010: 81).

2.3.1.5 The rectangular or straight body shape

The rectangular body shape, also referred to as a straight body shape does not have an indented waist but has similar width measurements at the shoulders, waist and hips making the shape have a straight appearance (see Figure 2.7). This type of body shape appears commonly in plus-size women with big body silhouettes and tall women. Individuals with a slimmer rectangular body have a more visible bone structure resulting in a tubular body shape appearance (Rasband & Liechty, 2006:25; Mastamet-Mason, 2008:70; Liechty *et al.,* 2010:82-83; Makhanya, 2015:57).

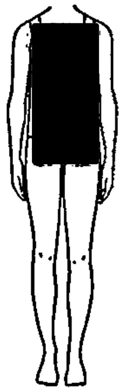


Figure 2.7: An illustration of a rectangular/straight body shape (Adapted from Liechty *et al.,* 2010: 81).

2.3.1.6 The oval or rounded body shape

The oval or rounded body shape also referred to as the apple body shape consist of a fully round body area in the bust, waist and abdomen area; hips that have a flat buttocks and slender legs (see Figure 2.8). An individual with an oval or rounded body shape usually has a full face, is with a shorter neck and the shoulders are not as angular as in other body shapes (Rasband & Liechty, 2006:25-26; Liechty *et al.,* 2010:83-84; Makhanya, 2015:59).

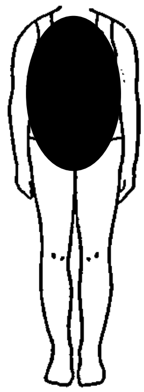


Figure 2.8: An illustration of an oval/rounded body shape (Adapted from Liechty *et al.*, 2010: 81).

2.3.1.7 The diamond body shape

A diamond body shape consists of relatively narrow shoulders and hips and a wide mid-section which is the stomach, waist and abdomen area. The hips are straight and taper inward at the side of the thighs, the buttocks are usually flat (see Figure 2.9). An individual with a diamond shape has relatively thin legs and arms (Rasband & Liechty, 2006:25; Liechty *et al.,* 2010:83; Makhanya, 2015:59).

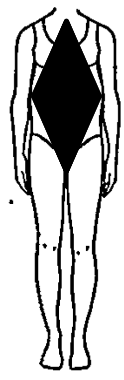


Figure 2.9: An illustration of a diamond body shape (Adapted from Liechty *et al.,* 2010: 81).

Pandarum's (2015) study used 3D full body scanned data to sample (n=115) South African women aged 20 to 65 years, comprising of all the race groups in different body height and weight categories. Six body shapes emerged in the sample based on the subjects' bust to waist and bust to hip ratios, with their BMI ranging from under-weight to morbidly obese resulting in the images presented in Figure 2.10.
The illustrations (Figure 2.10) are ranged from small body silhouettes (in row 1) and the average to plus-size women body silhouettes (in row 2) of the different body shapes that arose in Pandarum (2015) on-going Ph.D. study. The figure below is inclusive of petite women and is presented in the following order; the triangular, bottom hourglass, hourglass, rectangle, pear/spoon and the oval body shape figure types.

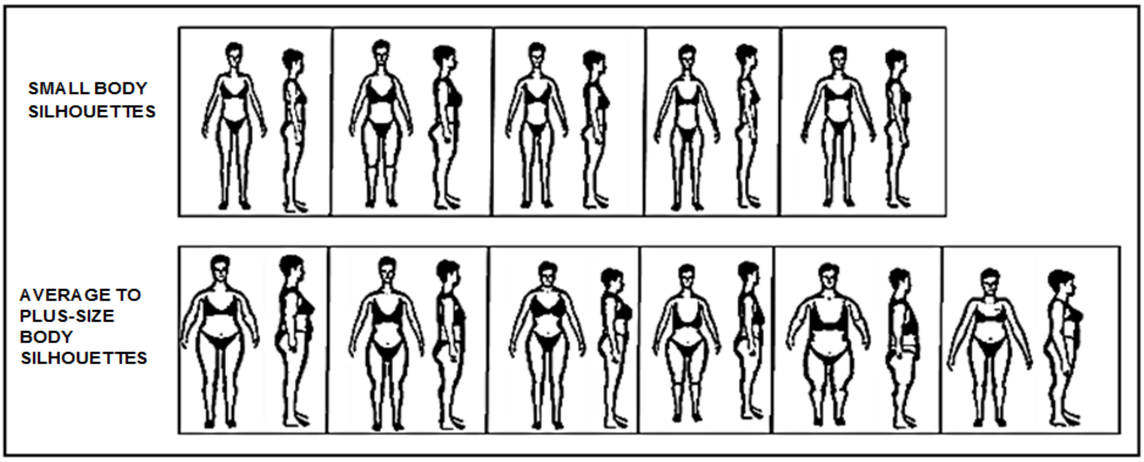


Figure 2.10: Body shapes classifications common to both small and average to plus-size women's silhouettes in different body heights and BMI including petite women, established by Pandarum (2015).

According to Rasband and Liechty (2006:24), the physical characteristics of an individual's body shape consist of the overall body contours, body proportions and weight distribution patterns. Defty's (1988:10) South African published book on creating patterns, classified women in three body shape profiles, namely, round, oval and oblong. The round body shape profile was classified as having wide scye measurements, a prominent full bust and a narrow back area. The oval body shape profile was specified to be medium in the scye measurements, bust prominence and the back width; while the oblong body shape profile was suggested to have a thin scye measurement, a small bust prominence and a wide back area.

Winks' (1990:75) study classified three body shapes, namely, A, M and H body shape profiles to use in his study. Winks (1990) further stated that the A body shape profile consisted of a hip girth measurement that was at least 9cm bigger than the bust girth measurement. The M body shape profile was suggested to have a hip girth measurement that was 4 cm to 8 cm bigger than the bust girth measurement. Additionally, the H body shape profile was described to have approximately equal hip and bust girth measurements. Furthermore, Bailey's (2010) study did not classify body shapes, as the study was more focused on studying the subject's perceptions and reflections through garments created for petite women as a form of communication between the garment manufacturers and the individual.

Makhanya's (2015) study on body shapes of 234 African and Caucasian women focused on the body shapes found on a University campus of women aged 18 to 25 years. Makhanya's (2015) study identified the women as having triangular, hourglass and rectangle body shapes. This South African study, conducted in 2015 highlighted differences in the women's body shapes using drop values of the African and Caucasian body dimension. This finding is similar to Lee *et al.'s* (2007:375) study on the American and Korean body shape which indicated that ethnicity influences the physical characteristics of an individual's body shape and is one of the many contributing factors on how the garment fits the body. Makhanya's (2015) study is also said to support Liechty *et al.'s* (2010:44) "*Fitting and pattern alterations*" American publication that stated that populations with African descendants' body shapes generally consist of a "raised curve on their buttocks". However, Makhanya's (2015) study only sampled 109 of the black South African women aged 18-25 and hence, this finding cannot be generalised to all South African women of black African descent and can only be verified with a larger sample size and in future, another study of black South African women.

Most recently, other South African academic studies by Muthambi (2012), Ola-Afolayan and Mastamet-Mason (2013), and Makhanya *et al.* (2014) have identified the triangular /pear body shape as the most prominent South African body shape arising from their dataset for 60, 50 and 234 women respectively. These authors describe the triangular /pear body shape as having a wider hip area than the bust and shoulder area with a scooped waist and full rounded breasts; nevertheless, this body shape differs from the western triangular /pear body shape (Ola-Afolayan, 2012; Ola-Afolayan & Mastamet-Mason, 2013:204).

According to Ola-Afolayan and Mastamet-Mason (2013:203), the South African women's triangular/pear body shape hip area is 30 cm larger than the bust area, whereas the western triangular/pear body shape consists of a hip area that is 8 cm larger than the bust (Simmons *et al.,* 2004b). Additionally, Makhanya's (2015) study established that the South African triangular shaped women had wider hips, with shorter overall body-to-waist and shorter overall body-to-hip height ratios than the Caucasian triangular shaped women did. However, these studies were reported on the average and plus-sized women body shapes and dimensions, and not on the petite women.

2.3.2 Petite women's body measurements

In South Africa the earliest recorded and published study on petite sizing systems, was by Defty (1988) who published a size chart for short (petite) women for the purpose of making patterns; followed by Winks (1990:74-76) who conducted a study on 25 female body dimensions from a sample size of 343 subjects in six South African prisons. Winks' (1990:74-76) data was rearranged into three height groups. The height groups were established as short, ranging from 156-163 cm with a 160 cm mean, regular, ranging from 164-171 cm with a 168 cm mean and long, ranging from 172-179 cm with a 176 cm mean. The data grouping from Winks' study considered the differences between the hip and bust girth measurements of three race groups, namely, the Whites, Blacks and Coloureds. However, Winks' (1990) study was not entirely focused on petite women. The size chart developed from the study was classified as generic data according to the subject's body shape. Defty's (1988:17-18) size chart, was classified in different sizes, some which differed from the currently industry used size ranges, ranging from a size 9, 11, 13, 14, 16, 18, 20, 22, and 24; focusing on body dimensions such as the bust, waist, hips, hip depth, across back, back length to waist, forearm length, upper arm length and the skirt length mid-calf. Bailey (2010:23) developed a size chart from her study. Her size chart was derived by grouping the data into three petite size ranges of 2, 4, and 6, based on three body measurements; viz. the bust, waist and hip girth measurements.

A personal conversation with Millam (2016) from the South African mannequin manufacturing company disclosed that in 2003, a measurement specification sheet for petite women was based on a total body height measurement of 160 cm. However, the data was not made available for public use as it was used to manufacture a mannequin for a private chain store company. To date this is the only known mannequin developed for petite women in the country.

The lack of information on the collection of women's anthropometric data in general is acknowledged, more especially for petite women in South Africa. However, there have been numerous international studies conducted for developing petite women sizing systems such as that in the USA by Kim *et al.* (2016), who compared body measurements used in petite sizing systems and regular sizing systems of 14 apparel companies in the USA for women aged 18-35, together with sizing measurements from the ASTM D7878 and ASTM D5585, with the purpose of investigating how apparel companies define petite women's body dimensions and the procedures used to scale down petite women's measurements using average garment sizes. Kim *et al*.'s (2016) study consisted of a sample size of 2,714 Size USA female dataset from research conducted in 2004 by the Textile Clothing Technology Incorporated to divide the size categories of petite and average women. The study selected 1,618 petite women and 1,096 average women from the sample and used those numbers as a basis for comparing the two female groups. Kim *et al.*'s (2016:58-59) study characterised four groups of petite women's body shapes, namely, the top petite for women with the shortest torso and relatively average limbs, the bottom petite for women with the shortest limbs and an average torso length, the regular petite for women with a relatively longer torso and long limbs, and the plus-size petite for women with a larger overall body size. The findings from Kim *et al*.'s (2016) study revealed significant differences in girth and width measurements between the two groups and a degree of reduction in measurements for petite women. However, the body shape definitions characterised in Kim *et al.'s* (2016) study differ from the industries' body shape definitions.

2.4 GARMENT FIT

2.4.1 Defining garment fit

The definitions of garment fit vary. Generally fit is an essential component that contributes to consumer satisfaction in garments (Song & Ashdown, 2012:315). A better fitting garment is supposed to enhance the wearer's body and make it more flattering (Rasband & Liechty, 2006:3).

The challenge for garment manufacturers in producing better fitting garments, is that garment manufacturers, patternmakers and consumers themselves all have different definitions, perceptions and evaluations with regard to the quality of the fit of a garment on the body (Doshi, 2006:1; Ashdown & O'Connell, 2006:137; Pisut & Connell, 2007:367). Doshi (2006:1) further states that garment manufacturers are mostly interested in creating aesthetic appealing designs that will provide the wearer with a clean look. Physical and psychological factors also have an influence on how garment manufacturers and consumers define fit. Pisut and Connell (2007:368) identified comfort, appearance, fashion trends, body shape, age, lifestyle, cultural standards, and personal choices as factors that have contributed to the fit of garments.

Pisut and Connell (2007:370), and Liechty *et al.* (2010:48), mention that garments should fit the body smoothly with comfort and without any restrictions in movement and wearability, but it is difficult to achieve that effect on all individuals because body structures differ, and this affects the positioning of the structural lines and how the garment balances on the body. Stamper *et al.* (2005:297), Chen (2007:123), Keiser and Garner (2008:368-370), and Petrova and Ashdown (2008:40) further suggest that the fabric grain, garment ease, line, set and balance are the five principles that individuals use as elements to evaluate the way their bodies fit into a garment, that ultimately contribute to the quality of a well-fitting garment on a consumer's body silhouette.

The above-mentioned five elements associated with garment fit is discussed below to provide the background to the fitting test criteria used to evaluate the fit of the prototype shirt and trouser prototype garments, developed in this study, as reported in Chapter 6.

2.4.1.1 Fabric grain

All fabrics should be cut relative to the fabric grain to ensure that the fabric of the garment drapes correctly and conforms to the wearer's body contour as required by the garment design style. The fabric grain is listed by Stamper *et al.* (2005:297) as the first and key component used to distinguish and understand garment fit and is classified by three fabric grains; namely, the lengthwise, the crosswise and bias grains (Rasband & Liechty, 2006:54; Liechty *et al.,* 2010:17-18). Branson and Nam (2007:265) suggest that lengthwise and crosswise grains lie at a 90° angle to each other, which allows the garment to hang evenly on both sides of the body with even seams. Rasband and Liechty (2006:54), Branson and Nam (2007:265), Keiser and Garner (2008:368), and Liechty *et al.* (2010:17-18) further explain lengthwise grains of the fabric as warp threads with little stretch in the fabric that lie parallel to the finished edge of the fabric and they are perpendicular to the floor. The crosswise grains of the fabric are weft threads that lie between, or at right angles to the selvages of the fabric. Crosswise grain fabrics have some stretch in them and lie parallel to the floor, across the chest and hip when worn. Bias grain cut fabrics stretch easily, they lie diagonally across the lengthwise and crosswise threads. Bias fabrics form a true bias grain at a 45° angle when folded, allowing the lengthwise grains to lie exactly on top of the crosswise grains.

A garment that is cut on the correct grain will appear balanced, smart and presentable when worn, opposing to a garment which is cut with a fabric grain that is out of line which may result in ripples at the hemline, and pulling or gaping at the seams, especially after it has been washed (Liechty *et al.,* 2010:17,40).

2.4.1.2 Garment ease

Garment ease is usually decided by the garment designer. According to Stamper *et al.* (2005:298), Chen (2007:132), Petrova (2007:61), Keiser and Garner (2008:369-370), and Liechty *et al.* (2010:18), ease refers to the extra measurements that should be incorporated into a pattern beyond those defined by the specific body measurements. This means that there should be a slight difference in measurements used to size a garment and the intended individual's body measurements that will fit into the garment, to allow the individual to be able to move comfortably in the garment. The amount of ease added depends on comfort, movement and the appearance required of the garment which is defined in terms of the tightness and looseness of the required fit. The ease is also highly dependent on fabric properties. Shirts should be designed to fit and hang smoothly on the upper body from the shoulders and trousers should be designed to fit and hang smoothly on the lower body from the waist or the hip area (Liechty *et al*., 2010:52).

According to Keiser and Garner (2003:316), the ease allowance for shirts is generally determined by the bust measurement, whilst the ease allowance of trousers is usually determined by the hip measurement. Rasband and Liechty (2006:36) further suggest critical aspects such as the style of the garment, the fabric used, the body shape and proportions of the targeted individuals who will fit into the garment, the occasion where the garment will be worn, and personal preferences and needs. Furthermore, the wearing/functional ease and design ease are factors that garment designers must consider when designing ease for garments. These are discussed below.

a. Wearing/ functional ease

Wearing ease is described by Chen (2007:123), Keiser and Garner (2008:370), and Liechty *et al.* (2010:18-19) as an amount of extra fabric added into a garment to allow movement and comfort such as breathability and flexibility for walking and sitting in the garment. A garment constructed without ease is likely to be uncomfortable to wear, as the garment strains and wrinkles. This may possibly highlight unattractive parts of the wearer's body silhouette (Branson & Nam, 2007:266). Therefore, appropriate body proportions should be considered when garment designers determine the amount of ease to add to a garment.

b.Design ease

According to Stamper *et al.* (2005:298), Chen (2007:132), Branson and Nam (2007:266), Keiser and Garner (2008:370), and Liechty *et al.* (2010:19) design ease refers to the amount of fabric used to determine a desired look for a garment; for example: whether the garment will be tight fitting, semi-fitting or loose fitting. Design ease is also used to improve easy movement in a garment and is also greatly influenced by fashion trends (Stamper *et al.,* 2005:298; Keiser & Garner, 2008:370).

2.4.1.3 Garment line

According to Stamper *et al.* (2005:298-299), Keiser and Garner (2008:369), and Liechty *et al.* (2010:17) garment line refers to structural lines that follow the body's natural silhouette, providing a proper fit appearance. This is achieved by garment features such as decorative seams, darts, hems and fabric folds made by pleats and tucks. Stamper *et al.* (2005:299) and Liechty *et al.* (2010:17-18) suggest that seams should be vertical to the floor at the centre back front, back and side and furthermore, correspond with the outer curves of the body they are designed to accommodate. These garment lines, including decorative lines and folds on the garment should appear smooth and balanced against the wearer's body, creating an appealing visual impression and at the same time accentuating the wearer's body silhouette (Stamper *et al.,* 2005:299; Keiser & Garner, 2008:369).

2.4.1.4 Garment set

Garment wrinkles are a good indication for analysing a good garment fit. A garment that is set reflects a garment that does not form undesirable wrinkles on the wearer's body; consumers should not confuse wrinkles caused by pulling and snagging with wrinkles that are created as part of the design aesthetic of the garment (Stamper *et al.,* 2005:299). Keiser and Garner (2008:369) mention that a garment that forms wrinkles, sagging or pulls from the body is an indication that the garment may be either too small or too large. Horizontal wrinkles indicate that the garment is too tight above or below the curve of the body. Vertical wrinkles indicate a garment is too large; these wrinkles are commonly visible in jackets and dresses. Diagonal wrinkles indicate that the garment is too small, short or narrow for the outer curves of the wearer's body.

Tight wrinkles occur on garments with little wearing ease, which adds strain to the fabric of the garment (Stamper *et al.,* 2005:299). Rasband and Liechty (2006:63) further suggest that generally, wrinkles are expected when walking, bending and reaching but the garment should hang smoothly when the wearer is standing still.

2.4.1.5 Garment balance

Stamper *et al.* (2005:300), Keiser and Garner (2008:369), and Liechty *et al.* (2010:36) suggest that the balance of most garments, including shirts and trousers is achieved through having a garment that evenly hangs on the wearer's body in every direction; this usually affects the fit of the garment. The authors further define a well-balanced garment as a garment that consists of even design details and a hemline that provides a balanced garment drape on both sides of the body and at the bottom of the garment. A poorly balanced garment will affect the fit of the garment, as the garment will shift or sag (Rasband & Liechty, 2006:13), which occurs mostly in garments that are uneven on the hemline. According to Stamper *et al.* (2005:300), poor body posture and body imperfections on the outer body curves may affect the balance of garments on the wearer's body that may contribute to mass-produced garment fit problems.

Challenges in constructing patterns may also affect the balance of garments on the wearer's body if the drafted pattern proportions do not correspond with the body measurements of the consumer the pattern is intended to fit (Keiser & Garner, 2008:369).

2.4.2 Garment Standards used in the evaluation of garment fit

In addition to the five elements of garment fit, mentioned above, there are standard guidelines which are basic rules introduced to describe and evaluate how a garment should fit the body. Socio-cultural factors such as ethnicity, age, gender, religion, occupation, fashion trends and economic influences affect how consumers evaluate fit (Liechty *et al.,* 2010:44-47).

Therefore, it is important that every country has its own population's sizing data to provide accurate body measurements for garment manufacturing to ensure better fitting garments and to increase consumers purchasing performances (Strydom & De Klerk, 2006:80; Vithanage et al., 2012:30,59; Ka Wai YIP, 2013:10; Zakaria, 2014:95).

Apparel fit standards are used to describe the quality of fit, on specific areas of a garment, on the body of the wearer that evaluates garment positioning and movement when the wearer is sitting, standing, walking or bending. Apparel standards are evaluated for accuracy or errors by following accepted fit guidelines and certain characteristics such as the wearer's body structural lines, body sections and segments, as well as lines present in garment which consist of interior seamlines, dart-lines, closures, pleats, tucks, pockets, bands, trims and decorations (Liechty *et al.,* 2010:46-47,59). According to Rasband and Liechty (2006:3), garments with poor fitting standards are distracting and may lead to unwanted attention to the wearer's appearance, therefore evaluating apparel fit standards is important, because a garment created to fit well on an individual's body contributes to the confidence and comfort of the wearer (Alexander *et al.,* 2005:52).

The fit/drape of the garment on the wearer's body also influences the quality of the fit and the overall appearance of a garment (Liechty *et al.,* 2010:160). Every stage of the production process has an influence on the quality of fit in garments (Bougourd, 2007:130). Nonetheless, standard sizing systems are usually voluntary, which means that the majority of the clothing manufacturers do not follow them, as a result, garment sizing standards vary per manufacturer (Winks, 1997:1; Alexander *et al.,* 2005:56). Voluntary garment sizing standards were initially developed by the National Bureau of Standards in 1941 in the United States of America and were revised in 1971. However, since the introduction of voluntary garment sizing standards, the garment sizing system has been a disappointment, as not all manufacturers and retailers are obliged to abide by these standards guidelines when manufacturing garments (Barona-McRoberts,2005:21; Pandarum and Yu, 2015:199-200). Consequently, this contributes to the potential for poor fitting garments (Alexander *et al.,* 2005:56; Pisut & Connell, 2007:368).

2.5 THE RELATIONSHIP BETWEEN BODY DIMENSIONS, BODY SHAPE AND GARMENT FIT

Body dimensions are used as the foundation for establishing effective sizing systems and manufacturing quality fitting garments (Strydom, 2006:60; Rasband & Liechty, 2006:4; Loker, 2007:256; Muthambi *et al.,* 2015:63). According to Loker (2007:256), to ensure a well-fitting garment, irrespective of how consumers perceive garment fit, starts with collecting accurate body measurement data for use when constructing garment pattern blocks.

An individual's body proportions influence how a garment balances and, the positioning of structural lines on the body (Pisut & Connell, 2007:370; Liechty *et al.,* 2010: 48). The importance of creating garment patterns with the accurate body dimension statistics is highly emphasised in the apparel industry (Loker, 2007:256). According to Strydom and De Klerk (2010:75-76), body measurements are the primary factors that contribute to garment fit and enhance the fit of ready-to-wear clothing. Body measurements also form part of an essential requirement for sizing systems, pattern and garment development.

Numerous international and national researchers, Alexander *et al.* (2005), Barona-McRoberts (2005), Zwane and Magagula (2007), Mastamet-Mason (2008), Nkambule (2010), Pandarum *et al.* (2011), and Muthambi (2012) conducted studies on the relationship between female body shapes and garment fit.

In Africa, Zwane and Magagula (2007:286) studied Swazi women who purchased ready-to-wear garments from size 34 to size 40 and Nkambule (2010:81), who studied plus-size Swazi women concluded that most of the participants, in their respective studies, were bottom-heavy or triangular body shaped. The respondents also experienced garment fit problems on the lower parts of their bodies where the garment at the waist was too loose and too tight at the hip, the buttocks and thigh areas. The participants further expressed that the length of their garments was also a problem, as 55% of the respondents from Nkambule's (2010) study indicated that the trousers length was too long. These studies were; however, conducted for the average and plus-sized women. Mastamet-Mason's (2008:64) study on Kenyan women revealed similar findings to those of Zwane and Magagula's (2007) and Nkambule's (2010) studies on Swazi women. Mastamet-Mason's (2008) Kenyan study also observed a loose fit around the upper bodies of triangular shaped women. Similarly, Muthambi's (2012:105) study on South African women of African descent, with triangular body shapes, when comparing the manual measurements in dress garments size 30 to 38, found that the garment fitted loosely on their upper bodies.

Pandarum *et al.'s* (2011) South African study focused on bra fit for plus-sized women and this study found that 85% of the women were wearing the incorrectly sized bra, and that the plus-sized women bra size ranges available in retail stores at the time, did not accommodate all the women sampled in the study. The result was that, as this study was conducted in conjunction with a bra manufacturer, the bra size ranges for plus-sized women were extended to include other larger bra sizes after the study was completed and consideration was given to the bra designs, styles and the trimmings on these larger sized garments. However, all these studies' findings were for the average and plus-sized women's garments and not for petite women.

A study by Alexander *et al.* (2005:57, 59) on 223 participants, aged between 18 and 29, enrolled in classes in a South Eastern University in the USA used four different body shapes; the pear, rectangle, hourglass and the inverted triangular to study the relationship between garment fit and the body shape. The study found that the participants who identified their bodies as hourglass, rectangle and pear body shapes were more prone to experience fit problems around their bust areas and did not prefer wearing fitted tops. The pear and hourglass shaped participants reported fit problems around their waist, hip and thigh areas and preferred more fitted trousers and jackets that were not body hugging.

In the United States, Song *et al.'s (*2013) study further assessed the reliability of the self-perceived lower body sizes and shapes of 83 college female students from a university in the North-East region of the United States (U.S); ranging from garment sizes 2 to 20 using the ASTM D5585-95 U.S standard for adult female Misses figure type sizes. The researcher used 3D body scanning technology to capture the female's body measurements and thereafter compared the captured data to the female's self-reported information on their lower-body sizes and shapes, together with assessing their relationship between body satisfaction and fit satisfaction. The body sizes in Song *et al.'s (*2013:149) study were determined by dividing each population variable into three categories based on percentile data, and using a body shape and size categorisation method developed from Size USA 3D body scan data. Three options were available for each listed body area (see Figure 2.11).

Areas (Survey)	Perceived Group			SizeUSA Group			Measurement (SizeUSA Data)
	Survey Options			*Size Distribution of Subjects for SizeUSA Data*			
	Option 1	Option 2	Option 3	Min ~ 33.3rd percentile	33.3rd ~ 66.9th percentile	66.9th Percentile ~ Max	
	Perceived Group 1	Perceived Group 2	Perceived Group 3	SizeUSA Group 1	SizeUSA Group 2	SizeUSA Group 3	
Height	Short	Average	Tall	~ 160.0 (~ 63.0)	160.1 ~ 165.1 (63.1 ~ 65.0)	165.2 ~ (65.1 ~)	Height (cm/in)
Weight	Light	Average	Heavy	~ 57.2 (~ 26.0)	57.3 ~ 66.2 (126.1 ~ 146.0)	66.3 ~ (146.1 ~)	Weight (kg/lb)
Waist Size	Small	Average	Large	~ 75.4 (~ 29.7)	75.5 ~ 82.3 (29.8 ~ 32.4)	82.4 ~ (32.5 ~)	Waist Girth (cm/in)
Abdomen Shape	Flat	Average	Full	~ 0.3 (~ 0.1)	0.4 ~ 1.0 (0.2 ~ 0.4)	1.1 ~ (0.5 ~)	Abdomen Front Depth – Waist Front Depth (cm/in)
Hip Size	Small	Average	Large	~ 97.0 (~ 38.2)	97.1 ~ 104.2 (38.3 ~ 41.0)	104.3 ~ (41.1 ~)	Hip Girth (cm/in)
Buttocks Shape	Flat	Average	Full	~ 21.0	21.1 ~ 24.3	24.4 ~	Buttocks Angle (°)
Thigh Size	Slim	Average	Full	~ 57.3 (~ 22.6)	57.4 ~ 62.0 (22.7 ~ 24.4)	62.1 ~ (24.5 ~)	Max-Thigh Girth (cm/in)
Calf Size	Slim	Average	Full	~ 35.3 (~ 13.9)	35.4 ~ 37.8 (14.0 ~ 14.9)	37.9 ~ (15.0 ~)	Calf Girth (cm/in)
Waist Height	Low	Average	High	~ 97.3 (~ 38.3)	97.4 ~ 102.6 (38.4 ~ 40.4)	102.7 ~ (40.5 ~)	Waist Height (cm/in)
Leg Length	Short	Average	Long	~ 72.0 (~ 28.4)	72.1 ~ 76.1 (28.5 ~ 30.0)	76.2 ~ (30.1 ~)	Crotch Length (cm/in)
Waist to Hip Shape	Straight	Average	Curvy	~ 1.26	1.27 ~ 1.33	1.34 ~	Ratio: Hip Girth/ Waist Girth

Figure 2.11: Observations of different female lower-body sizes and shapes established by Song *et al.* (2013:149).

The results from Song *et al.'s* (2013:153-154) study indicated that approximately 50% of the respondents preferred a smaller waist, flat abdomen, medium-sized hips, and thinner thighs, whilst they perceived their waist to be larger, bigger abdomen, larger hips and thicker thighs. Although their perception of the above-mentioned body areas had no relationship to how satisfied they were with their body and garment fit, the hip area presented a weak association between body satisfaction and fit satisfaction. The thigh area presented the second highest relationship between body satisfaction and fit satisfaction for all the perceived body groups. The findings further indicate that respondents that perceived their leg length to be short whilst they would prefer their leg length to be longer, had a lower body and fit satisfaction as compared to those who perceived their leg length to be long. Additionally, the respondents preferred to have prominent buttocks.

Moreover, the respondents preferred to have a curvaceous waist-to-hip area, as they had perceived they had a curvier waist-to-hip area. Both the buttocks and waist-to-hip area presented a correlation between the perceived body and the actual body and there was a weak relationship between body satisfaction and fit satisfaction for these two body areas.

Barona-McRoberts's (2005:44,50,53) study evaluated petite figure type variations in the United States of America using a "*modified proprietary database to manipulate a prototypical petite pattern*" for the apple and pear body shapes identified in her study. Her study consisted of 52 petite women from the ages of 20-49. Findings from her study resulted in a varied distribution of four apple-shaped, 19 pear-shaped, and 28 average-shaped women that were labelled average because they did not fall into any of the three industry shape definitions, as defined by the Voluntary Product Standard PS 42-70. The prototypical pattern from this study was compared to the PS 42-70 size 16 Misses Petite pattern standards that showed that the body dimensions established from the study varied from the industry's body dimensions definitions. Furthermore, the prototype pattern constructed, using the apple and pear shapes body dimensions, resulted in a better fit as compared to the voluntary standard PS 42-70 size 16 Misses Petite pattern fit developed for an hourglass body shape.

The relationship between South African petite women's body dimensions and apparel fit is unknown. The only known South African petite study was conducted by Bailey (2010) who focused on how garments created for petite women as a form of communication between the manufacturers and the individual and not on body shape nor on the prototypical garment fit assessment or made any comparisons on the currently used retail petite mannequin data in three dimension (3D).

All the aforementioned studies highlight that females, including petite women, have different body dimensions and every individual experience different garment fit issues, based on their body shapes and personal garment fit preferences.

2.6 CONSUMER'S PERCEPTIONS ON GARMENT FIT AND THEIR BODY SHAPES

The issue of garment fit is dependent on the consumer's individual preferences, indicating that "*a good fit*" has multiple meanings (Alexander *et al*., 2005:61; Kasambala *et al*., 2014:102; Pisut & Connell, 2007:369). Consumers perceive garment fit as an important attribute to consider purchasing garments (Ashdown & O'Connell, 2006:137). Consumers' attitudes and expectations towards their garment sizes have an influence on their garment purchasing choices; a garment that fits well is said to look better on the wearer's body and therefore, making the wearer to be more confident and satisfied with the garment (Coury, 2015:8-9). Mass produced, ready-to-wear garments are suggested to provide consumers with a "*standardized*" sizing system to assist them in deciding which garments should fit them based on their body sizes; however, the standardized sizing is not consistent across various garment manufacturers and retailers (Alexander *et al*., 2005:56; Pisut & Connell, 2007:368). As a result, dissatisfaction with garment fit is frequently reported as a major problem among female consumers who struggle with finding garments that fit well without having to alter them (Alexander *et al*., 2005;55). Kasambala's (2013) study on " *the exploration of female consumers' perceptions of garment fit and the effect of personal values on emotions*" conducted on 62 female consumers from Gauteng, Johannesburg showed that the majority of the participants in her study were not able to accomplish their personal values through garment fit due to "*inconsistent, unreliable and inaccurate*", garment sizing which was observed to not be suitable for the various body shapes present in South Africa , along with the inaccessibility of certain ready-to-wear garment sizes currently sold in retail stores. Garment manufacturers and retailers were recommended to take into consideration characteristics such as the relations between consumer's body shape variations, fit preferences and garment sizing when manufacturing ready-to-wear garments for their target market (Kasambala *et al.,* 2015:16). Coury (2015:1) further state that garment manufacturers and retailers need a better understanding on their target markets perceptions on garment fit and their body measurements in order to guide them in purchasing garments that fit well.

According to Alexander *et al. (*2005:52) garments are used as a form of non-verbal statement to either intentionally or unintentionally convey a message or project an image to others. Consumers often buy garments as a form of self-expression or to classify themselves with a certain social group. Alexander *et al*. (2005;53,59-60) suggest that consumers garment fit satisfaction might have a relation to their body satisfaction; indicating that the more satisfied the consumers are with their body shapes, the more they will be satisfied with the fit of their garments. Consumers who are likely to be more satisfied with their body shapes are inclined to prefer wearing a more fitted garment. The most common fit preference for garments is the semi-fitted garment which describes a garment that fits close to the wearer's body with added ease and comfort, followed by a loosely fitted garment preference. (Alexander et al., 2005:61; Kasambala *et al.,* 2014:102; Pisut & Connell, 2007:369). Consumer's feelings about their bodies have a substantial influence on their garment fit preferences, including style/design preferences because the way a specific garment sits on the wearers body have a potential of enhancing consumers perceptions and feelings on their body shapes (Pisut & Connell, 2007:369; Coury, 2015:5). Kinley's (2010) study on *"the effect of clothing size on self-esteem and body image"* has presented that there is a positive relationship between body image and self-esteem. Kinley (2010:397) and Kasambala *et al.* (2014:95) state that body size is a predictable influential factor in satisfaction with body image, which affects the individual's self-esteem. Findings from Kinley (2010:407) further suggested that women with small body shapes were more satisfied with their body shapes and had an increased self-esteem when they fit into their expected garment size.

2.7 HOW THE INDUSTRY BASE-SIZE GARMENTS ARE TESTED FOR FIT

The apparel industry also uses fit models or tailoring mannequins to establish the fit and drape of a given garment style on the body based on an industry established base-size as determined by their target markets. The following is a discussion on the different types of fit models used in the apparel industry to establish the foundation to the live fit models used in the fit test evaluations, in this study.

2.7.1 Using fit models to test garment fit

Tama and Öndoğan's (2014:108) study state that fit sessions are the fundamental foundation of evaluating the fit of a garment throughout the garment manufacturing process and at each stage of the garment production and the development process that influences the degree to which garment fit is achieved. Fit models may differ in measurements and proportions, according to the retailer or manufacturer's target market (Alexander *et al.*, 2005:56). Bougourd (2007:130) states that there are three forms used as fit models that represent the target consumer, namely: the dress form, the human (live) fit model and the virtual fit model.

Consequently, garment fit sessions are conducted to evaluate the performance parameters of the garment appearances such as the garment ease, set, line, balance, together with the drape and the stretch properties of the fabric (Keiser & Garner, 2003:318; Bougourd, 2007:134; Kadolph, 2008:91), to reduce errors in the manufactured garment(s) (Liechty *et al.,* 2010:3) for the retailer target market.

2.7.1.1 The dress form

A dress form is used by garment manufacturers to evaluate garment designs, garment proportions and dimensional fit (Bougourd, 2007:130-131), mainly because it is convenient to use as compared to a live human fit model and have consistent measurements (Song *et al.,* 2010:264). A dress form is a garment fitting model/mannequin stand created as either a whole body, a half body, a torso or just the lower half of the body in different dimensions as a representation of a human body in a specific garment size (see Figure 2.12). However, Song *et al.* (2010) further argument that a dress form does not accurately represent the shape of a realistic human's physique. According to Joseph-Armstrong (2014:35), dress forms are sometimes created using imperfect measurements that may not always be similar on each side; consequently, using a dress form to evaluate the fit of garments may result in problems of maintaining accuracy and consistency of the fit of garments on a realistic human body shape (Song *et al.,* 2010:264).

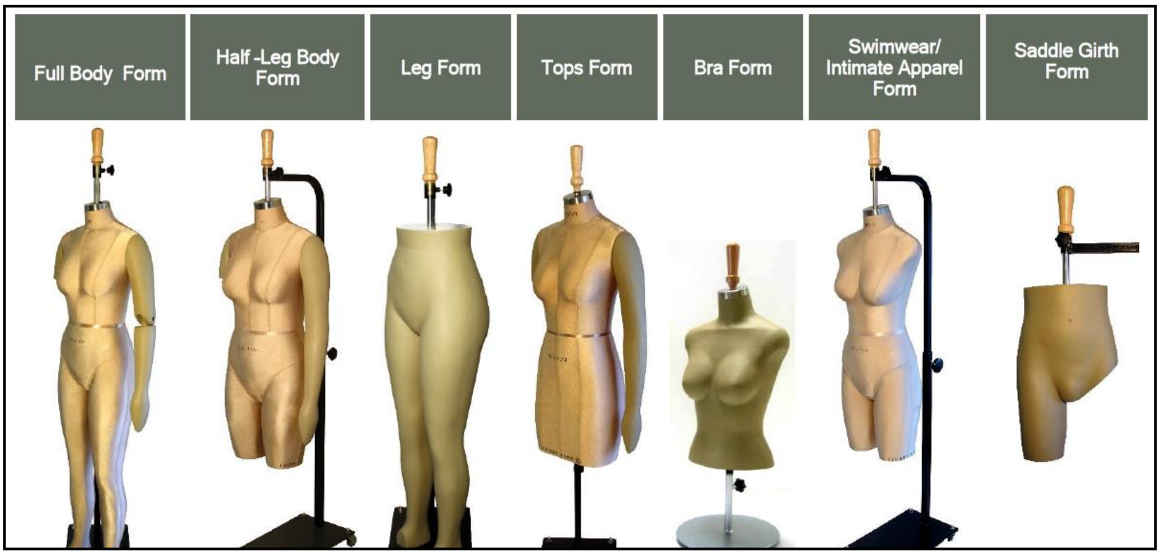


Figure 2.12: Illustrations of different types of dress forms by *Figure Forms* (2015)

2.7.1.2 The human fit model

A human (live) fit model is considered an important aspect of the garment development and production process. Individuals with body shapes and sizes that represent the manufacturing company's target market are hired to fit garments (in the pre-production stages) to assess their designs, drape and the quality of fit as production samples and graded samples (Bougourd, 2007:133; Joseph-Armstrong, 2014:38).

Kadolph (2008:91) suggests that using a live human model to assess garment fit provides a more realistic and functional garment fit assessment. Conducting human fit form analyses has the advantage of allowing the evaluator to touch the garment; have the model move and sit when wearing the garment, to assess where on the model's body the garment's stress folds are created and, to ask the model questions about how he/she feels about the fit of the garment on their body (Song *et al.,* 2010:274). Figure 2.13 is an image of a human (live) fit model

Figure 2.13: An image of a human (live) fit model with garment fit evaluators (Adapted from H&M, 2015).

2.7.1.3 The virtual fit model

According to Sohn and Sun (2013:74); Sayem and Bednall (2017:1) virtual fit models are used as a marketing tool for presenting online shopping products and for increasing efficiency in the garment product development process by providing instant visual presentations of the garment. A virtual fit model minimises the amount time and costs used for fit evaluation sessions tested on live human fit models or dress forms and also decrease the need to make garment samples for garment fitting (Apeagyei, 2010:65; Power *et al.*, 2011:213). 3D full body scan data can be exported for garment pattern modification and draping simulation, where 2D patterns of the prototype garments are morphed onto a virtual fit model to create a 3D appearance of the established garment (Kim & LaBat, 2013:171; Apeagyei & Otieno, 2007:354). An illustration of a virtual fit testing and pattern manipulation simulation on a virtual fit model is presented in figure 2.14.

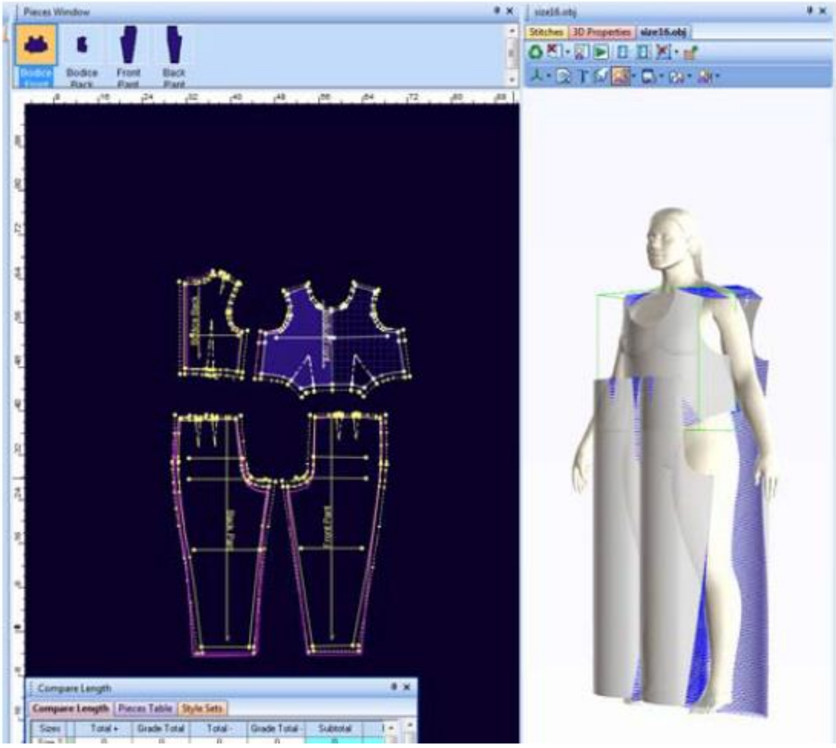


Figure 2.14: An illustration of a virtual fit testing and pattern manipulation simulation on a virtual fit model in OptiTex® (Sohn & Sun, 2013:69)

A Computer Aided Design (CAD) system overlays and transforms the appearance of the pattern onto the virtual model shape, thereafter, garment fit and pattern errors such as design elements, material selection and assembly technique are checked in order to refine the initial 2D pattern pieces (Sayem and Bednall, 2017:1). Garment manufacturers can easily experiment with a variety of fabrics and patterns on a 3D virtual model prior to manufacturing the actual, final garment (Apeagyei & Otieno, 2007:350). 3D full body scans can be utilised for reproducing a 3D virtual fit model to evaluate acceptable garment fit for the targeted consumer (Sohn & Sun, 2013:67; Apeagyei & Otieno, 2007:351). Figure 2.15 shows an image of a 3D body scan transformed into a virtual fit model for garment fit test evaluations.

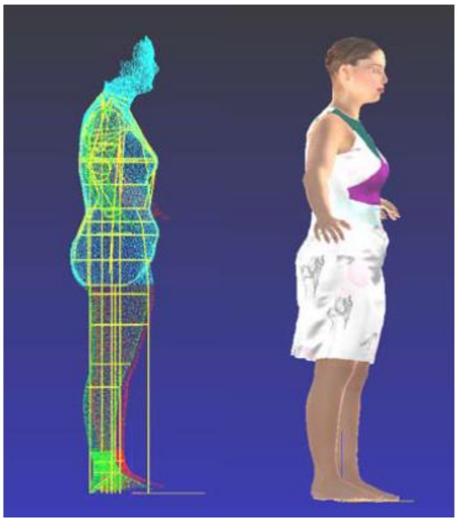


Figure 2.15: 3D body scan transformed into a virtual fit model for fit test evaluations (Apeagyei, 2010:63)

According to Sohn and Sun (2013:67-68) currently, there are discussions on the consistency and validity of virtual fit analysis for fit testing using 3D simulation technology as the application of both 2D and 3D garment images on virtual models entails accurate knowledge. The process requires sensitive detection of 3D full body scan data and garment fabric drape to successfully test the fit of the garment on a virtual model. However, visual presentation and analysis of the garment's fabric drape simulation, including the garment grain, set, line, balance, and ease using virtual 3D technology is considered to not be enough (often wrinkles on the garment are not properly simulated) to ensure that the fit of the garment on a virtual fit model provides accurate, satisfactory results. The appearance of a virtual model can significantly differ from that of a real human model (Kim & LaBat, 2013:172; Sohn & Sun, 2013:67; Apeagyei & Otieno, 2007:349,350). Additionally, virtual dressing rooms with modified, animated avatars are currently introduced in selected retail stores where customers are able to virtually try-on certain garments and preview the fit and appearance on a realistic 3D simulated image of the garment on their 3D virtual model before purchasing. Nonetheless, 3D virtual simulation technology is yet to be fully explored and made widely available in the fashion industry (Apeagyei 2010:66; Kim & LaBat, 2013:172).

In the next section garment sizing systems and size charts are defined and the researcher conceptualises garment sizing systems as a contributing factor to fit, together with factors that influence the development of sizing systems.

2.8 GARMENT SIZING SYSTEMS

2.8.1 Garment sizing Systems, body measurements and size charts

Sizing systems are described with terms such as, sizing standards, size charts or size specifications (LaBat, 2007:88). According to Petrova (2007:65), gaining a better insight into a targeted population's anthropometric information is a common starting point for establishing a sizing system. Petrova (2007:65) defines a sizing system as a set of pre- determined garment measurements divided into standardised size ranges with fixed intervals between sizes that is represented by a targeted population's anthropometric data. A sizing system may refer to different types of size charts. LaBat (2007:88) suggests that a sizing system consists of a series of size charts with each size chart calculated to serve garment sizing requirements for various body dimensions within a population. Schofield *et al.'s* (2005) study reiterate that key body dimensions and garment pattern grading size intervals need to be used in sizing systems to facilitate the establishment of size charts. Petrova (2007:57), Taylor (2014), and Aldrich (2015:8-12) define a size chart as a table presenting data consisting of body measurements established for a range of garment sizes that differ in sizes based on the manufacturer, (see Table 2.1).

Table 2.1: Petite size chart from size 6/32, representing the minimum size measurement to 20/46, representing the maximum size measurement adapted from *BurdaStyle* (n.d).

WOMEN'S SIZE CHART (*Petite*) centimeters								
BURDA SIZE	16	17	19	19	20	21	22	23
US SIZE	0	2	4	6	8	10	12	14
EUROPEAN SIZE	32	34	36	38	40	42	44	46
HEIGHT	160	160	160	160	160	160	160	160
BUST	76	80	84	88	92	96	100	104
WAIST	58	62	66	70	74	78	82	86
HIP	82	86	90	94	98	102	106	110
BACK LENGTH	38	38.5	39	39.5	40	40.5	41	415
SLEEVE LENGTH	57	57	57	58	58	59	59	59
NECK WIDTH	33	34	35	36	37	38	39	40
SIDE LEG WIDTH	97	98	98	99	100	100	101	101
FRONT WAIST LENGTH	40	41	42	43	44	45	46	47
BUST POINT	23	24	25	26	27	28	29	30
UPPER ARM CIRUMFERENCE	25	26	27	28	29	30	31	32

Size charts are devised using a range of garment sizes, taken from the primary and secondary key body measurements to ensure a consistent fit in the garment sizes developed for a fashion production (Gupta, 2014:55). A size chart is made up of different elements such as those indicated in Figure 2.16 by Pandarum and Yu (2015:193). The size-chart is for a women's trouser showing the waist girth measurements and inseam length measurements for a 161 cm body height, the garment sizes range from 10 to 14.

Women's trousers (a)

Size (b) Based on body height – 161 cm	10	12	14
Waist – (cm) (c)	74	80	86
Inseam – (cm)	73	74	73

Figure 2.16: A women's trouser size chart (Adapted from Pandarum and Yu, 2015:193)

Size charts are usually created by using average measurements for different garment size ranges, developed to fit various body dimensions in a population or target market (Vithanage *et al.,* 2015:482). Vithanage *et al.* (2012:30) and Zakaria (2014:95) emphasise that it is important to identify the target population for every country and to develop an associated sizing system using measurements that will improve garment sizing and fit, increasing customer satisfaction.

2.8.2 Developing sizing systems

Female consumers are said to be the least satisfied with how garments drape and fit the shape and size of their bodies (Locker *et al.,* 2005:12; Pisut & Cornell, 2007:375). Body measurements used to manufacture ready-to-wear garments in the apparel industry do not cater for most of the female consumers (Vuruskan & Bulgun, 2011:46-47; Whitney, 2011:3; *Alterations Needed*, 2010; Kasambala, 2013:3). Vithanage *et al.* (2012:30;59), Ka Wai YIP (2013:10), and Zakaria (2014:95) suggest that it is important to identify target population's anthropometric measurements and classify body shapes (Mastamet-Mason, 2008:224) for every country to develop its own sizing system to improve sizing fit and increase customer satisfaction. Identifying the correct body measurements for individuals in a target population for the development of a sizing system makes it easier for manufacturers to produce garments that fit well (Rasband & Liechty, 2006:4; Loker, 2007:256).

This may assist garment manufacturers in developing ready-to-wear garments in sizes that will not only complement consumers' body statures but also minimise their frustrations with garment sizing and fit (Rasband & Liechty, 2006:4; Strydom, 2006:60; Loker 2007:256; Williams, 2007).

2.8.2.1 Developing sizing systems using collected data from 3D full body scanners

The use of a 3D full body scanner in garment manufacturing is still to be widely recognised and adopted in South Africa, although internationally the technology continues to contribute to clothing sizing and fit theory and a better understanding of human body measurement, size, shape and body categorisation (Apeagyei, 2010:58). According to Yu (2004:164) and Pandarum and Yu (2015:187), 3D full body scanners have been used in garment sizing and fit studies since the 1980s, to facilitate and extract consistent, accurate, repeatable and non-intrusive body measurements of individuals in a short period of time where privacy is highly emphasised, since there is no physical contact between the operator and the subject being scanned (Pandarum, 2009:4; Kouchi, 2014:67).

3D full body scanners are also said to be rapidly replacing traditional anthropometry, developed as potential fit facilitators for varied body sizes and provide efficient approaches for a broader scope of outlying data (Apeagyei 2010:58). Connell *et al*. (2006:81) and Alexander *et al*. (2005:53) mention that 3D full body scanners provide a means of capturing and analysing data scientifically with the aim of developing patterns, which creates a direct link between the recorded data and the development of designing patterns and garment construction (Petrova & Ashdown, 2008:228). Thereby retailers and manufacturers can focus more on improving mass produced and customised garments (Petrova & Ashdown, 2008:227-228; Ka Wai YIP, 2013:13-14).

Yu (2004:136-142) mentions that Japan was the first country to capture anthropometric data using 2D and 3D profiles in the 1980’s in Asia, followed by Hong Kong’s University of Science and Technology in 1998; and the Industrial Technology Research Institute in 2000 in Taiwan. Yu (2004:143-145) further adds that in America, body scanner development started in early 1964, but was not popular until 1985. Cyberware was the first company to revolutionise laser scanning in the middle of the1980s, and thereafter announced the use of 3D body scanners for body shape analysis in 1995. $(TC)^2$ introduced their first commercial 3D body scanner in the apparel industry in 1998. In the U.K. the Loughborough Anthropometric Shadow Scanner (LASS) was developed in 1987 and the U.K. Defence Clothing and Textile Agency (DCTA) introduced an Auto-mate 3D measuring system in 1996, Wicks and Wilson also developed a TriForm scanning system in 1996. In France, the SYMCAD™ automated body scanner was established by Telmat Industrie in 1995. Germany introduced a Tecmath ergonomic human stimulation scanner in 1995 which provided Vitus 2D and 3D scanners. Body scanners use different light methods to scan a subject and different systems to extract the scanned data for the subject.

There are different 3D body scanning systems currently in use in the apparel industry; to name a few, the Human Solutions (e.g. Virtus Smart XXL) measures a height range of 210 cm, width of 100 cm and 120 cm depth in approximately 10 seconds, using eight laser sensor heads and an optical triangulation laser method (*Human Solutions*, 2015). Cyberware (e.g. Model WBX) extracts over 100 body measurements in a time frame of 17 seconds. High-speed 3D measurements are collected every 2 mm, using four scan heads to ensure the accuracy of the 3D head data set from head to toe (Cyberware, 2011). Wicks and Wilson (TriForm™/TriBody) uses invisible, harmless white light stripes and eight camera views to capture 3D scans in about 12 seconds. Images generated from the 3D scans are automatically analysed by the TriBody software, which is thereafter processed into a 3D cloud model containing about 15 million 3D co-ordinates that can be saved into various output formats (Apeagyei, 2010:60; The Edinburgh Virtual Environmental Centre, nd). Telmat (SYMCAD™) consists of Telmat’s turbo flash/3D system which uses structured light to measure and develop an anthropometric database; and projecting white light stripes to capture data. Full body measurements are captured in 0.5 seconds (Apeagyei, 2010:60; Telmat Industrie, 2015).

The CAESAR survey was conducted from 1998-2001, scanning male and female subjects from 18-65 years age. The UK Department of Trade and national sizing survey conducted in 2001-2002, used a (TC)² body scanner and discovered that body shapes have changed from earlier identifications. The Size UK further carried out a sizing survey in 2009 on 11,000 males and females from different parts of Britain with the aim of identifying current body size and shape differences among various populations (Apeagyei, 2010:58-59). The Size USA research collected anthropometric data for more than 10,000 men and women aged from 18 and above in 2003, using a (TC)² 3D body scanner. Levi's, a denim apparel brand, studied 60,000 3D body scans of consumers worldwide, to identify and resolve their denim fit problems (Manuel, 2009:26-27; Rzepka, 2011:2-3).

In South Africa, Pandarum and Yu (2015:195), state that limited, but focused and generic studies have been conducted in South Africa since 2004, using the (TC)² NX12 and (TC)² NX16 body scanners. In 2006, Pandarum conducted a study comprising of 12-year-old girls, their body measurements were compared to retail bought school-grey uniforms. In 2009, a plus-sized women study on bra sizing and fit was conducted with a local bra manufacturer, and Pandarum is currently conducting a woman sizing and fit study of 1300 women (Pandarum, 2017).

However, the only known retailer initiated studies that collected anthropometric data for the petite women market on a large scale are those of Edgars in 2003 and Woolworths in 2014. Although, Edgars did not use a 3D full body scanner to collect the body measurements, traditional anthropometry was used to collect the data to accommodate the South African consumers within the petite clothing size range; amongst others, is the Edcon Group. These garments in their stores are labelled, e.g. "*petite 6*", yet there are still large numbers of displeased petite consumers (*National Textile brief*, 2007). The number of women sampled for the Edgars study is unknown and the anthropometric data is propriety to the retailer, it is thus not available for comparison in this study. In 2014, Woolworths, a South African retailer, commissioned Avalon, an American mannequin manufacturer to collect 3D data using a SYMCAD™ body scanner. The Woolworths study is reported to have scanned a sample of 4000 men and women in their retail stores; however, the results of this initiative have not been published (Woolworths Holdings Limited, 2014) and the ratio of the number of men to women scanned is unknown. These are the only two known studies to date carried out on a large scale in South Africa and none of these studies were specifically focused on petite women and the data collected is propriety to the retailer.

2.8.3 Classifying the anthropometric data into different body shapes based on key body dimensions when developing sizing systems

The success of every sizing system is based on allocating the anthropometric data of a population into different body shape classifications that are established by relationships between body dimensions (Schofield & LaBat, 2005a:17; Strydom, 2006:60; Rasband & Liechty, 2006:4; Loker, 2007:256; Mastamet-Mason, 2008:224; Muthambi *et al*., 2015:63). Key body dimensions are used to divide the population's body measurements (Petrova, 2007:63; Strydom & De Klerk, 2006:81). A key body dimension is the body measurement that has a strong relationship with most other body dimensions and is one that is important in garment manufacturing (Petrova, 2007:63). Such measurements include the bust measurement for the upper body, the waist measurement for both the upper and lower body and the hip measurement for the lower body. Muthambi *et al.* (2015:63) and Petrova (2007:66) further state that key body dimensions define the population's body shapes and should be carefully selected to represent realistic body measurements that will assist garment manufacturers in establishing effective sizing systems and provide a better fit in manufactured garments.

In a sizing system, when developing size charts, the body measurements are divided into different categories to evaluate the proportions and dimensions requirement for each body shape (Schofield & LaBat, 2005a:17). The SABS published a garment measurement standard in 2012, SANS 8559, with the aim of classifying body measurements for pattern and garment manufacturing. Despite the SABS endorsing the SANS 8559 pattern and garment sizing measurements five years ago, there are still garment fit problems among consumers, as these standards are voluntary, and hence the South African clothing retail and manufacturing sectors are not obliged to use this (Pandarum, 2017). Mgwali (2014) claims that garment fit problems among consumers still occur as retailers and manufacturers are not monitored on how they size their garments because the majority of retailers and manufacturers use their own size charts to label garments. This shows that there is a need for updated current data and for developing sizing systems to fit various body shapes and sizes in the female population including South African petite females.

2.8.4 Establishing the size ranges for a sizing system

Establishing the size ranges for a sizing system is usually conducted after selecting key body dimensions and identifying the body shapes required for the development of the sizing system (Petrova, 2007:72). LaBat (2007:88) states that sizing systems are used to classify body shapes and segmenting their classified data into size measurements for garment production with the aim of providing consistent and clear garment sizing and labelling that will fit many consumers. Therefore, gaining a better insight on a targeted population’s anthropometric information is a common starting direction for establishing size ranges for sizing systems (Petrova, 2007:65).

According to Petrova (2007:64), sizing systems only consist of size ranges that are predetermined to fit a collectively populated target market and generally sizing systems cater for 65% to 85% of the targeted population. This is determined by the apparel industry that garments manufactured from the above-mentioned percentage coverage have a potential of facilitating a good fit for majority of individuals in that particular garment size group, minimising possible outliers that might distort the sizing system. Petrova (2007:57) further suggests that a sizing system that has more size groups indicates that each group will have a small number of individuals who will be similar to one another in body measurements.

A population’s size range is established by maximum and minimum values of the key body dimensions, including the size interval which is the measurement difference between two adjacent sizes (Petrova, 2007:64). The number of sizes in a sizing system is defined by the value of the size intervals (Chan, 2014:188) together with the required size ranges that will accommodate the population (Petrova, 2007:72).

2.8.5 The relationship between body measurements in sizing systems

Sizing systems usually use averages (Strydom & De Klerk, 2010:75-76; Chan, 2014:181) but other models such as regression analysis when calculating the relationship between body measurements (Maree, 2007:240; Shin & Istook, 2007:137) are also used to generate sizing systems. Maree (2007:240) and Shin and Istook (2007:137) refer to regression analysis as a statistical method commonly used to estimate body measurements from one size to the next size by examining the relationships between variables. Chan (2014:180-181) suggests that regression lines use identified key body dimension values to determine appropriate size intervals in a sizing system. A sizing sample is used as a base that represents body measurements of all the full sizes where prototype size ranges are developed. Patterns for the prototype size ranges are derived from a master pattern block through pattern grading (Keiser & Garner, 2008: 356,372).

2.8.6 Garment sizing systems as a contributing factor to fit

Garment sizes are currently identified by labels on ready-to-wear garments that are supposed to correspond to the measurements of a particular body size (Kinley, 2010:401). Variability in the methods used to designate garment sizes are believed to be one of the many factors that influence consumer dissatisfaction with garment fit (Barona-McRoberts, 2005:2). Manufacturers are usually uncertain as to the number of size ranges to divide the population in. A sizing system that is divided into more size ranges may result in a small number of individuals with similar body measurements within each group. Dividing the size ranges in large numbers may result in garment fit dissatisfaction and confusion. Conversely, an insufficient size range group will result in many body measurement variations which may affect the quality of fit for most of the individuals classified in that group (Petrova, 2007:57-59).

According to Alexander *et al.* (2005:56), Pisut and Connell (2007:368), and Otieno (2008:68), most garment manufacturers and retailers today use their own sizing standards, which may include vanity sizing to manufacture garments as a form of a market differentiation tool or advantage. This means that garments indicating the same size do not necessarily imply the same body and garment measurements in each store (Loker *et al.,* 2005:2; Pisut & Connell, 2007:368). Manufacturers and retailers are said to constantly try to flatter consumers by creating smaller sizing labels for garments instead of providing the actual size of the garment (LaBat, 2007:91). Garment manufacturers constantly change sizing measurements (Lee, 2005:27) into smaller size labels (Alexander *et al.,* 2005:56; Pisut & Connell, 2007:368) for example, the use of size 10 measurements and labelling the garment as a size 8 (Liechty *et al.,* 2010:45-46). Consequently, the consistency of fit among the assortment of apparel sizing systems is compromised (Shin, 2013:1).

The consumers' concern is that retailers offer a limited collection of fluctuating, inconsistent and unpredictable garment sizes that differ in fit from store to store (Lee, 2005:25; Salusso *et al.,* 2006:98). Consumers are therefore bound to come across different sizes of garments that are labelled with similar size numbers or *vice versa* (Loker *et al.,* 2005:2; LaBat, 2007:91; Pisut & Connell, 2007:368). This results in consumer dissatisfaction with the fit of the garment on their bodies (Petrova & Ashdown, 2008:230). Furthermore, consumers invariably must go through the process of trying on a number of garments before finding a garment that fits reasonably well (Strydom, 2006:4; Kasambala, 2013:6). Doshi (2006:1) argues that garment manufacturers are said to focus too much attention on the appearance of a garment with less emphasis on its sizing and fit. Consequently, this results in customer dissatisfaction while shopping for clothes (Petrova & Ashdown, 2008:230).

2.8.7 Communication of garment sizing systems

The communication of female garment sizing information has changed over time in the ready-to-wear apparel industry. The success of every sizing system depends on how it is communicated to the consumers. The sizing system must be clearly explained so that consumers can easily understand them and easily select the correct garment sizes (Kinley, 2010:401). Ashdown *et al.* (2005:2) suggest that creating sizing systems based on the actual target population's anthropometric data permits better fitting garments. Lee (2005:29) and Chun (2007:220-221) state that size label communication is important when it comes to garment fit and garment manufacturers should appropriately communicate sizing systems and size garments in accordance with the targeted population to meet their market needs and help consumers to select well-fitting garments.

Key body dimensions are often used when communicating garment sizing systems because garment size labels mainly consist of key body dimensions. However, the key body dimensions used on the size label do not solve the problem related to garment fit. Unless consumers know how, and are able to take their own body measurements accurately, they will not be able to select the correct garment size (Faust & Carrier, 2010:120). The average consumer has very little knowledge on how to evaluate their body dimensions against the key body dimensions that are listed in size labels such as the bust, waist and hip measurements (Howarton & Lee, 2010:221). Petrova (2007:63) states that, without having knowledge of key body dimensions and how to evaluate them against garment sizing measurements; it becomes a challenge for consumers to select garments that fit well from different brands in retail stores because garment sizing standards vary from manufacturer to manufacturer. At times, size variations within the same manufacturers are not directly communicated to the consumers (Kinley, 2010:401).

Chun (2007:223) suggests that selecting the correct garment size can only be effective if the sizing systems are easy to understand and at the same time constructed using the correct methods. Garment sizes for women were initially considered in the USA based on the target markets age or body measurements (Chun, 2007:224). Women's apparel is divided in a widespread variety of garment shapes, styles and a much broader variation in how different garment styles are designed to fit their bodies. This could be another attribute that confuses female consumers, as manufacturers rarely include information on different fit and style characteristics that may help female consumers with sizing choice when purchasing their garments. Therefore, different garment styles may also have different sizing and size labels (Faust & Carrier, 2010:120).

The fundamental objective of every garment manufacturer is to produce garments in correct sizing labels to prevent garment returns and sale loss (Petrova, 2007:57). Effective communication of sizing and fit on labels is essential for consumers to select garments that fit well and for the apparel industry to improve their reputation and sales of producing satisfactory fitting garments. According to Chun (2007:235), sizing labels with incorrect information communicated on the garments results in consumers wasting their time and add extra expense caused by the cost of transport when returning the purchased garment.

Garment sizes are labelled in either “words” or by numbers, such as extra small, small, medium and large or size 8 and size 10, etc. (Townsel, 2005:1). Chun (2007:224) adds that garment labels usually contain numbers, alphabetical letters or words with numerical relations to key body measurements. The South African apparel industries allocate inches and centimetres to their garment sizes. They, along with several countries, also use terms such as (small, medium and large), codes (XS (extra small), S (small), M (medium), L (large), XL (extra-large) and XXL (extra, extra-large) or numbers (8, 10, 12, 14, etc.) and pictograms (see Figure 2.17) which consist of a sketch of the human body with specified body measurements for sizing the fit of the garment (Chun, 2007:227; Zakaria & Gupta, 2014:30) and thereby differentiate their garments sizes (Van Huyssteen, 2006:2625). Nonetheless, the use of a pictogram for labelling the size of a garment has not yet been adopted by the South African’s clothing retailers (Kasambala, 2013:50), even though South Africa has published a national standard titled SANS 1360-2 (2008). Nonetheless, the industry use is voluntary (Pandarum, 2017).

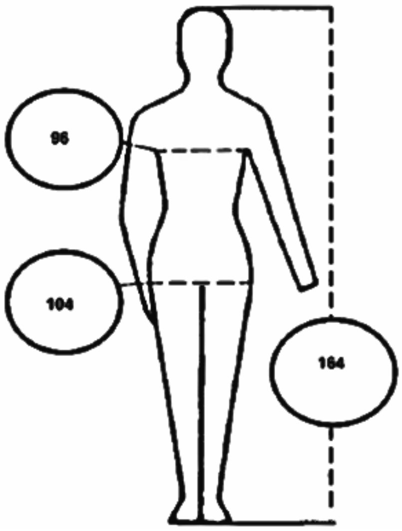


Figure 2.17: A pictogram size description illustration for a female's sizing labelling (Adapted from SANS 1360-2, 2008).

The use of symbols in conjunction with the key body dimensions in centimetres is recommended by the International Standardisation Organisation (ISO) to provide consumers with a quick communication of the body measurements for which the garment was designed for (Chun, 2007:227). Lee (2005:29) further suggests that sizing garments in number, letter or word size codes does not reflect body dimensions and is confusing to consumers and does not easily assist them in finding ready-to-wear garments that fit well in retail stores. As a result, consumers have to try on several garments before finding a garment that fits well and comfortably.

The increase in the internationally traded imports and exports of clothing contributes to the challenges of communicating the size dimensions of garments. The ISO developed an anthropometric size labelling system in 1991, based on communicating the key body dimensions (Chun, 2007:227). Thereafter, the ISO established a size labelling system in conjunction with several countries such as Russia, Australia, China and India with the purpose of co-ordinating international sizing standards so that the mentioned countries could attempt to include international standards in their national standards (Aldrich, 2007:46).

The purpose of sizing labels is to provide body measurements information as garment size communication from manufacturers to enable consumers to make better purchasing decisions in selecting ready-to-wear garments that would provide them with a satisfactory fit (Chun, 2007:220). However, the establishment of communicating satisfactory size labels to consumers is yet to be successful as Chun (2007:220) further states that current size labels used on women's ready-to-wear garments sold internationally, including South Africa, lack adequate information on basic body measurements to guide consumers in choosing proper garment sizes. According to Petrova and Ashdown (2008:230), size labels attached on garments provide little information and do not communicate as to the body dimensions that pertain to a specific garment. Kasambala's (2013:194) study on female consumers' perceptions of garment fit in South Africa revealed that South African female consumers' perceptions on the sizes of ready-to-wear garments sold in South African retail stores were inconsistent (21%) and unreliable with limited stock (16%). Only a few of the participants thought that the size labels used on garments were "*inaccurate*" (8%) and 15% of the sample expressed that the garment sizes was reasonable. However, the study was not focused on garment label sizing for petite women.

2.9 READY-TO-WEAR GARMENTS

According to Keiser and Garner (2003:93), and Zakaria and Gupta (2014:3), ready-to-wear garments are mass-produced in predetermined sizes and large quantities, designed with the purpose of being sold in stores, to be worn without alterations. Zakaria and Gupta (2014) further state that ready-to-wear garments became popular in the 1940s and were sold in retail stores as the customer demand increased. However, there were often fit problems because of the various body shape distinctions and therefore, the need for predetermined sizing systems for manufacturing ready-to-wear garments in the apparel industry was established using the most common size category for the average consumer.

Chun (2007:220) suggests that obtaining a good fit in ready-to-wear garments requires an appropriate sizing system and effective pattern making using the correct body measurements for the targeted consumer. Petite women were not catered for in the apparel industry until 1977 but due to the increase of demand for petite ready-to-wear garments; there is growth in opportunities for garment manufacturers to cater for petite women. Additionally, manufacturer's still face challenges in providing proper fitting ready-to-wear garments as female body shapes vary (Frings, 2014:80).

2.10 PETITE WOMEN'S GARMENT CATEGORISATION

According to Kam (2006), it is not easy to categorise petite women's garments in small, medium or large garment sizes, which makes it a difficult market to sell into when it comes petite garment label sizing. Petite garment label sizes can vary from a size 2 to 22 (Rayner, 1997:1), size 2 to 16 (Williams, 2007) or up to a size 18 (Bello, 1994), with Taylor's (2014) garment sizes alternating from a size 00p to16p, where the "p" indicates petite.

Everyone's body height, frame, proportion, contour and posture differ and as a result present challenges for petite women when they have to purchase ready-to-wear garments in retail stores (Chen, 2011:308-309). Rayner (1997:1) and Trulypetite (2007) suggest that petite garments focus on definite reductions in sizing and are specifically created with an emphasis on a height measurement that is 163 cm and shorter with a shorter trouser rise, taking into consideration their small body frames. Furthermore, Kgarza (2013) mentions that petite women should choose garments that are more fitted rather than a loose fit and should consist of small fabric prints so that the garments do not overpower their body structure. Nonetheless, a possible reason for petite consumers not being satisfied with their ready-to-wear garments, according to Liu (2011), is that many garment manufacturers do not have a clear understanding on how to categorise petite women's bodies.

2.11 PATTERN DRAFTING IN THE INDUSTRY

It is widely acknowledged in the apparel industry that the quality of pattern construction depends largely on skilled and experienced pattern makers to guarantee a satisfactory fit in garments (Smit, 2007:172; Sayem, 2012:22; Narang, 2014:6-7). According to Schofield *et al.* (2006:149, 159), pattern drafting standards are usually assumed as measurements for fit models and for representing body outlines for each size range to permit a perfect fit in garments. Drafting is a method of pattern construction based upon the systematic layout of measurements taken directly from the studied population’s body measurements (Narang, 2014:38).

Patterns are traditionally drafted using standard linear surface measurements that represent body measurement girths, lengths and sizes that correspond to an average body shape and are then graded into smaller or larger measurements to fit other desired garment sizes (Sayem, 2012:22). Aldrich (2015:13) states that patterns are graded differently from company to company based on their target markets. The apparel industry usually uses experiential procedures for making patterns and developing pattern samples which involves expensive and time-consuming methods (Narang, 2014:9).

The foundation of traditional pattern making is in the basic block pattern which is a master template used to provide appropriate garment fit (Narang, 2014:13; Lira & Munmun, 2015:886). The apparel industry refers to basic pattern blocks as the shape and form of a specific garment represented by a series of drafted lines on a flat pattern paper (Narang, 2014:33). A basic pattern block consists of the front and back half measurements of a specific body form or silhouette and it is developed without any design features; such a pattern block is used by the apparel manufacturing companies to produce ready-to-wear garments on a large scale (Iloeje & Anyakoh, 2010:24). Iloeje and Anyakoh (2010:24) further state that pattern blocks are used for manufacturing garments in the apparel industry where each block varies in the construction method and style. The first patterns are usually drafted as basic pattern blocks to be used as a foundation for developing other prototypical and stylised patterns.

The methods of pattern making in the apparel industry are classified as either two-dimensional patternmaking or three-dimensional patternmaking. The two-dimensional patternmaking methods consist of pattern drafting and flat pattern making by manipulating basic pattern blocks to fit the desired body or garment measurements. The three-dimensional patternmaking methods consist of draping the fabric directly on a dress form. Both the two-dimensional and three-dimensional patternmaking methods are commonly used by fashion designers, patternmakers in the industry and faculties in the fashion education fields (Narang, 2014:35-37).

This study focused on two-dimensional pattern drafting methods. The two-dimensional patternmaking method is the most popular method for industrial pattern makers as it is an efficient and logical technique to produce patterns for mass production because it is easy to understand (Narang, 2014:33, 37).

The pattern production is the technique of working with two-dimensional standards (viz. pattern paper) to develop pattern blocks (using either body or garment measurements) which will assist in making garments for a three-dimensional body to achieve the desired fit with the best possible utilisation of resources (Anand, 2011:358). According to Liechty *et al. (*2010:11-12) and Aldrich (2015:13), basic pattern blocks are two-dimensional template outlines of garment pieces drafted on a paperboard or cardboard that can be traced onto a fabric, cut out and assembled. Aldrich (2004) further states that two-dimensional patterns are effective for creating garment styles; the patterns are shaped on the pattern paper to represent the desired garment style. The final drafted pattern is transferred onto a calico fabric and joined together to form three-dimensional garments. Thereafter, the quality of the fit of the constructed garment is checked on a selected mannequin or a human model's body size and shape before manufacturing the actual garment on a fabric intended for manufacturing the final garment (Tama & Öndoğan, 2014:110; Lira & Munmun, 2015:888). This is done to correct and confirm the measurements and to test the quality of the garment fit obtained from the drafted patterns (Sayem, 2012:22). Nonetheless, the apparel industry uses different pattern drafting methods to develop their garments which are established according to every country's anthropometric data. Therefore, it is essential to identify individuals' body dimensions and shapes among their country's population (Tama & Öndoğan, 2014:108).

According to Joseph-Armstrong (2014:71), basic pattern blocks are usually drafted without seam allowances, but the pattern blocks consist of darts that are partially cut-out and punched with holes at the end of each dart to permit tracing precision when manipulating the pattern to a desired garment style. The final manipulated pattern pieces contain information such as seam allowance, grain line, garment size, balance marks and decorative placements such as buttons, zips and pockets that are stitched together to produce a sample garment (Narang, 2014:33). Narang (2014:13) further states that the final manipulated pattern blocks have seamlines and darts to make the pattern blocks fit well and flow with the curves of the body silhouette. Seamlines and dart lines represent structural interior lines used in most garments and they influence the silhouette of the garment (Liechty *et al.*, 2010:20-21). Fundamental horizontal seamlines are commonly positioned at the upper part of the garment's shoulder and midriff body area, whilst the lower garment's horizontal seamlines are positioned at the waist and hip area depending on the design of the garment. In upper garments such as shirts, dart lines should be positioned in the chest area and directed towards the bust and abdomen body protrusion whilst dart lines in lower garments such as trousers, should be positioned in the waistline area and directed toward the buttocks area. This is done to provide better fitting garments with dart lines that fall softly on the wearer's body (Liechty *et al*., 2010:20-21; Narang, 2014:33).

Basic shirt garments are mostly constructed from basic bodice pattern blocks, and then adapted according to the designer's desired style. Kass (2011:6-7) defines a bodice as an upper garment constructed with or without sleeves. Basic bodice pattern blocks consist of a form body block with bust darts to permit a balanced garment drape on the body and a sleeve block (see Figure 2.18 and Figure 2.19). A basic bodice block is usually manufactured in fabrics that have a minimal stretch.

A bodice block consists of curves in the neckline and armhole areas; the bust area is full, and it hollows at the waistline. Sleeve patterns are constructed to fit the bodice armhole; the grain line should be aligned to provide a well-fitted sleeve that hangs straight from the armhole to a required level on the arm (Joseph-Armstrong, 2014:45, 61).

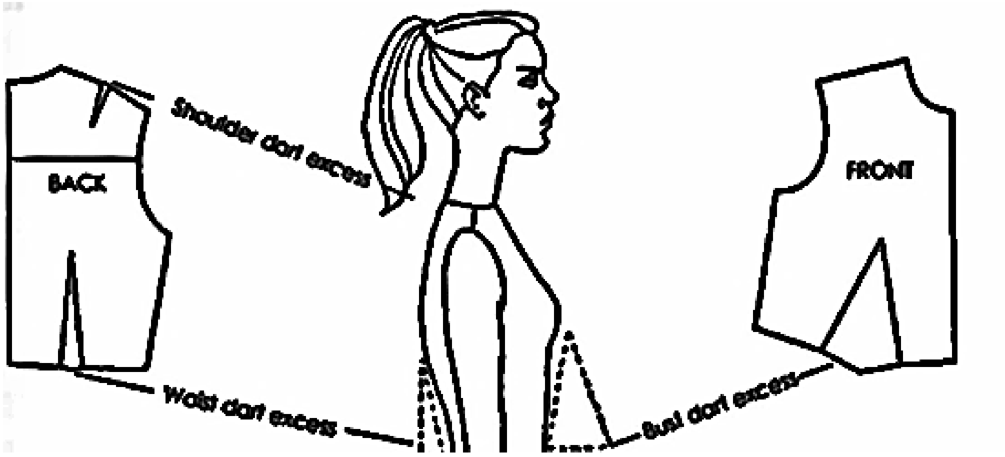


Figure 2.18: Examples of a basic bodice front and back pattern blocks (Adapted from Joseph-Armstrong, 2014:45).

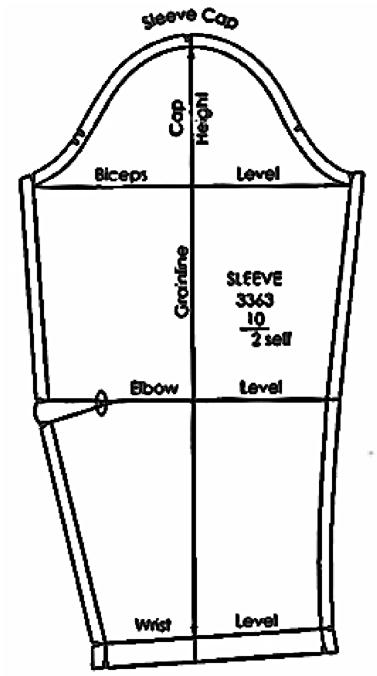


Figure 2.19: An illustration of a basic sleeve pattern block (Adapted from Joseph-Armstrong, 2014:61).

Pattern making for trousers vary in measurements, fit and styles. The pattern design specifications are guided by trends such as the positioning of the waistband and the type of fabric used to develop the garment (Aldrich, 2015:13, 61). Key locations for constructing trouser patterns include the waist area, hip, crotch depth, around the knee and around the ankle (Joseph-Armstrong, 2014:667). Additionally, Veblen (2012:194) suggests that when drafting trouser patterns, the curve of the crotch should reflect the shape of a realistic figure crotch shape, pelvic structure, abdomen and buttocks (see Figure 2.20).

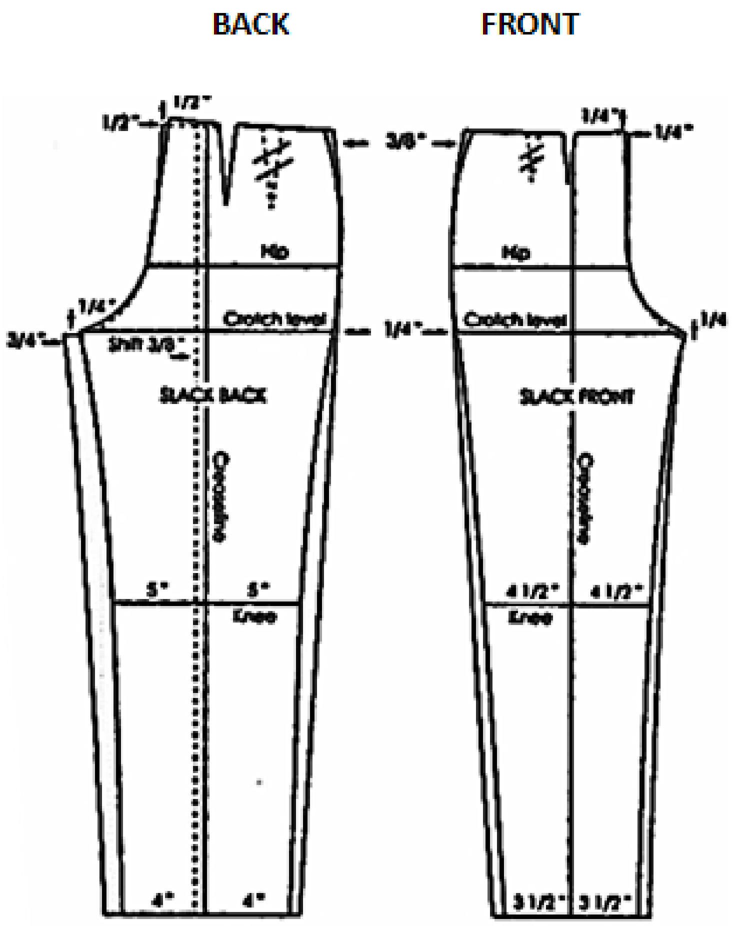


Figure 2.20: Illustrations of back and front basic trouser pattern blocks (Adapted from Joseph-Armstrong 2014:671).

2.11.1 Pattern grading

Pattern grading is a systematic process of increasing and decreasing size ranges within a master pattern (Mullet *et al*., 2009:1). This process is mainly used in the apparel industry to measure the difference between size ranges, since it reduces product development costs and saves time; otherwise, each size range would have to be developed and tested separately. Schofield and LaBat (2005b:135-136), Gupta (2014:58), and Aldrich (2015:208-209) refer to pattern grading as scaling a master pattern by increasing and decreasing the pattern block at the cardinal points to create the next size (see Figure 2.21).

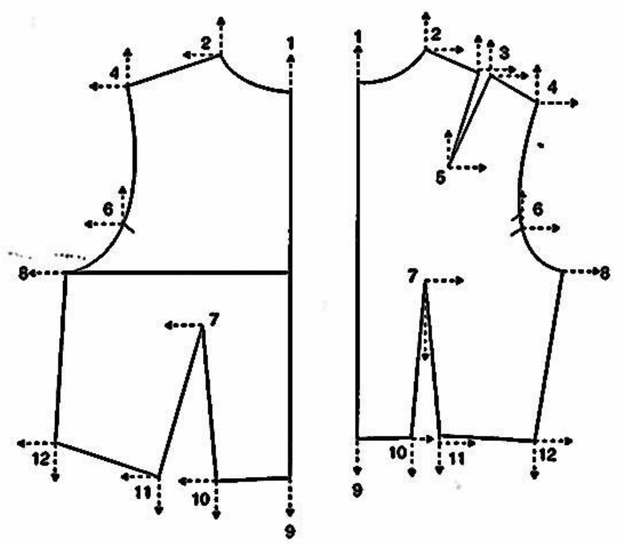


Figure 2.21: Examples of grading cardinal points on a basic master bodice (back and front) pattern blocks (Adapted from Gupta 2014:59).

To achieve a reasonable garment fit, accurate body shapes and size measurements should be used when drafting and grading patterns, in order to produce garments with similar body shapes and size measurements as that of the targeted population. According to Mullet *et al.* (2009:6-10), the apparel industry uses two different grading systems to grade patterns, namely, the two-dimensional grading system and the three-dimensional grading system. Two-dimensional grading systems are used by most ready-to-wear garment manufacturers since they are simple, easy to use and learn, but rely on assumptions of equally changing sizes in the front and back bodies by following corresponding grade rules to grade a pattern block up and down (see Figure 2.22) (Aldrich, 2015:208-209; Gupta, 2014:58; Schofield & LaBat, 2005b:135-136). The standard pattern measurements are increased and decreased with consideration given to the grade length, circumference and width of the desired garment size (Joseph-Armstrong, 2014:15).

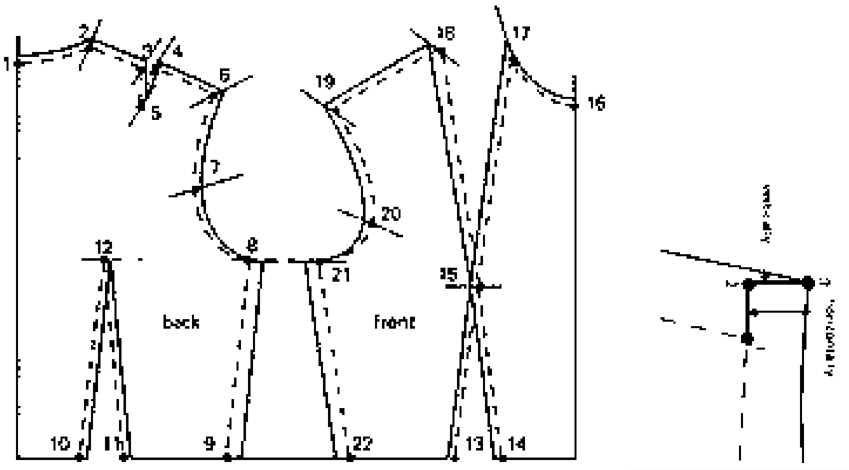


Figure 2.22: Back and front bodice block patterns graded one size up (Adapted from Aldrich 2015:208).

In a two-dimensional grading system, the total circumference grade is graded in half using half of the same measurements for the front and back pattern blocks to permit easy grading. Conversely three-dimensional grading systems are more complex; therefore, they are not commonly used in the ready-to-wear garment manufacturing industry. Additionally, three-dimensional grading systems use arch measurements to distribute throughout the total of the circumference grade without having to split the back and front patterns (Mullet *et al.*, 2009:6-10). Mullet *et al.* (2009) further suggest that a two-dimensional pattern grading is suitable for developing a limited size range; the total circumference grade is graded in half using half of the same measurements for the front and back pattern blocks.

Pattern grading is common practice in the apparel industry, many manufacturing companies, especially in the petite garment manufacturing sector, design petite garments by simply scaling down or shortening regular sizes by means of adapting the “average” women’s measurements to fit petite women (Rayner, 1997:1; Liu, 2011). Keiser and Garner (2008:374) state that pattern grading differs according to the size measurements that will accommodate size to size distinctions in the required length, width and circumference which consist of the grades of various body girths such as the bust, waist and hip measurements. According to Mullet *et al.* (2009:15), the value of the circumference grade differs per country and manufacturer, although the grade value assumptions are similar.

There is not much difference in grade lengths because adult vertical length measurements do not change as much as their horizontal measurements. Horizontal measurements changes in body weight in adulthood, whilst the vertical measurements remain constant in height (Mullet *et al.,* 2009:17). The patterns developed in this petite sizing and fit study focused on one size range where grading was not necessary, but half patterns were used for drafting the front and back of each shirt and trouser pattern blocks; as this is a commonly used pattern block drafting method in the apparel industry (Iloeje & Anyakoh, 2010:24).

Further information on the method of the procedure used for drafting the basic shirt and trouser pattern blocks are discussed in Chapter 5.

2.12 CONCLUSION

This chapter has reviewed literature on women, including petite women's apparel sizing and fit that indicate that most of the female consumers, including petite females' experiences and problems with ready-to-wear garment sizing and fit. From the literature, it is apparent that apparel manufacturing companies and retailers are said to create garments for consumers of average height and weight, and as a result, petite female consumers experience challenges in finding garments that fit well.

The collection of accurate and current body measurements and body shapes for a targeted population emerged as the most important factor in achieving a good quality fit in ready-to-wear garments. Establishing accurate body measurements ensures that the correct garment pattern blocks are constructed in measurements that correspond with the targeted population's body measurements to ensure better fitting garments (Van Huyssteen, 2006:14). Therefore, determining accurate body measurements, shapes and distinguishing effective information about garment sizing and fit is essential as it allows manufacturers to create garments for consumers to select better fitted garments easily (Chun, 2007:220).

The lack of information in garment sizing, the use of out-dated anthropometric data and the absence of communication among garment manufacturers, along with vanity sizing are some of the many challenges contributing to garment fit problems.

Variations in body shapes and sizes are repeatedly mentioned as the reason why garment manufacturers are failing to produce proper fitting garments. An individual's body proportions influence the position of structural lines and the balance of a garment (Liechty *et al.*, 2010: 48; Pisut & Connell, 2007:370). Pattern makers need to consider body proportions when drafting patterns, as fit problems may occur due to body proportional differences (Jones & Giddings, 2010).

Variations in petite women's ready-to-wear garment sizes indicate that garment manufacturers do not adhere to or have access to current South African anthropometric data and standard charts designed for petite women. Although, Kasambala's (2013:193) study on consumers' perceptions of garment fit did not focus on petite women, the results from the study revealed that problems mostly encountered by South African women when purchasing ready-to-wear garments were an improper fit. Hence, the correct and current data for developing sizing systems to fit various body shapes and sizes of South African petite females is essential in the sizing and fitting of a garment.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to explain the procedures and methods used in this petite women study; to obtain knowledge concerning the petite women's body dimensions. This knowledge was utilised to create the experimental upper and lower body dimensions size charts, used in the construction of the shirt and trouser patterns and of the prototype garments, as well as to assess the prototype garment fit test evaluations.

According to Babbie and Mouton (2007:49), the application and selection of methodological approaches depends on the objectives of the study, to ensure that scientific findings and valid conclusions can be drawn. The objectives of this study are outlined in section 1.3. This chapter presents the research design that includes a detailed explanation of the data sampling and the data collection techniques used, along with the protocols followed to ensure that the quality of the data is maintained. Finally, the ethical considerations that were applied throughout the study, is discussed.

3.2 THE RESEARCH DESIGN

To answer the research questions posed and to fulfil the objectives of this petite women study, the data collection and analysis adopted a mixed method, research design, comprising both qualitative and quantitative methods to investigate the petite women's body height and body dimensions and to assess garment fit. According to Maree (2007:262), applying both qualitative and quantitative methods improves the significance of a study and strengthens legitimacy in the objectives of the study by providing flexible ways of data collection and analysis. Additionally, Matthews and Kostelis (2011:133,138) state that mixed method studies usually permit different data collection techniques and analysis which add value to various concepts within the study.

The conceptual framework for this study was adapted from Ashdown (2007: xix), (refer to Figure 1.2 in section 1.5), showing the petite women's measurements and fit issues that were used as a guideline to determine the sizing methods for evaluating the fit of the prototype shirt and trouser garments developed in this study on petite women.

The data was collected using a $(TC)^2$ NX16 3D full body scanner and an Adam's® medical scale. A demographic and psychographic questionnaire comprising of both open-end and closed-ended questions inclusive of Likert and semantic differential scales was used to collect the data from the psychographic questionnaire.

3.2.1 Selection of subjects (Sampling)

The subjects were selected using purposive and convenience sampling which falls under the non-probability sampling method. The sampling strategy used in this petite women study applied to a particular group of women that is not easily accessible (Maree, 2007:76). The sampling strategy was guided by the study's objective, which was to recruit and collect 3D full body scan data from a sample of women based on a height range of 5' 4" (163 cm) and below, aged 20 to 54 years, of all the race groupings "from all walks of life", that are classed as petite residing in Gauteng (Pretoria and Johannesburg area), South Africa. The sample size was based on The Statistics South Africa (2011) and Statistics SA (2014) Gauteng women population proportions. When applied, the resulting number of petite women that needed to be recruited for the study was 200.

The 200 subjects' age distribution, race groupings and the total numbers of the recruited subjects' is indicated in Table 3.1.

Table 3.1: Age and race distribution of the sample of 200 petite women collected for this study based on Statistics S.A. (2011-2014) data.

Age group	Black	White	Coloured	Indian	All
20-24	32	6	2	1	41
25-29	33	2	2	2	39
30-34	30	1	1	0	32
35-39	30	0	0	1	31
40-44	21	1	1	0	23
45-49	17	1	0	0	18
50-54	9	6	1	0	16
All	172	17	7	4	200
Percentage	86%	9%	3%	2%	100%

As shown in Table 3.1, the subjects were divided into seven age categories and four race groupings, consisting of 86% Black (n=172), 9% of White (n=17), 3% of Coloured (n=7) and 2% Indian (n=4), residing in Gauteng (Pretoria and Johannesburg), aged between 20-54 years. It was predicted by the researcher and the study supervisor that working women earn an income which could influence their purchasing capacity in various low-end, middle class and high-end retail stores available in South Africa. The statistics South Africa (SA), Quarterly Labour Force Surveys (2015:58; 2016:xx and 2017:19) conducted surveys on employed individuals aged 15 to 64. A Republic of South Africa government publication's report on the status of women in the South African economy (2015:56-58), classified the South African employed female population between the ages of 15 to 65 years. Women who were below 20 years of age were not used in this study as they were projected as minors who will require consent from an elder to part-take in the study.

Women who were above 54 years of age were also not used in this study because they were observed to be slightly older to part-take in the study; taking into consideration Schofield *et al.'s* (2006:148) theory that an individual's body shape changes with age which may influence the fit of garments on the wearer's body.

The subjects sampled for this study was recruited on a convenience and voluntary basis, the sample did not contain an overall population percentage representation in each age category from the different race groups as the subjects were scanned based on their availability. The recruitment criterion was based on the subject's body height, as this is currently the commonly used criteria from other petite women studies as mentioned in section 2.2. The range of heights, in these studies, were from 5' 4" (163 cm) and below (Defty, 1988:16-18; Winks, 1990:74-76; Boston, 1992; Rayner, 1997:1; Knowles, 2005:35,37,40; Townsel, 2005; Barona-McRoberts, 2005:10; Petite Resource, 2007; Williams, 2007; Bailey, 2010:1; Kgarza, 2013; Simplicity, 2013; Lee, 2014; Taylor, 2014). The subjects were not pregnant and were not wearing any prosthesis, at the time of scanning taking place.

The sample of 200 petite women was recruited by the researcher and an additional recruiter, through either word of mouth (verbally approached to take part in the study), referrals from willing subjects that had been scanned and by handing out invitation letters, (see Appendix A for a copy of the letter). The invitation letter included all the relevant information, informing the petite women subjects about the procedure that will take place during the data collection process and explained what was required of them and how the data will be used. The invitation flyer also included the date, time and venue where the study will take place i.e. the UNISA, Florida Science campus where the scanner is located and that the data will be collected in total privacy, on conservative numbers and that no personal details of the subjects will be used in the study.

The subjects were firstly requested to sign a consent form (see Appendix B) to obtain their permission for them to take part in the study as guided by the Ethical Clearance Number 2015/CAES/116 (see Appendix C for a reference acceptance letter). Thereafter, they were verbally informed of all the procedures that will take place during the data collection process, including guidelines concerning measurements and scanning sessions, and other ethical considerations. A date and time slot were allocated for the subjects based on their availability, as their participation was voluntary. Transport to the UNISA, Florida, Science Campus was arranged for subjects who could not transport themselves to the scanning venue. The researcher subsequently ensured follow-ups with the additional recruiter and subjects to remind them of their scanning date where applicable.

3.2.2 Data collection instruments used in the study

3.2.2.1 A demographic and psychographic questionnaire

The demographic and psychographic questionnaire used in this petite study comprised of issues/concerns raised by other researchers within the literature from previous studies, including questions about the subject's geographical and marketing related information combined with overall body cathexis and self-perceived body shapes, together with their manually collected anthropometric height and weight measurements using an Adam's® medical scale, to address the objectives of this study.

The questionnaire contained both closed-ended questions, that provided the subjects with an assortment of possible answers to choose from, and open-ended questions that allowed the subjects to freely write down detailed answers in their own words and ranking scales (Maree, 2007:161). This study also included dichotomous questions that only permitted two possible answer choices for the question asked, multiple choice questions where the subjects could select three or more responses from the questions asked, and filter and follow-up questions where the question was divided into sub-classes that allowed further information to be obtained from one or more of the sub-classes. The ranking questions were also used to determine how the respondents ranked certain issues along with geographical questions that required the participant to fill in answers regarding their profiles (Leedy & Ormrod, 2010:189). A Likert scale was used to measure the subjects' ordinal measure of their attitude, for example, the range of garment sizes available to petite women shoppers. A semantic differential scale was used to measure how the subjects express their feelings, for example, ratings on their garment fit preferences.

The demographic questionnaire contained more focused on quantitative data and was used to gather information on who the petite subjects' were, answering questions such as each subject's age, height, weight, etc.

The psychographic questionnaire was used to collect qualitative data for the study that allowed the researcher to gain a deeper understanding of the petite female consumer's apparel sizing, fit preferences and problems/concerns that they experience with ready-to-wear shirt and trouser garments they purchase in apparel retail stores in South Africa. This was done to understand what was required to create better fitting garments for petite women in the hope of reducing the subject's frustration with the ready-to-wear shirt and trouser garment sizing and fit.
See Appendix D for an example of the demographic and psychographic questionnaire used in this petite women study.

Every subjects study pack also included the consent form and a “thank you” letter of appreciation for taking part in the study (see Appendix E). Printed copies of the questionnaire were hand delivered to some of the subjects who were interested in taking part in the study whilst the balance of subjects completed the form on their scheduled date for scanning.

3.2.2.2 The equipment used to collect the anthropometric data

This study used a $(TC)^2$ NX16 3D full body scanner and an Adam's® medical scale to collect and evaluate the anthropometric data used in this study. The 3D full body scanner and the medical scale was calibrated before every data collection session, as repeatability and precision are vital factors to consider when taking anthropometric measurements, to achieve realistic and meaningful evaluations of the collected data (Ka Wai YIP, 2013:14).

To collect the 200 petite women subject's 3D anthropometric data the researcher used the $(TC)^2$ NX16 3D full body scanner available at the UNISA Florida Science campus, in Gauteng (see Figure 3.1).

Figure 3.1: Images of the (TC)² NX16 3D full body scanner image and the cameras and sensors inside the scanner, captured on the Unisa Science campus scanner laboratory.

Pandarum's (2009:54) experience from previously using the (TC)² NX12 and the (TC)² NX16 3D full body scanners established that the colour of the scanning garments worn during the scanning process, on the different skin tones influenced the 3D scan generating process, where certain coloured garments did not generate a 3D point cloud of the subject. The colour of the inside of the scanning booth is black; hence, the scanning garments cannot be of a dark shade i.e. black or navy blue. The subjects were also required to wear a form-fitting garment that was not dark and did not bulk or obstruct the measuring points on the subject's body. Preferably, the bra should have a soft cup, slightly under-wired (Pandarum *et al.,* 2011:868). Therefore, the subjects were informed by the recruiter and the researcher to wear the correct coloured underwear on the day they were scheduled to be scanned. In instances where the subjects were not wearing the correct coloured underwear the subject was provided with scanning garments by the researcher.

Instructions on the scanning position were communicated to the subjects by the researcher, as body positioning is important and should be standardised to obtain similar and accurate body posture for all the scanned subjects. This was guided by foot markings on the floor of the scanning booth of the (TC)² NX16 3D full body scanner used in this study. Pandarum (2009:58) revised the instructions applicable to the (TC)² NX16 3D full body scanner and suggested that the scanned body posture should be relaxed and upright with the feet parallel to each other, at 350 mm apart to facilitate posture and in-seam data extraction. The arms should be stretched 1100 mm apart holding onto the fixed handrails inside the (TC)² NX16 3D full body scanner, with the right-hand thumb slightly hovering over the right hand grip to activate the button that will start the 3D scan generating process. This process was adopted throughout the entire data collection process (see Figure 3.2).

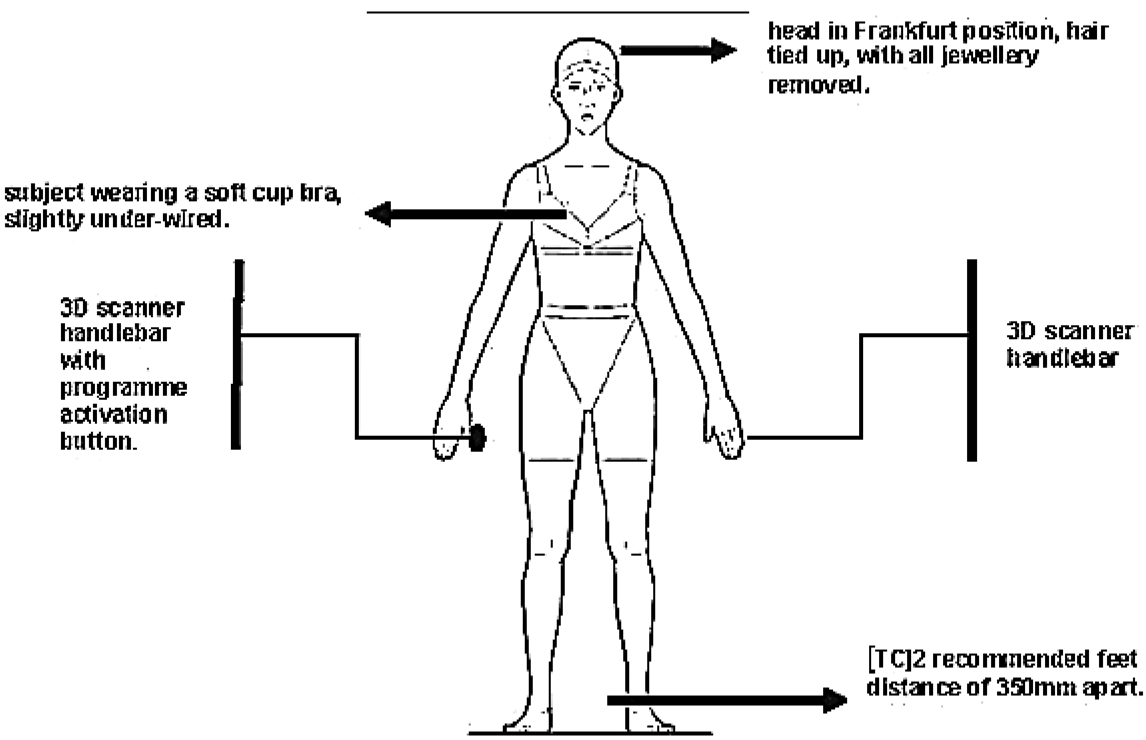


Figure 3.2: An illustration of the 3D scanning posture (Adapted from Pandarum, 2009:58).

The (TC)² body scanning system produces approximately 400 measurement points in 54 seconds. The body scans were collected using white lights to capture the 3D output of the subject in point cloud (Pandarum, 2009:8, 11) and is displayed as a 3D full body model image (see Figure 3.3) which provides for specific body measurements to be extracted (Petrova & Ashdown, 2008:227; Apeagyei, 2010:60; Ka Wai YIP, 2013:13-14). Additional measurements that were not automatically captured by the (TC)² NX16 full body scanning system, such as the height and weight measurements were manually extracted using an Adam's® medical scale. An Adam's® digital physician medical scale is used to measure height and weight measurements (Adam Equipment Company, 2011:4). The data was then recorded on every subject's demographic questionnaire for analysis.

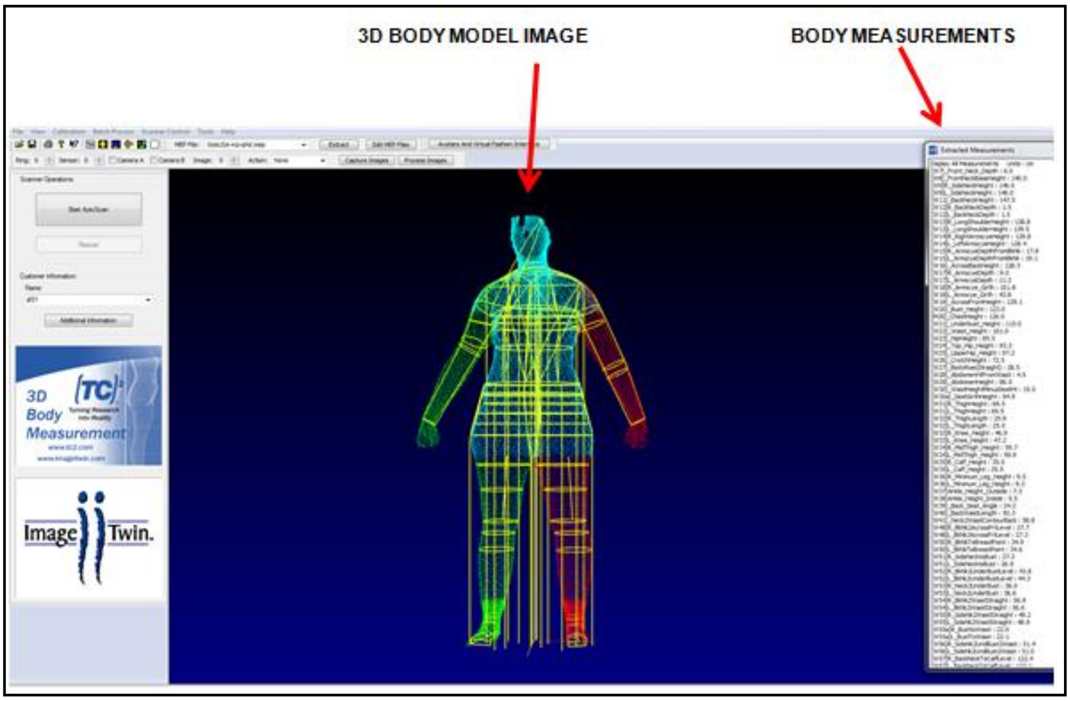


Figure 3.3: The (TC)² NX16 - 3D full body model in point cloud with extracted body measurements

During the scanning period, the recruiter assisted the researcher with the completion of the demographic forms while the researcher collected the 3D full body scans and manually measured the subjects' height and weight using an Adam's® medical scale. At any given time, there were seven to eleven women in the scanning area. Behind a closed curtain, the women privately undressed into their underwear garments before entering the scanning booth. The sampled 200 petite women subjects were scanned three times in one session; generating automatically a 3D coordinate set of cloud points from which body dimensions could be extracted. Every subject data was provided with a consecutive number and subsequently stored into a folder marked for the study. As a token of appreciation for taking part in the study, every subject was also provided with a colour copy of their scans with the extracted body measurements in centimetres, which they could use to custom fit garments for themselves after ease was added and consideration given to the fabric used.

The researcher also scanned a size 10/34, petite tailoring mannequin purchased by UNISA from a well-known South African mannequin manufacturing company. The scanning protocol adopted for scanning the mannequin was in the position as that adopted by the subjects that were scanned in this study (see Figure 3.4). The height measurement for the mannequin was obtained from information gathered from Millam (2016), from *Figure Forms* that manufactured the mannequin for a large-scale apparel retailer in 2003 that is still in use today.

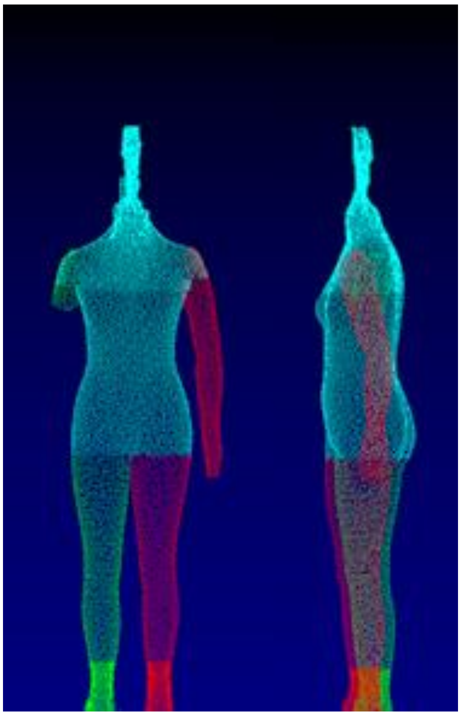


Figure 3.4: A 3D full body scanned front and side view image of the petite tailoring mannequin used in this study.

The measurements of the body landmarks required for constructing a basic shirt and trouser garments were extracted using a researcher input measurement extraction programme (mep), selected from the list of body landmarks available on the 3D scanners measurement system. Extractions of the different mep landmarks collected for this study for every subject and the petite tailoring mannequin is shown in Figure 3.5. The mep profile was programmed by the researcher and the researcher's study supervisor, thus ensuring that the landmarks were extracted at the body points as one would have taken using a dress-makers tape-measure, manually, for constructing the prototype shirt and trouser fit test garments. This then ensured that the prototype garments constructed from the size charts developed in this study used the apparel industry standardised body landmarks for ready-to-wear garment manufacturing.

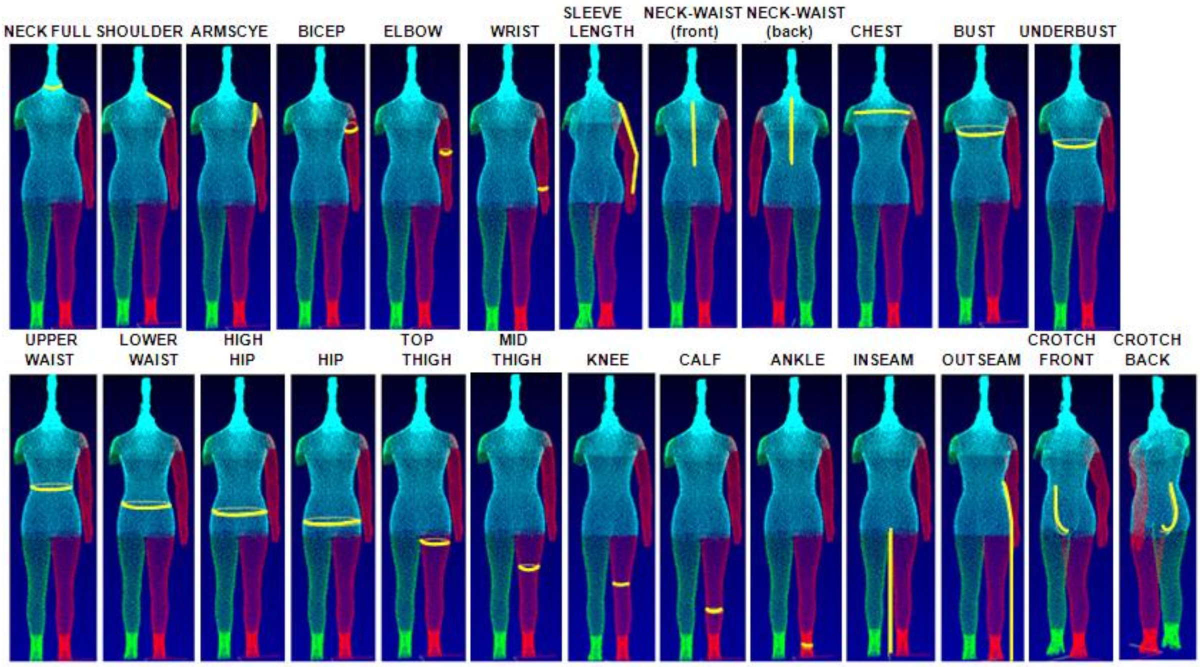


Figure 3.5: Illustrations of different body landmark mep used in the extraction of the 3D data collected for this study.

The body landmark measurement points are explained further below as it was extracted and used to programme the mep folder by the researcher.

- The neck full measurement was taken around the neckline.
- The shoulder length measurement was taken from where the neck ends to the tip of the bone that connects the shoulder and the arm.
- The armscye measurement was taken around the armhole.
- The bicep measurement was taken at the fullest upper part around the upper arm.
- The elbow measurement was taken where the arm bends.
- The wrist measurement was taken where the arm connects to the hand.
- The sleeve length measurement was taken from the tip of the bone that connects the shoulder to the arm, to the wrist
- The neck to upper waist front measurement was taken as the vertical length from the base of the front neckline (the top most prominent vertebra) to the upper waist.
- The neck to upper waist back measurement was taken as the vertical length from the base of the back neckline (the top most prominent vertebra) to the upper waist.
- The chest measurement was taken above the bust area, going under the arm and around the upper back.
- The bust measurement was taken around the fullest part of the bust.
- The under bust measurement was taken under the bust circumference.
- The upper waist measurement was taken around the narrowest part of the upper waist at the navel/midriff area. (The upper waist measurement was included for the lower body dimensions for high waist trousers; although this study was not focused on manufacturing high waist trousers, the data was analysed for developing the size chart for the lower body dimensions).
- The lower waist was taken 15 cm below the upper waist, at the lower waistline between the upper waist and high hip area.
- The high hip measurement was taken 10cm below the lower waist; around the narrowest part of the buttock between the lower waist and the hipline.
- The hip measurement was taken 20 cm below the lower waist; around the fullest part of the hipline across the seat.
- The top thigh measurement was taken around the fullest part of the upper leg.
- The mid-thigh circumference measurement was taken at 10 cm above the knee.

- The knee circumference was taken around the centre of the knee area, where the leg bends.
- The calf circumference measurement was taken at a point between the middle of the knee and ankle.
- The ankle measurement was taken around the left leg over the ankle bone that joins the leg and the foot.
- The inseam measurement was taken as the vertical length inside the leg from the crotch area to the ankle.
- The outseam measurement was taken as the vertical length from the upper waist to the ankle.
- The crotch length front measurement was taken at the crotch area vertical length to the front upper waist.
- The crotch length back measurement was taken at the crotch area vertical length to the back upper waist.

The extracted measurements of the 200 petite women subjects, together with the petite tailoring mannequin's 3D scanned data were thereafter "batch processed" into a Microsoft Excel spread sheet. According to Pandarum (2009:54) batch processing allows the user to process multiple body data files without having to load and process each scan individually into a Microsoft Excel spread sheet. This data, once captured, was saved in the IBM SPSS Statistics 24 2016 software for further analysis as discussed in Chapter 4. The individual scans were numbered consecutively and saved; thereafter, a printed copy was handed to each scanned subject to keep. The reference numbers of the scans were duplicated onto the subject's demographic and psychographic questionnaire form. The demographic and psychographic questionnaire was captured and coded on a Microsoft Excel spreadsheet for further analysis.

3.3 UNIT OF ANALYSIS AND INTERPRETATION

The 200, 3D scanned petite subject's measurements and the 3D scanned petite tailoring mannequin's measurements were analysed for this study using either Microsoft Excel or imported into the IBM SPSS Statistics 24 2016 Software for statistical analysis. The 3D scan body dimension data and every subject's body height were extracted and recorded in centimetres and every subject's body weight was recorded in kilograms.

As previously mentioned in section 1.5, the tailoring mannequin measurements is the only currently acceptable "*true values*" of the apparel retail industry standard for petite women, as there is no other petite, 3D scan, data measurements in South Africa with which to compare the 3D scan data of the subjects collected during this study. The analysis of the data in this study, did not differentiate between the different race groupings, as garments sold by apparel retailers, in their retail outlets, do not use "race grouping" as a criterion to code nor label ready-to-wear garments.
Gerber (2015) mentioned that the sample size used for testing the reliability and validity, the questionnaire constructs, and the type of variables used in a questionnaire will determine the statistical techniques to be used in the analysis of the data collected in this petite women study. Hence, the results from the demographic questions and psychographic data were analysed and interpreted through descriptive statistics (IBM SPSS Statistics 24 software 2016) where data conclusions were drawn from the petite women subject's sample from this study. Maree (2007:183) suggests that statistics can be used to describe or represent the collected data and are usually organised in different variables for each question on the computer. The different types of data to be analysed consisted of nominal, ordinal and ratio scales. Nominal scales consist of two or more categories that are established from one other by different names, e.g. a person's gender: male or female. Ordinal scales are similar to nominal scales; however, they also include numerical scales and the data are usually grouped orderly or in sequences, e.g. a level of agreement with a statement: agree, neutral, disagree or a person's level of education: Grade 6-9 or Grade 12. Ratio scales have no existing measured attribute, but the ratios can be taken out, e.g. the physical measurements: weight and height (Maree, 2007:148; Leedy & Ormrod, 2010:262).

Results from responses to the demographic questionnaire and an analysis of the 3D full body scanned data were analysed as the maximum and minimum scores, frequencies and percentages distributions, medians, means (averages), standard deviations, and the skewness distribution of the dataset. The maximum and minimum scores represented the highest and the lowest range distributions of the collected data for this petite women study.

The frequency distribution is summarised numerically where the frequency number of the sampled subjects is presented in a table, together with the percentages of the sample size (Maree 2007:184). The median is the centre of a distribution where the distribution is split in half and the mean represents the average number of the data distribution (Maree 2007:187-188; Leedy & Ormrod, 2010:266). The standard deviation represents variations of data distributions from the data value (Leedy & Ormrod, 2010:270). Skewness measures how far a distribution deviates from the regularity (Maree, 2007:189-190; Leedy & Ormrod, 2010:264).
Graphical methods such as tables, graphs, charts, histograms, normal quantile-quantile plots (Q-Q plots) and boxplots were included to aid the interpretation of the results derived from the descriptive analysis. The descriptions of the histograms, normal quantile-quantile plots (Q-Q plots) and boxplots are further discussed in Chapter 4.

The findings from the subjects' responses gathered from the open-ended questions asked in the psychographic questionnaire, were presented and formulated through different concepts derived from the obtained words of the subjects' answers. Maree (2007:105) refers to coding as a record of categorising data where the researcher seeks for relationships between the transcripts. The researcher firstly categorised the data into different categories, and thereafter linked the categorised data together and established conclusions from the related data.

The data analysis and interpretations to aid the development of the experimental upper and lower body size charts required for constructing the prototype shirt and trousers fit test garments are discussed in Chapter 4.

3.4 THE UPPER AND LOWER BODY GARMENT STYLES USED IN THIS PETITE WOMEN'S STUDY

The garments manufactured in this study are briefly discussed below to provide the background to the garments used in the fit test evaluations in Chapter 5 of this dissertation.

3.4.1 Basic style - women's shirt

Shirt garments consist of different styles ranging from being decorative to plain, the fit ranging from body hugging to loose in silhouette, fabric types and densities (Brough, 2008:3). A basic shirt style was used in this study because of its simplicity and that it does not have a lot of stylized features which makes it ideal for testing the fit of the upper body measurements of the petite women subjects collected in this study (see Figure 3.6).

Figure 3.6: An image of a basic shirt (Adapted from Patch 2009:76).

3.4.2 Basic style – women's trouser

Petite women's trousers are created with a shorter crotch and seat rise (Rayner, 1997:1). The front and back crotch allowances are the most vital parts that control the foundation of trousers which generally are constructed based on the front and back measurement ratios, considering measurements taken from the upper thigh.

According to Hamilton (2015:1), regardless of the current fashion trends, trouser styles fall into three basic silhouettes, namely: fitted, straight and flared. Joseph-Armstrong (2014:661) further identifies four main trouser styles which are trousers, slacks, culottes (which hang away from the body) and jeans which are designed to fit the silhouette of the wearer's abdomen and buttocks (see Figure 3.7). Veblen (2012:192) correspondingly categorises three trousers style silhouettes, namely, the trouser, slacks and jeans silhouettes. Hamilton (2015:1) suggests that style, fabric, and fit are three main factors that contribute to successful wearable trousers.

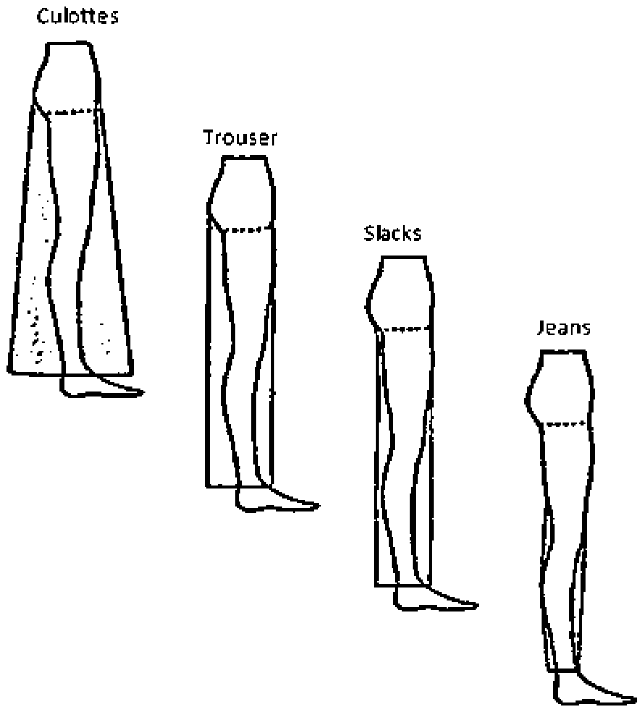


Figure 3.7: Four main trouser styles (Adapted from Joseph-Armstrong, 2014:661).

This study used the slacks silhouette as the basic style. This type of trouser is generally used as a base-pattern for most trouser designs and styles. The slacks trouser silhouette is constructed with a slightly narrow leg which provides a closer fit to the wearer's body and has a slight cup under the buttocks area which is caused by its short crotch measurement allowance (Veblen, 2012:192; Armstrong, 2014:671).

3.5 QUALITY OF THE DATA

The quality of data is judged by its level of reliability and validity required to obtain statistical significance and produce accurate and precise information (Matthews & Kostelis, 2011:24; Leedy & Ormrod, 2010:28). Matthews and Kostelis (2011:195) further suggest that reliability and validity guarantees consistent and appropriate findings, thus enhancing the study's credibility. Therefore, this study was benchmarked on previous 3D full body scanner studies conducted by Pandarum (2006, 2009) and an on-going (2015) study and on a pilot sample of petite women prior to conducting this study.

3.6 ETHICAL CONSIDERATIONS

Ethical considerations are the moral standards that should be considered in all stages of a research project. These mainly consist of "Protection from harm, informed consent and right to privacy" (Leedy *et al.,* 2010:101). Matthews and Kostelis (2011:146) regard ethics as issues that focuses on right or wrong principles along with honest and responsible conduct applied to scientific studies. Leedy and Ormrod (2010:101) advise that research studies that involve human beings as participants must address their ethical considerations prior to commencing with the study, throughout the study and after the study is conducted, to ensure that the subjects are protected against deception, dangerous procedures and invasion of their privacy. The researcher evaluated the measurement procedures and protocols, thus ensuring that every subject was comfortable and kept informed throughout the data collection process. Acts of politeness, honesty and understanding were extended towards individuals taking part in the study throughout the entire data collection process. Whenever participants required any clarity regarding the study, the researcher offered all the possible assistance; if not, necessary recommendations from qualified individuals were available to assist them.

Ethical issues relating to the dissertation's framework, the data collection process and the contribution of the individuals to the study were addressed by seeking approval for conducting the study from the College Ethics Committee of the College of Agricultural and Environmental Sciences at University of South African (UNISA). The ethical clearance reference number 2015/CAES/116, as presented in Appendix C was obtained for this study. This ethical clearance number is a supplementary application to be included within an existing approved generic ethical clearance reference number: 2011/CAES/044 obtained under the 3D body scanner theme in the Department of Life and Consumer Sciences at UNISA.

Creswell (2009:89) suggests that studies that include a consent form, which is a participant information sheet, should be distributed to the participants to sign before taking part in the study. Hence, the researcher ensured that all the subjects signed their consent forms before collecting their body measurement data. The subjects were informed about the purpose of the study and the procedures that took place, emphasising that their participation was voluntary. According to Leedy and Ormrod (2010:102-103), in any study, it is the researcher's responsibility to ensure that the subject's information is not disclosed or unrestricted for other people to see unless the participant approves. The researcher accentuated confidentiality by ensuring the subjects that their data was not made public without their knowledge. The researcher also retained all the returned documents in a safe place accessible only to the researcher.

A raffle draw incentive was offered, to show the subjects that their time and contribution in this study were appreciated and to avoid individual claims of the incentive prize. Göritz (2006:58) and Laguilles *et al*. (2011:549) state that incentives are used as a traditional motivation to increase people's willingness to participate in a study. All 200 of the subjects who took part in the study were eligible for the incentive offered in this study. The subjects were requested to complete a separate raffle draw form that was drawn at the conclusion of this study data collection process, where two lucky recipients shared a prize of R500 each.

According to Cobanoglu and Cobanoglu (2003:486), there are ethical considerations when using incentives, such as honesty in allocating the promised incentive. The subjects' completed raffle draw forms were stored in a closed box. The raffle was drawn in an environment where each of the subjects had an equal chance of being selected to win the lucky draw. The second ethical consideration suggested, was that the researcher openly inform the participants about the conditions of the incentive. The subjects were informed of the date and time when the lucky draw would be conducted.

The raffle draw forms were kept separate from the completed demographic and psychographic questionnaire forms used to collect data. Each subject completed the questionnaire form without the researcher interfering or influencing the subjects' answers, so that no biasness occurred. However, clarity was provided to subjects who had difficulty in completing the data forms. The subjects were encouraged to fill in their correct contact details and residential addresses to ensure that they stand a chance of being accessible when they win the prize or when contacted (as they had indicated in the demographic form) to assist with the assessment of the prototype garment fit test evaluations.

The following chapter presents the data analysis and interpretation of the data collected in this study.

CHAPTER 4

DATA ANALYSIS AND INTERPRETATION

4.1 INTRODUCTION

In this chapter, the anthropometric data obtained from the 3D full body scans of the petite women are statistically analysed to establish the most prevalent body shape emerging from the data-set and to identify the key body dimensions to develop the experimental size charts as set out in the objectives for this study. This chapter also analyses the responses in the psychographic questionnaire of the subject's self-perceptions of their body shapes and body proportions together with their ready-to-wear apparel shopping behaviour when purchasing a basic shirt and trouser garment in retail outlets.

The approach to the data analysis was to firstly "fill in" the missing areas (holes) in the subjects' 3D scan surface that were not captured by the 3D full body scanner. This was done by using the "MeshLab" software, thereby avoiding inaccurate measurement values within the 3D full body scanned data as a result of missing data, especially in the bust area. Cignoni *et al*. (2008: 47) defines MeshLab as a mesh processing system that provides a set of tools for "*editing, cleaning, healing, inspecting, rendering and transforming*" 3D surfaces arising from sensor imperfections and low surface reflectivity of 3D scanned models.

The bust was the area that typically required re-construction as there were holes in some of the scans. Descriptions on how the missing areas were filled and the percentage of the sample are presented in the latter half of the following section. Thereafter, the raw data was exported into a Microsoft Excel spreadsheet. The statistical analysis of the 3D full body scanned data was performed using the IBM SPSS Statistics 24 2016 software to develop size charts for the upper and lower body dimensions for use in the garment fit test evaluations. The data from the experimental upper and lower body size charts were used to create the prototype shirt and trouser garment pattern blocks for a size 10/34 subject, to evaluate the accuracy of the size charts developed in this study.

4.2 SUBJECTS' DEMOGRAPHIC AND BODY SHAPE INFORMATION

As mentioned in Chapter 3, 200 petite women subjects were recruited for the study (refer to Table 3.1 in section 3.2.1 for the number and percentages of the subjects within the different demographic group viz. Blacks, Coloureds, Indians and White). The statistical distributions of the 200 subjects' age groups; weight and height measurements are presented as graphs in Figure 4.1.

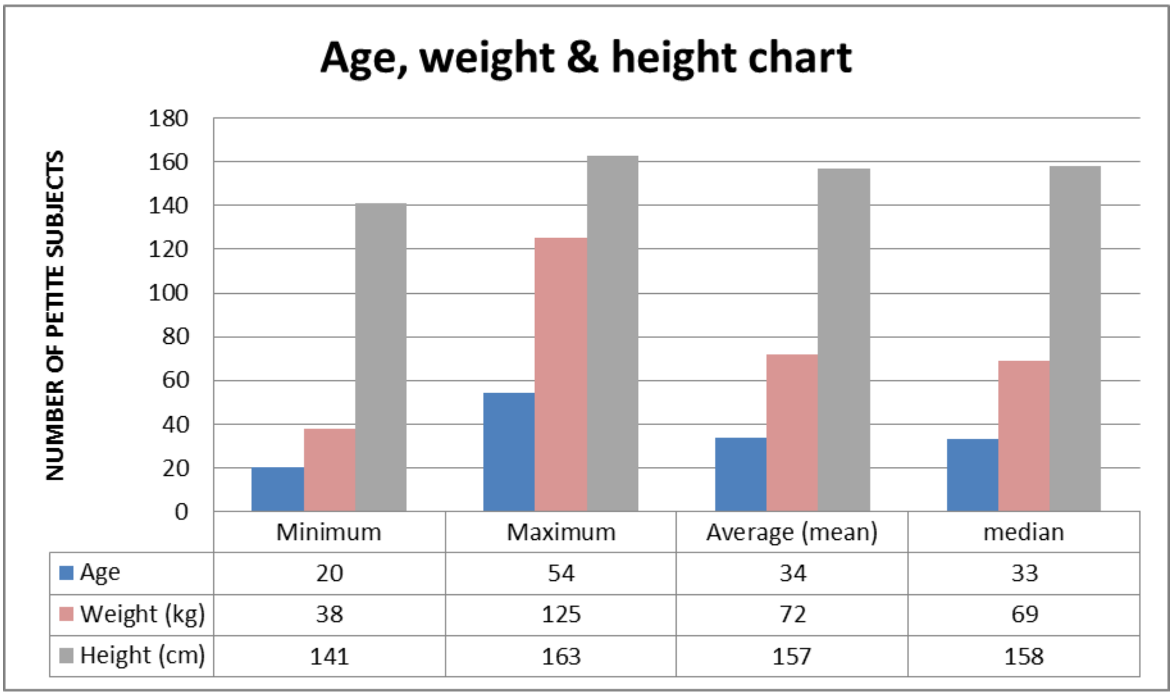


Figure 4.1: The age, weight and height measurements distributions of the 200, 3D full body scanned South African petite women subjects collected for this study.

Figure 4.1 demonstrates that the ages of the 200 petite women subjects scanned in this study ranged from 20 to 54. Their body weights ranged between 38 kilograms to 125 kilograms and their height measurements from 141 cm to 163 cm, with an average height measurement of 157 cm. This addresses, Objective 1 of this study.

The subjects' body shapes were identified using the shape identification programme installed in the $(TC)^2$ NX16 3D full body scanner to determine the most commonly occurring body shapes of the 200 subjects that were 3D scanned.

The justification, for using the $(TC)^2$ NX16 3D full body scanner installed body shape software as opposed to visually assessing the 3D full body scans to identify the different and, hence, the predominantly emerging body shape in this study, was that two previous research projects also used computer software to analyse body shapes using 3D full body scanned data. These were the Figure Identification Technique (FFIT©) for Apparel research, developed by Simmons *et al*. in 2004b and the Body Shape Assessment Scale (BSAS©) developed by Connell *et al*. in 2006, both these studies are within the scope of this study.

Similar to Simmons *et al.'s* (2004b) and Connell *et al.'s* (2006) studies as explained in section 2.3.1, the body shape profiles extracted by the (TC)² NX16 3D full body scanner in this study used the petite bust, upper waist, and hips girth proportions to classify their body shapes. Four body shape profiles emerged from the data after using the software, namely: the inverted triangular, hourglass, straight and the pear shape profiles (see Table 4.1).

Table 4.1: The different body shapes that emerged from the 200, 3D scanned subjects

BODY SHAPE PROFILE	NUMBER	PERCENTAGE
HOURGLASS	5	2.5%
INVERTED TRIANGULAR	7	3.5%
STRAIGHT	24	12%
PEAR	180	90%
Total	200	100%

Table 4.1 shows the number and percentage distributions of the different petite women's body shapes for the 200 subjects' 3D data in this study. As noted the majority of the 200 petite women subjects' 3D scanned body shapes were classified as being a pear shape profile represented by 90% (n=180) of the subjects. The balance of the shapes that were extracted from the 200, 3D full body scans included the straight 12% (n=24), inverted triangular 3.5% (n=7), and the hourglass 2.5% (n=5).

There was a crossover on 16 subjects scanned body shapes where the shape profiles were categorised between two body profiles. This resulted in a total of 216 body shape representations, in 200 subjects.

The arising crossover body shape profiles were all included in the pear body shape sample for further analysis. All five of the hourglass and 11 of the straight body shapes crossed over into the pear body shape; this could be attributed to the body shapes software's algorithms not being able to clearly distinguish between the body outlines. The body shapes that had crossed over were included in the 180 petite pear body shape profiles sample for further data analysis in this petite sizing and fit study. The remaining 20 subjects were omitted from the data analysis because their body shapes and proportions differed from the pear body shape profile.

Following in Figure 4.2, are examples of the pear body shape 3D profiles for subjects that were identified as being small and plus-size women's body shape profiles.

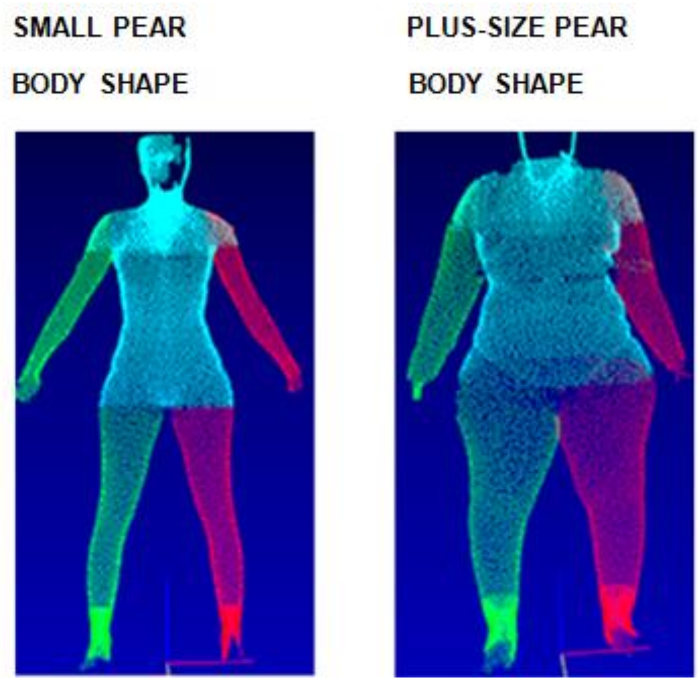


Figure 4.2: An example of the small and plus-size women's pear body shape profiles.

Examples of crossover body shape profiles are presented in Figure 4.3 and Figure 4.4.

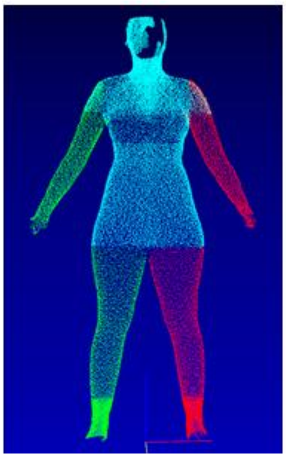


Figure 4.3: An example of a crossover body shape classified between hourglass and pear body shape profiles.

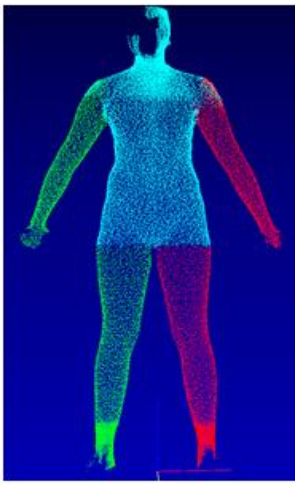


Figure 4.4: An example of a crossover body shape classified between straight and pear body shape profiles.

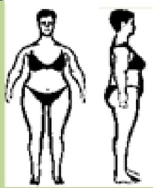
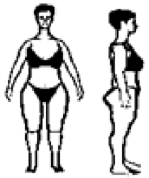
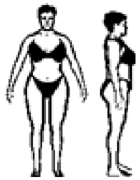
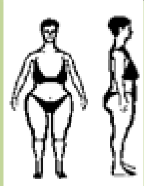
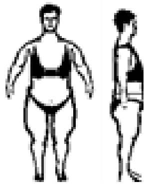
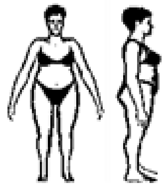
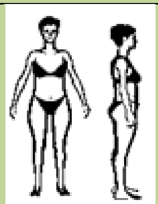
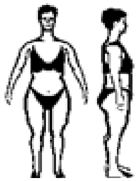
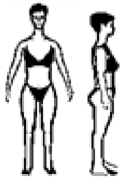
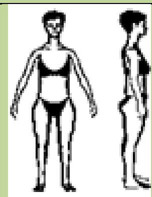
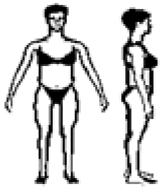
Twelve of the 180 subjects’ scans were identified as having missing data in the bust area. Therefore, these scans were imported into the MeshLab, 2016 software, where the perimeter of the busts were determined and thereafter “filled” by using a pivoting reconstruction algorithm sphere based on the calculations of the curve surfaces for each bust point perimeter as used in studies conducted by Ter Haar (2009:13-4) and Lovato (2010:15-16), ensuring that the output surfaces of the filled bust areas retained the subject’s initial bust shape.

To establish whether the body shape profiles identified by the software accurately represented the body shapes of the 3D full body scanned petite women's body shapes, visual assessments of the 180 subjects' 3D full body scanned body shapes was conducted. The visual assessments were performed by the researcher and two experts who have more than five years of experience in the apparel industry by looking at the 3D full body scans and comparing the shapes extracted by the 3D full body scanner with body shapes that were perceived by the experts and the researcher. The accuracy of the 3D full body scanned body shape profile predictions verified that (inclusive of the crossover scans identified in this study which were retained as pear body shape profiles), 180 of the 3D full body scanner extracted body shape profiles were extracted as a pear shaped profile for the subjects in this study. Therefore, only the 3D full body scans with the pear body shape profiles identified by the $(TC)^2$ NX16 3D full body scanner software used for this study were considered for further analysis to develop the experimental upper and lower body dimensions size charts for developing pattern blocks and creating the fit test shirt and trouser garments; inclusive of both the plus-size and small body silhouettes. A study by Strydom (2008:6) suggests that the best way to provide for body shape variation in a population is to construct separate size charts for each available body shape in the studied population. To overcome this problem, the other (hourglass, inverted triangular and straight) body shapes established in Table 4.1 were discarded as the body shape profiles were minimally represented among the 3D full body scanned subjects.

The data analysis for classifying the subjects' body shapes was conducted on the initial 200 subjects recruited for the study. The subjects' 3D full body scanned body shape profiles were then compared with the subject's self-assessed body shapes as presented in the psychographic questionnaire, where each subject indicated which body shape they perceived themselves to have (see Table 4.2). The petite women were presented with images of two body builds to choose from, representing a smaller body silhouettes and plus-size body silhouettes, and asked which image they thought best represented the silhouette that they perceived themselves to be.

These body builds were taken from a pilot study of current South Africa women's body shapes by Pandarum (2015).

Table 4.2: The petite subjects' body shape profile perceptions based on each individual's personal evaluations of their body shapes.

		TRIANGULAR	BOTTOM HOURGLASS	HOURGLASS	PEAR/SPOON	RECTANGLE/STRAIGHT	OVAL	TOTAL
BODY SHAPE PROFILE	**Plus-size body silhouettes**							
	Small body silhouettes							
SELF-PERCEIVED BODY SHAPES	**Number**	50	30	42	33	15	30	**200**
	Percentage	25%	15%	21%	16%	8%	15%	**100%**

From the psychographic questionnaire, most of the subjects 25% (n=50) perceived themselves as having a triangular body shape. The second most perceived body shape was the hourglass 21% (n=42), followed by the pear/spoon with 16% (n=33). The bottom hourglass and the oval shape profiles were both 15% (n=30) and the least self-perceived body shape was the rectangle/straight body profile having only 8% (n=15) of the subjects. Furthermore, 56% (n=113) of the subjects perceived themselves as having plus-size body silhouettes and 44% (n=87) of the subjects perceived themselves as having small body silhouettes.

To gain further insight into the petite women's (pear) body shape distribution within the different demographic groupings (in the country) in this study, the number and percentage representations was determined (see Table 4.3).

Table 4.3: Number and percentage distributions of the pear body shape profile within the petite ethnic groups.

ETHNIC GROUP	**NUMBER**	**PERCENTAGE**
Blacks	157	87%
Coloureds	6	3%
Indians	2	1%
Whites	15	9%
Total	**180**	**100%**

The majority of the 180 subjects with a pear body shape profile were Black South Africans 87% (n=157), followed by the white South African with 9% (n=175), the coloured South African with 3% (n=6) and the Indian South African as 1% (n=2). Nonetheless, the subsequent data analysis and the development of the size charts were inclusive of all the demographic groupings.

The methods and procedures used in analysing the 180 petite pear shaped subjects' data for the development of the upper and lower body size charts are discussed in the next section.

4.3 PRINCIPAL COMPONENT ANALYSIS (PCA) FOR THE UPPER AND LOWER BODY DIMENSIONS

In this section, the upper and the lower body dimensions of the 180 pear shaped subjects were analysed separately. A total of 14 upper body dimensions required for creating the shirt garments, and 13 lower body dimensions required for creating the trouser garments for every 3D full body scanned subject was exported into the SPSS software. Multivariate data analysis was used, to identify the relationship between the body dimensions and how these correlate with each other. PCA was used to identify the body dimensions that show a strong correlation with each other (Zakaria, 2014:104) and the correlation coefficient was used to measure the strength of the relationship between the body dimensions extracted for this study.

In this study, a correlation matrix was calculated to identify the critical body dimensions for the upper and lower body dimensions and to group the body dimension variables into a smaller number of factors based on the factor loadings. The datasets consisting of factor loadings are presented in the Principal Component matrix, reported later in this chapter.

The correlation matrix used in calculating the factor loadings for determining the relationships between the body dimensions in this study was derived and interpreted using the guidelines and criteria provided by Maree (2007:234-236) and Leedy and Ormrod (2010:273). These researchers stated that correlations measure the strength of linear relationship between two quantitative variables, x and y. A correlation coefficient that is closer to zero indicates a weak correlation between the two variables. The values for a correlation coefficient are between -1 (minimum value) and +1 (maximum value). The - sign indicates a negative relationship and the + sign indicates a positive relationship between the two variables. Furthermore, a value of -1 denotes a perfect negative relationship and a +1 value denotes a perfect positive relationship. A positive correlation indicates that, if the key body measurement increases, then the correlated body dimension also increases. A negative correlation indicates that, if the key body measurement increases, then the correlated body dimension decreases, while 0 means that there is no correlation between the body dimensions (Zakaria, 2014:100).

Table 4.4 and Table 4.6 show the correlation matrices which present the correlations between the studied variables in the upper and lower body dimensions required for constructing the prototype shirt and trouser garment pattern blocks in this study. The significance of the correlations is presented in Table 4.5 and Table 4.7.

Table 4.4: The correlation matrix of the upper body dimensions required to construct the prototype shirt pattern block.

Correlation Matrix for the upper body dimensions														
	GIRTHS											LENGTHS		
CORRELATIONS	**NECK FULL**	**SHOULDER**	**ARMSCYE**	**BICEP**	**ELBOW**	**WRIST**	**CHEST**	**BUST**	**UNDERBUST**	**UPPER WAIST**	**LOWER WAIST**	**NECK TO UPPER WAIST (Back)**	**NECK TO UPPER WAIST (Front)**	**SLEEVE LENGTH**
NECK FULL	1.00	0.09	0.51	0.64	0.59	0.34	0.61	0.66	0.65	0.68	0.67	0.20	0.21	0.05
SHOULDER	0.09	1.00	0.09	0.11	-0.01	0.04	0.12	0.11	0.04	0.10	0.14	0.11	0.09	-0.01
ARMSCYE	0.51	0.09	1.00	0.60	0.50	0.29	0.58	0.62	0.60	0.61	0.58	0.13	0.15	0.17
BICEP	0.64	0.11	0.60	1.00	0.73	0.36	0.73	0.79	0.77	0.81	0.79	0.15	0.15	0.08
ELBOW	0.59	-0.01	0.50	0.73	1.00	0.56	0.70	0.75	0.75	0.78	0.74	0.27	0.25	-0.08
WRIST	0.34	0.04	0.29	0.36	0.56	1.00	0.37	0.36	0.36	0.36	0.37	0.09	0.09	-0.14
CHEST	0.61	0.12	0.58	0.73	0.70	0.37	1.00	0.87	0.80	0.84	0.81	0.20	0.19	0.08
BUST	0.66	0.11	0.62	0.79	0.75	0.36	0.87	1.00	0.95	0.92	0.86	0.26	0.27	0.08
UNDERBUST	0.65	0.04	0.60	0.77	0.75	0.36	0.80	0.95	1.00	0.93	0.86	0.30	0.33	0.09
UPPER WAIST	0.68	0.10	0.61	0.81	0.78	0.36	0.84	0.92	0.93	1.00	0.91	0.34	0.34	0.09
LOWER WAIST	0.67	0.14	0.58	0.79	0.74	0.37	0.81	0.86	0.86	0.91	1.00	0.27	0.26	0.10
NECK TO UPPER WAIST (Back)	0.20	0.11	0.13	0.15	0.27	0.09	0.20	0.26	0.30	0.34	0.27	1.00	0.83	0.19
NECK TO UPPER WAIST (Front)	0.21	0.09	0.15	0.15	0.25	0.09	0.19	0.27	0.33	0.34	0.26	0.83	1.00	0.10
SLEEVE LENGTH	0.05	-0.01	0.17	0.08	-0.08	-0.14	0.08	0.08	0.09	0.09	0.10	0.19	0.10	1.00

Table 4.5: The significance values of the upper body dimensions required to construct the prototype shirt pattern block.

Significance of the correlation Matrix for the upper body dimensions														
	GIRTHS											**LENGTHS**		
Sig. (2-tailed)	**NECK FULL**	**SHOULDER**	**ARMSCYE**	**BICEP**	**ELBOW**	**WRIST**	**CHEST**	**BUST**	**UNDERBUST**	**UPPER WAIST**	**LOWER WAIST**	**NECK TO UPPER WAIST (Back)**	**NECK TO UPPER WAIST (Front)**	**SLEEVE LENGTH**
NECK FULL		0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
SHOULDER	0.11		0.12	0.07	0.44	0.28	0.05	0.07	0.31	0.10	0.03	0.08	0.11	0.47
ARMSCYE	0.00	0.12		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.01
BICEP	0.00	0.07	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.14
ELBOW	0.00	0.44	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
WRIST	0.00	0.28	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.13	0.11	0.03
CHEST	0.00	0.05	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.01	0.16
BUST	0.00	0.07	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.15
UNDERBUST	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.11
UPPER WAIST	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.11
LOWER WAIST	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.09
NECK TO UPPER WAIST (Back)	0.00	0.08	0.04	0.02	0.00	0.13	0.00	0.00	0.00	0.00	0.00		0.00	0.01

Continued on the next page

Significance of the correlation Matrix for the upper body dimensions														
	GIRTHS											LENGTHS		
Sig. (2-tailed)	**NECK FULL**	**SHOULDER**	**ARMSCYE**	**BICEP**	**ELBOW**	**WRIST**	**CHEST**	**BUST**	**UNDERBUST**	**UPPER WAIST**	**LOWER WAIST**	**NECK TO UPPER WAIST (Back)**	**NECK TO UPPER WAIST (Front)**	**SLEEVE LENGTH**
NECK TO UPPER WAIST (Front)	0.00	0.11	0.02	0.03	0.00	0.11	0.01	0.00	0.00	0.00	0.00	0.00		0.09
SLEEVE LENGTH	0.26	0.47	0.01	0.14	0.14	0.03	0.16	0.15	0.11	0.11	0.09	0.01	0.09	

Table 4.6: The correlation matrix of the lower body dimensions required to construct the prototype trouser pattern block.

Correlation Matrix for the lower body dimensions													
	GIRTHS									LENGTHS			
CORRELATIONS	UPPER WAIST	LOWER WAIST	HIGH HIP	HIP	TOP THIGH	MID-THIGH	KNEE	CALF	ANKLE	OUTSEAM	INSEAM	CROTCH LENGTH FRONT	CROTCH LENGTH BACK
UPPER WAIST	1.00	0.91	0.83	0.87	0.64	0.57	-0.13	0.68	0.26	-0.09	-0.20	0.32	0.32
LOWER WAIST	0.91	1.00	0.87	0.89	0.64	0.54	-0.12	0.70	0.25	0.00	-0.20	0.42	0.39
HIGH HIP	0.83	0.87	1.00	0.89	0.52	0.41	-0.12	0.65	0.22	-0.04	-0.39	0.55	0.63
HIP	0.87	0.89	0.89	1.00	0.64	0.58	-0.15	0.73	0.25	0.07	-0.25	0.50	0.51
TOP THIGH	0.64	0.64	0.52	0.64	1.00	0.85	-0.02	0.76	0.17	0.04	0.25	0.09	-0.03
MID-THIGH	0.57	0.54	0.41	0.58	0.85	1.00	-0.12	0.77	0.18	0.18	0.38	0.12	-0.09
KNEE	-0.13	-0.12	-0.12	-0.15	-0.02	-0.12	1.00	-0.14	0.04	0.04	0.09	-0.08	-0.06
CALF	0.68	0.70	0.65	0.73	0.76	0.77	-0.14	1.00	0.23	0.13	0.07	0.35	0.23
ANKLE	0.26	0.25	0.22	0.25	0.17	0.18	0.04	0.23	1.00	0.03	0.00	0.09	0.11
OUTSEAM	-0.09	0.00	-0.04	0.07	0.04	0.18	0.04	0.13	0.03	1.00	0.45	0.52	0.29
INSEAM	-0.20	-0.20	-0.39	-0.25	0.25	0.38	0.09	0.07	0.00	0.45	1.00	-0.33	-0.61
CROTCH LENGTH FRONT	0.32	0.42	0.55	0.50	0.09	0.12	-0.08	0.35	0.09	0.52	-0.33	1.00	0.84
CROTCH LENGTH BACK	0.32	0.39	0.63	0.51	-0.03	-0.09	-0.06	0.23	0.11	0.29	-0.61	0.84	1.00

Table 4.7: The significance values of the lower body dimensions required to construct the prototype trouser pattern block.

Significance of the correlation Matrix for the lower body dimensions													
	GIRTHS									LENGTHS			
Sig. (2-tailed)	**UPPER WAIST**	**LOWER WAIST**	**HIGH HIP**	**HIP**	**TOP THIGH**	**MID-THIGH**	**KNEE**	**CALF**	**ANKLE**	**OUTSEAM**	**INSEAM**	**CROTCH LENGTH FRONT**	**CROTCH LENGTH BACK**
UPPER WAIST		0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.11	0.00	0.00	0.00
LOWER WAIST	0.00		0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.50	0.00	0.00	0.00
HIGH HIP	0.00	0.00		0.00	0.00	0.00	0.06	0.00	0.00	0.31	0.00	0.00	0.00
HIP	0.00	0.00	0.00		0.00	0.00	0.03	0.00	0.00	0.17	0.00	0.00	0.00
TOP THIGH	0.00	0.00	0.00	0.00		0.00	0.37	0.00	0.01	0.28	0.00	0.11	0.33
MID-THIGH	0.00	0.00	0.00	0.00	0.00		0.05	0.00	0.01	0.01	0.00	0.05	0.12
KNEE	0.05	0.05	0.06	0.03	0.37	0.05		0.03	0.30	0.32	0.12	0.14	0.20
CALF	0.00	0.00	0.00	0.00	0.00	0.00	0.03		0.00	0.05	0.19	0.00	0.00
ANKLE	0.00	0.00	0.00	0.00	0.01	0.01	0.30	0.00		0.35	0.50	0.13	0.07
OUTSEAM	0.11	0.50	0.31	0.17	0.28	0.01	0.32	0.05	0.35		0.00	0.00	0.00
INSEAM	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.19	0.50	0.00		0.00	0.00
CROTCH LENGTH FRONT	0.00	0.00	0.00	0.00	0.11	0.05	0.14	0.00	0.13	0.00	0.00		0.00
CROTCH LENGTH BACK	0.00	0.00	0.00	0.00	0.33	0.12	0.20	0.00	0.07	0.00	0.00	0.00	

The PCA provided the grouped factors for the correlation matrix. The correlation coefficients show the strength and direction of the relationships between the analysed body landmarks. The analysis extracted 14 upper body landmarks and 13 lower body landmarks for use in the construction of the prototype pattern blocks and subsequently for the fitting test garments. The number of the body dimensions extracted was the same as the number of the original body dimensions which indicates that no data was omitted. The correlation coefficients observed in Table 4.4 and Table 4.6 are presented to measure the relationship between the body dimensions extracted for developing the upper and lower body dimensions size charts in this study.

This study established that the correlation within the body dimensions differed, some of the body dimensions were observed to correlate strongly with specific body dimensions where two paired sets of data were related (girths) but have weak correlations with other body dimensions where the two paired datasets were not related (girths and lengths). For example: the chest, bust, and underbust for the upper body dimensions and the high hip and the hip for the lower body dimensions represent girth measurements, show high correlations, indicating that they are related to each other. However, they have low correlation values with the body dimensions related to length measurements.

The significance values of the body dimensions were further analysed to measure the mathematical probability of whether there is some evidence or no evidence at all within the analysed data to suggest that linear correlation exists in the body dimensions data taken from the subjects' 3D full body scanned data. The significance values for testing the correlations related to the upper and lower body dimensions are presented in Table 4.5 and Table 4.7.

According to Beaumont (2012:9) and Wasserstein and Lazar (2016:8) the standard method that statisticians use to measure the significance of their experimental analyses is the P-value for measuring the strength of the evidence against the null hypothesis, which represents the probability that the analysed data was the result of chance alone and would "*have arisen if the null hypothesis were true*".

P-values decide whether to reject the null hypothesis or not. The smaller the P-value, the stronger the evidence against the null hypothesis; P- values close to zero show that the perceived variance is not likely to be unexpected, while P- values close to one suggest that there are no variances between the clustered data other than by coincidence. Thus, the significance rating depends on how close to zero the value is. Should the P-value be a small number, it means that the probability is that the prediction of the results, not by chance alone, accounts for the difference of the analysed data. It can therefore be concluded that the results obtained from the 3D full body scanned petite sample's body dimension correlation's data will produce significant results, suggesting that the null hypothesis can be discarded with P-values less than 0.05. Davies and Crombie (2009:2) consider P-values less than 0.05 to be an accepted standard probability that researchers use to produce statistically significant results. The significance level of 0.05 was used for testing the significance correlations of the body dimensions in this study.

The results of the significance correlations in this study were based on a two-tail significance test. Two-tailed significance tests both the large and small values on both ends of its distribution of the test value, regardless of the direction of the hypothesised relationship, to provide evidence against the null hypothesis. The two-tailed significance test in this study examines that the null hypothesis of a correlation is "*equal to 0.05*". The formula is often written as "$H0: \mu = 0.05$" (Levine *et al.*, 2008: 334-335).

The researcher had no prior knowledge as to which body dimensions had more effective significance than the other. Hence, a two-sided hypothesis test was appropriate. For this study, the statistical significance was determined with P-values. The researcher tested the null hypothesis that is rejected if the P-values for the correlations in the analysed upper and lower body dimensions were not equal to 0.05.

The significance values for the analysed data as observed in Table 4.5 and Table 4.7 show that most of correlations for the body dimensions had P-values that were 0.00 and some values were larger than 0.05, with only minor values of the significance correlations having P-values equal to 0.05. The P-values observed in the analysed data represent strong evidence against the null hypothesis, suggesting a significant relationship between the analysed body dimensions; which means that as one body dimension variable goes up or down so will the correlated body dimension variable.

Beaumont (2012:9) suggests that the Bartlett's test of sphericity, together with the Kaiser-Meyer-Olkin (KMO) can be used in SPSS to check whether the correlations are valid for PCA. The Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) are further discussed later in this chapter. Age, height and weight were not incorporated when defining the key (primary) body dimensions. Daniels (2008:45) and Zakaria (2014:168-169) state that height and weight are not directly associated with the fit of a garment, but they are used as a measure in assigning an individual to a size group when developing size charts. It is also said that the body height and weight classify the subject's body size and shape; height demonstrates the length and weight demonstrates the thickness of the body.

The size chart for this study was constructed for the petite woman having an average body height measurement of 157 cm; their body weight was between 37.6 kg -124.7 kg and, their age ranged from 20-54 years. Nonetheless, a correlation matrix was initially performed inclusive of the age, height and weight to test how well the age, height and weight correlate with the other body dimensions (see Table 4.8 and Table 4.10 for the age, height and weight correlations and the significance values in Table 4.9 and Table 4.11 for the upper and lower body dimensions).

Table 4.8: Correlation matrix of the age, weight and height against upper body dimensions required to construct the shirt prototype pattern block.

Correlation Matrix for the age, weight and height measurements (upper body)			
Correlation	**Age**	**Weight**	**Height**
Age	1.00	0.40	-0.04
Weight	0.40	1.00	0.20
Height	-0.04	0.20	1.00
NECK FULL	0.26	0.71	0.12
SHOULDER	0.02	0.11	-0.04
ARMSCYE	0.26	0.62	0.20
BICEP	0.40	0.85	0.05
ELBOW	0.29	0.76	0.07
WRIST	0.16	0.34	0.10
CHEST	0.36	0.84	0.15
BUST	0.40	0.90	0.12
UNDERBUST	0.41	0.89	0.14
UPPER WAIST	0.40	0.93	0.11
LOWER WAIST	0.42	0.92	0.15
NECK TO UPPER WAIST (Back)	0.11	0.24	0.22
NECK TO UPPER WAIST (Front)	0.09	0.24	0.13
SLEEVE LENGTH	-0.02	0.13	0.50

Table 4.9: The significance values of the age, weight and height against upper body dimensions required to construct the prototype shirt pattern block.

Significance of the correlation Matrix for the age, weight and height measurements (upper body)			
Sig. (2-tailed)	**Age**	**Weight**	**Height**
Age		0.00	0.32
Weight	0.00		0.00
Height	0.32	0.00	
NECK FULL	0.00	0.00	0.05
SHOULDER	0.38	0.08	0.31
ARMSCYE	0.00	0.00	0.00
BICEP	0.00	0.00	0.27
ELBOW	0.00	0.00	0.17
WRIST	0.02	0.00	0.10
CHEST	0.00	0.00	0.02
BUST	0.00	0.00	0.05
UNDERBUST	0.00	0.00	0.03
UPPER WAIST	0.00	0.00	0.07
LOWER WAIST	0.00	0.00	0.02
NECK TO UPPER WAIST (Back)	0.07	0.00	0.00
NECK TO UPPER WAIST (Front)	0.11	0.00	0.04
SLEEVE LENGTH	0.42	0.05	0.00

Table 4.9: Correlation matrix of the age, weight and height against lower body dimensions required to construct the prototype trouser pattern block.

Correlation Matrix for the age, weight and height measurements (lower body)			
Correlation	**Age**	**Weight**	**Height**
Age	1.00	0.40	-0.04
Weight	0.40	1.00	0.20
Height	-0.04	0.20	1.00
UPPER WAIST	0.40	0.93	0.11
LOWER WAIST	0.42	0.92	0.15
HIGH HIP	0.44	0.87	0.07
HIP	0.44	0.92	0.12
TOP THIGH	0.30	0.69	0.15
MID-THIGH	0.25	0.63	0.22
KNEE	-0.07	-0.13	0.09
CALF	0.32	0.78	0.13
ANKLE	0.08	0.28	0.09
OUTSEAM	-0.10	0.08	0.59
INSEAM	-0.10	-0.15	0.52
CROTCH LENGTH FRONT	0.21	0.47	0.09
CROTCH LENGTH BACK	0.20	0.43	0.01

Table 4.10: The significance values of the age, weight and height against lower body dimensions required to construct prototype trouser pattern block.

Significance of the correlation Matrix for the age, weight and height measurements (lower body)			
Sig. (2-tailed)	**Age**	**Weight**	**Height**
Age		0.00	0.32
Weight	0.00		0.00
Height	0.32	0.00	
UPPER WAIST	0.00	0.00	0.07
LOWER WAIST	0.00	0.00	0.02
HIGH HIP	0.00	0.00	0.17
HIP	0.00	0.00	0.06
TOP THIGH	0.00	0.00	0.03
MID-THIGH	0.00	0.00	0.00
KNEE	0.19	0.05	0.13
CALF	0.00	0.00	0.04
ANKLE	0.14	0.00	0.12
OUTSEAM	0.09	0.13	0.00
INSEAM	0.10	0.03	0.00
CROTCH LENGTH FRONT	0.00	0.00	0.12
CROTCH LENGTH BACK	0.00	0.00	0.47

As indicated in Table 4.8 and Table 4.10, there is a low correlation between the age and height measurements when evaluated against both the upper and lower body dimensions. Weight had significant correlations with nine upper body dimensions, namely; neck full, armscye, bicep, elbow, chest, bust, underbust, upper waist and the lower waist. The body dimensions with significant correlations with the weight measurement in the lower body dimensions included seven body dimensions, namely; the upper waist, lower waist, high hip, hip, top thigh, mid-thigh, and the calf.

It was evident from the results that weight strongly correlated with only the girth measurements in both the upper and lower body dimensions, which endorse Zakaria’s (2014:96) study that the body weight is determined by the thickness of the body. As a result, girth measurements were used as an alternative to the weight measurement when analysing the size charts sizing measurements.

Similarly, since the height had no correlation with any of the body dimensions, both the upper and lower body dimensions representing the petite women's body length measurements were used when analysing the sizing measurements for the size charts to be developed in this study.

The significance evidence in the analysed data in Table 4.9 and Table 4.11, for both the upper and lower body dimensions show that most of the P-values observed for the body dimensions were lower than 0.05 and therefore, were significantly correlated between the body dimension parameters. There were minor values in the analysed data that were not statistically significant. Nonetheless, the age, height and weight were not included when defining the key (primary) body dimensions required for developing the size charts in this study.

Prior to conducting the PCA, the Bartlett's Test of "Sphericity" and the Kaiser-Meyer-Olkin (KMO) Test of Sampling Adequacy were used to authenticate whether or not the factor analysis used to analyse the data was viable and to establish whether the data can be well factored. This was done to ensure that the observed correlation matrix was statistically reliable and that linear combinations exist within the data. The KMO must be greater than 0.5 and the Bartlett's test must be less than 0.05 to be considered significant for use. Values that are between 0.5 and 0.7 are average, whilst values between 0.7 and 0.8 are good. Values between 0.8 and 0.9 are very good in producing statistically valid data and values, above 0.9 indicate that the results are the best for indicating whether the factor analysis will produce applicable and well factored data (Zakaria, 2011:351; Beavers *et al*., 2013:4; Muslim *et al*., 2014:18; Zakaria, 2014:104-05). Table 4.12 and Table 4.13 present KMO values and the Bartlett's Test for the upper body dimensions required for developing the shirt pattern block and the lower body measurements required for developing the trouser pattern block.

Table 4.11: The Bartlett's Test of "*Sphericity*" and the Kaiser-Meyer-Olkin Test of Sampling Adequacy (KMO) for the upper body dimensions.

KMO and Bartlett's Test for the upper body dimensions		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.89
Bartlett's Test of Sphericity	Approx. Chi-Square	2330.81
	df	91
	Sig.	0.00

Table 4.12: The Bartlett's Test of "*Sphericity*" and the Kaiser-Meyer-Olkin Test of Sampling Adequacy (KMO) for the lower body dimensions.

KMO and Bartlett's Test for the lower body dimensions		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.79
Bartlett's Test of Sphericity	Approx. Chi-Square	2448.35
	df	78
	Sig.	0.00

As shown in Table 4.12 and Table 4.13, the Kaiser-Meyer-Olkin Test (KMO) values were very good (0.89) for the upper body dimensions required for developing the shirt pattern block; the lower body measurements were good (0.79), indicating that the factor analysis data for both the upper and lower body dimensions were applicable to produce well factored results. The Bartlett's test, representing both the upper and lower body measurements, had a low significance value of 0.00, as a result both the variables, as a set, were significantly correlated and, thus, the factor analysis used in this research was appropriate. It can be further concluded that the relationship between the body dimensions were good to great in rating. It can therefore be assumed that the factor analysis can be performed and is likely to factor well in the PCA.

PCA was performed on the data to gain several critical understandings into the characteristics of the data. Gupta and Gangadhar (2004:459), Bagherzadeh *et al*. (2010:925), and Zakaria (2011:349) suggest that PCA can assist in selecting representative divisions of variables and establishing which variables may act in performance together, as well as detecting how many variables may be expected to have influences in the data analysis.

PCA was performed using the IBM SPSS Statistics 24 2016 statistical software and an orthogonal method, called the varimax technique, was used to extract and transform all the data collected by the 3D full body scanner into components. The body dimensions in this study were extracted using PCA and the varimax rotation.

To establish the key (primary) body dimensions to be used when developing the experimental size charts for this study, the collected 3D full body scanned data was segmented into upper and lower body dimensions. This was done to identify the number of component variables to be retained based on factor loadings.
The factor loadings extracted in this study were determined for both the upper and lower body dimensions based on Eigen values greater than 1 to determine the number of significant factors to retain. Eigen values represent the amount of variance accounted for by a factor (body dimension). Eigen values that are greater than 1 account for a meaningful amount of variance in the body dimensions and are worthy of being retained (Yong & Pearce, 2013: 85; Zakaria, 2014:106).

Prior to establishing the Eigen values, the total percentage of variance and a screen test plot of the 3D full body scanned data were analysed and performed respectively to identify how many factors should be retained for further analysis (see Table 4.14 and Table 4.15).

Table 4.13: The total variance explained for the upper body dimensions required for developing the prototype shirt pattern block.

Total Variance Explained for the upper body dimensions									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	7.3	52.2%	52.2%	7.3	52.2%	52.2%	6.8	48.7%	48.7%
2	1.7	12.3%	64.5%	1.7	12.3%	64.5%	2.1	15.1%	63.8%
3	1.1	8.2%	72.7%	1.1	8.2%	72.7%	1.2	8.9%	72.7%
4	1.0	7.2%	79.9%						
5	0.7	5.2%	85.1%						
6	0.5	3.7%	88.8%						
7	0.5	3.3%	92.1%						
8	0.3	2.2%	94.3%						
9	0.2	1.5%	95.8%						
10	0.2	1.4%	97.2%						
11	0.2	1.2%	98.4%						
12	0.1	1.0%	99.3%						
13	0.1	0.4%	99.8%						
14	0.0	0.3%	100.0%						

Table 4.14: The total variance explained for the lower body dimensions required for developing the prototype trouser pattern block.

Total Variance Explained for the lower body dimensions									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	5.8	44.6%	44.6%	5.8	44.6%	44.6%	5.2	40.2%	40.2%
2	2.5	18.9%	63.5%	2.5	18.9%	63.5%	2.8	21.2%	61.4%
3	1.6	12.7%	76.2%	1.6	12.7%	76.2%	1.9	14.8%	76.2%
4	1.0	8.0%	84.2%						
5	0.9	6.7%	90.9%						
6	0.4	3.1%	94.0%						
7	0.2	1.5%	95.5%						
8	0.2	1.2%	96.7%						
9	0.1	1.0%	97.7%						
10	0.1	0.9%	98.6%						
11	0.1	0.7%	99.2%						
12	0.1	0.5%	99.7%						
13	0.0	0.3%	100.0%						

Table 4.14 show that the upper body dimensions had 52.2% of the variance explained by the first component, 12.3% by the second component and 8.2% by the third component. In Table 4.15, the lower body dimensions had 44.6% of the variance explained by the first component, 18.9% by the second component and 12.7% by the third component. According to Zakaria (2014:107) the first few components should explain at least 50% of the variance to prove the practicality of PCA. Therefore, three components were retained for both the upper and lower body dimensions showing the extracted and rotated cumulative percentages of 72.7% for the upper body dimensions and the lower body dimensions showing the extracted and rotated cumulative percentages of 76.2%, validating that the analysed data was practical for use in PCA.

The Eigen values of each of the 14 upper body dimensions and 13 lower body dimensions were derived. The scree plot was analysed to determine where the Eigen value was greater than 1 to verify the number of components to retain for use in this study. The scree plot is usually used together with the Eigen values to determine the number of factors to retain; which is determined by the break point (curve) of the line in the scree plot. The x-axis represents the components and the Eigen values are along the y-axis. The first component accounts for the highest amount of variance and has the highest Eigen value. The Scree plot has a cut-off area, resulting in a line illustrating an “elbow” shape where the number of components to be retained is limited (Yong & Pearce, 2013:85; Zakaria 2014:106). Each component that appeared before the break point, at an Eigen value range that was greater than 1 was considered to be meaningful and was retained for the analysis in this study. The scree plots for retaining factor loadings for both the upper and lower body dimensions required for developing the shirt and trouser pattern blocks are illustrated in Figure 4.5 and Figure 4.6.

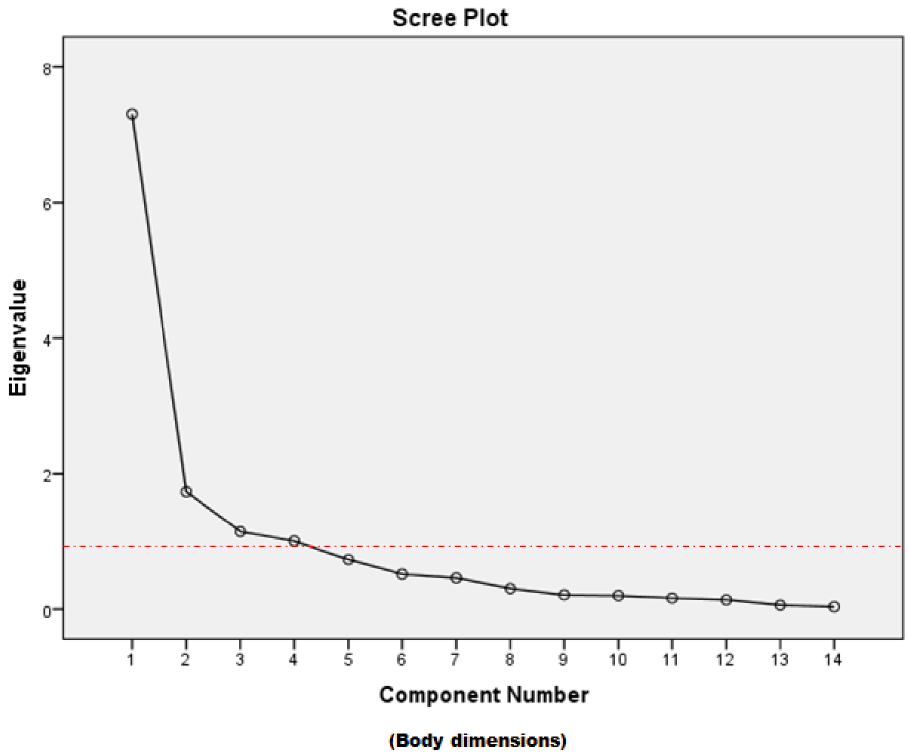


Figure 4.5: A scree plot for the upper body dimensions required for developing the prototype shirt pattern block.

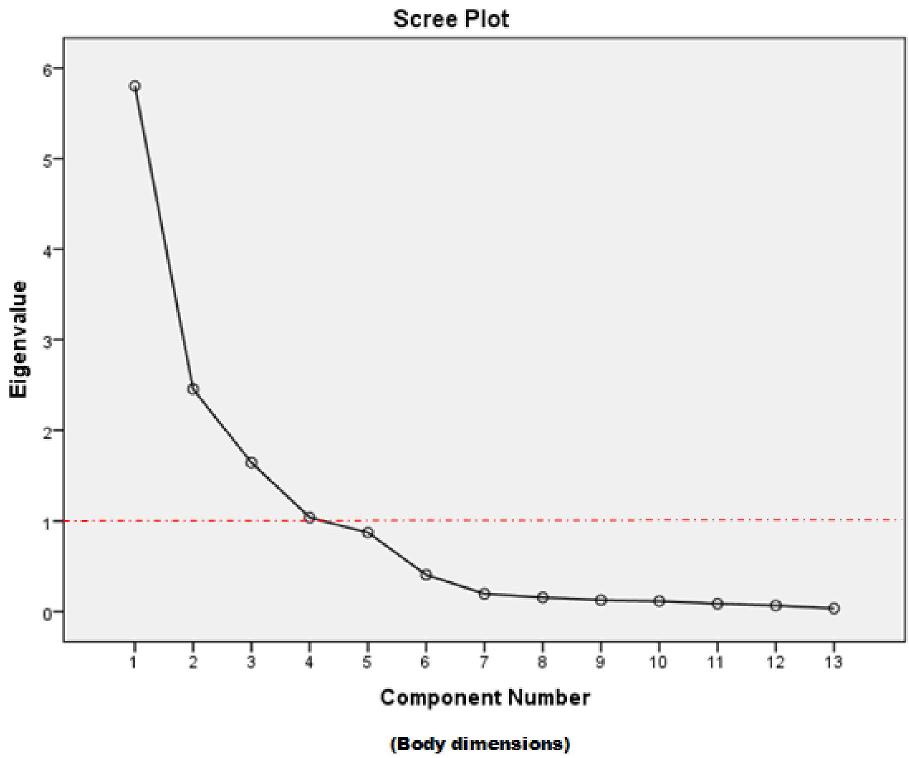


Figure 4.6: A scree plot for the lower body dimensions required for developing the prototype trouser pattern block.

As shown in Figure 4.5 and Figure 4.6, the components (body dimensions) for the Eigen values were greater than 1, for both the upper and lower body dimensions. Based on the results from the scree plot, it was concluded that most of the variances in the data could be accounted for by just above 4 component factor loadings for both the upper and lower body dimensions; however only three component factor loadings were practically significant for further analysis. The reason for considering three component factor loadings for further data analysis is justified by all three criteria's; the Eigen values, cumulative percentage of variance and the scree plots used together, which all shows 3 factors for both the upper and lower body dimensions.

The rotated component matrix established that the body dimension with the highest loaded factors and strong correlations is a good predictor for secondary body measurements when developing the experimental size charts for upper and lower body dimensions. The rotated component matrix was used to identify the key body dimensions existing in the three factor loadings. The component factor loadings are presented in Table 4.16 and Table 4.17. The factor loadings provide an indication of how strong the body dimensions have loaded onto a factor, meaning that body dimensions with large factor loading values are more essential body measurement landmarks required to develop the prototype shirt and trouser pattern blocks.

In this study, the body dimensions that were related to one other were clustered in factor loadings to make the interpretations of the body dimensions more definite and understandable. In situations where the body dimensions were loaded in multiple components, the component with a higher loading of the body dimension was considered and further reported.

Table 4.15: A rotated component matrix showing factor loadings for the upper body dimensions required for developing the prototype shirt pattern block.

Rotated Component Matrix for the upper body dimensions				
BODY DIMENSIONS		Component		
		1	2	3
GIRTHS	BUST	.928		
	UPPER WAIST	.920		
	UNDERBUST	.904		
	LOWER WAIST	.903		
	CHEST	.883		
	BICEP	.879		
	ELBOW	.788		.370
	NECK FULL	.742		
	ARMSCYE	.728		
LENGTHS	NECK TO UPPER WAIST (Back)		.950	
	NECK TO UPPER WAIST (Front)		.946	
	SHOULDER			
	SLEEVE			-.837
GIRTH	WRIST	.415		.604

As shown in Table 4.16: The highest loading per factor was considered when reporting.

- The factor loadings that were considered in Principal Component 1 were nine girth related body dimensions for the upper body dimensions, i.e. the bust, upper waist taken at navel/midriff area, underbust, lower waist taken 15 cm below the upper waist, at the lower waistline between the upper waist and high hip area; the chest, bicep, elbow, neck full and the armscye. Although, the bicep and elbow are associated with the arm, for this study they were included in the girth measurements as extracted in the component matrix.
- Principal Component 2 loaded two length related body dimensions for the upper body, i.e. the neck to upper waist back and the neck to upper waist front.
- The factor loadings that were considered in Principal Component 3 were sleeve related body dimensions, i.e. the sleeve length and the wrist. The shoulder length was not loaded in any component; however, the shoulder is related to the sleeve (arm) which clarifies the reason why it was included as part of the sleeve (arm) related body dimensions.

Table 4.16: A rotated component matrix showing factor loadings for the lower body dimensions required for developing the prototype trouser pattern block.

Rotated Component Matrix for the lower body dimensions				
BODY DIMENSIONS		Component		
		1	2	3
GIRTHS	TOP THIGH	.888		
	CALF	.872		
	UPPER WAIST	.868		
	LOWER WAIST	.860		
	HIP	.848	.390	
	MID-THIGH	.847		.365
	HIGH HIP	.748	.473	-.357
	ANKLE	.301		
	KNEE			
LENGTHS	CROTCH LENGTH BACK		.929	
	CROTCH LENGTH FRONT		.925	
	INSEAM		-.435	.842
	OUTSEAM		.543	.804

- Principal Component 1 loaded eight girth related body dimensions for the lower body, i.e. the top thigh, calf, upper waist, lower waist, hip, mid-thigh, high hip and the ankle. The knee was not loaded in any component; however, the knee is related to most of the body dimensions in Component 1 which explains the reason why it is included as part of the girth related body dimensions.
- Principal Component 2 loaded two crotch length related body dimensions for the lower body, i.e. the crotch length back and the crotch length front.
- Principal Component 3 loaded two length related body dimensions for the lower body, i.e. the inseam and the outseam lengths.

The selected key body dimensions in Table 4.16 and Table 4.17 are discussed further in the latter part of this chapter.

The purpose of the factor loading analysis was to select key body dimensions for developing the size charts for the upper and lower body dimensions in this study. According to Zakaria (2014:96), key body dimensions are primary body dimensions that define an individual's body size; they are used as control dimensions to develop a sizing system and to assign garment size ranges to facilitate a good fit.

A body dimension is considered key (primary) when it plays an essential role in assessing whether a specific garment is wearable and can cover the entire body of a consumer or not; whilst a secondary dimension assesses the fit of a garment on the wearer's body. Secondary dimensions are often used together with the key (primary) body dimensions to define the full body size of a person. Mpampa *et al*. (2009:51) state that for consistency in garment sizing, it is important that the key dimensions are presented in a constant way by all manufacturers and retailers.

Various researchers, Gupta and Gangadhar (2004: 465), Strydom (2006: 234,236), Petrova (2007:64,70), and Zakaria (2014:113) ascertain that the most commonly used girth measurements that have proven to be useful and essential by garment sizing and fit experts for establishing size charts for shirt garments is the bust for the upper body; and the trouser garments is the hip for the lower body. Strydom's (2006:232) study suggest that the most used key body dimensions for creating trouser garments by South African garment manufacturers and retailers is the outer leg length (outseam), the waist circumference and the hip circumference.

The results obtained from the component matrix in Table 4.16 and Table 4.17 were used to identify the key body dimensions to consider when developing the experimental petite upper and lower body dimensions size charts for constructing the pattern blocks for creating the prototype shirt and trouser garments in this study. The results are further discussed below.

4.3.1 Results of the component matrix for the upper body dimensions to be used as key body dimensions when developing the size chart in this study

According to Gupta and Zakaria (2014:4), a high factor loading, indicates that the body dimension is strongly associated with the other body dimensions loaded in the component. However, Zakaria (2014:113-114) suggests that a high factor loading does not necessarily mean those identified body dimensions should be selected as key body dimensions, but should be easily recognised by the consumer since they are used as an essential feature in garment size labelling that the consumers use as a guideline for selecting their garment sizes when shopping.

The highest loading factors in each of the three components presented in Table 4.16 were evaluated for the selection of the key body dimensions to be used when developing the upper body size chart in this study. As seen in Table 4.16, the bust was the highest loading body dimension for the girth factor for component 1. The upper waist (at navel/midriff), was also included as the key body dimension for the girth measurement. Because of the varied abdominal protrusions occurring in different individuals, the upper waist is a body dimension that could be used to evaluate the wearability of the prototype shirt garments to be produced in this study. The highest loaded body dimension in component 2 was a length related body dimension; namely, the neck to upper waist back. The sleeve length was recognised in component 3 as the highest loading body dimension.

The above-mentioned body dimensions namely, bust, upper waist, neck to upper waist back and sleeve length, were identified among the variables to use as key body dimensions when developing the size charts for constructing pattern blocks for the prototype shirt garments.

4.3.2 Results of the component matrix for the lower body dimensions to be used as key body dimensions when developing the size chart in this study

The highest loading factors in each of the three components presented in Table 4.17 were evaluated for the selection of the key body dimensions to be used when developing the lower body size chart in this study. As seen in Table 4.17, the component matrix recognised the top thigh as the highest loading body dimension to the girth factor for component 1; followed by the calf. The above-mentioned body dimensions have not been previously identified by researchers as essential body dimensions for the lower body. Consumers are not familiar with using the top thigh and calf measurements as a guideline for selecting their garment sizes when shopping (Zakaria, 2014:113). The top thigh and calf body dimensions were not considered as key body dimensions because they do not evaluate the wearability of a trouser garment and consumers are not familiar with using those body dimensions for selecting their trouser garment sizes (Mpampa *et al*., 2009:51; Zakaria, 2014:113). Including all these body dimensions as key body dimensions will lead to a size label that has too many measurement sizing options for the consumers to choose from, which will confuse them when shopping for their garments.

The upper waist, lower waist and the hip were considered as key body dimensions for the girth measurement by researchers such as Gupta and Gangadhar (2004: 465), Strydom (2006: 232,234,236), Petrova, (2007:64, 70), Mastamet-Mason (2008:77), and Zakaria (2014: 96,113). Therefore, the upper waist, lower waist and hip girths were selected as critical body dimensions for component 1 to use when developing size charts for the lower body dimensions in this study. The highest loaded body dimension in component 2 was a length related body dimension; namely, the crotch length back. The inseam length was recognised in component 3 as the highest loading body dimension. The component matrix identified the above-mentioned body dimensions namely, upper waist, lower waist, hip, crotch length back and inseam length as the variables to use as key body dimensions when developing the size charts for constructing pattern block for the prototype trouser garment.

The identified upper and lower key body dimensions are the important landmarks to use for the classification of the upper and lower body size charts for the pear shaped South African petite women. The results from the upper body dimensions identified four key body dimensions and the lower body dimensions identified five key body measurements as critical measurements required when developing prototype shirt and trouser garments. The PCA performed in this study confirmed that the key body

dimensions established for developing the size charts for the upper and lower body dimensions prove to be primary body dimensions.
Furthermore, most of the key body dimensions established in this study are also commonly found and acknowledged in literature from other garment sizing and fit studies such as Gupta and Gangadhar (2004: 465), Strydom (2006: 232,234,236), Petrova, (2007:64, 70), and Zakaria (2014:113); apart from the neck to upper waist back length, sleeve length for the upper body and the crotch length back and the inseam for the lower body.

The next section describes and explains the methods and procedures used to develop the upper and lower body dimensions size charts, using the key body dimensions.

4.4 METHODS AND PROCEDURES FOR DEVELOPING THE EXPERIMENTAL SIZE CHARTS FOR PETITE WOMEN IN SOUTH AFRICA

Objective 2 of this study was to develop the experimental size charts from the 3D full body scanned extracted data collected in this study based on the upper body dimensions required for creating the prototype shirt garments and lower body dimensions required for creating the prototype trouser garments. The most prevalent body shape was identified as the pear body shape profile; and the subjects within the sample had an average height measurement of 157 cm. Therefore, a size chart for the shirt and trouser garment prototypes for the South African petite women was developed for the sample of women with pear shaped body profiles, with an average height of 157 cm, and aged from 20-54 years.

The key body dimensions established in this study were used to generate the size of the intervals on which the size ranges in the size charts were imposed. Regression analysis was applied to determine the relationship between the established key (primary) body dimensions and the secondary body dimensions to predict size intervals and allocate the various sizes in the size charts. Regression analysis was used to determine how a body dimension increases or decreases as the measurement value of each key body dimension changes (Chan, 2014:170).

A descriptive statistical analysis for both the upper and lower body dimensions was conducted to determine the range of various 3D full body scanned dimensions required for the prototype basic shirt and trouser garments, to establish size ranges for the size charts to be developed in this study. The collected data of the 3D full body scanned petite body measurements were analysed to derive their mean, standard deviation, skewness of the data, and the minimum and maximum values. The mean value was used as a convenient indication for obtaining the central (average) measurement number for the collected data and for establishing the size ranges in the size charts, as suggested by Chan (2014:177). The standard deviation, according to Leedy and Ormrod (2010:270) indicates how the analysed body measurements are distributed and represents variations of data distributions from the data. Skewness measures how far a distribution deviates from the regularity (Maree, 2007:189-190 and Leedy & Ormrod, 2010:264).

The standard deviation and the skewness of the data were critically observed by the researcher and statistician prior to conducting the regression coefficient analysis. Appendix F and Appendix G present examples of the box plots and histogram distributions for all the upper and lower body 3D full body scanned petite women's data. The frequency distributions for all the observed body dimensions were analysed to conclude visually the normality distribution of the analysed data, using the graphical methods such as histograms, normal quantile-quantile plots (Q-Q plots) and boxplots from the SPSS software. The histograms, normal Q-Q plots and boxplots were produced in the SPSS software to show how the data was distributed and present outliers in the data for each body dimension. A histogram that has a dumb-bell shape indicates a normal distribution curve of the analysed data (Chan, 2014:170). The histograms provided a visual judgment about whether the distribution is bell curve shaped. There was an observable bell-curve shape in most of the histograms for the analysed data, with a few measurement values of the petite women present in the lower and higher ends of the distribution. A Q-Q plot is a graphical data analysis method that evaluates whether the analysed data observations are derived from a normal distribution (Castillo-Gutiérrez *et al*., 2012:243). Boxplots present information on where the analysed data is located, how the data is spread and how skew the data lies (Hubert & Vandervieren, 2006:1).

Furthermore, Hubert and Vandervieren (2006:2) state that boxplots present the median of the analysed data as a horizontal line inside the box and the interquartile range as the length of the box to detect how skewed the data is. The boxplots observed in this study were symmetric and linear. The average measurement lines were observed at approximately the middle of the box suggesting that the data was derived from a normal distribution. Although, there were minor differences between the plotting line positions.

According to Petrova (2007:64), the size range of a sizing system needs to be determined by establishing the minimum and maximum measurement values of the analysed data to distribute within the size intervals. The lower and upper limit of each body dimension was calculated to establish the limit of each size range and demonstrate the extent of coverage of the body measurements for the size ranges.
The maximum and minimum measurement values for the body dimensions were established from the 3D full body scanned subjects' data as indicated in Table 4.18 and Table 4.19 below.

Table 4.17: The minimum and maximum measurement values for the upper body dimensions

	MIN (cm)	**MAX (cm)**	**BODY DIMENSIONS**
UPPER BODY GIRTH MEASUREMENTS	74	140	Bust
	60	131	Upper waist
	62	135	Underbust
	61	142	Lower waist
	56	140	Chest
	19	46	Bicep
	19	41	Elbow
	28	49	Neck full
	25	58	Armscye
UPPER BODY LENGTH MEASUREMENTS	29	49	Neck to upper waist back
	24	45	Neck to upper waist front
ARM MEASUREMENTS	44	59	Sleeve length
	12	21	Wrist
	8	17	Shoulder length

Table 4.18: The minimum and maximum measurement values for the lower body dimensions

	MIN (cm)	MAX (cm)	BODY DIMENSIONS
LOWER BODY GIRTH MEASUREMENTS	60	131	Upper waist
	61	142	Lower waist
	81	144	Hip
	45	78	Top thigh
	39	71	Mid-thigh
	28	58	Calf
	71	145	High hip
	20	39	Ankle
	31	64	Knee
LOWER BODY CROTCH LENGTH MEASUREMENTS	21	59	Crotch length back
	22	57	Crotch length front
LOWER BODY LENGTH MEASUREMENTS	60	90	Inseam
	94	113	Outseam

Thereafter, the established key body dimensions (as highlighted in Table 4.18 and Table 4.19) were applied in the regression analysis to predict the size ranges of the secondary body dimensions.

Chan (2014:175) advises that a selection from both the girth measurements and the length measurement should be applicable in the regression analysis; using their identified key body dimensions so that each body dimension predicts measurements that represent their cluster. The girth and length measurements for each key body dimension were established in this study (refer to Table 4.18 and Table 4.19). The key body dimensions selected for the upper and lower body dimensions, when performing the regression analysis, were based on the practicality of the selected body dimensions, since they were used to assign sizing categories in the shirt and trouser garments to be produced in this study. The bust and the upper waist were used for the upper body girth measurements, the neck to upper waist back was used for the upper body length measurements and the sleeve length was used to represent the arm measurements.

The upper waist, lower waist and the hip were used for the lower body girth measurements, the crotch length back was used to represent the crotch area and the inseam was used for the lower body length measurements.

From the findings of the descriptive statistical analysis, it was concluded that the numerical and graphical distributions of the analysed body dimensions provided a more accurate representation of the data and of possible outliers present in the data. Outliers were observed in the neck full, shoulder length, armscye, elbow, chest, underbust, upper waist, neck to upper waist back, neck to upper waist front, mid-thigh, calf, knee, outseam, inseam, crotch length front, and the crotch length back showing measurement values that lie outside the main dataset.

4.4.1 Regression analysis for predicting the size ranges for the size charts

Sizing systems usually use regression analysis when calculating the relationship between body measurements. Maree (2007:240) and Shin and Istook (2007:137) refer to regression analysis as a statistical method commonly used to estimate body measurements from one size to the next size by examining the relationships between variables. Regression analysis may be used to predict the values of a dependent variable from new values of an independent variable (Leedy & Ormrod, 2010:282). In the regression analysis for this study, the key body dimensions (the bust, upper waist, neck to upper waist back and sleeve length for the upper key body dimensions and the upper waist, lower waist, hip, crotch length back and inseam for the lower key body dimensions) were used as independent variables, whilst the secondary body dimensions (the underbust, lower waist, chest, bicep, elbow, neck full, armscye, neck to upper waist front, shoulder length and wrist) for the upper secondary body dimensions and the top thigh, calf, mid-thigh, high hip, ankle, knee, crotch length front and outseam for the lower secondary body dimensions were used as dependent variables.

According to Chan (2014:177), the regression analysis influences how garment sizing for each person is assigned since the key body dimensions determine which size group a specific person belongs to; based on their measurements. A population's size range is established by the maximum and minimum values of the key dimensions, including the size interval which is the measurement difference between two adjacent sizes (Petrova, 2007:64). The number of sizes in a sizing system is defined by the value of the size intervals (Chan, 2014:188) together with the required size range that will accommodate the population (Petrova, 2007:72). Chan (2014:180-181) suggests that, because the design of a sizing system is determined in terms of convenience and is based on the fit and practicality, size intervals should be systematically uniform between sizes to permit effective pattern grading. Petrova and Ashdown (2012:268) state that size intervals may vary across the size ranges; it may be smaller for the smaller sizes or increase for the larger sizes. The point of change in the size intervals is called the break.

According to Chan (2014:179), garment size intervals often start from 3 cm to 8 cm depending on the body dimension, standard of garment fit and many other factors. In South African studies, Defty (1988:17-18) used 1 cm - 2 cm size intervals for the bust and hip girth measurements; however, the size ranges were labelled in odd numbers and the numbers were not corresponding with currently used size range number labelling. Winks (1990:74-76) used a 4 cm - 6 cm size interval for the bust and hip girth measurements; the size ranges were not defined. Bailey's (2010:1) size intervals ranged from 1 cm for the bust, 2 cm for the waist and hip for a size chart designed for South African petite women size 2/28 to size 6/30.

The guidelines on how the regression analysis was calculated to allocate the size ranges in the size charts are presented in steps below.

Step 1:

To determine the size intervals for all the body dimensions in this study, firstly each key body dimension was calculated by subtracting the minimum value from the maximum value of that specific key body dimension, then dividing the difference by the number of size ranges to be allocated in the size chart (see the calculations below in sections 4.4.1.1 and 4.4.1.2, used to determine the size intervals for the upper key body dimensions and the lower key body dimensions).

The size ranges in this study were designed to accommodate the 3D full body scanned petite pear body shape measurements. Chan (2014:182) states that size ranges are usually developed using an odd number. Size intervals are used to adjust the sizing proportions of the analysed data into different size ranges as a scientific estimate of garment fit (Salusso *et al*., 2006:99). Chan (2014:182) further advises that the size ranges should not be restricted to a small range but should meet the requirements of the population. Therefore, 11 size ranges were established for developing the size charts in this study, using the minimum and maximum measurement coverage of the body dimensions from the analysed 3D full body petite pear shaped subjects' data. Other size ranges were tested, but 11 was found to be the best number to use for developing the size charts in this study for the upper and lower body dimensions.

4.4.1.1 Calculations for determining the size intervals for the upper key body dimensions.

a. Calculations of the size intervals for the upper body girth related key body dimensions

- Upper waist: 131 - 60 = 71/11 = 6.4, which was rounded down to 6
- Bust: 140 - 74 = 66/11= 6

b. Calculations of the size intervals for the upper body length related key body dimension

- Neck to upper waist back: 49 – 29 = 20/11 = 1.8, which was rounded up to 2

c. **Calculations of the size intervals for the upper body arm related key body dimension**

- Sleeve length: 59 – 44 = 15/11 = 1.3, which was rounded down to 1

4.4.1.2 Calculations for determining the size intervals for the lower key body dimensions

a. **Calculations of the size intervals for the lower body girth related key body dimensions**

- Upper waist: 131-60= 71/11 = 6.4 rounded down to 6
- Lower waist: 142 - 61 =81/11= 7.3, which is rounded down to 7
- Hip: 144 - 81 = 63/11 = 5.7, which was rounded up to 6

b. **Calculations of the size intervals for the lower body crotch length related key body dimension**

- Crotch length back: 59-21 =38/11= 3.4 rounded down to 3

c. **Calculations of the size intervals for the lower body length related key body dimension**

- Inseam: 60-90 =30/11= 2.7 rounded up to 3

The size intervals for the upper key body dimensions were determined as the upper waist: 6 cm, bust: 6 cm, neck to upper waist back: 2 cm and sleeve length: 1 cm; for the lower body dimensions were the upper waist: 6 cm, lower waist: 7 cm, hip: 6 cm, crotch length back: 3 cm and inseam: 3 cm. The appropriate size intervals for the secondary body dimensions in this study were determined from the regression analysis. The regression equations were computed in the SPSS and then calculated in Microsoft Excel.

Step 2:

The SPSS statistical program was used to calculate the regression equations of the form z= D+ (aw) + (bx) (where z represents the predicted secondary dimension number, D represents the constant; a, b represents the coefficient constants and w, x represents the key body dimensions). The regression calculation formula depends on the number of key dimensions allocated in the PCA (see Table 4.16 for the upper body dimensions and Table 4.17 for the lower body dimensions); indicating that one or more than two key body dimensions can be used in each equation.

Thus, for example, the Chest girth =21.073 + 0.246 x Upper waist girth + 0.565 x Bust girth.

The regression coefficient constants for the upper body dimensions are presented in Table 4.20, Table 4.21 and Table 4.22. Table 4.23, Table 4.24 and Table 4.25 present the lower body dimensions, to predict the secondary body dimensions within the size ranges for the size charts.

4.4.1.3 Calculations for determining the regression constants in the equations that relate to the primary (upper key) body dimensions and the secondary body dimensions

Table 4.19: Regression coefficient constants calculations for the upper body girth related body dimensions.

Regression coefficient constants calculations for the upper body girth related body dimensions			
Secondary body dimension	**Constants**	**Bust**	**Upper waist**
Chest	21.07	0.57	0.25
Underbust	-6.69	0.61	0.41
Lower waist	2.13	0.17	0.92
Bicep	3.46	0.11	0.21
Elbow	4.38	0.07	0.18
Neck full	20.16	0.06	0.13
Armscye	14.50	0.16	0.11

Table 4.20: Regression coefficient constants calculations for the upper body length related body dimension.

Regression coefficient constants calculations for the upper body length related body dimension		
Secondary body dimensions	**Constant**	**Neck to upper waist back**
Neck to upper waist front	5.88	0.72

Table 4.21: Regression coefficient constants calculations for the upper body arm related body dimension

Regression coefficient constants calculations for the upper body arm related body dimension		
Secondary body dimension	**Constants**	**Sleeve length**
Shoulder length	12.34	-0.00
wrist	19.85	-0.08

4.4.1.4 Calculations for determining the regression constants in the equations that relate to the primary (lower key) body dimensions and the secondary body dimensions

Table 4.22: Regression coefficient constants calculations for the lower body girth related body dimensions

Regression coefficient constants calculations for the lower body girth related body dimensions				
Secondary body dimensions	**Constants**	**Upper waist**	**Lower waist**	**Hip**
Top thigh	23.88	0.14	0.08	0.15
Mid-thigh	15.88	0.17	-0.04	0.21
Calf	9.05	0.03	0.06	0.19
High hip	1.57	0.02	0.33	0.63
Ankle	19.27	0.06	0.01	0.02
Knee	46.11	-0.01	0.01	-0.06

Table 4.23: Regression coefficient constants calculations for the lower body crotch length related body dimension

Regression coefficient constants calculations for the lower body crotch length related body dimension		
Secondary body dimensions	**Constant**	**Crotch length back**
Crotch length front	4.93	0.84

Table 4.24: Regression coefficient constants calculations for the lower body length related body dimension

Regression coefficient constants for the lower body length related body dimension		
Secondary body dimensions	**Constant**	**Inseam**
Outseam	73.21	0.41

<u>Step 3:</u>

The regression equations for allocating the different size range measurements in the size charts were entered into a Microsoft Excel spreadsheet to calculate the values of the secondary body dimensions according to the value of each key body dimension. An example of the regression calculations for determining the values within the size ranges is presented in Appendix H. The upper body girth related body dimensions (upper waist and bust) were used as the key body dimensions and the chest as the secondary body dimension.

The remaining calculations for the other upper and lower body dimensions in the size charts were calculated using the same guidelines.

The development of the experimental size charts was carried out using the average values of the key body dimensions obtained from the statistical analysis to define the start of the size ranges. These average measurements usually lie at the centre of the size ranges in the size chart to permit evenly distributed measurements (Chan, 2014:181). The average measurements for the key upper body dimensions were the upper waist: 82 cm, bust: 100 cm, neck to upper waist back: 37 cm and sleeve length: 50 cm; for the lower body were the upper waist: 82, lower waist: 95 cm, hip: 108 cm, crotch length back: 41 cm and inseam: 72 cm

Step 4:

To allocate size ranges for the key body dimensions, the average measurements (see the highlighted data in Table 4.26 to Table 4.31) established for each key body dimension were calculated together with their assigned size intervals by either subtracting or adding the size intervals from the average measurements. The size ranges for the 3D full body scanned petite body measurements were arranged in order, from the smallest body dimensions size measurements to the largest body dimensions size measurements present in the dataset using the size intervals.

4.4.1.5 Predictions and allocation of the size range measurements for the upper key body dimensions

Table 4.25: Size range measurement predictions and allocation of the upper body girth related key body dimensions.

Size range measurement predictions and allocation of the upper body girth related key body dimensions (cm)												
	1	2	3	4	**5**	Size intervals	6	7	8	9	10	11
BUST	**76**	**82**	**88**	**94**	**100**	6	**106**	**112**	**118**	**124**	**130**	**136**
UPPER WAIST	**58**	**64**	**70**	**76**	**82**	6	**88**	**94**	**100**	**106**	**112**	**118**
Secondary body dimensions												
Chest	78	83	88	93	98		103	107	112	117	122	127
Underbust	63	69	75	81	87		93	99	105	111	117	123
Lower waist	68	75	81	88	94		101	107	114	121	127	134
Bicep	24	26	28	30	31		33	35	37	39	41	43
Elbow	20	21	23	24	26		27	29	30	32	33	35
Neck full	32	33	35	36	37		38	39	40	41	42	44
Armscye	33	34	36	38	39		41	42	44	46	47	49

Table 4.26: Size range measurement predictions and allocation of the upper body length related key body dimension.

Size range measurement predictions and allocation of the upper body length related key body dimension (cm)												
	1	2	3	4	**5**	Size interval	6	7	8	9	10	11
NECK TO UPPER WAIST BACK	**29**	**31**	**33**	**35**	**37**	2	**39**	**41**	**43**	**45**	**47**	**49**
Secondary body dimension												
Neck to upper waist front	27	28	30	31	32		34	35	37	38	40	41

Table 4.27: Size range measurement predictions and allocation of the upper body arm related key body dimension.

Size range measurement predictions and allocation of the upper body arm related key body dimension (cm)												
	1	2	3	4	5	Size interval	6	7	8	9	10	11
SLEEVE LENGTH	**46**	**47**	**48**	**49**	**50**	1	**51**	**52**	**53**	**54**	**55**	**56**
Secondary body dimension												
Shoulder length	12	12	12	12	12		12	12	12	12	12	12
Wrist	16	16	16	16	16		16	16	16	16	16	16

4.4.1.6 Predictions and allocation of the size range measurements for the lower key body dimensions

Table 4.28: Size range measurement predictions and allocation of the lower body girth related key body dimensions.

Size range measurement predictions and allocation of the lower body girth related key body dimensions (cm)												
	1	2	3	4	5	Size intervals	6	7	8	9	10	11
UPPER WAIST	**58**	**64**	**70**	**76**	**82**	6	**88**	**94**	**100**	**106**	**112**	**118**
LOWER WAIST	**67**	**74**	**81**	**88**	**95**	7	**102**	**109**	**116**	**123**	**130**	**137**
HIP	**84**	**90**	**96**	**102**	**108**	6	**114**	**120**	**126**	**132**	**138**	**144**
Secondary body dimensions												
Top thigh	50	53	55	57	60		62	64	67	69	71	74
Mid-thigh	41	43	45	47	49		51	53	55	57	59	61
Calf	31	33	35	36	38		40	42	43	45	47	49
High hip	78	84	90	96	103		109	115	121	127	133	140
Ankle	25	26	26	27	27		28	29	29	30	30	31
Knee	40	40	41	41	41		41	42	42	42	42	43

Table 4.29: Size range measurement predictions and allocation of the lower body crotch length related key body dimension

Size range measurement predictions and allocation of the lower body crotch length related key body dimension (cm)												
	1	2	3	4	5	Size interval	6	7	8	9	10	11
CROTCH LENGTH BACK	**29**	**32**	**35**	**38**	**41**	3	**44**	**47**	**50**	**53**	**56**	**59**
Secondary body dimensions												
Crotch length front	29	32	34	37	40		42	45	47	50	52	55

Table 4.30: Size range measurement predictions and allocation of the lower body length related key body dimension.

Size range measurement predictions and allocation of the lower body length related key body dimension (cm)												
	1	2	3	4	5	Size interval	6	7	8	9	10	11
INSEAM	**60**	**63**	**66**	**69**	**72**	3	**75**	**78**	**81**	**84**	**87**	**90**
Secondary body dimensions												
Outseam	98	99	100	102	103		104	105	107	108	109	110

These findings provided the framework for the development of the experimental upper and lower body size charts in this study. The upper and lower body experimental size charts were developed for the South African petite women’s prototype shirt and trouser garments.

Table 4.32 and Table 4.33 below present the experimental size charts developed for South African petite women’s prototype shirt and trouser garments, including the size intervals for each size range.

4.4.2 The experimental size charts developed for the South African petite women

Table 4.31: The experimental size chart (with size intervals) for constructing the pattern blocks for creating prototype shirt garments for South African petite women.

PETITE WOMEN'S SIZE CHART FOR THE UPPER BODY DIMENSIONS (cm)												
	SIZE RANGES	**6/30**	**8/32**	**10/34**	**12/36**	**14/38**	**16/40**	**18/42**	**20/44**	**22/46**	**24/48**	**26/50**
	Bust	76	82	88	94	100	106	112	118	124	130	136
GIRTHS	**Upper waist** (at navel, midriff area)	58	64	70	76	82	88	94	100	106	112	118
	Chest	78	83	88	93	98	103	107	112	117	122	127
	Underbust	63	69	75	81	87	93	99	105	111	117	123
	Lower waist (15cm below the upper waist)	68	75	81	88	94	101	107	114	121	127	134
	Bicep	24	26	28	30	31	33	35	37	39	41	43
	Elbow	20	21	23	24	26	27	29	30	32	33	35
	Neck full	32	33	35	36	37	38	39	40	41	42	44
	Armscye	33	34	36	38	39	41	42	44	46	47	49
LENGTHS	**neck to upper waist back**	29	31	33	35	37	39	41	43	45	47	49
	neck to upper waist front	27	28	30	31	32	34	35	37	38	40	41
SLEEVE AREA	**sleeve length** (shoulder-wrist)	46	47	48	49	50	51	52	53	54	55	56
	Shoulder length	12	12	12	12	12	12	12	12	12	12	12
	Wrist	16	16	16	16	16	16	16	16	16	16	16

Table 4.32: The experimental size chart (with size intervals) for constructing the pattern blocks for creating prototype trouser garments for South African petite women.

	PETITE WOMEN'S SIZE CHART FOR THE LOWER BODY DIMENSIONS cm)											
	SIZE RANGES	**6/30**	**8/32**	**10/34**	**12/36**	**14/38**	**16/40**	**18/42**	**20/44**	**22/46**	**24/48**	**26/50**
GIRTHS	**Upper waist**	58	64	70	76	82	88	94	100	106	112	118
	Lower waist (15cm below the upper waist)	67	74	81	88	95	102	109	116	123	130	137
	Hip (20cm below lower waist)	84	90	96	102	108	114	120	126	132	138	144
	Top thigh	50	53	55	57	60	62	64	67	69	71	74
	Mid-thigh	41	43	45	47	49	51	53	55	57	59	61
	Calf	31	33	35	36	38	40	42	43	45	47	49
	high hip (10cm below lower waist)	78	84	90	96	103	109	115	121	127	133	140
	Ankle (under the feet-over side ankle bones)	25	26	26	27	27	28	29	29	30	30	31
	Knee	40	40	41	41	41	41	42	42	42	42	43
CROTCH AREA	**Crotch length back**	29	32	35	38	41	44	47	50	53	56	59
	Crotch length front	29	32	34	37	40	42	45	47	50	52	55
LENGTHS	**Inseam** (inside leg length)	60	63	66	69	72	75	78	81	84	87	90
	Outseam (outside leg length)	98	99	100	102	103	104	105	107	108	109	110

4.5 CALIBRATION OF SIZE CHARTS

The size 10/34 of the 3D full body scanned tailoring mannequin was used as a standard to allocate the 3D subject's body scanned data into different size ranges; since the tailoring mannequin's measurements were the only currently acceptable "true values", as there are no other petite 3D scan data measurements in South Africa with which to compare the 3D scan data of the subjects collected during this study. The measurement differences are compared in Table 4.34 for the upper body and Table 4.35 for the lower body.

Table 4.33: The differences between the size 10/34 3D full body scanned petite women's upper body measurements and the size 10/34 3D full body scanned petite tailoring mannequin's measurements.

Body dimensions	**Size 10/34 3D full body scanned petite women's measurements (in this study)**	**Measurement differences**	**Size 10/34 3D full body scanned petite tailoring mannequin measurements**
	UPPER BODY (cm)		
Bust	88	-2	86
Upper waist	70	-1	69
Chest	88	-1	87
Underbust	75	-2	73
Lower waist	81	+4	85
Bicep	28	-1	27
Elbow	23	-3	20
Neck full	35	-1	34
Armscye	36	-3	33
Neck to upper waist back	33	+6	39
Neck to upper waist front	30	+5	35
sleeve length	48	+3	51
Shoulder length	12	0	12
Wrist	16	-1	15

Table 4.34: The differences between the size 10/34 3D full body scanned petite women's lower body measurements and the size 10/34 3D full body scanned petite tailoring mannequin's measurements.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Measurement differences	Size 10/34 3D full body scanned petite tailoring mannequin measurements
	LOWER BODY (cm)		
Upper waist	70	-1	69
Lower waist	81	+4	85
Hip	96	-1	95
Top thigh	55	-1	54
Mid-thigh	45	-4	41
Calf	35	-1	34
High hip	90	+2	92
Ankle	26	-1	25
Knee	41	-2	39
Crotch length back	35	+1	36
Crotch length front	34	+2	36
Inseam	66	+7	73
Outseam	100	+2	102

Table 4.34 and Table 4.35 present the size 10/34 garment measurements for the mannequin's 3D full body scanned measurements when compared to the 3D full body scanned subjects' measurements in the size charts developed for this study. The above-mentioned measurements of the 3D full body scanned data were observed as closest to that of the size 10/34 tailoring mannequin measurements and were, therefore, used as a base size for labelling the size charts. A set of size ranges from the remaining data were proportionally graded from this size. The size ranges established from the 3D full body scanned subjects' data used for developing the experimental size charts in this study ranged from size 6/30 to size 26/ 50.

The differences between the size 10/34 3D full body scanned petite women's upper and lower body measurements and the size 10/34 3D full body scanned petite tailoring mannequin's measurements are elaborated on below.

- 7 cm measurement differences were observed in the inseam. The size 10/34 tailoring mannequin's inseam measurement was 7 cm longer than the subjects' size 10/34 size range measurement.

- 6 cm measurement differences were observed in the neck to upper waist back. The size 10/34 tailoring mannequin's neck to upper waist back measurement was 6 cm longer than the subjects' size 10/34 size range measurement.
- 5 cm measurement differences were observed in the neck to upper waist front. The size 10/34 tailoring mannequin's neck to upper waist front measurement was 5 cm longer than the subjects' size 10/34 size range measurement.
- 4 cm measurement differences were observed in the lower waist and mid-thigh. The size 10/34 tailoring mannequin's lower waist measurement was 4 cm bigger than the subjects' size 10/34 size range measurement; although, the mannequin's mid-thigh measurement was 4 cm smaller when compared to the subjects' size 10/34 size range measurement.
- 3 cm measurement differences were observed in the elbow, armscye and sleeve length. The size 10/34 tailoring mannequin's sleeve length measurement was 3 cm longer than the subjects' size 10/34 size range measurement. The mannequin's elbow and armscye measurements were 3 cm smaller when compared to the subjects' size 10/34 size range measurements.
- 2 cm measurement differences were observed in the bust, underbust, high hip, crotch length front, knee and outseam. The size 10/34 tailoring mannequin's bust, underbust, crotch length front and outseam measurements were 2 cm bigger than the subjects' size 10/34 size range measurement; while the high hip, knee measurements of the mannequin were 2 cm smaller compared to the subjects' size 10/34 size range measurements.
- 1 cm measurement differences were observed in the upper waist, chest, bicep, neck full, wrist, hip, top thigh, calf, ankle and crotch length back. The size 10/34 tailoring mannequin's upper waist, chest, bicep, neck full, wrist, hip, top thigh, calf, ankle measurements were 1 cm bigger than the subjects' size 10/34 size range measurements; while the crotch length back measurement was 1 cm smaller when compared to the subjects' size 10/34 size range measurement.
- The shoulder length measurements remained the same in both compared measurements.

The results show that there were variations between the 3D full body scanned subjects' measurements and the 3D full body scanned tailoring mannequin's measurements that are currently used for creating shirt and trouser garments for

South African petite women. The data suggests that the size 10/34 subjects are shorter than the mannequin, concluding that garments made to fit the mannequin are likely to be too long for the subjects. This further suggests that South African petite women are still likely to find challenges when shopping for their ready-to-wear shirt and trouser garments in retail stores.

The 3D full body scanned data for the petite women was developed for the pear body shape profile; however, the shape of the mannequin was unknown as it could not be detected by the 3D full body scanner body shape software. Nonetheless, the relationship between the 3D full body scanned measurements (see Table 4.34 and Table 4.35) of the mannequin's bust, upper waist and hip body landmarks were used to determine the shape of the mannequin; as above-mentioned body landmarks are the most commonly used body landmarks used to identify and categorise different body shapes through visual observations. The size 10/34 mannequin's bust (86 cm), upper waist (69 cm) and hip (95 cm) measurement relationship were in accordance with the bust (88 cm), upper waist (70 cm) and hip (96 cm) measurement relationship of the pear body shaped size 10/34 size chart measurements. As a result, the mannequin was classified as having a pear body shape profile. However, visual shape classification observations of the mannequin suggested that the mannequin had a crossover shape between the hourglass body shape and the pear body shape profiles. Nonetheless, the pear shape profile was considered for comparisons in this study.

The sizing specifications for each body dimension were developed adopting an experimental approach. The size intervals were calculated from the founded measurement values between each size range of the secondary body dimensions. A personal conversation with the manager of a well-known petite tailoring mannequin mentioned that there are no size charts developed specifically for petite women in South Africa (Millam, 2016), therefore the grade rules for petite women's garment sizing measurements are unknown. Size intervals are beneficial and applicable when grading patterns to allow effective pattern grading from one size to another; from either a smaller size to a larger size (or vice versa), according to the requirements of the size chart and consumers (Chan, 2014:181).

In a sizing system, size intervals can either be the same or vary (Zakaria, 2011:350). The size intervals for the primary (key) body dimensions remained the same. It was observable that the size intervals in the developed, experimental upper body and lower body size charts differed in each body dimension from one size range to another, mostly in the secondary body dimensions. This could be determined by the fact that actual human body measurements were used for this study. Although the shape profile was similar, each body dimension differs in body proportions. The size intervals of most of the key body dimensions, maintained similar corresponding values between each size range.

This study was exploratory and cannot be applied to the widespread South African population as the final data was limited to a 3D sample size of 180 pear body shaped petite women; only residing in the Gauteng (Pretoria and Johannesburg) area. The minimum and maximum measurement value limits of the analysed 3D pear body shape scanned data were observed along with the minimum and maximum limits of the body dimensions in the size charts to determine the accuracy of the size charts, the percentage of the analysed sample covered by the developed size charts, and possible errors within the size charts (see Table 4.36 and Table 4.37).

Table 4.35: The minimum and maximum measurement coverage of the upper body dimensions required to construct the shirt garment in this study.

UPPER BODY (cm)				
Minimum measurement values of the analysed data	**Maximum measurement values of the analysed data**	**Body dimensions**	**Minimum measurement coverage**	**Maximum measurement coverage**
74	140	Bust	76	136
60	131	Upper waist	58	118
56	140	Chest	78	127
62	135	Underbust	63	123
61	142	Lower waist	68	134
19	46	Bicep	24	44
19	41	Elbow	20	35
28	49	Neck full	32	44
25	58	Armscye	33	49
29	49	Neck to upper waist back	29	49
24	45	Neck to upper waist front	27	41
44	59	Sleeve length	46	56
8	17	Shoulder length	12	12
12	21	Wrist	16	16

Table 4.36: The minimum and maximum measurement coverage of the lower body dimensions required to construct the trouser garment in this study.

LOWER BODY (cm)				
Minimum of the analysed data	**Maximum of the analysed data**	**Body dimensions**	**Minimum measurement coverage**	**Maximum measurement coverage**
60	131	Upper waist	58	118
81	144	Hip	84	144
61	142	Lower waist	67	137
45	78	Top thigh	51	74
39	71	Mid-thigh	41	61
28	58	Calf	31	49
71	145	High hip	78	140
20	39	Ankle	25	31
31	64	Knee	39	42
21	59	Crotch length back	29	59
22	57	Crotch length front	29	55
60	90	Inseam	60	90
94	113	Outseam	98	110

Table 4.36 shows that extreme measurement values in the upper waist, bust, chest, underbust, lower waist, shoulder length and wrist body dimensions that were not covered in the developed size chart for this study. However, the bust (for the upper body dimensions) and the hip (for the lower body dimensions) were used to determine the extreme measurements that were not covered in the size chart. As previously stated by various researchers, Gupta and Gangadhar (2004: 465), Strydom (2006: 234,236), Petrova (2007:64,70), and Zakaria (2014:96, 113) the bust and hip body dimensions are the most commonly used girth measurements that have proven to be useful and important by garment sizing and fit experts for establishing size charts. The observed extreme measurement values for both the upper and lower body dimensions were only represented by a minimum number of 5 (3%) of the individuals from the analysed 180 pear shaped subjects' sample. The percentage coverage of the developed upper body size chart measurements represented 98% (n=177) of the 180, 3D full body scanned petite pear shaped women's sample. One of the subjects' measurements was below the minimum requirement limit and two of the subject's measurements were above the maximum requirement limit.

As shown in Table 4.37, some extreme measurement values were not covered in the developed size chart for the lower body dimensions. It was observed in the collected petite pear body shape data that the available extreme measurement values in the hip body dimensions were represented by five individuals from the analysed sample, the rest of the body dimension measurements were distributed with minor variances. The percentage coverage of the developed lower body size chart measurements represented 97% (n=175) of the 180, 3D full body scanned petite pear shaped women's sample size chart size.

The following section compares the developed size charts with other published petite size women charts.

4.6 COMPARISON BETWEEN THE PETITE SIZE CHARTS DEVELOPED IN THIS STUDY AND OTHER PUBLISHED PETITE SIZE CHARTS

The following section addresses Objective 3 of this study: to compare the 3D full body scanned size chart measurements developed for this study with the 3D full body scanned mannequin's data and previously published size charts for petite women from other South African studies that are in the public domain, i.e. Defty (1988:17-18), Winks (1990:74-76), and Bailey (2010:23). The size 10/34 was selected for comparison with Defty (1988:17-18) and Winks (1990:74-76) published South African petite size charts and the 3D full body scanned tailoring mannequin, which was developed as a retail size 10/34. However, Bailey's (2010:23) published size chart measurement specifications only consisted of petite size 2(26), 4(28) and 6(30), therefore, it could not be used for comparisons with the size chart measurement specifications developed in this study as the measurements were below the range of the 10/34 sizing measurements established in this study. Table 4.38 shows the size chart developed by Bailey (2010:23). Nonetheless, the petite size 6 bust (81 cm), waist (66 cm) and hip (85 cm) measurements established by Bailey's study were observed to be bigger than the size 6/30 bust (76 cm), upper waist (58 cm) and hip (84 cm) measurements developed in Table 4.32 and Table 4.33. It is therefore clear that the South African petite women subjects who were sampled in this study, for the Gauteng population, were smaller in size when compared to the women in Bailey's study on petite women, sampled in Cape Town. The size 6 hip girth measurement for Bailey's size chart was only 1 cm larger than the size 6 in this study.

Table 4.37: The petite women's size chart developed by Bailey (2010:23)

	PETITE 2	**PETITE 4**	**PETITE 6**
BUST	79cm	80cm	81cm
WAIST	62cm	64cm	66cm
HIP	81cm	83cm	85cm

The comparable size 10/34 range by Defty (1988:17-18) and Winks (1990:74-76) and the 3D full body scanned tailoring mannequin's data are tabulated in Table 4.39 for the upper body measurements and Table 4.40 for the lower body.

Table 4.38: Comparison between the size 10/34 petite size upper body measurements developed for this study with the 3D full body scanned petite tailoring mannequin, Defty's (1988:17-18) and Winks' (1990:74-76) published South African petite size charts that are in the public domain.

		3D full body scanned data of the petite subjects (Size 10/34)	Differences between the 3D full body scanned petite subjects and the petite tailoring mannequin's measurements	3D full body scanned petite tailoring mannequin	Differences between the 3D full body scanned petite subjects and Defty's measurements	Defty (1988:17-18)	Differences between the 3D full body scanned petite subjects and Winks' measurements	Winks (1990:74-76) Based on the M body shape
	HEIGHT (mean/average)	157cm	+3	160cm	-4	153cm	+3	160cm
	Measurements: (cm)							
GIRTHS	BUST	88	-2	86	0	88	0	88
	UPPER WAIST (at navel, midriff area)	70	-1	69	-4	66	-	-
	NECK FULL	35	-1	34	-	-	-	-
	ARMSCYE	36	-3	33	-	-	-	-
	BICEP	28	-1	27	-	-	-	-
	ELBOW	23	-3	20	-	-	-	-
	CHEST	88	-1	87				
	UNDERBUST	75	-2	73	-		-	-
	LOWER WAIST (15cm below the upper waist)	81	+4	85	-	-	-	-
LENGTHS	NECK TO UPPER WAIST (front)	30	+5	35	+3	33	-	-
	NECK TO UPPER WAIST (back)	33	+6	39	-	-	-	-
SLEEVE AREA	SLEEVE LENGTH (shoulder-wrist)	48	+3	51	-	-	-	-
	SHOULDER LENGTH	12	0	12	-	-	-	-
	WRIST	16	-1	15	-	-	-	-

Table 4.39: Comparison between the size 10/34 petite size lower body measurements developed for this study with the 3D full body scanned petite tailoring mannequin, Defty's (1988:17-18) and Winks' (1990:74-76) published South African petite size charts that are in the public domain.

		3D full body scanned data of the petite subjects (Size 10/34)	Differences between the 3D full body scanned petite subjects and the petite tailoring mannequin's measurements	**3D full body scanned petite tailoring mannequin**	Differences between the 3D full body scanned petite subjects and Defty's measurements	**Defty (1988:17-18)**	Differences between the 3D full body scanned petite subjects and Winks' measurements	**Winks (1990:74-76) Based on the M body shape**
	HEIGHT (mean/average)	157cm	+3	160cm	-4	153cm	+3	160cm
	Measurements: (cm)							
GIRTHS	WAIST (at navel, midriff area)	70	-1	69	-4	66	-	-
	LOWER WAIST (15cm below the upper waist)	81	+4	85	-	-	-	-
	HIP(20cm below lower waist)	96	-1	95	-3	93	-1	95
	HIGH HIP(10cm below lower waist)	90	+2	92	-	-	-	-
	TOP THIGH	55	-1	54	-	-	-	-
	MID THIGH	45	-4	41	-	-	-	-
	CALF	35	-1	34	-	-	-	-
	ANKLE(under the feet-over side ankle bones)	26	-1	25	-	-	-	-
	KNEE	41	-2	39	-	-	-	-
CROTCH AREA	CROTCH LENGTH FRONT	34	+2	36	-	-	-	-
	CROTCH LENGTH BACK	35	+1	36		-	-	-
LENGTHS	INSEAM (inside leg length)	66	+7	73	+5	71	-	-
	OUTSEAM (outside leg length)	100	+2	102	-4	96	-	-

The shape of the size 10/34 petite mannequin was classified in section 4.5 as being a pear body shape profile, based on the bust, upper waist and hip 3D scanned measurements. Although the petite tailoring mannequin was headless, the height was obtained from information gathered from Millam (2016), a well-known South African mannequin manufacturing company that created the mannequin; who disclosed that the mannequin was developed using a measurement specification sheet established in 2003 for petite women based on a total body height measurement of 160 cm. The scanned mannequin's measurements were comparable with all the size 10/34 subjects' measurements developed in this study, because both sets of data were derived from 3D full body scans. However, a limitation of the comparison is that Defty (1988:17-18) and Winks' (1990:74-76) size charts only listed a few measurements in their size charts that corresponded with the measurement specifications derived for the size chart in this study.

Overall, seven body measurements; namely, the height, bust, waist, back length to waist (front neck to upper waist), the hip, inside leg length (inseam) and the outside leg length (outseam) from Defty's (1988:17-18) study were comparable with the body measurements from the size ranges derived for this study see Defty's (1988:17-18) size charts in Table 4.41 and Table 4.42.

Table 4.40: Size chart for short women used for comparing upper body dimensions by Defty (1988:17).

SIZING CHART SHORT WOMEN – who, without shoes stand 153cm/60” in height.

SIZE		**9**	**11**	**13**	**14**	**16**	**18**	**20**	**22**	**24**
BUST	in	31	33	34½	36	38	40	42	44	46
	cm	80	84	88	92	97	102	107	112	117
WAIST	in	23	24½	26	27½	29½	31½	33½	35½	37½
	cm	58	62	68	70	75	80	85	90	95
HIPS	in	33½	35	36½	38	40	42	44	46	48
	cm	85	89	93	97	102	107	112	117	122
HIP DEPTH	in	8	8	8	8	8	8	8	8	8
	cm	20	20	20	20	20	20	20	20	20
ACROSS BACK	in	12	12½	13½	14	14½	15	15½	16	16½
	cm	30.5	32	33	35.5	37	38	39.5	41	42
BACK LENGTH	in	15	15	15	15	15	15	15	15	15
TO WAIST	cm	38	38	38	38	38	38	38	38	38
FOREARM LENGTH	in	17¼	17¼	17¼	17¼	17¼	17¼	17¼	17¼	17¼
	cm	44	44	44	44	44	44	44	44	44
HINDARM LENGTH	in	21¼	21¼	21¼	21¼	21¼	21¼	21¼	21¼	21¼
	cm	54	54	54	54	54	54	54	54	54
SKIRT LENGTH	in	26½	26½	26½	26½	26½	26½	26½	26½	26½
MIDCALF	cm	66	66	66	66	66	66	66	66	66

Table 4.41: Size chart for short women used for comparing lower body dimensions by Defty (1988:17).

SHORT WOMEN – HEIGHT 153cm/60".

SIZE		**9**	**11**	**13**	**14**	**16**	**18**	**20**	**22**	**24**
WAIST	in	22½	24	25½	27	29	31	33	35	37
	cm	57	61	65	69	74	79	84	84	89
HIPS	in	33½	35	36½	38	40	42	44	46	48
	cm	85	89	93	97	102	107	112	117	122
INSIDE LEG LENGTH	in	28	28	28	28	28	28	28	28	28
	cm	71	71	71	71	71	71	71	71	71
RISE HEIGHT	in	10½	10½	10½	10½	10½	10¾	11	11¼	11½
	cm	27	27	27	27	27	27,5	28	28,5	29
OUTSIDE LEG LENGTH	in	37½	37½	37½	37½	37½	37¾	38	38¼	38½
	cm	95,5	95,5	95,5	95,5	95,5	96	96,5	97	97,5
KNEE	in	19¼	19½	19¾	20	20¼	20½	20¾	21	21¼
	cm	49,5	50	50,5	51	51,5	52	52,5	53	53,5
BOTTOMS	in	17¼	17½	17¾	18	18¼	18½	18¾	19	19¼
	cm	44,5	45	45,5	46	46,5	47	47,5	48	48,5

Defty (1988) did not specify which ethnic group was used to develop her size chart but she indicated that an average height of 153 cm was used for "short" women, measured without wearing shoes. The sizing ranges in Defty's (1988) study were labelled in odd numbers and the numbers did not correspond with currently used size range number labelling methods. Additionally, Defty's (1988) across range sizes (see Table 4.41 and Table 4.42) were compared with the upper and lower body dimensions size chart (see Table 4.32 and Table 4.33) size ranges developed in this study using the bust, upper waist, back length to waist (front neck to upper waist), hip and outside leg length (inseam) and outside leg length (outseam) since they were the corresponding body dimensions. Most of the size chart measurements developed in this study was bigger and longer than Defty's (1988) size chart measurements. However, the bust became smaller in the bust measurements from the developed upper body dimension's size chart for the size 6/30 and 8/32 size ranges; the front neck to upper waist and inseam measurements became smaller and bigger as the sizes decreased and increased, the hip size 6/30 size range also became smaller.

Furthermore, similar measurements were observed in the size 10/34 bust and size 6/30 upper waist measurements. Defty's (1988) outside leg length measurements were smaller than the outseam measurements developed in this study for the lower body dimensions size chart. The size 13 was selected for comparison, seeing that it contained the best matching body measurements with the size 10/34 body measurements established from the 3D full body scanned petite women's size chart developed in this study; the measurement comparisons are presented in table 4.39 for the upper body dimensions and 4.40 for the lower body dimensions.

Only three body measurements; namely, the height, bust and hip from Winks' (1990:74-76) study were applicable for comparison with body measurements derived for this study. Winks' (1990) data was collected using White, Black and Coloured ethnic groups with an average height of 160 cm. Three body shapes, namely A, M and H with body size distribution measurement distinctions were established from the data; each body shape having different ranges of body size measurements (see the different body shapes and size distribution chart in Table 4.43).

Table 4.42:The different body shapes and size distribution chart established by Winks (1990:76)

Body Type	Bust girth	Height		
		160	168	176
		Hip girth		
	80	96	94	95
	84	97	95	99
	88	103	100	100
	92	104	104	103
A	95	109	108	107
	100	113	111	112
	104	116	114	118
	110	-	121	121
	116	-	127	-
	80	88	88	87
	84	92	91	91
	88	95	96	95
	92	99	98	98
M	95	103	102	100
	100	106	105	106
	104	110	109	109
	110	116	117	112
	116	-	-	120
	80	83	-	-
	84	87	86	-
	88	90	88	89
	92	93	93	94
H	95	96	95	96
	100	99	101	100
	104	100	103	104
	110	105	109	107
	116	112	-	-

A 160 cm height range and the third body size distribution range from the M body shape best matched the size 10/34 body measurements developed from the petite women's size chart developed in this study. As a result, this body shape and size is reported in the comparison for this study. Findings from this study as shown in Table 4.39 and Table 4.40 demonstrate that there are notable differences between the size 10/34 3D full body scanned petite women subjects' measurements when compared to the 3D full body scanned petite tailoring mannequin's measurements (developed in 2003), Defty's (1988:17-18) and Winks' (1990:74-76) published South African petite size charts that are in the public domain. There are; however, some similarities amongst the compared measurements (refer to the highlighted measurement areas in Table 4.39 and Table 4.40). The average height, bust and hip measurements were the only common measurements present in all the compared petite size charts. For that reason, the average height, bust and hip measurements are tabulated in Table 4.44, to consider the differences between the 3D full body scanned petite women subject's size 10/34 body measurements and the 3D full body scanned mannequin's measurements, together with Defty's (1988:17-18) and Winks' (1990:74-76) petite size chart measurements.

Table 4.43: Measurement differences of the 3D full body scanned petite measurements when compared to commonly occurring 3D full body scanned petite mannequin measurements, Defty (1988:17-18) and Winks (1990:74-76) petite measurements using the average height, bust and hip.

Size 10/34	**3D full body scanned petite subjects' data**	**3D full body scanned petite mannequin**	**Defty (1988:17-18)**	**Winks (1990:74-76)**
HEIGHT (average)	157 cm	160cm	153cm	160cm
	Measurements: (cm)			
Differences		+3	-4	+3
BUST	88	86	88	88
Differences		-2	0	0
HIP(20cm below lower waist)	96	95	93	95
Differences		-1	-3	-1

The limitations of the comparison in Table 4.44 consider the lack of data for Defty (1988) and Winks (1990). As shown in Table 4.44, the average of the petite heights in this study was 157 cm. Both the average height range of the 3D full body scanned mannequin and the average height range established by Winks (1990:74-76) was 160 cm; whilst the average height measured in Defty's (1988:17-18) study was 153 cm. There is a 3 cm height difference between both the 3D full body scanned mannequin's average height measurement and Winks' average height measurement when compared to the average height measurement established for the petite women subjects in this study. Defty's average height measurement is lower by 4 cm when compared to the average height established for the petite women subjects in this study. The bust measurement established for the size 10/34 petite women subjects is similar to that of Defty's (1988:17-18) and Winks' (1990:74-76) study. The 3D full body scanned mannequin's bust measurement is the only bust measurement that is different with a minus 2 cm difference. The hip measurements of the 3D full body scanned petite women subjects' data and Defty's measurements differs with 3 cm, while the 3D full body scanned petite mannequin and Winks' hip measurement remain the same. Additionally, Defty included a waist measurement in her size chart which was 68cm, 2cm smaller than the subjects' size 10/34 size range upper waist measurement and 1 cm smaller than the mannequin's upper waist measurement.
The self-perceived perceptions obtained from the subject's responses in the psychographic questionnaire are discussed in the next section.

4.7 THE PETITE SUBJECTS' PERCEPTIONS OBTAINED FROM THE PSYCHOGRAPHIC QUESTIONNAIRE

Objective 4 was to investigate the petite women's perceptions of their body shapes and body proportions together with their purchasing behaviour regarding their shirt and trouser garments. The responses in the psychographic questionnaire were evaluated to discover the petite women's satisfaction with their body shapes and challenges they face when purchasing currently available ready-to-wear shirt and trouser garments.

This section analysed the 180 sampled petite pear shaped subjects' responses to gain insightful knowledge on their perceptions. A quantitative approach was used to analyse most of the data which was reported as numbers, percentages and frequencies. In some questions the subjects had an option of selecting more than one answer; therefore, the number of the responses to those questions exceeded the 180 sampled numbers. However, some responses were less than the 180 subjects sampled because some questions were left unanswered by the subjects. The responses are discussed below.

The relationship between women's body shapes and garment fit is very important (Liechty *et al.,* 2010:160; Strydom & De Klerk, 2010:75-76). Body shapes are a contributing factor to garment fit; hence the petite women's self-perceived body shapes should be essential criteria when selecting ready-to-wear shirt and trouser garments. The subjects' body proportions, satisfaction with their body parts, shirt and trouser garment fit evaluations were further analysed to determine the influence of their body shapes on garment fit.

Regarding the 180 petite women subjects' body proportions, 29% (n=53) of the subjects perceived their body proportions to be a short torso with long legs; whereas 35% (n=63) of the subjects perceived their body proportions to be a long torso with short legs and 35% (n=63) perceived to have evenly proportioned body proportions. Only 1% (n=1) of the subjects was unsure which body proportion they have and, therefore, did not select either of the provided three body proportions question.

The subjects' perceived proportions were compared with the bust to upper waist and hip to upper waist ratios of the subjects' measurements derived from the 3D full body scanner to compare their body proportions. Somewhat 82% (n=147) of the subjects were observed to have short torso with long legs body proportions, while 15% (n=27) of the subjects were observed to have long torso with short legs body proportions and the remaining 3% (n=6) were observed to have evenly proportioned body proportions. This indicates that most of the subjects have short upper torsos and long legs. The subject who indicated that she was not sure of her body proportion was classified as a having a short torso/long legs body proportion. The above-mentioned body proportions are illustrated in Chapter 1, section 1.1.

The subjects were asked how satisfied they are with certain parts of their bodies; their responses were tabulated in Table 4.45 and the subjects' percentage satisfaction ratings with their body parts are presented in Figure 4.7.

Table 4.44: Satisfaction of the subjects with certain body parts

	Not answered	**Extremely Satisfied**	**Somewhat Satisfied**	**Satisfied**	**Mostly Dissatisfied**	**Extremely Dissatisfied**	**Total**
1) Overall Height	5	74	29	50	19	3	180
2) Overall body weight	6	13	36	56	39	30	180
3) Posture	9	45	37	60	23	6	180
4) Head	8	68	26	71	3	4	180
5) Upper body	9	54	20	68	22	7	180
6) Lower body	6	49	31	56	27	11	180
7) Face	10	72	33	51	11	3	180
8) Neck	8	83	27	54	8	0	180
9)Shoulder length	8	71	33	55	12	1	180
10) Arm length	7	73	23	67	9	1	180
11) Upper Arm girth	8	64	22	60	22	4	180
12) Upper waist	6	57	22	45	36	14	180
13) Hips	7	49	27	53	36	8	180
14) Thighs	8	44	24	56	41	7	180
15) Knee	8	52	23	77	17	3	180
16) Calves	7	53	35	66	16	3	180
17) Legs	10	59	28	60	18	5	180
18) Leg length	9	67	27	61	10	6	180
19) Feet	7	65	27	59	18	4	180
20) Bust	6	58	30	59	20	7	180

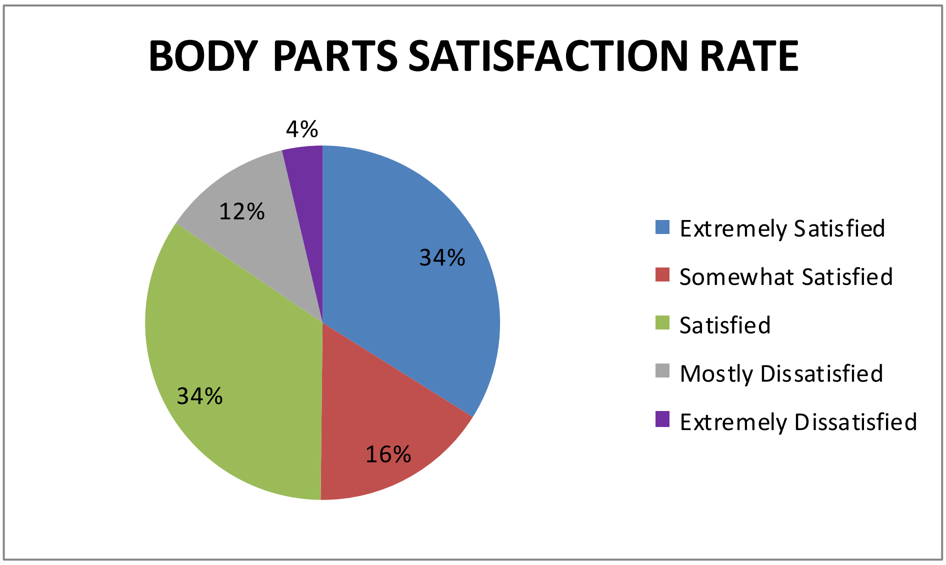


Figure 4.7: The subjects' percentage satisfaction ratings of their body parts.

The total number for each satisfaction rate in Table 4.45 was added to generate the percentage terms in Figure 4.7 to distinguish between the subjects who were satisfied and those who were not satisfied; the column that was not answered was not included. The overall satisfaction percentage calculated from the subjects who indicated that they were satisfied with their body parts was 84%, which shows that the majority of the subjects were satisfied with 11 of their body parts, namely: their overall body, posture, head, upper body, lower body, hips, thighs, knee, calves, legs and bust and extremely satisfied with 9 of their body parts, namely: their overall height, face, neck, shoulder, arm length, upper arm girth, upper waist, leg length and feet. Although the satisfaction rate from the petite women with their body parts was extremely satisfied and satisfied as highlighted (the highlighted areas shows the most selected level of satisfaction, representing the majority of the subjects within the 180 sampled number); when asked if they have concerns with the currently offered ready-to-wear shirt and trouser garments, 74% (n=134) of the subjects stated that they did have concerns with ready-to-wear garments that are currently being sold at retail outlets in South Africa. Subjects claiming that they did not have concerns totalled to 25% (n=45), only 1% (n-1) did not answer the question.

Table 4.46 and Table 4.47 represent how the currently available shirt and trouser garments fit on certain parts of the subject's bodies. N= the number of the subjects that answered.

Table 4.45: Body fit evaluation of shirt garments for the petite women subjects.

	1	N	2	N	3	N	No answer
Neckline	Too high	30	Too low	49	No problem	92	9
Collar	Too tight	33	Too loose	45	No problem	93	9
Across shoulders	Too tight	37	Too loose	40	No problem	95	8
Across back	Too tight	50	Too loose	46	No problem	76	8
Across bust	Too tight	59	Too loose	52	No problem	61	8
Around upper waist	Too tight	60	Too loose	37	No problem	74	9
Around hips	Too tight	43	Too loose	46	No problem	83	8
Sleeve – Around upper arm	Too tight	35	Too loose	55	No problem	80	10
Sleeve length	Too short	39	Too long	60	No problem	71	10
Garment length	Too short	52	Too long	52	No problem	63	13

Table 4.46: Body fit evaluation of trouser garments for the petite women subjects.

	1	N	2	N	3	N	No answer
Trouser- Around lower waist	Too tight	60	Too loose	58	No problem	52	10
Trouser – Around hips	Too tight	68	Too loose	44	No problem	57	11
Trouser – Around thighs	Too tight	58	Too loose	37	No problem	73	12
Trouser – Crotch length	Too short	39	Too long	49	No problem	78	14
Trouser – Length	Too short	44	Too long	60	No problem	67	9

As shown in Table 4.46 and Table 4.47 the highlighted answers indicate the majority of the subject's ready-to-wear shirt and trouser garment fit problems in each body category. The results show that the number of the subjects who indicated that they experienced fit problems (for example: either being too high or too low, too tight or too loose, too short or too long) with their currently available shirt and trouser garments when added together, were greater than the number of subjects who indicated that they do not have problems. The exception to this was in the neckline, collar and across shoulder where the highest number of petite females indicated that they do not have a problem with their currently available shirt and trouser garments.

Of the petite women subjects who experienced problems with the fit of their ready-to-wear shirt garments, the majority indicated that they found their shirt garment to have

a low neckline, loose collar, to be loose across the shoulders, too loose around their hips, too tight across the back, bust and around their upper waist area having a long sleeve length. The shirt garment length had equal representations of being either too short or too long, depending on the style of the garment. The fit evaluations of currently sold ready-to-wear trousers were identified as being too tight around the lower waist, hips and thighs. The majority deemed the crotch length and the trouser length to be too long.
Answers on the subjects' purchasing behaviours indicated that 87% (n=166) of the subjects preferred purchasing their garments by physically going to the retail stores, followed by 7% (n=14) who indicated that they purchase their garments clothing through the internet; whilst 4% (n=8) selected the "others" option where they answered that they either make their own clothes or approach a dressmaker to make their clothes. One of the subjects mentioned that her mother buys her clothes because she does not like shopping for clothes. Additionally, 2% (n=3) of the subjects preferred purchasing their garments through catalogues. Nonetheless, the petite women are still not satisfied with the ready-to-wear garments they purchase because they end up having to alter their garments to maintain a better fit. A total of 37% (n=66) of the subjects indicated that they alter up to 25% of their garments after purchasing them; 22% (n=40) alter up to 50% of their garments, 20% (n=36) alter up to 75%, and 5% (n=9) alter up to 100% of their ready-to-wear store-bought garments.

Having said that, 16% (n=29) of the subjects stated that they were satisfied with their current ready-to-wear garment sizes as they do not have to alter them after purchasing. A total number of subjects 84% (n=151) of the 180 sampled subjects specified that they alter their garments after purchasing, which indicates that improvements must be made on garment sizing for South African petite women. The 3D full body scans of the subjects who indicated that they need to alter their garments show a more indented upper waist and larger hip measurements (larger hip to upper waist body proportions, which represents a distinctive description of a pear body shape profile); some have shorter leg outseam length measurements that are below 100 cm, as compared to the subjects who did not alter their garments as they appeared to be more of a straight body shape. Figure 4.8 and Figure 4.9 show examples taken from the 3D full body scan data of the subjects who indicated they alter their garments and those who indicated that they do not alter their garments. The 3D full body scanned images are provided as evidence to suggest the body shapes of the subjects were noticeably different to those who did not alter their garments.

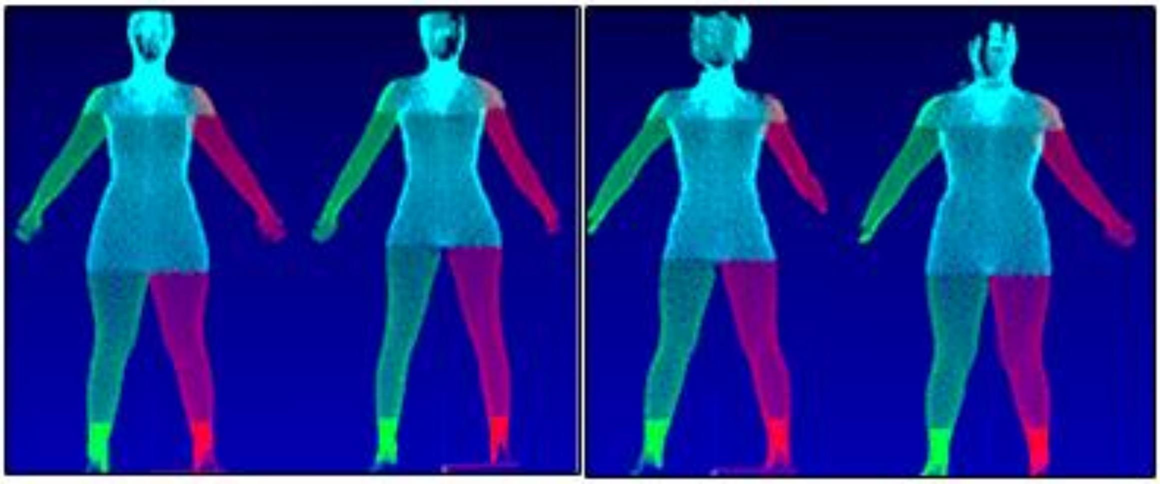


Figure 4.8: Examples of the 3D full body scans showing the body shapes of the subjects who answered that they altered their garments after purchasing them in retail stores (n=151 of the 180 subjects).

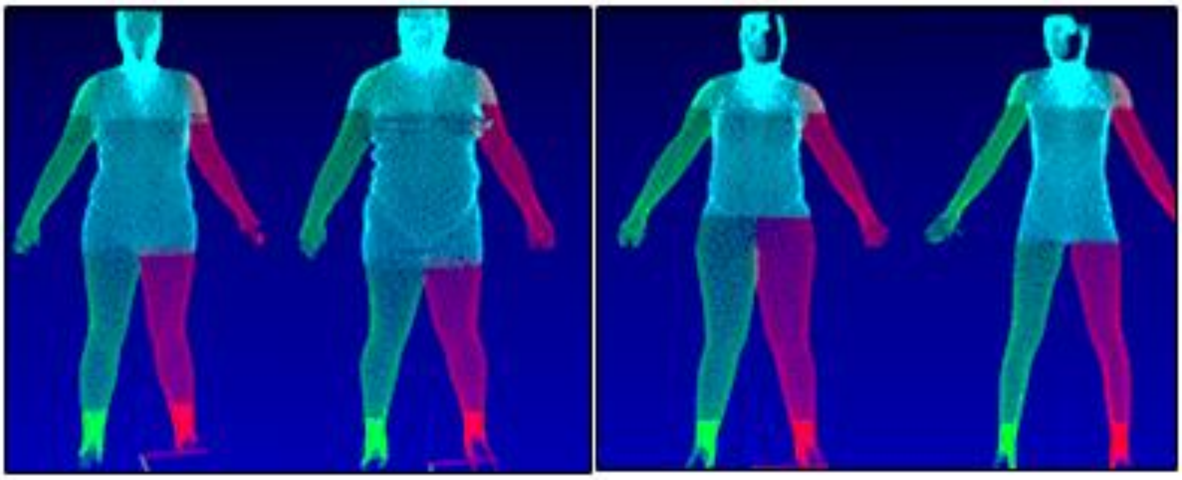


Figure 4.9: Examples of the 3D full body scans showing the body shapes of the subjects who stated that they do not alter their garments after purchasing them in retail stores (n=29 of the 180 subjects).

The alterations were more frequently encountered in the trouser garments. Because of the petite women's pear body shapes, they responded that the garment sizes that would fit their upper waist (at navel, midriff area) or lower waist (the lower waistline between the upper waist and high hip area), resulted in a tight fit on their hips. Therefore, they end up having to purchase larger ready-to-wear trouser sizes to accommodate their hip measurements, having to alter the lower waist or upper waist (if the trouser is high waist) to obtain a better fit. The subject's ratings for the most considered criteria used when purchasing their shirt and trouser garments are presented in Table 4.48.

Table 4.47: Ratings for the most considered criteria used when purchasing shirt and trouser garments.

Criteria	Rating (in order of preference from 1-10)
1) Garment brand name	1113
2) Latest trends	1046
3) Style / Design	960
4) Appearance	842
5) Garment sizing measurements	801
6) Quality	726
7) Comfort	713
8) Price	625
9) Fit	604
10) Other(s) Specify: colour, durability and exclusivity	21

The ratings from the subjects' responses were added together to easily create Table 4.48 and were arranged from the highest to the lowest ranking score. The subjects ranked the garment brand name as the highest priority when purchasing their garments, followed by the latest trends, style/design, and appearance of the garment, then the garment sizing measurements, comfort, quality and the price of the garment. Interestingly, the fit of the garment was rated as the least priority, this could be attributed to the 84% (n=151) of the 180 sampled subjects who stated that they alter their garments. It is possible that fit was rated the least because the subjects know that they have to alter their garments after purchasing. Some of the subjects included the colour of the garment, durability and exclusivity as the determining factor for their purchasing decisions. When asked what they use as a guide for purchasing sizes that fit their bodies, the majority, 43% (n=77) of the subjects stated that they use number labelling (e.g. size 10/34, 12/36, etc.) as the size guide for purchasing their clothing; alphabet labelling (e.g. S for small, M for medium, etc.) was second with 38% (n=68) of the subjects, followed by hang tags 13% (n=23) and lastly pictograms with 6% (n=12). Nevertheless, 75% (n=112) of the subjects indicated that they do not select the same garment sizes from different retail stores, whilst 25% (n=32) stated that they do select the same garment size. Table 4.49 and Table 4.50 present the garment sizes that the subjects perceive themselves to be and are more likely to select when purchasing their ready-to-wear shirt and trouser garments.

Table 4.48: Garment sizes that the subjects perceive themselves to be and are more likely to select when purchasing their ready-to-wear shirt garments.

WOMEN'S SHIRTS		
Size ranges	**Number**	**Percentage**
2/26	4	1%
4/28	10	3%
6/30	30	9%
8/32	52	15%
10/34	84	25%
12/36	42	12%
14/38	32	10%
16/40	33	10%
18/42	32	10%
Other. Specify:	13	4%
Not answered	2	1%
Total	334	100%

Table 4.49: garment sizes that the subjects perceive themselves to be and are more likely to select when purchasing their ready-to-wear trouser garments.

WOMEN'S TROUSERS		
Size ranges	**Number**	**Percentage**
2/26	0	0%
4/28	7	2%
6/30	26	9%
8/32	42	13%
10/34	51	17%
12/36	54	18%
14/38	48	16%
16/40	35	12%
18/42	24	8%
Other. Specify:	12	4%
Not answered	2	1%
Total	301	100%

From Table 4.49 and Table 4.50 it was evident that a number of the 180 pear body shaped petite women indicated more than one or more than two sizes in their perceived/purchased size ranges for both the shirt (n=334) and trouser (n=301) garment size selection. It thereby relates to Winks' (1997:1) and Alexander *et al*.'s (2005:56) statement that garment sizing varies between each manufacturer, and endorsing Barona-McRoberts' (2005:21) suggestion that some garment manufacturers and retailers use voluntary sizing to size their garments, resulting in consumers selecting different garment sizes in different retail stores.

Additionally, in the shirt garment size selection table, the size 10/34 was the most represented size comprising of 25% (n=84) of the respondents, followed by the size 8/32 with 15% (n=52), size 12/36 with 12% (n=42), and the sizes 16/40 (n=33), 14/38 (n=32), and 18/42 (n=32) all with 10%. Size 6/30 had 9% (n=30), the sizes 20/44, 22/46 and 24/48 listed by 4% (n=13) of the subjects as "other" size ranges they fit into; then size 4/28 3% (n=10), and the last was size 2/26 1% (n=4). Additionally, 1% (n=2) of the subjects did not answer the question. For the trouser garments, size 12/36 was the most represented size comprising of 18% (n=54) of the respondents, followed by size 10/34 17% (n=51), size 14/38 16% (n=48), size 8/32 13% (n=42), then size 16/40 12% (n=35), size 6/30 9% (n=26), and size 18/42 8% (n=24), followed by the sizes 20/44, size 22/46 and 24/48 listed by 4% (n=12) of the subjects as “other” size ranges they fit into, then size 4/28 with 2% (n=7); size 2/26 had no representation and 1% (n=2) of the subjects did not answer the question.

Plots of the purchased/perceived size ranges and the size chart size ranges are presented in Figure 4.10 and Figure 4.11, using the bust and hip key body dimension measurements of the 180 subjects. The bust (for the upper body) and hip (for the lower body) measurements were used to construct the plots because various researchers, such as Gupta and Gangadhar (2004: 465), Strydom (2006:234,236), Petrova (2007:64, 70), and Zakaria (2014:113) ascertain that they are the most commonly used girth measurements established to be beneficial and necessary by garment sizing and fit experts for creating size charts.

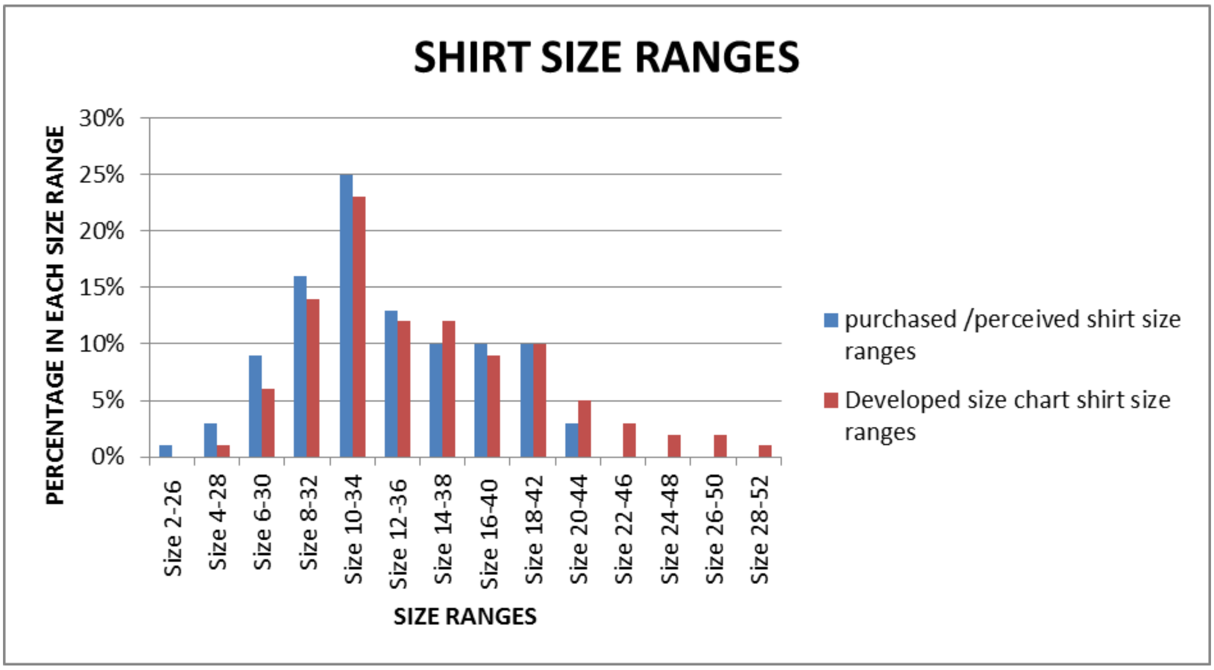


Figure 4.10: Plots of the purchased/perceived shirt size ranges and the size chart shirt size ranges.

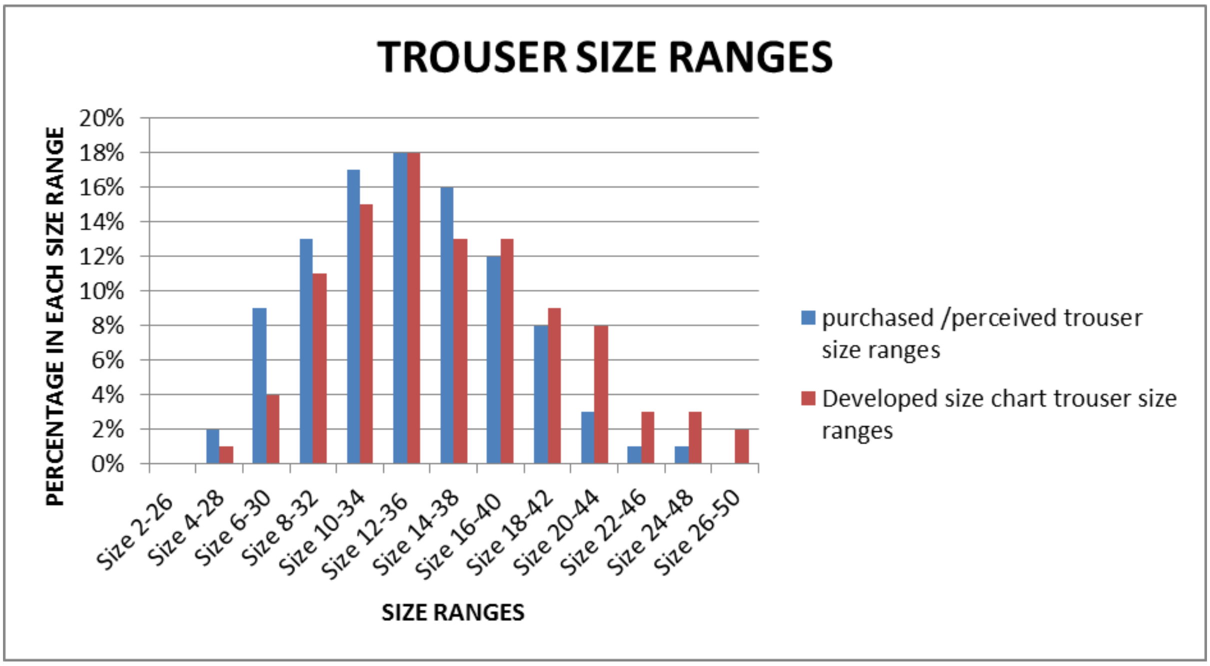


Figure 4.11: Plots of the purchased/perceived trouser size ranges and the size chart trouser size ranges.

As observed in Figure 4.10 and Figure 4.11, for the ready-to-wear shirt size ranges, most of the subjects were clustered in the size 10/34 size range whilst the majority of the subjects' ready-to-wear trouser size ranges were clustered in the size 12/36 size range. The following sizes 4/28 and 28/52 (for the upper body dimensions) and size 4/28 (for the lower body dimensions) are shown in the graph "as developed size ranges" because there were a few subjects in these sizes, but the sizes could not be included in the experimental size charts due to the maximum and minimum size limitations that could be covered by the size charts. The results from the size range representations for both the shirt and trouser garments validate the 90% (n=180) pear body shape profiles extracted in this study on South African petite women, as established in the study to have a heavy bottom body section where the hip area is fuller and bigger than the upper body section (shoulder and bust area) of the body. The range of garment sizes available in retail outlets was rated as being good by 39% (n=70), average by 32% (n=57), excellent by 11% (n=20), fair by 8% (n=15) and poor by 7% (n=13) of the subjects; 3% (n=5) did not answer the question. From the available garment size ratings, it was concluded that the range of garment sizes currently offered for petite women in South Africa is good to average.

Figure 4.12, Figure 4.13, Figure 4.14, and Figure 4.15 present the minimum and maximum perceived size ranges plotted against the size chart predicted size ranges for both the upper and lower garments based on the bust and hip girths of the subjects, respectively. In each observed shirt and trouser size range scatter plot, there are two graphs corresponding to the minimum and maximum size chart size ranges and the perceived sizes for all the subjects, including those whom specified that they fit into more than one size range. Graphs of y=x are presented as linear trend lines to show where the points should lie on if there was perfect agreement between the size chart sizes and the perceived sizes.

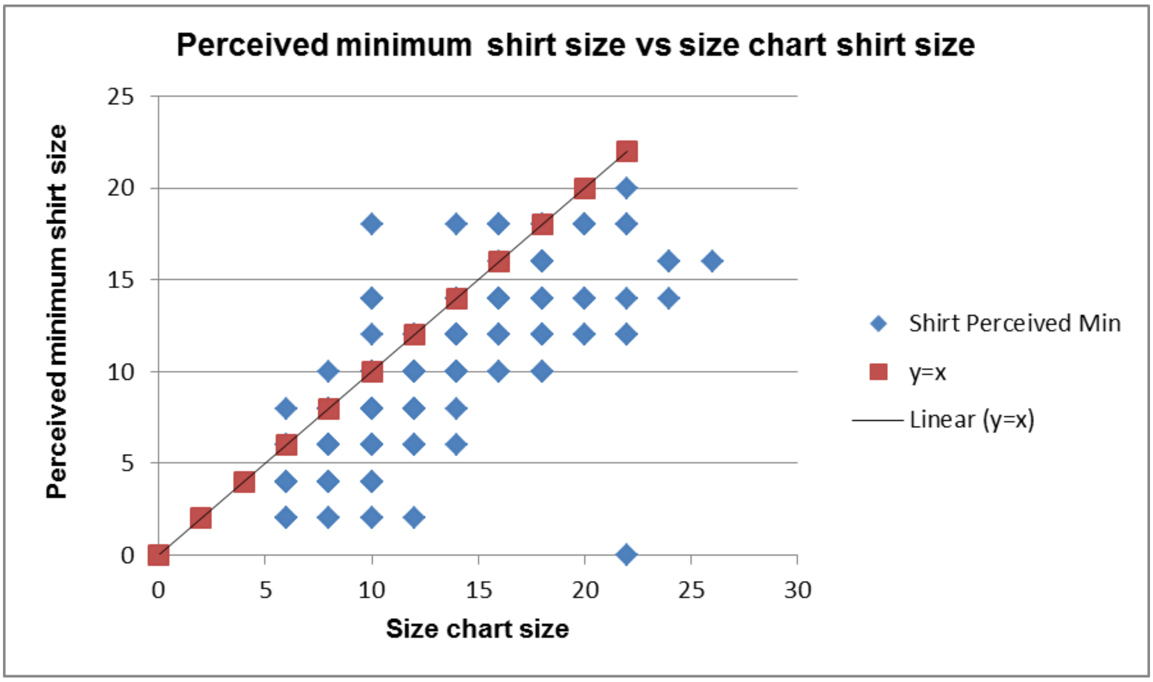


Figure 4.12: The perceived minimum shirt sizes vs the size chart shirt sizes.

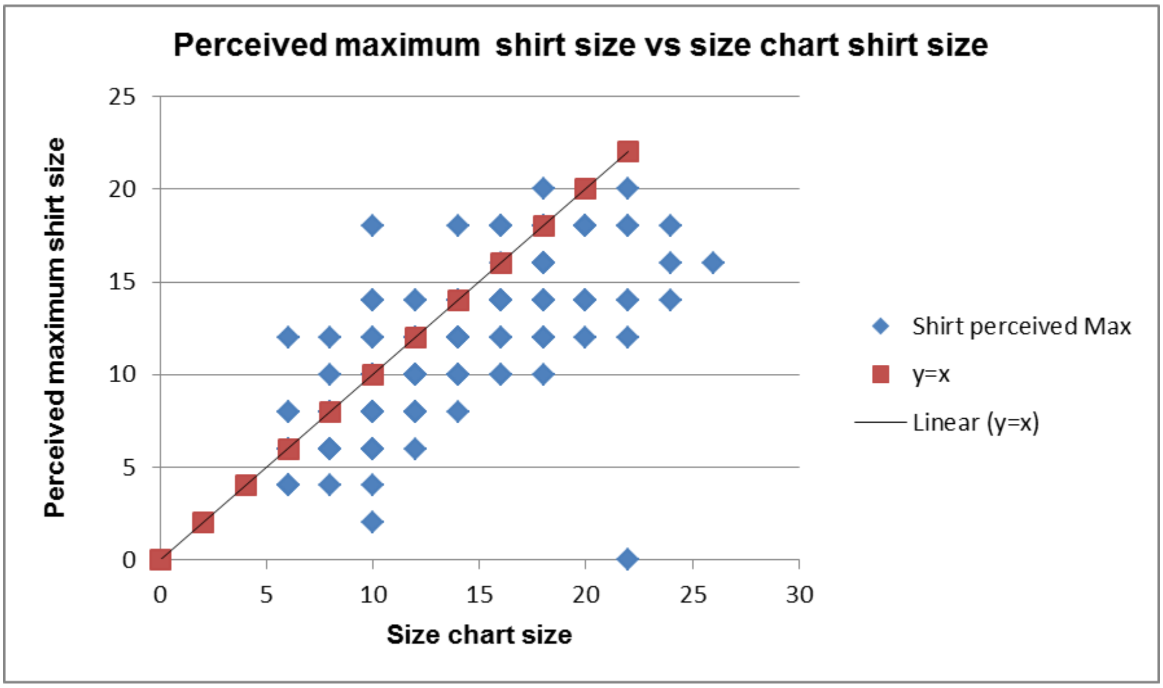


Figure 4.13: The perceived maximum shirt sizes vs the size chart shirt sizes.

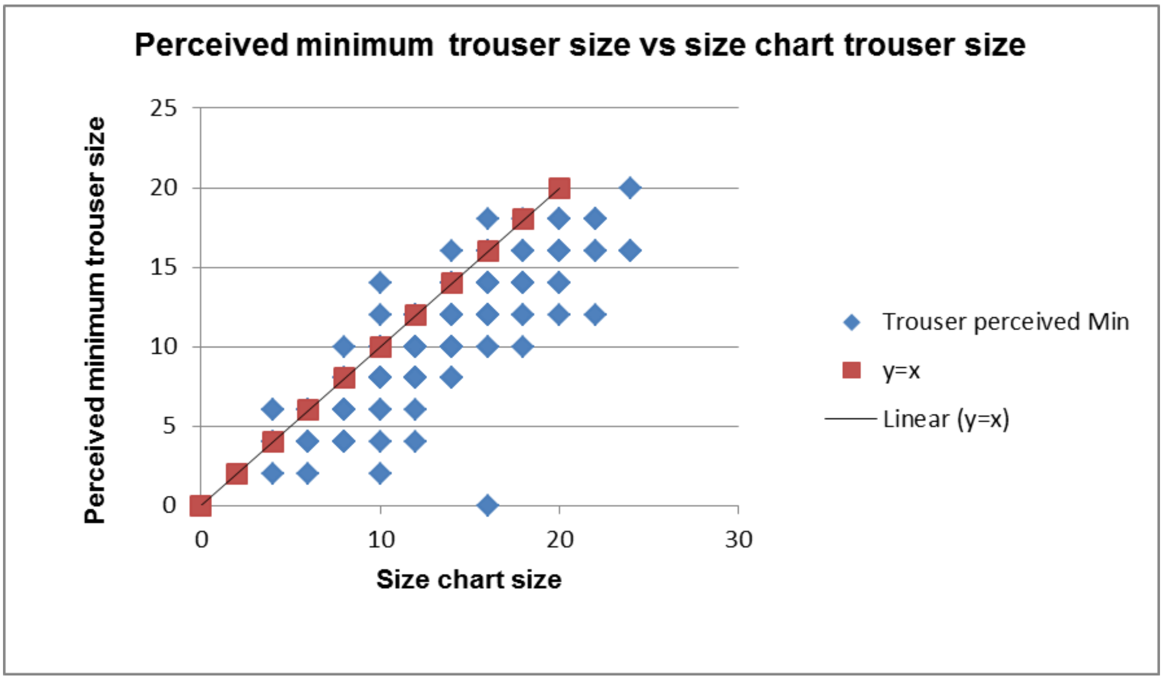


Figure 4.14: The perceived minimum trouser sizes vs the size chart trouser sizes.

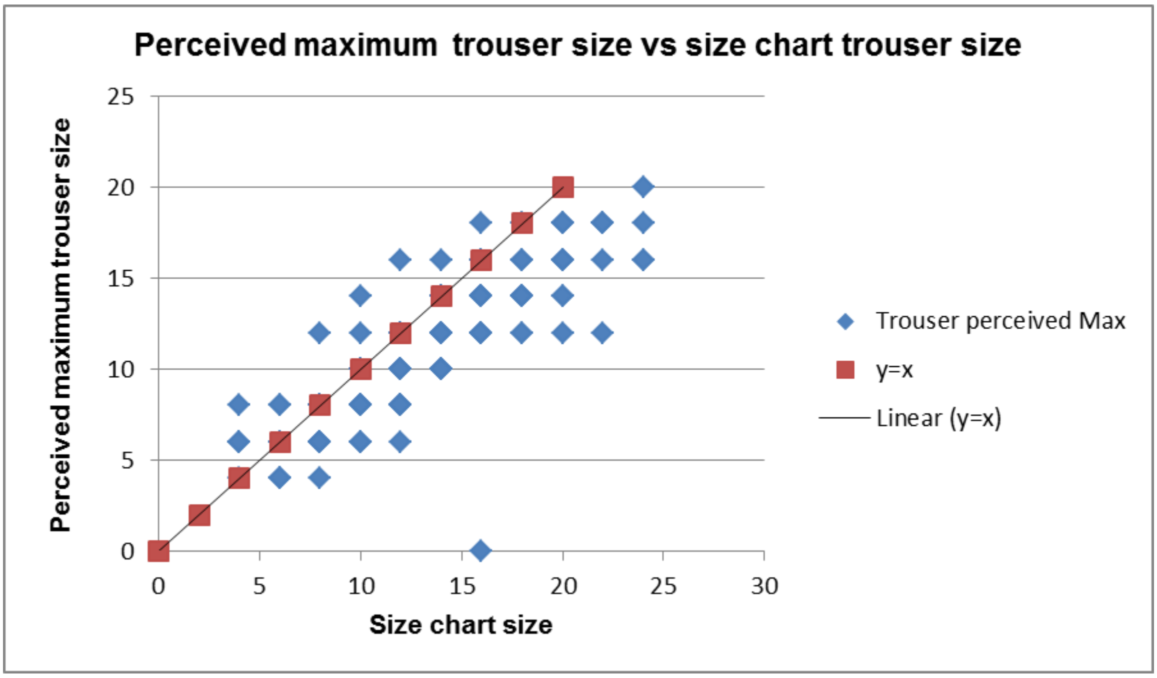


Figure 4.15: The perceived maximum trouser sizes vs the size chart trouser sizes.

Looking at the graphs in Figure 4.12, Figure 4.13, Figure 4.14, and Figure 4.15, most of the subjects perceived themselves to be a smaller size than the size chart size predicts, in both the perceived minimum and maximum sizes. The spread of the perceived sizes for each size chart size encourages investigations about some of the subjects' knowledge of their garment size. One possible implication on the effect of the size perceptions vs the ready-to wear retail size chart measurements would be, if the garments are manufactured adapted from British, mainland European and American sizing systems as suggested by previous researchers (Strydom, 2006:217; Zwane & Magagula, 2007:283; Kahn, 2008; Ola-Afolayan & Mastamet- Mason, 2013:202-203; Mbandazayo *et al*., 2014; Pandarum & Yu, 2015:192). The garments might not offer a satisfactory fit to the South African female consumers since the data was not developed specifically for the South African petite women's target market. Another possible explanation could be, if the minimum sizes fitted the subjects, this may be due to an element of vanity sizing used by manufacturers as a marketing tool to sell their garments, by placing a size label on a garment that is smaller than it should be to lead the consumer into believing that they are slimmer than they actually are (Alexander *et al*., 2005:56; Barona-McRoberts, 2005:21; Pisut & Connell, 2007:368; Apeagyei, 2008:4) in the currently used garment sizing system when compared to the size charts and the measurements developed in this study.

In terms of how the petite women preferred the fit of ready-to-wear shirt and trouser garments on their bodies, most of them 33% (n=60) indicated that they preferred wearing close-fitting shirt garments, whilst 27% (n=49) preferred loose fitting, followed by 23% (n=42) preferred semi-fitted, 11% (n=19) preferred figure hugging, 2% (n=3) preferred very loose-fitting shirts and 4% (n=7) did not answer the question. With the trouser garments, the majority of the subjects 41% (n=78) indicated that they preferred wearing close-fitting trousers, whilst 24% (n=46) preferred semi-fitted, followed by 18% (n=32) preferred loose fitting, 10% (n=18) preferred figure hugging, 1% (n=1) preferred very loose-fitting trousers and 7% (n=14) did not answer the question. The size 10/34 subjects were observed to have small to medium body silhouettes, therefore, based on the results of the ready-to-wear shirt and trouser fit preferences, it was decided that the shirt and trouser garments to be constructed in this study would either be close-fitted or semi-fitted to the body as indicated by most of the subjects to be their most preferred garment fit. The type of fabric used to make the garments will have an influence on the fit of the shirt and trouser garments to be produced for garment fit test evaluations in this study, hence the researcher chose a 100% calico cotton fabric for the fit test evaluations to remove any bias during the fit evaluation assessments.

4.8 CONCLUSION

Sizing systems originate from body measurements and body shapes taken from a specific population (Bye *et al*., 2006:66; Petrova, 2007:56) to permit accurate size chart developments that will enhance better garment fit and enable the production of garments that correspond with the analysed body shape.

In this chapter, the experimental upper and lower body size charts required to construct the prototype shirt and trouser garments for South African petite women who have pear body shape profiles as determined by the 3D installed software, were developed. The experimental size charts were developed by statistically analysing 3D full body scanned data of 180 petite, pear shaped female subjects residing in the Gauteng area. PCA and regression analysis were used to develop the experimental size charts in this study.

The subjects' perceptions of their body shapes and body proportions, together with evaluations and purchasing behaviour regarding their ready-to-wear shirt and trouser garments were also analysed in this chapter. It can be concluded from the findings of this chapter that, from the evidence of the sample of women in the study, the South African petite women consumers are aware of the quality of fit and availability of ready-to-wear shirt and trouser garments currently offered in retail stores. The petite women also have some knowledge of their body shapes, how the garments fit on their bodies and the meanings of various garment size descriptions used on garment sizing labels. However, they lack knowledge of their own key body dimensions which serve as indicators of suitable garment sizes.

The pear body shape profile (which has a narrow upper body and a wider lower body circumference) identified to be dominant in this 3D study for South African petite women differs from the western ideal body shape that appears to be balanced in upper and lower body. Garments made for the ideal body shape use the apparel industry's standard-sized body measurements. The sizing systems currently in use for petite women do not accurately reflect the varied body dimensions, shapes and proportions of the South African women of today (Pandarum & Yu, 2015:192). Hence the purpose of this study was to collect 3D full body scanned data of actual, up-to-date and accurate petite women's body measurements and develop an experimental size charts for the upper and lower body dimensions with the aim of improving the fit of the shirt and trouser garments manufactured for petite women in South African.

To determine whether the developed experimental size charts offer an improved, overall quality of fit for South African petite women pear body shape profiles; identified in this study, the following chapter presents the results of the size 10/34 upper and lower body size charts developed from the 3D full body scanned petite women's data and a size 10/34 3D full body scanned petite tailoring mannequin's data Thereafter a basic prototype shirt and trouser pattern blocks were constructed. The garment development methods and procedures are also discussed in this chapter.

CHAPTER 5

CONSTRUCTING THE BASIC SHIRT AND TROUSER PATTERN BLOCKS; MANUFACTURING THE GARMENTS AND CONDUCTING GARMENT FIT TEST EVALUATIONS

5.1 INTRODUCTION

This chapter reports on the evaluations conducted between a base sized 10/34 petite tailoring mannequin used by retailers and manufacturers, and the 3D petite women anthropometric data collected in this study. The data was used to develop size 10/34 fitting test pattern blocks for developing the prototype shirt and trouser garments for fit test evaluations to fulfil objective 5 as specified in section 1.3. This chapter further describes how the shirt and trouser garments were manufactured using the pattern blocks drafted in this study. Moreover, this chapter reports on the garment fit test evaluations of prototype shirt and trouser garments designed from the 3D full body scanned subjects' size 10/34 measurements and the 3D full body scanned mannequin's size 10/34 measurements.

The average height measurement of the subjects in this study was found to be 157 cm (see Figure 4.1) and only the pear-shaped petite women subjects' 3D scanned body measurements were considered throughout the pattern construction process.

5.2 DEVELOPING THE PATTERN BLOCKS FOR CONSTRUCTING THE PROTOTYPE SHIRT AND TROUSER GARMENTS

The entire concept of constructing standard patterns revolves around achieving specific fit requirements for the end use of garments, since proper patternmaking ensures a good fit for the target consumers. To be able to evaluate the accuracy of the size chart measurements established in this study, the prototype shirt and trouser pattern blocks were manually constructed from the size 10/34 3D full body scanned subjects' body measurements as well as the measurements from a size 10/34 3D full body scanned petite tailoring mannequin used commercially, to produce the shirt and trouser garments for fit test evaluations. These evaluations also served to assess the relevance and accuracy of the mannequin to the fit of garments on a selection of size 10/34 petite women.

5.2.1 Constructing the prototype shirt and trouser pattern blocks

The procedures for drafting the pattern blocks were adopted from Defty's (1988:22-30) pattern making book, supplemented by the researcher's pattern making experience. The justification for using Defty's pattern drafting method, in this study, was that Defty (1988:17-18) is the only South African author who published upper and lower body size charts for petite "*short*" women and additionally provided pattern making instructions for drafting the bodice, sleeve for the shirt garments and the "*slacks*" for the trouser garments.

The patterns developed in this petite sizing and fit study focused on one size range (size 10/34) therefore pattern grading was not necessary. Half patterns were used for constructing the front and back of each shirt and trouser pattern. Two-dimensional pattern drafting methods were used to construct the patterns; these are described in section 2.11. The basic pattern blocks consist of a set of plain, flattened pattern pieces and adapted for a particular garment style. The design styles for the prototype shirt and trouser garments constructed in this study have been presented in sections 3.4.1 (Figure 3.6) and 3.4.2 (Figure 3.7).

Two sets of shirt and trouser patterns were drafted from the size chart size 10/34 subjects' size chart measurements and the size 10/34 petite tailoring mannequin's measurements. Adjustments to the pattern blocks were made at the shoulder which was shortened in length because Defty's pattern drafting method resulted in a longer shoulder length measurement for both sets of the drafted prototype shirt pattern blocks. The shirt front collar measurements were lowered by 1.5 cm to accommodate movement in the neck area. Thereafter a skirt pattern was incorporated into the shirt pattern design to extend the length of the shirt to the lower waist as the initial shirt length ended at the upper waist area. The pattern measurements for the prototype shirt sleeve were adjusted slightly at the armhole to match the measurements collected in this study.

The trousers pattern blocks were created using the lower waist measurements because the trouser was not intended to be high-waisted. The front and back crotch lengths were lowered with 15 cm, as the crotch lengths were taken at the upper waist area. 15 cm was the measurement distance used to measure the lower waist from the upper waist when scanning the subjects. Thereafter, the pattern blocks were shaped according to the desired fit of the garments. The tables of data used to draft the prototype shirt and trouser pattern blocks are as indicated in Table 4.34 and Table 4.35, in section 4.5.

The measurements on the two sets of shirts and trouser pattern blocks were further compared to distinguish the shape differences in the pattern blocks (see Figure 5.1 and Figure 5.2). Both sets of pattern blocks were drafted for a pear body shape profile as this was the body shape determined from the 3D full body scanned measurements of the subjects and the petite tailoring mannequin. The size 10/34 mannequin's bust (86 cm), upper waist (69 cm) and hip (95 cm) measurement relationship were established to be in accordance with the bust (88 cm), upper waist (70 cm) and hip (96 cm) measurement relationship of the pear body shaped size 10/34 size chart measurements, and was therefore classified as a pear body shape profile. However, visual shape classification observations of the petite mannequin suggested that the mannequin had a crossover shape between the hourglass body shape and the pear body shape profiles. Hence, the researcher found some differences in the pattern blocks developed in this study using the size 10/34 upper and lower body dimensions size chart measurements.

The girth measurements from the size 10/34 upper body dimensions size charts developed in this study were larger than the girth measurements from the mannequin's data. Furthermore, the bodice, sleeve and trouser pattern blocks were shorter in length for both the shirt and trouser garments. The length of the shirt garment created using the size 10/34 size chart measurements was 5.5 cm shorter than the length of the shirt garment created using the size 10/34 mannequin's measurements. This could be attributed to the neck to upper waist front (30 cm) and back (33 cm) measurements from the size 10/34 size chart being shorter than the neck to upper waist front (35 cm) and back (39 cm) measurements from the size 10/34 mannequin.

The trouser crotch lengths from the size 10/34 size chart data (front: 34 cm and back: 35 cm) measurements were shorter than the crotch length (front: 36 cm and back: 36 cm) measurements from the size 10/34 mannequin; the inseam (66 cm) and the outseam (100 cm) from the size 10/34 size chart data were shorter than the inseam (73 cm) and the outseam (102 cm) measurements from the size 10/34 mannequin. Hence the trouser pattern block drafted using the size 10/34 lower body dimensions size chart measurements was shorter in garment length when compared to the trouser pattern block drafted using the size 10/34 size mannequin measurements.

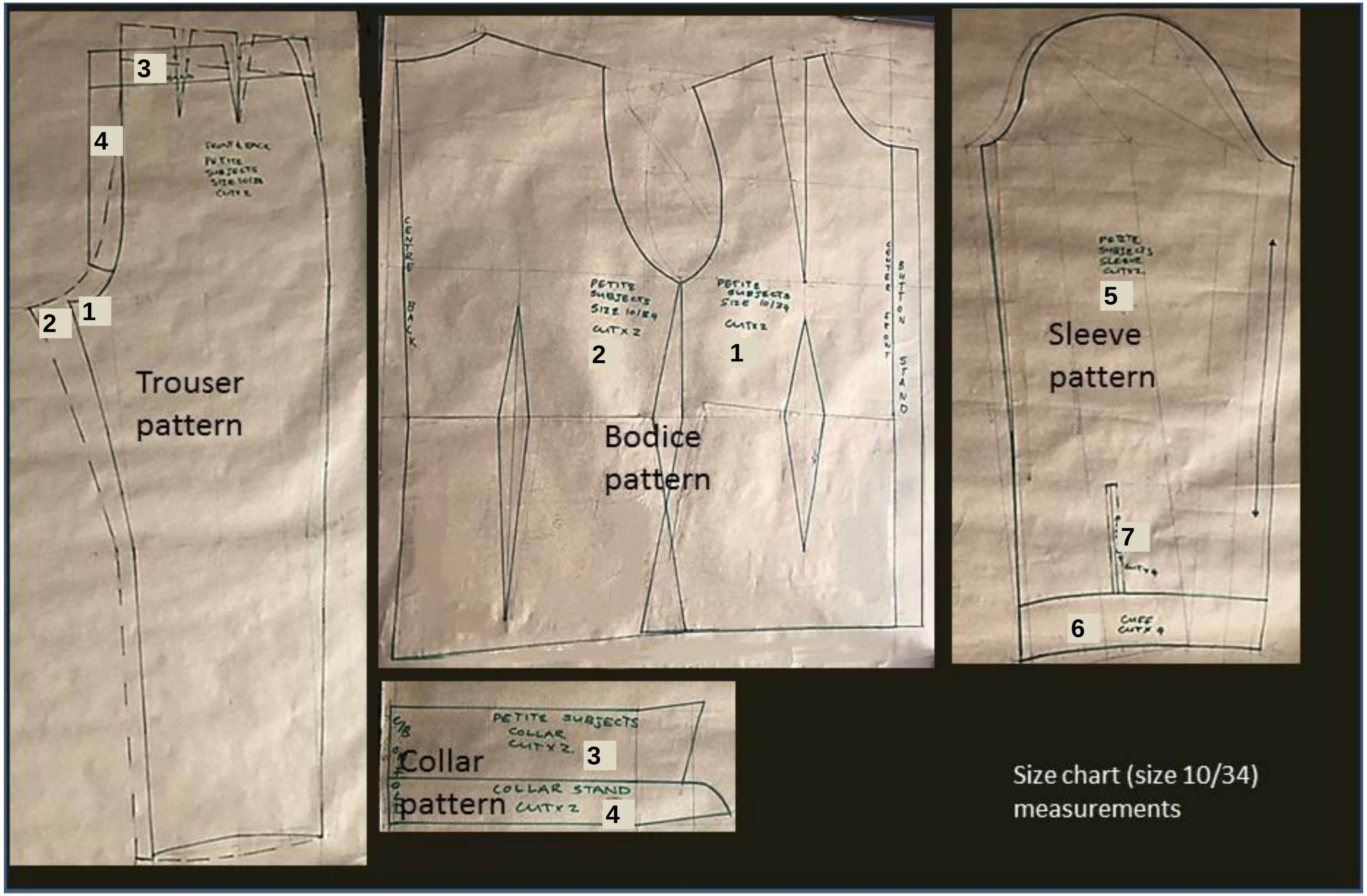


Figure 5.1: Patterns blocks developed from the subjects’ size chart, size 10/34 measurements collected in this study.

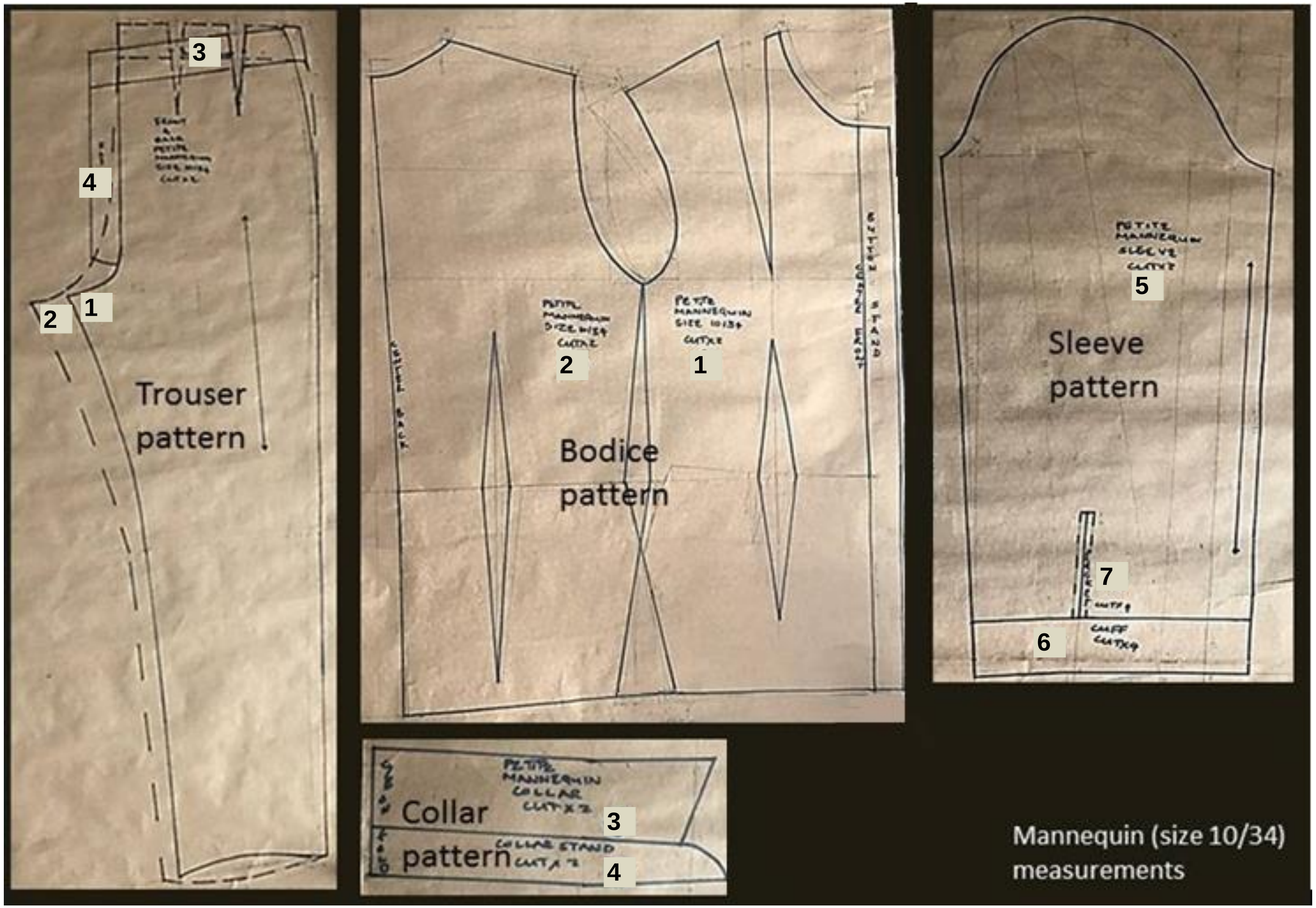


Figure 5.2: Patterns blocks developed from the size 10/34 tailoring mannequin measurements used in this study.

The shirt patterns were developed from seven pattern pieces, as shown in Figure 5.1 and Figure 5.2. The front left and right (**1**) basic shirt block patterns with darts (the front patterns had button stands), back left and right (**2**) basic shirt block patterns with darts, a standing collar (**3**) with a collar stand (**4**), a sleeve (**5**) and a sleeve cuff (**6**) that had a bound placket (**7**). The trouser patterns, shown in Figure 5.1 and Figure 5.2, consisted of four pieces: front left and right (**1**) trouser patterns, back left and right (**2**) patterns, with a contoured 4 cm-wide front and back waistband (**3**) that formed a tilted pants waist sitting at the lower waist area of the body and a fly-front zipper closure (**4**); both the front and back trouser block pattern pieces had waist darts: one for each side of the front patterns and two for each side of the back patterns.

Wearing/functional ease and the design garment ease were considered when drafting the shirt and trouser pattern blocks. Although in section 4.7, most of the subjects indicated that they preferred close-fitted garments, it was noted that the size 10/34 subjects had small to medium body silhouettes (according to their body measurements) and their overall shirt and trouser garment fit preference ranged between close-fitting to semi-fitted. Therefore, the pattern blocks for the shirt and trouser garments were drafted as semi-fitted to allow ease of movement in the garment since the fabric used to create the garments in this study was a non-stretchable calico cotton fabric.

Calico fabric is an inexpensive alternative to other fabrics and is extensively used for mock-ups of garments in the fashion industry (Redmore, 2012:10; Trish Newbery Design, 2014). The calico fabric used for the shirt garment was lighter than the calico fabric used to manufacture the trouser garment, to ensure that the shirt garment was light in weight. 100% Natural Cotton Calico Fabric Medium weight, 190 grams per square metre (g/m^2) was used for the shirt garments and 245 g/m^2 was used for the trouser garments. Sewing and Craft Alliance (2008:1-2) suggest that lightweight fabrics are best suited for shirt garments and medium to heavy fabrics for trouser garments.

The basic shirt silhouette (see Figure 3.6) was used as the shirt style for this study. Garment ease was added to the upper waist circumference: 0.75 cm on the front and back sides, hip circumference 0.75 cm on the front and back sides, and sleeve circumference 0.75 cm on the front and back sides to allow comfort and movement in the garment. The overall left and right side of the shirt bodice and sleeve had a 1.5 cm ease value (front pattern ease value: 0.75 cm + back pattern ease value: 0.75 cm). Hemline measurements of 2 cm were added on the length of the shirt and sleeve length for both the size 10/34 size chart measurements and the 3D full body scanned size 10/34 mannequin's measurements.

The slacks silhouette (see Figure 3.7) was used as the basic trouser style for this study. The patterns for the trousers were drafted as straight, semi-fitted trousers. Up to 1.5 cm ease was added to the hip circumference and 1.5 cm knee circumference. The added ease measurements were drafted to blend with the ankle (hemline) area. Seam allowances of 2 cm were used on all the constructed shirt and trouser garments. The amount of ease allowance used was based on the researcher's personal experience, information gathered from pattern books and consultations with two experts with experience in garment sizing and fit in the Department of Consumer Science, clothing field. The length of the trouser garments was drafted to correspond with the size 10/34 trouser inseam and out-seam measurements from the size chart and the 3D full body scanned mannequin's measurements respectively.

The shirt and trouser sizing measurements together with the design styles of the garments produced in this study were made to fit as smoothly as possible over the subjects' largest body protrusions (bust for the shirt and hip for the trouser garments) and easily hang on the wearer's body.

Methods and procedures on how the garments were manufactured are described and discussed in the next section.

5.3 MANUFACTURING THE PROTOTYPE SHIRT AND TROUSER GARMENTS

Pattern pieces represent a piece of a garment and contain information such as seam allowances, grain lines, garment sizes, balance marks, darts and button placements. The pattern pieces are then sewn together to obtain a prototype garment style of a fashion design illustration (Narang, 2014:33). To create the shirt and trouser garments for this study, all the pattern pieces were cut from the calico fabric prior to joining the pattern pieces together, using the same construction techniques to ensure uniformity in the appearance of the test garments.

Two garments were created for each of the size 10/34 subjects' size chart measurements and the size 10/34 petite tailoring mannequin's measurements to avoid testing the fit of the garments on the subjects with one garment that could be easily worn out and distort the quality of fit on the wearer's body. The measurements (see Table 4.34 and Table 4.35) on each of the produced shirt and trouser garments were cross-checked with that from the actual patterns for accuracy

The fabric grain and the garment line from the five elements associated with garment fit mentioned in section 2.4.1.1 and 2.4.1.3 were considered when constructing the shirt and trouser garments for this study. The positioning of the pattern grain lines, when cutting the pattern pieces on the fabric, were set relative to the fabric grain to ensure that the fabric of the garment draped correctly and conformed to the wearer's body contour as required by the garment design style. The pattern pieces were placed crosswise parallel to the finished edge of the fabric and lengthwise using the grain line as a guideline to place the pattern pieces. Seamlines and dart lines were marked as structural lines from the pattern pieces to be used as guidance when stitching the shirt and trouser garments. This was done to permit accurate and even garment lines that followed the body's natural silhouette, providing a proper garment fit and appearance.

A fusible non-woven interlining was used to fuse the garment pieces that required reinforcement; such as the collars, button stands, cuffs for the shirt garments and the waistbands for the trouser garments. To allow closure in the garments, five buttons were placed on the button stand of each of the finished shirt garments and one button was placed on the trouser waistbands and coil zippers were inserted at the front fly area. The sewing specifications used in this study to manufacture the shirt and trouser garments ensured that the design requirements of the garments were met by applying guidelines formulated by the ISO 4916:1991 stitch type standards. The instruction manuals from the Empisal dress maker 270D free arm sewing machine and the Empisal model S4D free arm overlocker sewing machine that were used to assemble the prototype shirt and trouser garments were also followed. A domestic sewing machine and a domestic overlock machine were used to manufacture the shirt and trouser garments.

The speed of the sewing and overlock machines were kept moderate and controlled to minimise a lot of heat generation when sewing the garments and to avoid seam damage caused by cutting the fabric yarn during the sewing process. The lockstitch and over locker stitch machine parameters were adjusted according to the researcher's experience in sewing garments, keeping in mind the sewing and over locker machine's manual book instructions. The same machine operator (the researcher) was used to manufacture all the garments. The technical specifications consisting of the structure of procedures used to assemble the shirt and trouser garments manufactured in this study; along with the parameters specified for the assembling process are presented in Appendix I.

5.4 GARMENT FIT TEST EVALUATIONS

Fit and wear test evaluations are important evaluators to achieve a good garment fit (Smit 2007:9) and testing the fit of garments makes it easier for the tailor to identify the functionality of the garment and resolve its fit problems. According to Petrova and Ashdown (2012:271), testing the fit of garments made of measurements from sizing systems should be performed by testing the garments on several participants used as fit models. Each of the models should represent the measurements of the sizes presented in the size chart table used to develop the garment sizes.

Petrova and Ashdown (2012) further suggest that it is essential to test the fit of a garment on a selected number of individuals to ensure validity in the garment fit test evaluations.

Considering that this study was exploratory in nature and that the fit test evaluations are time consuming, the fit test evaluations were conducted on nine subjects that took part in the study. Those subjects who had a pear body shape profile and whose measurements, as extracted by the 3D full body scanner, corresponded to size 10/34 in the size chart, and who had indicated (on their demographic form) that they were willing to partake in the fit test evaluations, were selected for the fit test evaluations.

The bust (for the shirt garments) and the hip (for the trouser garments) were used as the criteria for selecting the size 10/34 subjects. The bust and hip measurements used to create the shirt and trouser garments in this study and the actual body measurements of the participants selected for the fit test evaluations are presented in Table 5.1. The size intervals established in the size charts presented in Table 4.32 and Table 4.33 were used to determine the minimum and maximum measurement ranges for selecting the size 10/34 subjects for the fit test evaluations.

Table 50: Bust and hip dimensions of the size chart measurements, petite mannequin measurements and the selected subject's actual body measurements.

BODY DIMENSIONS	**Size 10/34 size chart measurements**	**Size 10/34 mannequin measurements**	**SUBJECTS ACTUAL 3D FULL BODY SCANNED MEASUREMENTS**								
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
HEIGHT	157cm	160cm	155cm	159cm	160cm	160cm	158cm	161cm	157cm	161cm	160cm
BUST	88 cm – 93.9 cm	86 cm	87 cm	88 cm	90 cm	92 cm	92 cm	90 cm	89 cm	93 cm	88 cm
HIP	96 cm – 101.9 cm	95 cm	98 cm	97 cm	98 cm	100 cm	97 cm	97 cm	98 cm	100 cm	97 cm

Garment fit sessions were scheduled with each subject. Prior to conducting the fit test evaluations, the selected subjects were reminded of the objectives of the study. The subjects were further informed on the amount of time needed to conduct the fit evaluations and what was expected from them during the garment evaluation process. A panel of two judges evaluated the fit qualities of the prototype shirt and trouser garments created for this study. The garment fit evaluators were experts and academics who had approximately 6 and 15 years respectively of experience in the Consumer Science Clothing field and were clothing practical lecturers in the department. The evaluators were provided with written standards, consisting of descriptions of the criteria required to evaluate the quality of fit of the test garments. This was done to enhance "*interrater-reliability*" in the garment test evaluations, since the concept of fit varies for everyone (Leedy & Ormrod, 2010:93). The standards for evaluating the fit of the constructed garments were designed to assess the fit of the shirt and trouser garments which were applicable and relevant to the garments tested. The specifications were based on relevant theory, applying the principles formulated by Stamper *et al.* (2005); Liechty *et al.* (2010:54), and Marshall *et al.* (2012).

The standards for evaluating the fit of the test garments were structured around the five principle components of garment fit mentioned in section 2.4.1. The standards that were used to evaluate the fit quality of the shirt and trouser test garments are presented in Appendix J. A total of 18 standards were allocated for evaluating the shirt garments and 17 standards for the trouser garments. The rating scales (from the evaluators' independent ratings) for the fit of the prototype shirt and trouser garment were further assessed to provide a quantitative measure of the quality of fit for each assessed garment on each subject. The fit rating scales of each evaluator for the tested garment and garment component are discussed in section 5.4.2 to determine the overall fit ratings for each of the evaluated shirt and trouser garments.

5.4.1 Conducting the garment fit test evaluations

Traditionally, garment fit is described in terms of five components: ease, line, grain, balance and set. The garment ease, line and grain components had been developed thoroughly in the pattern construction and garment constructing process. The garment set, and garment balance referred to in section 2.4.1.4 and 2.4.1.5 were applicable for conducting the fit test evaluations. In this process, the direction, flow of the fabric, and the number of wrinkles that caused specific problems in the shirt and trouser garments were identified. Petrova and Ashdown (2012:271) advised that in general, there are three types of wrinkles or stress folds that can occur in a garment, namely: horizontal, vertical, and diagonal. Petrova and Ashdown (2012) further suggest that each type of wrinkle or stress fold indicate different problems, comprising of inadequate, excess, or an improper ease. Therefore, to identify fit problems and to suggest garment alterations that would correct the problem; garment experts should use their knowledge in analysing the wrinkle or stress folds of a garment in both still and moving body positions.

Joseph-Armstrong (2014:50, 69) suggests that, when fitting bodice (shirt) garments on a model, the garment's seam-lines should be well pressed with an iron that does not have steam. Analysing a bodice (shirt) garment fit requires measuring areas that need corrections and adjusting the patterns, thereafter transferring the adjusted corrections on the constructed garment to acquire a good quality fit. The fit of the bodice (shirt) sleeve is evaluated on its alignment and hang on the arm, together with the appearance of the sleeve cap around the armhole. Conducting trouser fit test evaluations requires the trouser to be constructed from a firm fabric and thereafter tested on a model with the waistband and zipper attached to ensure a good base for fit evaluation. Trouser fit is evaluated through three dimensions, namely: the height, which is the length from the waist to the floor (or desired garment length), the width, which is the distance between one side of the body to the other, and the depth, which is the measured distance from the front to the back of the body (Joseph-Armstrong, 2014:663). The pelvic bone structure along with the amount of flesh on the wearer's stomach and buttocks must be considered when determining the trouser crotch depth for fit evaluations (Veblen, 2012:193).

The fit test evaluations of the prototype shirt and trouser garments produced in this study took place in a clothing laboratory at UNISA, Florida Campus. Photographic images were taken of the nine subjects to authenticate the analysed data. The criteria for the goodness of the semi-fitted shirt and trouser garments being evaluated were established in section 5.2.1.

The subjects wore their undergarments for the garment fit test evaluations. The test garments were labelled PS (for the subjects' measurements) and M (for the mannequin's measurements) to avoid confusion and mixing up the garments. During the garment fit evaluation sessions, each evaluator independently evaluated the quality of the constructed shirt and trouser garments fit. The panel of evaluators assessed the front, side, and back of the shirt and trouser size chart and mannequin sized garments worn in turn by the petite size 10/34 subjects. The garment fit test evaluators followed specified criteria to evaluate the fit of the tested shirt and trouser garments. The fit evaluation data was summarised into three rating scale categories, namely 'good fit', 'moderate fit', and 'poor fit; further comments were reserved for the evaluators to transcribe when evaluating the fit of the garments.

The evaluators carefully observed the fit of the shirt and trouser garments on human subjects in standing and movement positions. The subjects were asked to perform the movements continuously to assess whether the evaluated garment allowed the wearer to perform common tasks without interference or resistance. During the fit test evaluations, the evaluators asked the subjects to walk, sit, and go through a normal range of body motions while wearing the garments to evaluate whether the garment looked good on the body in terms of line, balance, and the grain of the fabric. The subjects were encouraged to express their opinions of the quality of fit of the tested garments during the fit test evaluations.

The analysis of the rating scales for the evaluated prototype shirt and trouser garment prototypes are discussed in the next section.

5.4.2 Analysis of the shirt and trouser garment fit test evaluating rating scales

The quality of the fit of the prototype shirt and trouser garments were evaluated for the different body dimension areas as indicated in the garment fit assessment standards form, which is available in Appendix J. Three garment fit evaluating rating scales were applied, namely: good, moderate and poor quality of fit were used to evaluate the quality of the shirt and trouser garments, and to assign the evaluator's scores on how they perceived the quality of the shirt and trouser garments. A good rating scale (**3**) indicated that the garment fitted well, a moderate rating scale (**2**) indicated that the fit of the garment was acceptable and a poor rating scale (**1**) indicated that the garment did not fit well on the wearer's body. The results from the garment fit test evaluations were further analysed by calculating the overall mean values of the rated evaluating scales per evaluator, for each of the assessed garment on each subject to determine the extent to which of the created garments offered an overall good quality of fit (see Table 5.2 and Table 5.3 for the shirt garments, and Table 5.4 and Table 5.5 for the trouser garments).

Table 5.1: The shirt garments rating scales assessed individually by each fit test evaluator (Subjects 1-5).

SHIRTS																				
	Subject 1				Subject 2				Subject 3				Subject 4				Subject 5			
	SC		**M**		**SC**		**M**		**SC**		**M**		**SC**		**M**		**SC**		**M**	
	Evaluators																			
EVALUATING STANDARDS	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1. Compatibility & ease	2	2	2	2	3	2	2	1	DOES NOT FIT		DOES NOT FIT		1	2	DOES NOT FIT		2	2	3	2
2. Garment rest	3	2	2	2	2	2	2	1					2	2			1	2	2	2
3. Drape front garment	3	3	3	3	3	2	2	2					2	2			2	1	2	2
4. Drape back garment	3	2	3	2	2	2	2	2					2	2			3	1	2	1
5. Neckline collar	3	3	3	3	3	3	2	2					3	3			3	3	3	3
6. Shoulders	2	2	2	2	3	2	2	1					2	2			3	3	3	3
7. Armholes	2	1	2	2	1	2	2	2					3	1			2	2	2	1
8. Sleeve length	3	2	1	1	3	2	1	1					2	2			2	2	2	1
9. Sleeve biceps	3	2	2	1	3	2	1	1					2	1			3	2	1	2
10. Sleeve elbow	2	3	2	3	2	2	2	1					2	2			2	2	2	2
11. Sleeve wrist	3	3	3	3	3	3	2	2					2	3			3	3	3	3
12. Ease bust	3	2	3	2	3	2	2	2					1	2			1	1	2	1
13. Closure alignment	3	3	3	2	3	3	2	1					2	3			2	2	2	2
14. Garment closure	3	2	3	2	2	2	2	2					1	2			2	1	2	1
15. Hems & finishes	3	2	3	3	1	2	3	3					3	3			3	3	2	3
16. Garment length	3	3	3	3	2	3	2	2					1	2			2	3	1	3
17. Comfortability & movement	3	2	2	2	3	2	2	1					2	2			2	2	2	1
18. Can the wearer sit?	3	3	3	2	3	3	2	2					3	3			3	2	2	2
OVERALL FIT (mean)	**2.8**	**2.3**	**2.5**	**2.2**	**2.5**	**2.3**	**1.9**	**1.6**	**0.0**	**0.0**	**0.0**	**0.0**	**2.0**	**2.2**	**0.0**	**0.0**	**2.3**	**2.1**	**2.1**	**1.9**

Evaluating scales: 3 = good quality of fit; 2 = moderate quality of fit; 1 = poor quality of fit

*SC = Size chart measurements; M = Mannequin measurements

Table 5.2: The shirt garments rating scales assessed individually by each fit test evaluator (Subjects 6-9).

SHIRTS																
	Subject 6				Subject 7				Subject 8				Subject 9			
	SC		M		SC		M		SC		M		SC		M	
	Evaluators															
EVALUATING STANDARDS	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1. Compatibility & ease	3	2	1	1	3	2	2	2	DOES NOT FIT		DOES NOT FIT		2	2	DOES NOT FIT	
2. Garment rest	3	2	1	1	3	2	3	1					3	2		
3. Drape front garment	3	2	2	1	2	2	2	2					3	2		
4. Drape back garment	3	2	3	2	2	2	2	1					3	2		
5. Neckline collar	3	3	3	3	3	3	3	3					3	3		
6. Shoulders	2	2	3	2	3	3	3	2					3	3		
7. Armholes	1	1	2	1	2	2	2	1					3	2		
8. Sleeve length	2	3	2	2	3	2	2	1					2	2		
9. Sleeve biceps	2	2	1	1	3	2	2	1					2	1		
10. Sleeve elbow	3	2	1	1	3	3	3	2					2	2		
11. Sleeve wrist	3	3	2	3	3	3	3	3					3	2		
12. Ease bust	2	2	2	1	2	2	3	2					2	2		
13. Closure alignment	2	2	1	2	2	2	3	2					2	2		
14. Garment closure	2	1	1	1	3	3	2	2					2	2		
15. Hems & finishes	2	3	2	2	2	3	3	3					2	3		
16. Garment length	2	3	2	3	2	3	3	3					2	3		
17. Comfortability & movement	2	1	1	1	3	3	2	2					2	2		
18. Can the wearer sit?	3	3	1	2	3	3	2	2					3	2		
OVERALL FIT (mean)	**2.4**	**2.2**	**1.7**	**1.7**	**2.6**	**2.5**	**2.5**	**1.9**	**0.0**	**0.0**	**0.0**	**0.0**	**2.4**	**2.2**	**0.0**	**0.0**

Evaluating scales: 3 = good quality of fit; 2 = moderate quality of fit; 1 = poor quality of fit

*SC = Size chart measurements; M = Mannequin measurements

Table 5.3: The trouser garments rating scales assessed individually by each fit test evaluator (Subjects 1-5).

TROUSERS																				
	Subject 1				Subject 2				Subject 3				Subject 4				Subject 5			
	SC		M		SC		M		SC		M		SC		M		SC		M	
	Evaluators																			
EVALUATINGSTANDARDS	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1.Compatibility & ease	3	2	2	1	3	2	2	2	3	2	2	2	2	2	2	1	2	2	2	2
2.Garment rest	3	3	1	1	3	3	2	2	3	2	2	1	2	2	2	1	2	2	3	2
3.Lower waist fit	3	3	3	3	3	3	3	3	3	3	2	3	3	2	2	2	3	2	3	2
4.Hip fit	3	2	2	1	2	2	2	2	3	2	2	2	3	3	2	3	3	3	3	2
5.Front crotch	3	2	1	1	2	2	2	2	2	2	3	2	2	1	2	1	3	2	2	2
6.Back buttocks	3	3	3	3	2	2	3	3	2	2	3	2	3	3	2	2	3	3	3	2
7.Seat drape	3	2	2	2	2	2	3	2	2	2	2	2	3	2	2	2	3	2	3	2
8.Thigh fit	2	2	2	2	2	2	2	2	3	3	3	2	3	2	2	2	2	2	3	2
9.Knees fit	2	2	3	2	2	2	3	3	3	3	2	3	2	3	3	3	3	3	2	3
10.Ankles fit	2	2	2	2	2	2	3	3	3	3	2	3	3	3	3	3	2	2	3	2
11.Inseam length	3	3	2	3	3	3	3	3	3	3	2	2	3	2	3	3	3	2	3	3
12.Outseam length	3	3	3	3	3	3	3	2	2	1	2	2	3	2	3	2	3	3	3	3
13.Hems& finishes	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
14.Ease for closure	2	3	3	1	3	3	3		3	3	2	3	3	3	2	3	2	1	3	3
15.Bottom of garment	3	1	1	1	3	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2
16.Comfortability & movement	3	3	3	3	3	3	3		3	3	2	2	3	3	2	3	3	3	3	2
17. Can the wearer sit?	3	3	3	3	3	3	3		3	3	3	2	3	2	3	1	2	2	3	1
OVERALL FIT (mean)	**2.6**	**2.3**	**2.1**	**1.9**	**2.4**	**2.3**	**2.6**	**1.9**	**2.6**	**2.4**	**2.2**	**2.2**	**2.6**	**2.3**	**2.3**	**2.1**	**2.5**	**2.2**	**2.6**	**2.1**

Evaluating scales: 3 = good quality of fit; 2 = moderate quality of fit; 1 = poor quality of fit

*SC = Size chart measurements; M = Mannequin measurements

Table 5.4: The trouser garments rating scales assessed individually by each fit test evaluator (Subjects 6-9).

TROUSERS																
	Subject 6				Subject 7				Subject 8				Subject 9			
	SC		M		SC		M		SC		M		SC		M	
	Evaluators															
EVALUATING STANDARDS	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1.Compatibility & ease	2	2	2	2	3	2	2	1	3	2	3	2	3	2	2	1
2.Garment rest	2	2	3	2	2	2	3	2	3	2	3	2	2	2	2	1
3. Lower waist fit	3	2	3	3	3	2	3	3	3	3	3	3	3	2	3	2
4.Hip fit	3	3	2	2	3	2	3	2	3	3	3	3	3	2	2	1
5.Front crotch	2	2	2	2	2	2	2	1	3	2	2	1	2	2	2	1
6.Back buttocks	3	3	3	2	2	2	3	2	3	3	3	2	2	2	2	2
7.Seat drape	3	2	3	2	3	2	3	2	3	3	3	3	2	2	2	1
8.Thigh fit	3	2	3	1	3	2	3	2	3	2	3	2	2	2	2	1
9.Knees fit	3	3	2	3	2	2	3	2	3	3	3	3	3	2	3	2
10.Ankles fit	3	3	3	3	2	2	3	2	3	3	3	3	3	2	3	2
11.Inseam length	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	2
12.Outseam length	3	2	3	3	3	2	3	2	3	2	3	2	3	3	3	1
13.Hems& finishes	3	3	3	3	2	3	1	3	3	3	3	3	3	3	3	3
14.Ease for closure	3	3	3	2	2	3	3	3	3	3	3	2	3	3	3	2
15.Bottom of garment	3	3	3	3	1	1	2	1	3	3	3	3	3	3	3	3
16.Comfortability & movement	3	3	3	3	3	3	2	2	3	3	3	3	2	3	3	3
17. Can the wearer sit?	3	3	3	1	3	3	3	2	3	3	3	3	2	3	3	2
OVERALL FIT (mean)	**2.7**	**2.4**	**2.6**	**2.2**	**2.3**	**2.1**	**2.5**	**1.9**	**2.8**	**2.5**	**2.8**	**2.4**	**2.4**	**2.3**	**2.4**	**1.7**

Evaluating scales: 3 = good quality of fit; 2 = moderate quality of fit; 1 = poor quality of fit

*SC = Size chart measurements; M = Mannequin measurements

As seen in Table 5.2 and Table 5.3, evaluator 1 rated the shirt garments created from both the size 10/34 size chart and petite tailoring mannequin's measurements higher than evaluator 2 for subjects 1, 2, 5 and 7, with broadly good-moderate quality of fit rating scores. Subjects 4, 6 and 9's shirt garment fit quality produced by the garments made from the size chart measurements were also rated higher by evaluator 1, with fit rating scores considered to be broadly moderate. The shirt garments created from the mannequin's measurements were considered to produce a generally good-moderate quality of fit by the two fit test evaluators for subjects 1, 2, 5, 6 and 7. The garments created from the mannequin's measurements were rated to offer the same (moderate) quality of fit on subject 6 by both fit test evaluators. Subjects 3 and 8 did not fit into both evaluated shirt garments; whilst subjects 4 and 9 did not fit into the shirt garments produced from the mannequin's measurements. The reasons are further elaborated in section 5.5 where the assessments of the shirt and trouser garment fit test trial evaluations for the size 10/34 petite subjects are presented.

Table 5.4 and Table 5.5 show that the trouser garments developed from both the size 10/34 size chart and mannequin's measurements were rated high by evaluator 1 when compared to evaluator 2's garment fit score ratings for subjects 1, 2, 4, 5, 6, 7, 8, 9; and were considered to have generally good-moderate garment fit rating scales. Subject 3 was also highly rated by evaluator 1 who considered the fit quality to be good for the trouser garments created using the size 10/34 size chart. The trouser garments produced from the mannequin measurements were considered to offer subject 3 with only a broadly moderate quality of fit. Major disagreements were observed in the fit of the trouser garment on subject 6's thigh area and whether the subject was able to sit when wearing the garment created using the mannequin measurements (see Table 5.5). Evaluator 1 rated the quality of fit on both evaluated standards to be good, whilst evaluator 2 considered the fit of both evaluated standards to be of poor quality. This is further elaborated in section 5.5.7.3. Thereafter, the mean score rating values of each of the evaluating standards from the shirt and trouser garments created using the size 10/34 chart and the mannequin's measurements, per subject were compared with one another. Prior to comparing the mean values of the evaluating standards, the averages of the evaluators independent rating scores for each of the evaluating standards on each of the assessed shirt and trouser garments were calculated for each subject; i.e. the rated scores from both evaluator one and evaluator two were combined to establish the combined mean value for each evaluating standard for each subject in the assessed similar garment (for example; the shirt garment created using the size chart measurements).

This calculation was applied for all the evaluated shirt and trouser garments created, using both the size chart and mannequin measurements evaluated for each subject who took part in the fit test evaluations. The criteria used for defining the quality of fit using the mean values after averaging the evaluators independent rating scores was the same as previously defined; 3 as a good fit, 2 as a moderate fit and 1 as a poor fit. The comparative overall mean rating values are presented in Table 5.6 (for the shirt garments) and Table 5.7 (for the trouser garments). The comparative mean data is plotted in Appendix K to show the variations between the rating score means.

Table 5.5: Comparative mean ratings of the evaluated shirt garments per subject

SHIRT MEAN RATINGS																		
	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6		Subject 7		Subject 8		Subject 9	
EVALUATING STANDARDS	**SC**	**M**	**SC**	**M**	**SC**	**M**	**SC**	**M**	**SC**	**M**	**SC**	**M**	**SC**	**M**	**SC**	**M**	**SC**	**M**
1. Compatibility & ease	2	2	2.5	1.5	DOES NOT FIT		1.5	DOES NOT FIT	2	2.5	2.5	1	2.5	2	DOES NOT FIT		2	DOES NOT FIT
2. Garment rest	2.5	2	2	1.5			2		1.5	2	2.5	1	2.5	2			2.5	
3. Drape front garment	3	3	2.5	2			2		1.5	2	2.5	1.5	2	2			2.5	
4. Drape back garment	2.5	2.5	2	2			2		2	1.5	2.5	2.5	2	1.5			2.5	
5. Neckline collar	3	3	3	2			3		3	3	3	3	3	3			3	
6. Shoulders	2	2	2.5	1.5			2		3	3	2	2.5	3	2.5			3	
7. Armholes	1.5	2	1.5	2			2		2	1.5	1	1.5	2	1.5			2.5	
8. Sleeve length	2.5	1	2.5	1			2		2	1.5	2.5	2	2.5	1.5			2	
9. Sleeve biceps	2.5	1.5	2.5	1			1.5		2.5	1.5	2	1	2.5	1.5			1.5	
10. Sleeve elbow	2.5	2.5	2	1.5			2		2	2	2.5	1	3	2.5			2	
11. Sleeve wrist	3	3	3	2			2.5		3	3	3	2.5	3	3			2.5	
12. Ease bust	2.5	2.5	2.5	2			1.5		1	1.5	2	1.5	2	2.5			2	
13. Closure alignment	3	2.5	3	1.5			2.5		2	2	2	1.5	2	2.5			2	
14. Garment closure	2.5	2.5	2	2			1.5		1.5	1.5	1.5	1	3	2			2	
15. Hems & finishes	2.5	3	1.5	3			3		3	2.5	2.5	2	2.5	3			2.5	
16. Garment length	3	3	2.5	2			1.5		2.5	2	2.5	2.5	2.5	3			2.5	
17. Comfortability & movement	2.5	2	2.5	1.5			2		2	1.5	1.5	1	3	2			2	
18. Can the wearer sit?	3	2.5	3	2			3		2.5	2	3	1.5	3	2			2.5	
OVERALL MEAN RATINGS	**2.6**	**2.4**	**2.4**	**1.8**	**0.0**	**0.0**	**2.1**	**0.0**	**2.2**	**2.0**	**2.3**	**1.7**	**2.6**	**2.2**	**0.0**	**0.0**	**2.3**	**0.0**

Evaluating scales: 3 = good quality of fit; 2 = moderate quality of fit; 1 = poor quality of fit

*SC = Size chart measurements; M = Mannequin measurements

Table 5.6: Comparative mean ratings of the evaluated trouser garments per subject

TROUSER MEAN RATINGS																		
	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6		Subject 7		Subject 8		Subject 9	
EVALUATING STANDARDS	SC	M	SC	M	SC	M	SC	M	SC	M	SC	M	SC	M	SC	M	SC	M
1.Compatibility & ease	2.5	1.5	2.5	2	2.5	2	2	1.5	2	2	2	2	2.5	1.5	2.5	2.5	2.5	1.5
2.Garment rest	3	1	3	2	2.5	1.5	2	1.5	2	2.5	2	2.5	2	2.5	2.5	2.5	2	1.5
3. Lower waist fit	3	3	3	3	3	2.5	2.5	2	2.5	2.5	2.5	3	2.5	3	3	3	2.5	2.5
4.Hip fit	2.5	1.5	2	2	2.5	2	3	2.5	3	2.5	3	2	2.5	2.5	3	3	2.5	1.5
5.Front crotch	2.5	1	2	2	2	2.5	1.5	1.5	2.5	2	2	2	2	1.5	2.5	1.5	2	1.5
6.Back buttocks	3	3	2	3	2	2.5	3	2	3	2.5	3	2.5	2	2.5	3	2.5	2	2
7.Seat drape	2.5	2	2	2.5	2	2	2.5	2	2.5	2.5	2.5	2.5	2.5	2.5	3	3	2	1.5
8.Thigh fit	2	2	2	2	3	2.5	2.5	2	2	2.5	2.5	2	2.5	2.5	2.5	2.5	2	1.5
9.Knees fit	2	2.5	2	3	3	2.5	2.5	3	3	2.5	3	2.5	2	2.5	3	3	2.5	2.5
10.Ankles fit	2	2	2	3	3	2.5	3	3	2	2.5	3	3	2	2.5	3	3	2.5	2.5
11.Inseam length	3	2.5	3	3	3	2	2.5	3	2.5	3	3	3	3	3	2.5	3	3	2.5
12.Outseam length	3	3	3	2.5	1.5	2	2.5	2.5	3	3	2.5	3	2.5	2.5	2.5	2.5	3	2
13.Hems & finishes	3	2.5	3	3	3	3	3	3	3	3	3	3	2.5	2	3	3	3	3
14.Ease for closure	2.5	2	3	3	3	2.5	3	2.5	1.5	3	3	2.5	2.5	3	3	2.5	3	2.5
15.Bottom of garment	2	1	2.5	3	3	3	3	3	2.5	2	3	3	1	1.5	3	3	3	3
16.Comfortability& movement	3	3	3	3	3	2	3	2.5	3	2.5	3	3	3	2	3	3	2.5	3
17.sit	3	3	3	3	3	2.5	2.5	2	2	2	3	2	3	2.5	3	3	2.5	2.5
OVERALL MEAN RATINGS	**2.6**	**2.2**	**2.5**	**2.7**	**2.7**	**2.3**	**2.6**	**2.3**	**2.5**	**2.5**	**2.7**	**2.6**	**2.4**	**2.4**	**2.8**	**2.7**	**2.5**	**2.2**

* Evaluating scales: 3 = good quality of fit; 2 = moderate quality of fit; 1 = poor quality of fit

*SC = Size chart measurements; M = Mannequin measurements

As presented in Table 5.6, the overall mean rating values of the garment fit test evaluators show that the shirt garments created using the size chart measurements were considered to provide a better quality of fit on seven subjects, namely: subjects 1, 2, 4, 5, 6, 7 and 9 when compared with the fit rating scores of the shirt garments created using the mannequin's measurements. Two of the subjects, namely: subjects 3 and 8 could not fit into both evaluated shirt garments; subjects 4 and 9 could not fit into the shirt garment created using the mannequin's measurements, as the shirt garments were too small to fit their body proportions. Although, subject 4 had a larger bust than subject 3, she was able to fit in one of the shirt garments. Subject 3 had big biceps, therefore, the fit of the sleeves was too tight, and the subject could not put her arms in the garment, as a result, the whole garment fit on the subject's body was restricted. From the evaluated shirt garments produced using the size 10/34 size chart measurements, the garments that could fit the subjects were considered to offer a good quality of fit on two subjects (subjects 1 and 7), and a moderate quality of fit on five subjects (subjects 2, 4, 5, 6, 9). The evaluated shirt garments produced from the mannequin's measurements that could fit the subjects were considered to offer a moderate quality of fit on five subjects (subjects 1, 2, 5, 6 and 7).

Table 5.7 shows the overall mean ratings of the trouser garments. The fit evaluators considered the trouser garments created using the size chart measurements to offer a better-quality fit on six subjects, namely: subjects 1, 3, 4, 6, 8, and 9 when compared with the fit rating scores of the garments created from the mannequin's measurements. Subject 2 was assessed to fit better in the trouser garment created using the mannequin's measurements. Most of the fit criteria were rated similar for subject 2; however, the fit on the back buttocks area, knees, ankles and the length at the bottom of the garment created using the mannequin measurements, were rated higher than the fit of the size chart garment in the above-mentioned areas. As shown in Appendix L2 (for the lower body measurements), the knee, ankle and the inseam measurements were more compatible to the mannequin's measurements. Although, the subject's outseam measurement was 3 cm longer than the mannequin's measurement, the subject's crotch length back and front measurements were more compatible to the measurements from the mannequin, which was enough to accommodate the subject's body length proportions.

Additionally, most of the subject's measurements, except for the lower waist, hip, top thigh and outseam measurements were closer to the measurements of the mannequin (refer to appendix L2 for the lower body measurements). Subjects 5 and 7 were considered to have the same quality of fit in both evaluated trouser garments. A good quality of fit was assessed on eight subjects (subjects 1, 2, 3, 4, 5, 6, 8, 9) and subject 7 was considered to have a moderate quality of fit in the trouser garments created using the size 10/34 size chart measurements. The trouser garments created using the mannequin's measurements presented a good fit rating score on four of the observed subjects (subjects 2, 5, 6, 8) and a moderate fit rating score on five of the subjects (subjects 1, 3, 4, 7, 9).

Consequently, based on the fit test rating scales and mean value evaluations, the findings demonstrate that the garments created using the size 10/34 petite size chart measurements had the highest rating scores and produced better fitting garments than the garments produced from the mannequin's measurements.

5.5 THE ASSESSMENTS OF THE SHIRT AND TROUSER GARMENT FIT TEST EVALUATIONS FOR THE SIZE 10/34 PETITE SUBJECTS

The fit test evaluations for the size 10/34 petite tailoring mannequin are presented in Figure 5.3. The fit was tested on the size 10/34 mannequin to highlight, more specifically, the differences in fit between the two sets of the shirt and trouser garments created in this study and, more importantly, to gain useful insight into the accuracy of the size charts developed in this study for the upper and lower body dimensions.

5.5.1 The petite tailoring mannequin fit test evaluations

Figure 5.3: Images of the fit comparison between the shirt and trouser garments created using the size 10/34 mannequin measurements and the shirt and trouser garments created using the size 10/34 size chart measurements.

The findings from the fit comparisons between the shirt and trouser garments created using the size 10/34 mannequin's measurements and the size chart measurements show that the garments created from the size 10/34 mannequin's measurements were longer and slightly more fitted, in accordance with the measurements established in Table 4.34 and Table 4.35. As a result, the shirt and trouser garments created using the mannequin's measurements provided a better fit on the mannequin, having minor creases when compared to the garments created using the size chart measurements.

However, the crotch length was slightly long in both sets of the tested trouser garments. The results of the collected 3D full body scanned data for both the size chart and mannequin's measurements, as presented in Table 4.35, show that the front and back crotch length measurements of the mannequin's measurements were slightly longer than the front and back measurements from the size chart measurements.
Therefore, how the crotch area in both sets of the evaluated trouser garments fit on the mannequin's body could be attributed to the crotch length measurements. Irrespective of the garments created from the mannequin's measurements fitting better on the

mannequin, the overall fit on both sets of the assessed shirt and trouser garments provided satisfactory results. However, the effect of the pear shaping of the subjects was evident in the shirt garment created using the size 10/34 size chart measurements. The garment was more curved and wide at the bottom part of the upper body. The trouser fitted well but was slightly loose on the mannequin. The findings indicate that the shape of the mannequin needs to be made slightly fuller at the lower part of the body, a little curvier at the hip area and with slightly thicker legs.

Each subject's 3D full body scan and photographs of the fit test evaluations are presented below. The fit test evaluations for each subject are documented with photographs to validate the findings. Each subject's measurements, collected using the 3D full body scanner, are compared with the size chart measurements and measurements from the mannequin in Appendix L, to demonstrate why the quality of the explained fit was good, moderate or poor. The evaluating standard areas that were left blank with no comments by the evaluators were not considered when reporting the findings of the fit test data as this indicated that the evaluators observed no problems in those areas.

Explained below are the fit test comparisons, comments and fitting issues with the prototype shirt and trouser garments manufactured using the mannequin's measurements and the size 10/34 upper and lower body dimensions size charts. Furthermore, the study tested garment fit on the subjects who represented the size variability within the lower-end to the higher-end of the established size 10/34 size range measurements.

5.5.2 Fit test evaluations for Subject 1

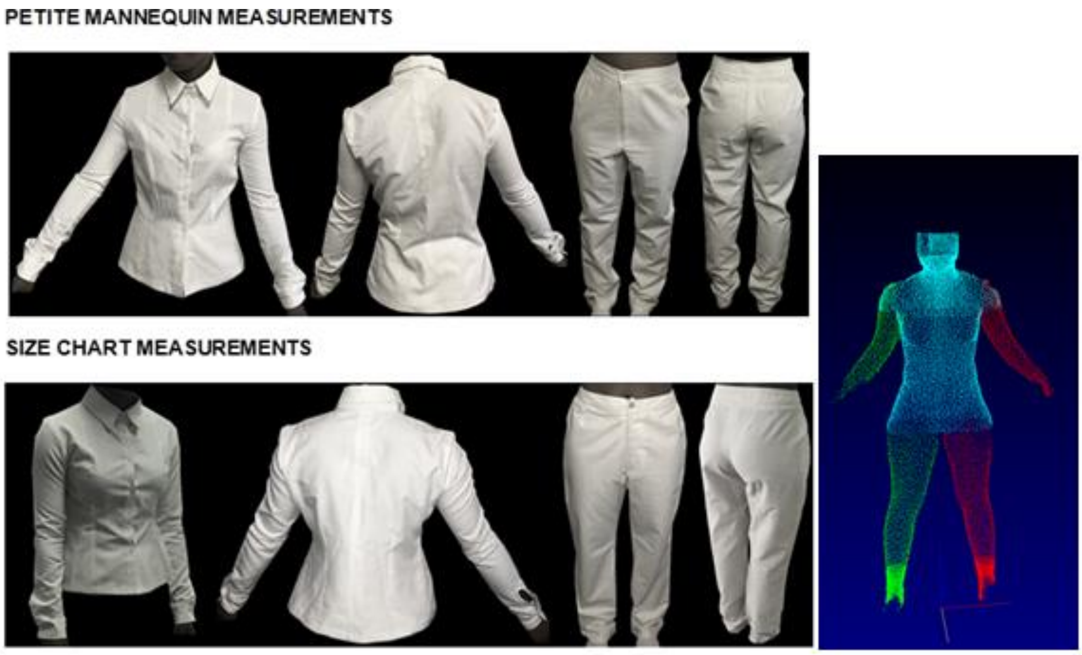


Figure 5.4: The prototype shirt and trouser garments fitted on subject 1 and the subject's 3D full body scan

5.5.2.1 Subject 1 mannequin size 10/34 shirt fit test evaluations

Evaluator 1 considered the shirt test to pull around the arm, causing gatherings in the back. Evaluator 1 further observed the back of the shoulder to rest loose on the subject's body with some bulking in the back of the shirt, the subject's neck to upper waist back length measurement was 7 cm shorter than the neck to upper waist back measurement of the mannequin (refer to appendix L1 for the upper body measurements); hence some bulking was observed on the shirt. The way the shirt draped in the front was considered to look good by evaluator 1, whilst evaluator 2 observed creases under the bust area. Although, the subject's under bust measurement was 1 cm smaller than the mannequin's under bust measurement, the subject's upper waist measurement was 6 cm smaller than the upper waist measurement of the mannequin. This produced an imbalance in the shirt's proportions against the subject's body proportions. The fit of the shirt could also be influenced by the subject's 155 cm height measurement, which was 5 cm shorter than the mannequin's height measurement (see the height measurements in Table 5.1). Evaluator 1 considered the darts at the front to be well placed.

The sleeve length was stated to be long by both evaluators, who perceived the sleeve to hang over the cuff; the mannequin’s sleeve length measurement was 6 cm longer than the subjects sleeve length measurement. Evaluator 1 further indicated that the fit of the sleeve on the bicep area was tight; the subject’s bicep measurement was observed to be 3 cm bigger than the mannequin’s bicep measurement, which was also 1 cm more than the size interval used to allocate the bicep measurement from one size to another.

The subject’s bicep measurement was further established to fit in the size 12/36 size chart size range (see Table 4.32). Evaluator 2 indicated that the fit of the wrist circumference was “*ok*”, because the subject’s wrist measurement was 1 cm smaller than the mannequin’s measurements and further stated that the problem was the length of the sleeve that was observed to be too long. The ease on the bust area was considered to offer a good fit, with buttons placed at the right height by evaluator 1; whilst evaluator 2 observed some folds on the side of the bust area. The subject’s bust measurement was 1 cm bigger than the mannequin’s bust measurement. Evaluator 2 further indicated that one of the buttons should be aligned with the bust area to permit a straight closure alignment that doesn’t pull. Furthermore, the hems and finishes of the evaluated shirt were considered to provide a neat fit by evaluator 1.

5.5.2.2 Subject 1 size chart size 10/34 shirt fit test evaluations

The shirt was considered to have a comfortable ease with a loose upper waist fit by evaluator 1, even though, the subject’s upper waist measurement was 7 cm smaller (refer to appendix L1 for the upper body measurements) than the size chart measurement. The measurement difference between the subject’s upper waist measurement and the mannequin’s upper waist measurement was 1 cm more than the size interval used to allocate the upper waist measurement from one size to another in the size chart developed for this study (see Table 4.32). As a result, the upper waist measurement inclined to the size 8/30 size range. The fit of the neckline collar of the shirt created using the size 10/34 size chart measurements was better than the fit of the neckline collar created using the mannequin’s measurements by evaluator 1, because the subject’s neck full measurement was the same as the neck full measurement from the size 10/34 size chart range. The armholes were slightly loose at the back of the shoulder area by evaluator 1.

The subject's armscye measurements were 3 cm smaller than the armscye measurement from the size 10/34 size chart range, which was observed to be 1 cm more than the size interval used to allocate the armscye measurements from one size to another in the size chart developed for this study. Accordingly, the measurement was below the size 10/34 size range (see Table 4.32). The sleeve length was considered to be a little long by evaluator 2, with a 3 cm measurement difference. Evaluator 2 further observed that the fit of the sleeve, at the bicep area to be much better than the fit of the sleeve on the shirt created using the mannequin's measurements and some slight wrinkles were evident, a 2 cm measurement difference was observed in the bicep area. The fit of the sleeve around the elbow was considered to be a little tight but further stated to produce a better fit by evaluator 1. The subject's elbow measurement was observed to be 1 cm bigger than the size chart's elbow measurement. A little gaping was observed at the bust area by both evaluators, irrespective of the subject's bust measurement being 1 cm smaller than the size chart bust measurement.

Evaluator 1 further stated that the shirt button may be positioned too low for the subject's bust dimensions. Evaluator 2 considered the shirt closure to have a neat finish. Furthermore, evaluator 1 indicated that there was enough ease for comfortability and movement. The darts were considered to look good by both evaluators.

5.5.2.3 Subject 1 mannequin size 10/34 trouser fit test evaluations

Evaluator 1 considered the trouser to have a pleat between the lower waist and hip area and further stated that the high hip area was bulging. Although the mannequin's lower waist measurement was the same as the subject's lower waist measurement, the high hip measurement was 2 cm bigger and the hip measurement was 3 cm smaller than the subject's measurements (refer to appendix L1 for the lower body measurements). Because the subject was 5 cm shorter than the mannequin (see Table 5.1), her upper waist to hip body proportions may influence how the trouser sits on the subject's body. The front crotch length was observed to be too long by the two evaluators; evaluator 1 further stated that the trouser was ill-fitting as the crotch hung too low for the model, the mannequin's crotch length back and crotch length front measurements were 3 cm longer than the subject's crotch length back and crotch length front measurements.

Therefore, the zip fly was considered to be too long by evaluator 2. The seat drape was indicated to offer an overall good fit by evaluator 1, although both evaluators stated that they observed creases in the trouser. The trousers inseam length measurement was observed to be too long (7 cm) for the subject by the two evaluators, which resulted in the trouser having creases from the thigh to the bottom of the trouser. Evaluator 1 further stated that the hems and finishes of the trouser were bulking at the ankle, due to the trouser length being too long. The darts were considered to be well positioned by both of the evaluators.

5.5.2.4 Subject 1 size chart size 10/34 trouser fit test evaluations

The compatibility and ease of movement in the trouser was considered by evaluator 1 to be better than in the trouser created using the mannequin's measurements, because most of the size chart girth measurements were observed to be bigger than the mannequin's measurements and were also observed to be more compatible to the subject's measurements (refer to appendix L1 for the lower body measurements). Evaluator 2 mentioned that she observed minor horizontal folds between waistline and hip area; this could be attributed to the subject's upper waist measurement that was 6cm smaller than her hip measurement which produced wrinkles between her upper waist and hip area. The subject's lower waist measurement was 4 cm below the size 10/34 lower waist measurement from the size chart; whereas the subject's hip measurement was 2 cm above the hip measurement established in the size 10/34 size chart measurements. Although, both evaluators considered the front crotch length to be long, evaluator 1 further indicated that the fit was better than the crotch length on the trouser created using the mannequin's measurements. The subject's crotch length back measurement was 2 cm smaller and crotch length front measurement was 1 cm shorter than the size chart measurements, as opposed to the mannequin's measurements that were both 3 cm longer. Both of the evaluators indicated that the length of the trouser was long; however, evaluator 1 further indicated that the length was better than the length observed in the trouser created using the mannequin's measurements and added that there were no creases visible in the trouser. The subject's inseam and outseam length measurements were observed to be more compatible with the inseam and outseam measurements established in the size 10/34 size chart, as opposed to the inseam and outseam measurements of the mannequin.

The overall fit of the trouser was considered by evaluator 1 to better than the fit observed in the trouser produced from the mannequin's measurements. Evaluator 2 further stated that the dart positioning was good.

Additionally, subject 1 mentioned that she was more comfortable in the shirt and trouser garments created using the size chart measurements as opposed to the shirt and trouser garments produced from the mannequin's measurements because, according to her the fit was better and not tight.

5.5.3 Fit test evaluations for Subject 2

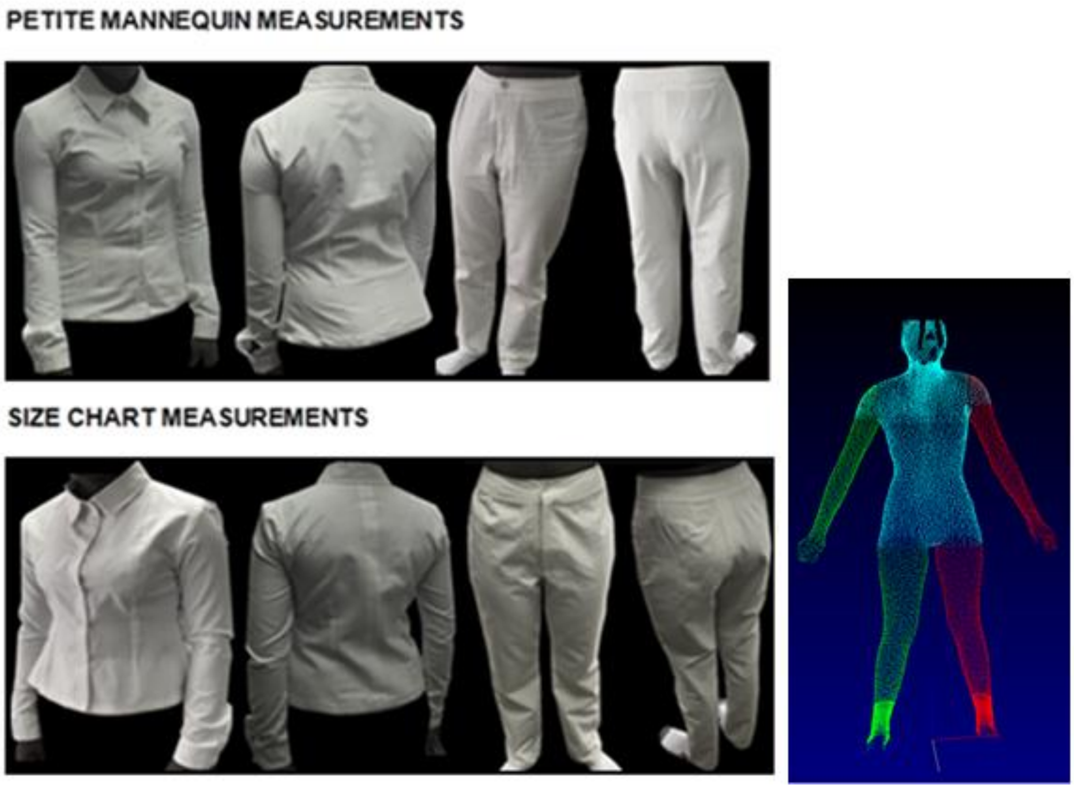


Figure 5.5: The prototype shirt and trouser garments fitted on subject 2 and the subject's 3D full body scan

5.5.3.1 Subject 2 mannequin size 10/34 shirt fit test evaluations

Compatibility and ease of movement in the shirt was considered by evaluator 1 to be restrictive and tight on the arms. Both evaluators considered the fit of the shirt to pull at the biceps and elbow and to be a little tight. The subject's bicep measurement was 3 cm bigger and the elbow measurement was 4 cm bigger than the mannequin's bicep and elbow measurements (refer to appendix L2 for the upper body measurements). The measurement differences were (1 cm for the bicep) and 2 cm (for the elbow) more than the size intervals used to allocate the bicep and elbow measurements from one size range to another in the size chart developed for this study. Accordingly, the measurements fell into the size 12/36 size range (see Table 4.32); hence movement was slightly restricted in the shirt. The back part of the shirt was regarded to have some gatherings and extra fabric in the middle by evaluator 2, the subject's neck to upper waist back length measurement was 5 cm shorter than the mannequin's neck to upper waist back measurement. The sleeve lengths were regarded to be too long by both evaluators. The mannequin's sleeve length measurement was 5 cm longer than the subject's sleeve length measurement. Additionally, the quality of fit in the darts was indicated by evaluator 2 to be good.

5.5.3.2 Subject 2 size chart size 10/34 shirt fit test evaluations

Evaluator 1 indicated that the subject's one shoulder was higher than the other; the evaluator further suggested that this was common from results of carrying bags on one side of the shoulder. Folds at the upper arm were observed by evaluator 2, who further stated that the subject had sloping shoulders; as a result, some pulling was observed towards the shoulder at the back of the shirt. Evaluator 1 indicated that the overall fit of the shirt was better than the fit of the shirt created using the mannequin's measurements. Most of the subject's measurements, such as the bust, upper waist, chest, underbust, neck full, armscye, neck to upper waist back, neck to upper waist front and the sleeve length (refer to appendix L2 for the upper body measurements) were more compatible to the size 10/34 size chart measurements, when compared to the mannequin measurements. Evaluator 1 further indicated that there was enough ease in the shirt, permitting comfortability and movement. The darts were considered to be well position, presenting a good quality of fit by evaluator 2.

5.5.3.3 Subject 2 mannequin size 10/34 trouser fit test evaluations

Compatibility and ease in the trouser was considered to be good by evaluator 1. Most of the subject's measurements, except for the lower waist, hip, top thigh and outseam measurements were more compatible to the measurements of the mannequin (refer to appendix L2 for the lower body measurements). The two evaluators regarded the fit of the crotch length to be slightly long and in contrast, to fit well on the subject's body. The subject's crotch length back and front measurements were observed to be more compatible to the mannequin's crotch length back and front measurements than the size chart measurements. Evaluator 1 considered the length of the trouser to be long; evaluator 2 further indicated regardless the trouser length, the quality of the trousers fit was good. The subject's height measurement of 159 cm was sufficient enough to accommodate the trousers measurements because the mannequin was only 1 cm longer than the subject's height measurement (see Table 5.1). The subject's body silhouette was further observed to be similar to that of the mannequin's silhouette (see the subject's 3D full body scan in Figure 5.5).

5.5.3.4 Subject 2 size chart size 10/34 trouser: fit test evaluations

Compatibility and ease of movement in the trouser was considered to be good by evaluator 2, who further indicated that the way the trouser rested on the subject's body was "*not bad*", even though minor vertical folds were observed at the back of the trouser. Evaluator 1 stated that the fit of the crotch length was good. The subjects' crotch length back and front measurements (refer to appendix L2 for the lower body measurements) were within the size 10/34 size range, being consistent with the size intervals (see Table 4.33). Both evaluators indicated that the trouser length fitted well; evaluator 1 further added that the trouser length would fit well if the subject wore shoes. The length of the size 10/34 size chart measurement was 1 cm longer than the subject's length measurement; therefore, the fit was not affected. Evaluator 2 specified that the fit of the darts at the front of the trouser were bulging, and considered the quality of fit to be moderate. This may be influenced by the subject's lower body proportions, the subject's lower waist measurement was 9 cm bigger, the high hip 4 cm bigger and the hip measurement was 1 cm bigger than the size 10/34 size chart measurements.

The measurement differences were irregular, as a result, some pulling, and gathers were observed at the front of the trouser.

Additionally, subject 2 indicated that the shirt created from the mannequin measurements was tight and that she preferred the trouser produced from the size chart measurements because the fit was better, and the length was not too long.

5.5.4 Fit test evaluations for Subject 3

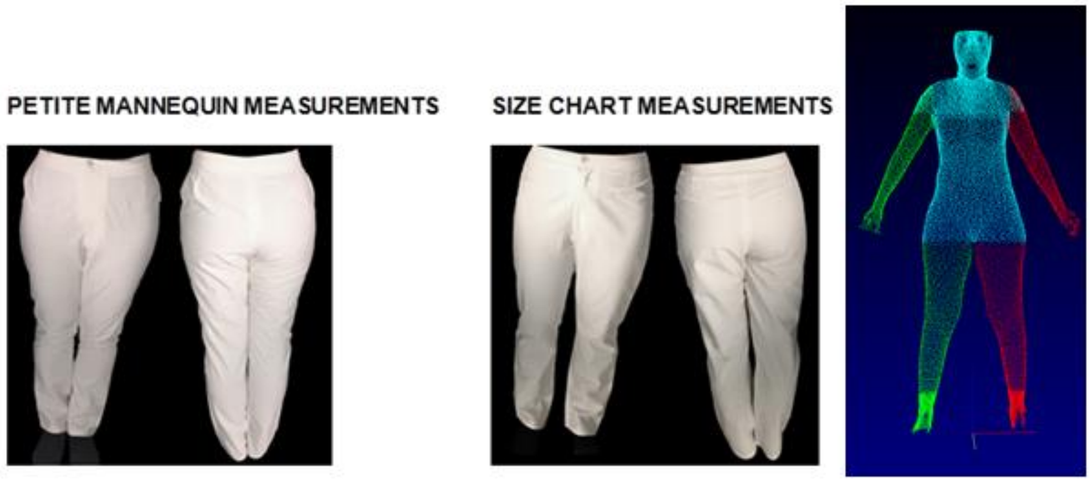


Figure 5.6: The prototype shirt and trouser garments fitted on subject 3 and the subject's 3D full body scan.

5.5.4.1 Subject 3 mannequin size 10/34 shirt fit test evaluations

The shirt created from the mannequin's measurements did not fit subject 3, therefore the shirt could not be evaluated. Evaluator 1 indicated that the shirt could not fit because the sleeves were too tight; whilst evaluator 2 considered the shirt to be too narrow for the subject to put her arms in the shirt. The subject's bicep measurement was 8 cm bigger and elbow measurement was 6 cm bigger than the mannequin's bicep and elbow measurements (refer to appendix L3 for the upper body measurements). The subject's bicep and elbow measurements were also observed to be compatible to the bigger size ranges in the size chart (see Table 4.32); as a result, the fit of the whole shirt was constrained on the subject's body.

5.5.4.2 Subject 3 size chart size 10/34 shirt fit test evaluations

The shirt created from the size chart measurements did not fit subject 3, therefore, the shirt could not be evaluated. Evaluator 1 considered the shirt to be too tight and evaluator 2 observed that the subject had bigger biceps and could not put her arms in the shirt; therefore, it constrained the whole shirt to fit the subject's body. The subject's bicep measurement was 35 cm (refer to appendix L3 for the upper body measurements).
The measurements difference between the subject's bicep measurement and the size chart measurement was 7 cm more than the size interval used to allocate the bicep measurement from one size range to another in the size chart developed for this study (see Table 4.32). Accordingly, the subject's bicep measurement fell into the size 18/42 size range which was too big to fit into a size 10/34 size range.

5.5.4.3 Subject 3 mannequin size 10/34 trouser fit test evaluations

Evaluator 1 considered the high hip area to have minor fabric excess, whereas evaluator 2 observed small bulging caused by the little extra fabric between the waistline and hip areas. The subject's high hip measurement was observed to be 3 cm below the mannequin's high hip measurement (refer to appendix L3 for the lower body measurements). Although, the lower waist and hip measurements were within the size 10/34 size range, the high hip measurement was observed to be below the size 10/34 size range established in the size chart developed for this study (see Table 4.33). Evaluator 1 further stated that the fit of the trouser looked good, but more ease was required. The subject's hip, top thigh, mid-thigh, crotch length back and the crotch length front measurements were observed (refer to Appendix L3 for lower body measurements) to be bigger than the mannequin's measurements; while the lower waist measurement was 2 cm smaller. Evaluator 1 considered the overall fit of the trouser to be a little comfortable. However, comfortability and movement were considered restrained by evaluator 2, who further indicated that there was some pulling at the calves. The subject's calf measurement was 36 cm; the measurement difference was 2 cm more than the size interval used to allocate the calf measurements from one size range to another in the size chart developed for this study.

The subject's calf measurement was further observed to fall into the size 12/36 size range (see Table 4.33). Additionally, evaluator 2 stated that the darts on the trouser had a moderate fit.

5.5.4.4 Subject 3 size chart size 10/34 trouser fit test evaluations

The compatibility and ease of the evaluated trouser was considered to look good and having minor creases by evaluator 1. The trouser was regarded to fit at the hip area well by evaluator 1, who further stated that the fit was much better than the fit of the trouser created using the mannequin's hip measurement. The hip, top thigh, mid-thigh and high hip measurements were observed to be more compatible to the size 10/34 size chart measurements. The lower waist measurement was 2 cm bigger, while the outseam measurement was similar to the size 10/34 size range outseam measurement (refer to appendix L3 for the lower body measurements). Hence, the outseam length was considered by both evaluators to fit better than the fit observed in the trouser manufactured using the mannequin's measurements. Evaluator 2 further stated that the length of the trouser became shorter when the subject was sitting, but the overall fit of the trouser was considered to be comfortable in sitting and movement. Evaluator 1 regarded the fit of the trouser on the front thigh area to be good and further stated that she observed minor fold lines at the knee area. However, evaluator 2 indicated a slightly tight fit in the thigh area. The subject's top thigh measurement was 3 cm bigger and the knee measurement was 1 cm bigger than the top thigh and mid-thigh measurements established in the size 10/34 size chart. Additionally, the subject's top thigh measurement was observed to be in the size 12/36 size range (see Table 4.33), indicating that the subject's top thigh measurement was bigger than what the size chart predicted.

Furthermore, subject 3 stated that the fit on both analysed shirt and trouser garments were *"ok"* but the fit that she preferred was the fit produced by the shirt and trouser garments created from the size chart measurements.

5.5.5 Fit test evaluations for Subject 4

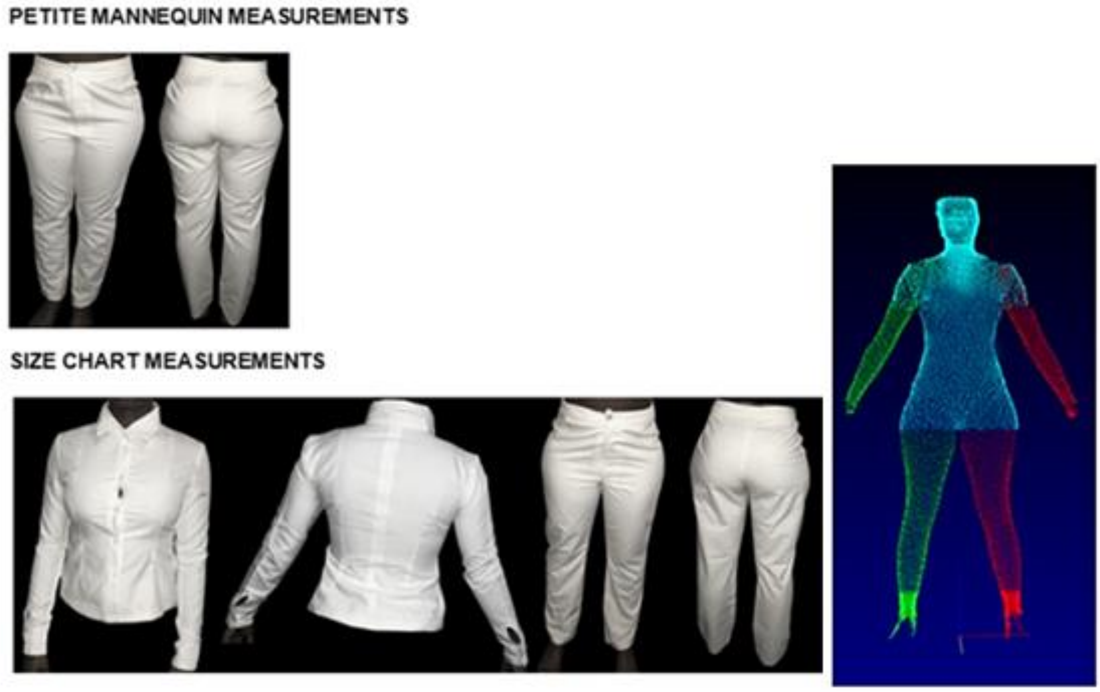


Figure 5.7: The prototype shirt and trouser garments fitted on subject 4 and the subject's 3D full body scan.

5.5.5.1 Subject 4 mannequin size 10/34 shirt fit test evaluations

The shirt created from the mannequin's measurements did not fit subject 4, therefore the shirt could not be evaluated. Evaluator 2 considered the shirt to be so small that it constrained the fitting on the subject's body. The subject's bust measurement (refer to appendix L4 for the upper body measurements) was 92 cm, making the subject to be at the higher end of the size 10/34 size range in the size chart (see Table 4.32) and was 6 cm bigger than the mannequin's bust measurement. The subject's size 10/34 size chart bicep measurement was 4 cm bigger than the mannequin's bicep measurement.

5.5.5.2 Subject 4 size chart size 10/34 shirt fit test evaluations

The ease for the bust was indicated by evaluator 1 to make the shirt too close-fitting to the body to accommodate the subject's bust measurement. The subject's bust measurement (refer to appendix L4 for the upper body measurements) was 4cm bigger than the established 3D full body scanned size 10/34 bust measurement established in the size chart, but was within the size 10/34 size range. Evaluator 2 observed some gaping in the bust area and further stated that this may be because the placement of the button was not aligned with the subject's bust height. The two evaluators considered the shirt closure to be close-fitting and evaluator 2 further suggested that more ease was required in the bust area. Evaluator 2 indicated that the armholes were slightly pulling at the back of the shirt because the sleeve was tight around the bicep area. Evaluator 1 further stated that the sleeves at the biceps area was tight and had visible wrinkles in the sleeve area. The subject's bicep measurement was observed to be 3 cm above the size10/34 size chart measurement and fell into the size 12/36 in the size chart developed for this study (see Table 4.32). The subject's elbow measurement was similar to the size 10/34 elbow measurement. For that reason, the elbow measurement provided enough ease for the subject to be able to fit into the shirt. However, the fit of the shirt around the bicep area was too tight; hence the wrinkles were produced on the shirt. Both evaluators observed the sleeve length to fit well. The subject's sleeve length measurement was 1 cm above the size10/34 size chart sleeve measurement. Evaluator 1 considered the shirt's comfortability and movement to be good, while evaluator 2 indicated that the overall shirt fit looked tight on the subject's body. The darts were stated by evaluator 2 to produce a good quality of fit.

5.5.5.3 Subject 4 mannequin size 10/34 trouser fit test evaluations

Compatibility and ease in the trouser was considered to be gathering a little at the high hip and a few wrinkles were observed at the crotch area by evaluator 1. The subject's lower waist measurement was 2 cm bigger, the high hip measurement was 4 cm bigger and the hip measurement was 5 cm bigger than the mannequin's measurements (refer to appendix L4 for the lower body measurements). The subject was observed to have a protruding stomach which may influence the fit of the trouser on the subject's body. The fit of the trouser at the hip area was regarded to be pulling and a little tight by evaluator 1. The subject's hip measurement was 100 cm, making the subject to be at the higher end of the size 10/34 size range that was established in the size chart developed for this study (see Table 4.33) and was 5 cm bigger than the mannequin's hip measurement. As observed in Appendix L4 (for the lower body dimensions). The subject's inseam length measurement was similar to the mannequin's inseam measurement, while the outseam measurement was 2 cm below the mannequin's outseam measurement. Nonetheless, evaluator 1 indicated that the length of the trouser was "*just right*". Comfortability and movement in the trouser was considered to be slightly tight at the buttocks area. Evaluator 2 indicated that the trouser became uncomfortable when the subject was sitting down. The subject's lower waist, hip, top thigh, mid-thigh, crotch length back and the crotch length front measurements were bigger than the respective measurements for the mannequin. Furthermore, the dart positioning was regarded to be good by evaluator 2.

5.5.5.4 Subject 4 size chart size 10/34 trouser fit test evaluations

Compatibility and ease in the trouser was considered to create some pulling at the front high hip area by evaluator 1. Evaluator 2 observed horizontal folds between the front waistline and hip area. The subject's lower waist measurement was 6 cm bigger, the high hip measurement was 6 cm bigger and her hip measurement was 4 cm bigger than the measurements established in the size 10/34 size chart measurements (refer to appendix L4 for the lower body measurements). Nonetheless, the subject's measurements were within the higher-end of the size 10/34 size range.

There were some differences observed in the subject's upper waist to hip ratios when evaluated against the size 10/34 size chart lower body measurement proportions, hence, the wrinkles and some pulling occurred in the area. The subject also had a protruding stomach which may have influenced the fit of the trouser on her body. Evaluator 1 further indicated that the fit of the trouser offered a better fit than the fit at the hip area than in the trouser manufactured using the mannequin's measurements. This was because the trouser was not as tight as the trouser manufactured using the mannequin's measurements. Evaluator 1 considered the fit of the ankles, inseam and outseam length, hems and finishes, the length of the trouser, the comfortability and movement of the trouser to be better than that of the trouser produced from the mannequin's measurements. The positioning of the darts on the trouser was regarded to be correct by evaluator 2.

Subject 4 indicated that she preferred the fit of the trouser created using the size chart measurements and that the shirt was a little too close-fitting on her body.

5.5.6 Fit test evaluations for Subject 5

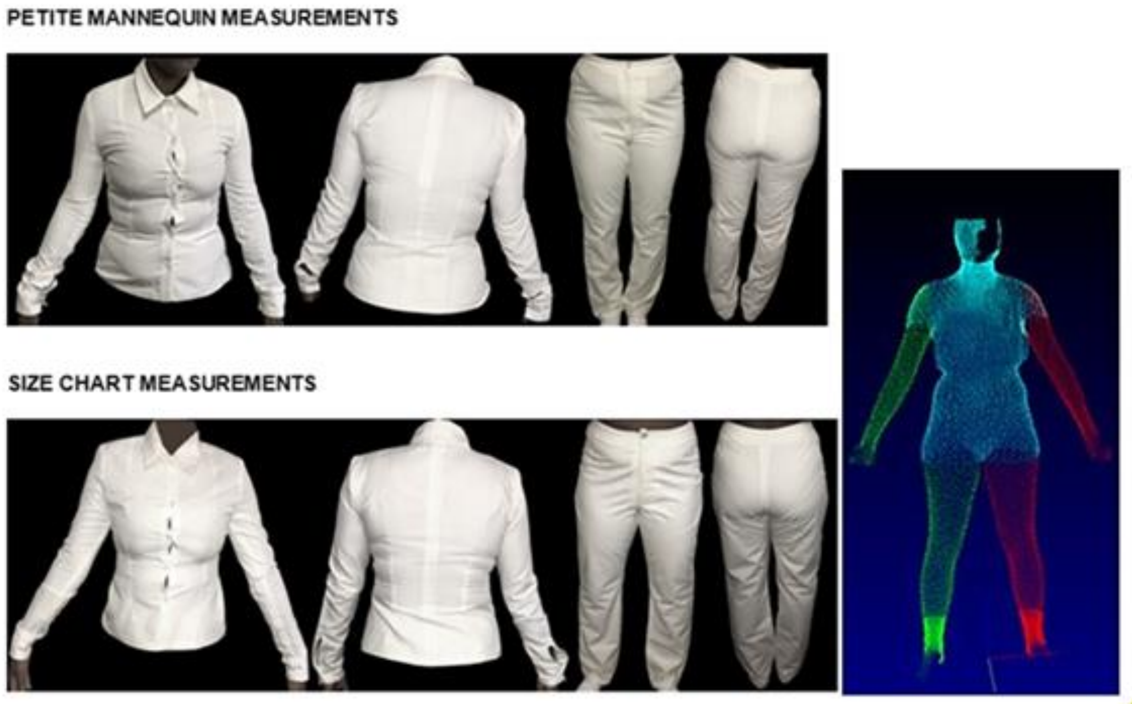


Figure 5.8: The prototype shirt and trouser garments fitted on subject 5 and the subject's 3D full body scan.

5.5.6.1 Subject 5 mannequin size 10/34 shirt fit test evaluations

Compatibility and ease in the shirt was considered by the two evaluators to make for a very tight fit around the subject's body. The subject's bust measurement (refer to appendix L5 for the upper body measurements) was 92 cm. The mannequin's bust measurement was 6 cm less than the subject's bust measurement. Additionally, the subject's upper waist measurement was 7 cm bigger than the mannequin's measurement and was observed to be in the size 12/36 size chart size range; while the lower waist measurement was 87 cm, at the higher end of the size 10/34 size range that was established in the size chart (see Table 4.32). The two evaluators stated that the bust and upper waist areas were very close-fitting, heavily stretching and gaping; as a result, the closure was too tight. Evaluator 2 further added that the shirt closure was not aligned because of the observed tight fit in the shirt. The collar was stated to be slightly loose by evaluator 1; the subject's full neck measurement was 2 cm below the mannequin's full neck measurement. The fit of the armhole was considered to be tight fitting by the two evaluators because the subject's armscye measurement was 4 cm above the mannequin's armscye measurement. Both evaluators regarded the sleeves to fit tightly on the subject's body at the biceps and elbows. The mannequin's bicep measurement was 3 cm less than the subject's bicep measurement and the mannequin's elbow measurement was 5 cm less.

The difference in the measurements was more than the established size interval measurements used in the size chart (see Table 4.32) to establish the bicep and elbow size ranges from one size to another. As a result, the bicep and elbow measurements were observed to fall into the size 12/36 size range; hence movement was restricted at the arms. The shirt's sleeve length was observed to fit too long on the subject's body; the subject's sleeve length measurement was 6 cm shorter than the mannequin's sleeve length measurement. Evaluator 1 regarded the hems and finishes to be of good quality. Evaluator 2 observed the darts to be well positioned, offering a moderate quality of fit.

5.5.6.2 Subject 5 size chart size 10/34 shirt fit test evaluations

Evaluator 1 considered the compatibility and ease in the shirt to be a little tight, it was further stated that the fit was better than the fit of the shirt produced from the mannequin's measurements. The bust, upper waist, chest, underbust, bicep, elbow, neck to upper waist front, sleeve length and wrist measurements were more compatible to the size 10/34 size chart measurements than the measurements established for the mannequin (refer to appendix L5 for the upper body measurements). The back of the shirt was regarded to fit "*just right*" by evaluator 1; whilst evaluator 2 stated that the shirt was tight and there were horizontal pleats at the upper waist and lower back part of the shirt. The subject's neck to upper waist back measurement was 3 cm longer than the size 10/34 size chart neck to upper waist back measurement and her upper waist measurement was 6 cm bigger than the size 10/34 size chart measurement. It was observed that the measurements fell into the starting point of the size 12/36 size chart size range (see Table 4.32 for measurements); hence the observed tight fit in the shirt. The sleeve length was regarded to be slightly long by evaluator 2, who observed a better fit in the size 10/34 size chart shirt than the fit observed in the shirt created using the size 10/34 size chart measurement. A 3 cm difference was observed when comparing the subject's and the size 10/34 size chart sleeve length measurements. Evaluator 1 stated that the bust fit was too close-fitting; evaluator 2 further regarded the fit at the bust and upper waist area to be tight and gaping. The subject's bust measurement was at the higher end of the size 10/34 size range and 4 cm bigger than the size 10/34 size chart bust measurement. The subject's upper waist measurement was 6 cm bigger than the size 10/34 size chart measurement, which was further observed to be in the size 12/36 size range. Therefore, evaluator 1 suggested more ease should be added at the bust and upper waist area. Both evaluators thought the shirt closure was too tight. Evaluator 2 further stated that due to the tightness of the fit, the closure alignment was not straight. Additionally, evaluator 2 indicated that regardless the tight fit of the shirt, the subject was able to move in the shirt, indicating that comfortability and movement in the shirt was better than in the observed shirt created from the mannequin's measurements. Evaluator 2 also considered the darts to fit good and that is was well positioned.

5.5.6.3 Subject 5 mannequin size 10/34 trouser fit test evaluations

Evaluator 1 considered the compatibility and ease of the trouser to fit too tight on the subject's body. Evaluator 2 observed fold lines at the front of the trouser. The fit at the lower waist area was indicated by evaluator 2 to be a little tight, the subject's upper waist measurement was 7 cm bigger than the mannequin's measurement (refer to appendix L5 for the lower body measurements) and was observed to be in the size 12/36 size chart size range (see Table 4.33); her lower waist measurement was 2 cm bigger than the mannequin's measurement. For that reason, the fit was observed to be tight. Evaluator 1 considered the fit of the trouser to be good at the hip area and evaluator 2 indicated that the fit was body-hugging. As shown in Figure 5.8, the subject has a protruding stomach, which may influence the quality of the trousers fit on the subject's body. Evaluator 2 further stated that comfortability and movement in the trouser was not satisfactory around the tummy, lower waist and hip area. Both evaluators stated that the trouser was too long for the subject. The subject's inseam measurement was 1 cm shorter and her outseam measurement was 4 cm shorter than the mannequin's outseam and inseam measurements. Evaluator 2 further indicated that the darts were good and well positioned.

5.5.6.4 Subject 5 size chart size 10/34 trouser fit test evaluations

Evaluator 1 stated that there was a tight fit and few fold lines in the upper abdomen area of the trouser, evaluator 2 indicated that there was slight pulling between the lower waist and hip area, which caused minor horizontal wrinkles. As shown in Figure 5.8, the subject has a protruding stomach, as a result, comfortability and movement in the trouser was restricted between the lower waist and high hip area. Although the subject's hip measurement corresponded to a size 10/34, her lower waist measurements was 6 cm bigger than the size 10/34 size chart lower waist measurement (refer to appendix L5 for the lower body measurements). The subject's lower waist measurement was observed to be at the higher end of the size 10/34 size range (see Table 4.33). The two evaluators considered the ease added for the closure of the trouser to be tight because of the subject's lower waist measurements. Evaluator 1 indicated that the fit of the trouser was good at the front and back leg area. The subject's top thigh, mid-thigh and calf measurements were observed in Appendix L5 (see lower body measurements) to be more compatible with the top thigh, mid-thigh and calf measurements from the size 10/34 size chart measurements. Evaluator 1 indicated that the inseam, outseam length, the hemlines and finishes were straight. Although, the subject's inseam measurement was 8 cm longer, her outseam measurement was 2 cm shorter than the size 10/34 size chart measurements, which influenced how the trouser length fitted the subject. The length of the trouser was observed to be slightly long for the subject by evaluator 2, who further added that the trouser length would fit well if the subject was wearing high heeled shoes.
Both evaluators further indicated that the overall fit of the trouser was better than the fit observed in the trouser created using the mannequin's measurements. Evaluator 2 added that the dart was well positioned, and the fit was good.

Furthermore, subject 5 did not elaborate on her preference in the evaluated shirt and trouser garments except that the shirt and trouser garments fitted well; subject 5 further stated that both of the assessed shirt closures were tight at the bust and upper waist area.

5.5.7 Fit test evaluations for Subject 6

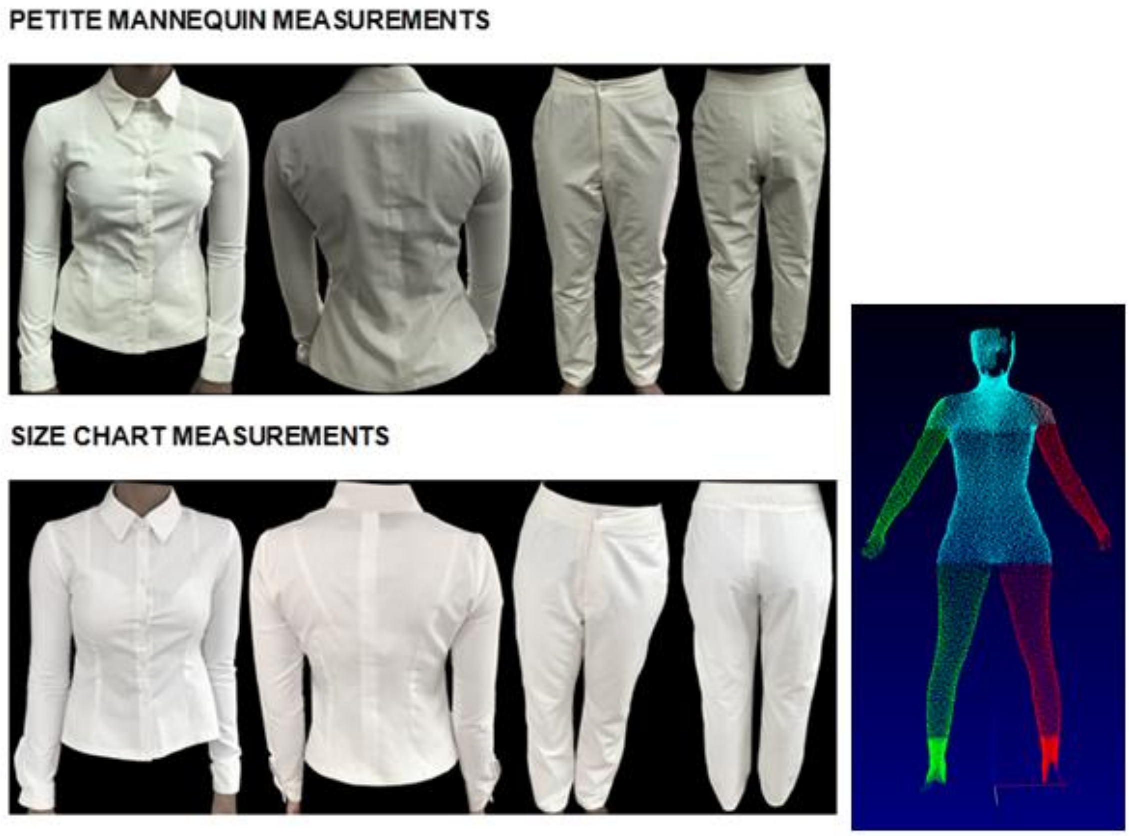


Figure 5.9: The prototype shirt and trouser garments fitted on subject 6 and the subject's 3D full body scan.

5.5.7.1 Subject 6 mannequin size 10/34 shirt fit test evaluations

Evaluator 1 stated that the bust was fitting well but was slightly pulling. The subject's bust measurement was 4 cm bigger than the mannequin's measurement (refer to appendix L6 for the upper body measurements). Evaluator 1 further indicated that the closure alignment was observed to not be straight because of the pull produced in the bust area. Evaluator 2 stated that the subject's bust was upright and a little big to accommodate the fit of the shirt, making the closure close-fitting to the subject's body.

Evaluator 2 noticed that comfortability and movement in the shirt was constrained by the subject's arms and considered the rest of the shirt to have a moderate quality of fit. The subject's bicep measurement was observed to be 4 cm bigger, and her elbow measurement was 6 cm bigger than the mannequin's bicep and elbow measurements.

Both the bicep and elbow measurements were observed to be in the size 14/38 size chart size range in the size chart developed for this study (see Table 4.32). The subject's armscye measurement was 2 cm bigger than the mannequin's armscye measurement; hence, evaluator 1 regarded the shirt to be constricted over the subject's arms. Evaluator 2 regarded the fit of the shirt at the back to have diagonal folds; the mannequin's neck to upper waist back length measurement was 4 cm longer than the subject's neck to upper waist back measurement, making the subject's back length proportions shorter. Both evaluators considered the armhole tight and small. The armscye measurement was observed to be 2 cm smaller than the size chart measurement in Appendix L6 (see upper body measurements). Both evaluators deemed the sleeve length too long. The length of the subject's sleeve measurement was 4 cm shorter than the mannequin's sleeve length measurement. Evaluator 2 stated that the subject could sit with little comfort when wearing the assessed shirt. Evaluator 2 further added that the positioning and alignment of the darts on the shirt was good.

5.5.7.2 Subject 6 size chart size 10/34 shirt fit test evaluations

Both evaluators stated that the compatibility and ease in the shirt was good. Most of the subject's measurements, such as the bust, upper waist, underbust, lower waist, bicep, elbow, armscye, neck to upper waist back, neck to upper waist front and sleeve length were more compatible to the size 10/34 size chart measurements than the measurements established for the mannequin (refer to appendix L6 for the upper body measurements). Evaluator 2 considered the overall shirt fit at the front and back of the shirt to be "*very good*". Evaluator 1 specified that the sleeve length fitted well on the subject and the biceps were indicated to fit better than the fit observed in the shirt created using the mannequin's measurements. The subject's sleeve length measurement was 1 cm shorter and her bicep measurement was 2 cm bigger than the size 10/34 sleeve length and bicep in the size 10/34 size chart measurements. Although the bicep and elbow measurements were observed to fit in the size 14/38 size chart size range in the size chart developed for this study (see Table 4.32), the subject was still able to fit into the shirt. Both evaluators indicated that the sleeve fit at the bicep was tighter on the right side of the subject's arm, showing that the subject might not have similar arm girth measurements. Comfortability, movement, and the darts on the shirt were considered to offer a good quality of fit by evaluator 2.

5.5.7.3 Subject 6 mannequin size 10/34 trouser fit test evaluations

The two evaluators considered the assessed trouser to be a little loose and bulging around the hip area. Evaluator 2 observed a few diagonal pleats on sides between the lower waist and hip. The fit of the trouser could be influenced by the subject's lower body proportions, the subject's lower waist measurement was 5 cm smaller, high hip was 3 cm smaller and hip was 2 cm bigger than the mannequin's measurements (refer to appendix L6 for the lower body measurements). The trousers ease of closure was considered to be pulling and not well aligned by evaluator 2, who further added that the darts offered a good quality of fit. Major disagreements were evident when evaluating the fit of the trouser on the subject's thigh area and whether the subject was able to sit when wearing the trouser created using the mannequin measurements (see Table 5.5). Evaluator 1 rated the quality of fit on both evaluated standards to be good, whilst evaluator 2 considered the fit of both evaluated standards to be of poor quality. The subject's top thigh measurement was similar to that of the mannequin and her mid-thigh measurement was 3 cm bigger, making the trouser to be tight at the mid-thigh area when the subject was sitting, hence the disagreement that occurred between the evaluators. Evaluator 1 further stated that the trouser length, hemlines and finishes were "just right". The subject's inseam length measurement was 2 cm shorter and the outseam measurement was 1 cm below the mannequin's outseam measurement.

5.5.7.4 Subject 6 size chart size 10/34 trouser fit test evaluations

Compatibility and ease in the trouser was considered to be good by evaluator 1, evaluator 2 observed minor folds between the lower waist and hip area at the front of the trouser. The subject's lower waist measurement was 1 cm smaller, high hip was 1 cm smaller and hip was 1 cm bigger than the size 10/34 size chart measurements (refer to appendix L6 for the lower body measurements). This shows that the subject's above-mentioned measurements, along with the mid-thigh and ankle measurements were more compatible with the size 10/34 size chart measurements when compared to the measurements established for the mannequin. Evaluator 1 observed a "very neat" fit in the seat drape of the trouser. Evaluator 1 further stated that the trouser had a good length, but the length might become shorter when the subject is sitting. Irrespective of the subject's inseam length measurement being 9 cm shorter, and the outseam measurement which was 1 cm longer than the size chart outseam measurement it provided sufficient measurements to produce a good trouser fit. The quality of the fit of the darts was evaluated as good by evaluator 2.

Furthermore, subject 6 mentioned that she preferred the fit of the shirt created from the size chart measurements and further stated that improvements could be made to the crotch of the trouser to provide a better fitting trouser garment.

5.5.8 Fit test evaluations for Subject 7

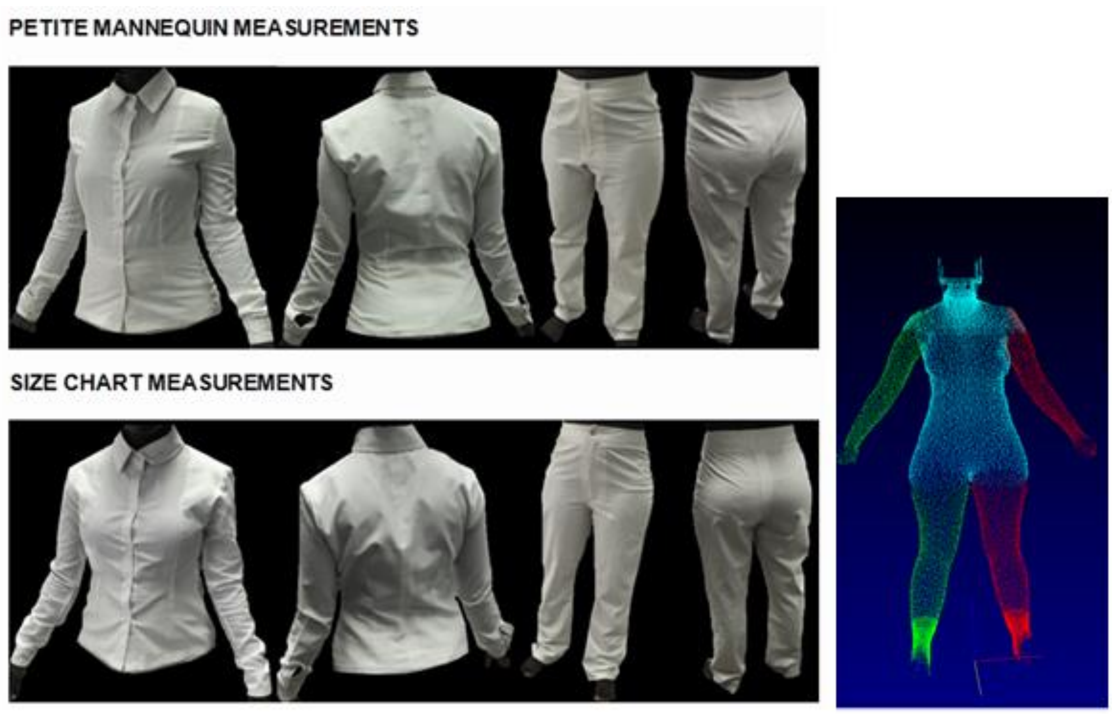


Figure 5.10: The prototype shirt and trouser garments fitted on subject 7 and the subject's 3D full body scan.

5.5.8.1 Subject 7 mannequin size 10/34 shirt fit test evaluations

The evaluators stated that the shirt was mainly restricted in the upper waist, bicep and elbow areas. The subject's upper waist measurement was 6 cm bigger than the mannequin's measurements (refer to appendix L7 for the upper body measurements). The upper waist measurement was at the higher end of the size 10/34 size range established in the size chart (see Table 4.32). Additionally, minor pulling was observed by evaluator 2 at the shirt closure between the underbust and upper waist. The subject's bicep measurement was 3 cm bigger and her elbow measurement was 5 cm bigger than the mannequin's bicep and elbow measurements. The size interval differences between the subject's bicep and elbow measurements, and the mannequin's bicep and elbow measurements were more than the 1 cm size interval used to allocate the bicep and elbow measurements from one size to the next in the size chart developed for this study. Both, the bicep and elbow measurements were established to be in the size 12/36 size chart size range (see Table 4.32), hence the shirt sleeve fit was tight in the above-mentioned body dimensions. The evaluators indicated that the drape at the back of the shirt was considered to have a big width and was bulging at the subject's back body area; evaluator 2 observed folds at the upper waist area.

The subject's neck to upper waist back length measurement was 7 cm shorter than the neck to upper waist back measurements of the mannequin, whilst the upper waist was tight. This indicates that the differences between the subject's neck to upper waist back and upper waist body proportion measurement and the mannequin's neck to upper waist back and upper waist measurement ratios have an influence on how the shirt fitted on the subject's body. The subject's height measurement was 3 cm shorter than the mannequin's 160 cm height measurement (Table 5.1). The evaluators regarded the length of the sleeves to be too long. The mannequin's sleeve length measurement was 5 cm longer than the subjects sleeve length measurement. Evaluator 2 further indicated that the darts on the observed shirt offered a moderate quality of fit.

5.5.8.2 Subject 7 size chart size 10/34 shirt fit test evaluations

The compatibility and ease in the shirt was considered to be enough and produced a better fit than the fit of the shirt created using the mannequin's measurements. The subject's bust measurement was 1 cm bigger, and her upper waist measurement was 5 cm bigger than the size 10/34 size chart measurements (refer to appendix L7 for the upper body measurements). Although the subject's upper waist measurement was at the higher end of the size 10/34 size range established in the size chart (see Table 4.32), most of the subject's girth measurement such as the bust, upper waist, underbust, lower waist, bicep, elbow, neck to upper waist back, and sleeve length were more compatible to the size 10/34 size chart measurements than the measurements established for the mannequin. Both evaluators considered the button closure not to be correctly aligned with the bust area; as a result, the positioning of the button was too low. However, evaluator 1 further stated that the shirt closure positioning was better than that of the closure observed in the shirt created using the mannequin's measurements. The armholes were considered to have extra fabric by the two evaluators. The subject's armscye measurement was 6 cm smaller than the size 10/34 armscye size chart measurement. Evaluator 2 stated that the sleeve length was slightly long and the fit on the right bicep was slightly tight. The size 10/34 size chart sleeve length measurement was 2 cm longer than the subjects sleeve length measurement and her bicep measurement was observed to be 2 cm bigger than the size 10/34 size chart bicep measurement. Furthermore, the subject's bicep and elbow measurements fitted in the size 12/36 size chart size range in the size chart developed for this study (see Table 4.32).

Additionally, both evaluators indicated that the comfortability and movement in the shirt was good, but was restricted at the arms. The darts positioning in the shirt were considered to afford a good fit by evaluator 2.

5.5.8.3 Subject 7 mannequin size 10/34 trouser fit test evaluations

The assessed trouser was considered to pull at the high hip area by evaluator 1; whilst evaluator 2 observed horizontal folds between the lower waist and the hip at the front and back of the trouser. The subject's lower waist measurement was 4 cm smaller, her high hip was 4 cm bigger and hip was 3 cm bigger than the mannequin's lower waist, high hip and hip measurements (refer to appendix L7 for the lower body measurements). Evaluator 1 observed a few creases at the side of the seat drape. The subject's upper waist to hip body proportion measurements, when compared to the mannequin's upper waist to hip measurement ratios, may influence how the trouser sits on the subject's body. Both evaluators stated that the thigh, knee and ankle areas fitted well on the subject's body. The subject's top thigh and mid-thigh measurements were both 1cm smaller than the mannequin's top thigh and mid-thigh measurements; whereas the subject's ankle and knee measurements were 1 cm bigger than the ankle and knee measurements of the mannequin. Although, the subject's knee measurement was observed to be in the size 8/30 size range in the size chart developed for this study (see

Table 4.33), the rest of the subject's lower body girth measurements permitted a good fit in the trouser. Furthermore, the two evaluators indicated that the trouser length was too long; evaluator 1 further stated that, because the trouser length was too long, some wrinkles were observed from the knee area. The subject's inseam measurement was 6 cm shorter and her outseam measurement was 4 cm shorter than the mannequin's inseam and outseam measurements. Evaluator 2 further added that the darts offered a good quality of fit.

5.5.8.4 Subject 7 size chart size 10/34 trouser fit test evaluations

The subject's lower waist measurement was the same, her high hip was 6 cm bigger and hip was 2 cm bigger than the size 10/34 size chart measurements (refer to appendix L7 for the lower body measurements). It is evident that the fit of the trouser on the subject's body could be affected by her upper waist to hip body proportion measurements when compared to the size 10/34 size chart upper waist to hip measurement ratios. Evaluator 1 indicated that the fit of the trouser at the back buttocks area had minor pulling on the side and evaluator 2 considered the fit to be good, except for a few visible folds on the side of the trouser. The fit of the trouser at the thighs, knees and ankles was indicated by both evaluators to be good. The subject's top thigh measurement was 2 cm smaller and her mid-thigh measurement was 5 cm smaller than the size 10/34 size chart top thigh, mid-thigh and ankle measurements; her ankle measurement was similar and knee measurement was 1 cm below the size 10/34 size chart ankle and knee measurements. However, the subject's knee measurement was observed to be in the size 8/30 size range in the size chart developed for this study (see Table 4.33). Nonetheless, comfortability and ease of movement was considered by evaluator 1 to be better than the comfortability and ease in the trouser produced from the mannequin's measurements. Evaluator 2 stated that the trouser length was long, the subject's inseam measurement was 1 cm shorter and the outseam measurement was 2 cm shorter than the size 10/34 size chart measurements. Evaluator 1 further indicated that the overall fit of the trouser length was better than the fit observed in the trouser created from the mannequin's measurements. The darts were offering a good quality of fit by evaluator 2.

Additionally, subject 7 stated that she preferred the fit of the shirt and trouser garments created using the size chart measurements because the shirt produced from the mannequin's measurements was too tight for her and the trousers had more creases when compared to the trousers created from the size chart measurements.

5.5.9 Fit test evaluations for Subject 8

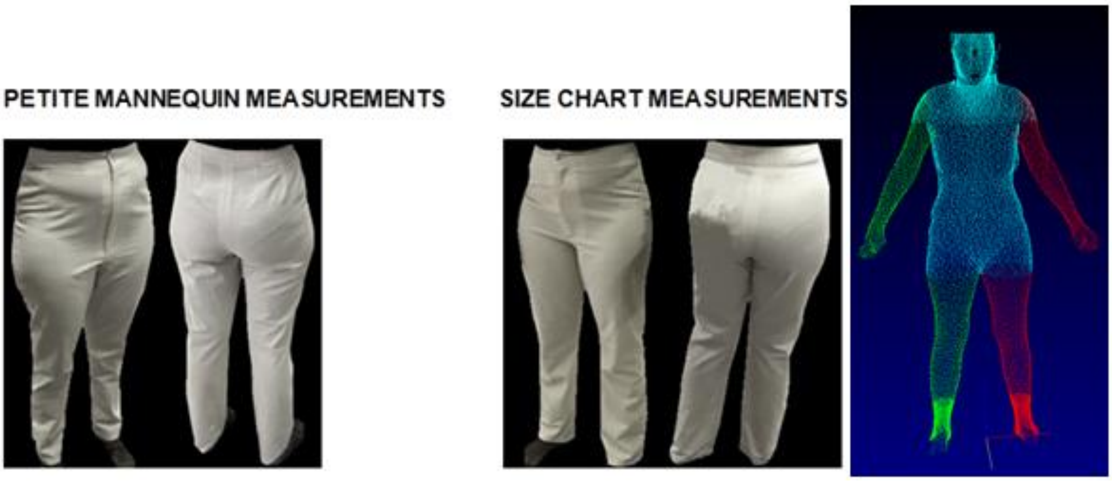


Figure 5.11: The prototype shirt and trouser garments fitted on subject 8 and the subject's 3D full body scan.

5.5.9.1 Subject 8 mannequin size 10/34 shirt fit test evaluations

The shirt created from the mannequin's measurements did not fit subject 8, therefore the shirt could not be evaluated. Evaluator 1 expressed the opinion that the shirt was too tight and evaluator 2 added that the shirt had restrictions and could not button-up. The subject's bust measurement (refer to appendix L8 for the upper body measurements) was 93 cm, making the subject to be at the higher end of the size 10/34 size range that was established in the size chart (see Table 4.32). The subject's bust measurement was 7 cm bigger than the mannequin's bust measurement, which is also more than the established 6 cm size interval for the bust measurement in the size chart.

5.5.9.2 Subject 8 size chart size 10/34 shirt fit test evaluations

The shirt created from the size chart measurements did not fit subject 8, as a result the shirt could not be evaluated. Similar to the above-mentioned reasons for the mannequin shirt fit; the subject's bicep and elbow measurements (refer to appendix L8 for the upper body measurements) were observed to be more than the established size interval measurements in the size 10/34 size range established in the size chart developed for this study. For that reason, the subject's bicep and elbow measurement effectively shifted her to other bigger sizes. No comments were made by the evaluators.

5.5.9.3 Subject 8 mannequin size 10/34 trouser fit test evaluations

The assessed trouser was considered to offer a tight fit between the lower waist and hip area by evaluator 1. The subject's measurements, especially as the lower waist measurement was (91 cm) (refer to appendix L8 for the lower body measurements and Table 4.33 for the lower body dimensions size chart measurements) which fell into a size 12/36 size range. Her hip measurements were at the higher end (100 cm) of the size 10/34 size range. Evaluator 2 stated that there was some tightness in the crotch area; the subject's crotch length front measurement was 3 cm bigger than the mannequin's crotch length front measurement. As shown in Figure 5.11, the subject had a bulging stomach, evaluator 2 suggested that, that could possibly influence the tight fit observed in the crotch. Evaluator 1 stated that the fit on the subject's ankles was a little tight and as a result the trouser became slightly short when the subject was sitting. The subject's ankle measurement was 3 cm bigger than the mannequin's ankle measurement, which was more than the established size interval used in the size chart (see Table 4.33) to establish the size ranges from one size to another in the size chart developed for this study.

5.5.9.4 Subject 8 size chart size 10/34 trouser: fit test evaluations

Evaluator 2 stated that the fit was better than the fit of the trouser created using the mannequin's measurements. The majority of the subject's lower body measurements (refer to appendix L8 for the lower body measurements), such as the hip, top thigh, mid-thigh, calf, ankle, crotch length back, inseam and outseam were more compatible with the size chart measurements than the measurements from the mannequin.

Evaluator 1 considered the trouser length to become shorter at the ankles when the subject was sitting, whilst evaluator 2 stated that the trouser length was *"ok*" for flat shoes. As shown in Appendix L8 (see lower body measurements), the subject's inseam and outseam measurements where more than the inseam and outseam measurements established in the size 10/34 size chart. Moreover, the subject's height measurement that was 161 cm, which was 4 cm longer than the established size 10/34 average height measurement (see Table 5.1). The overall trouser fit was evaluated to produce a great fit by evaluator 1. Evaluator 2 further added that the darts on the trouser were to be good.

Subject 8 commented that both evaluated trouser garments fitted her body well.

5.5.10 Fit test evaluations for Subject 9

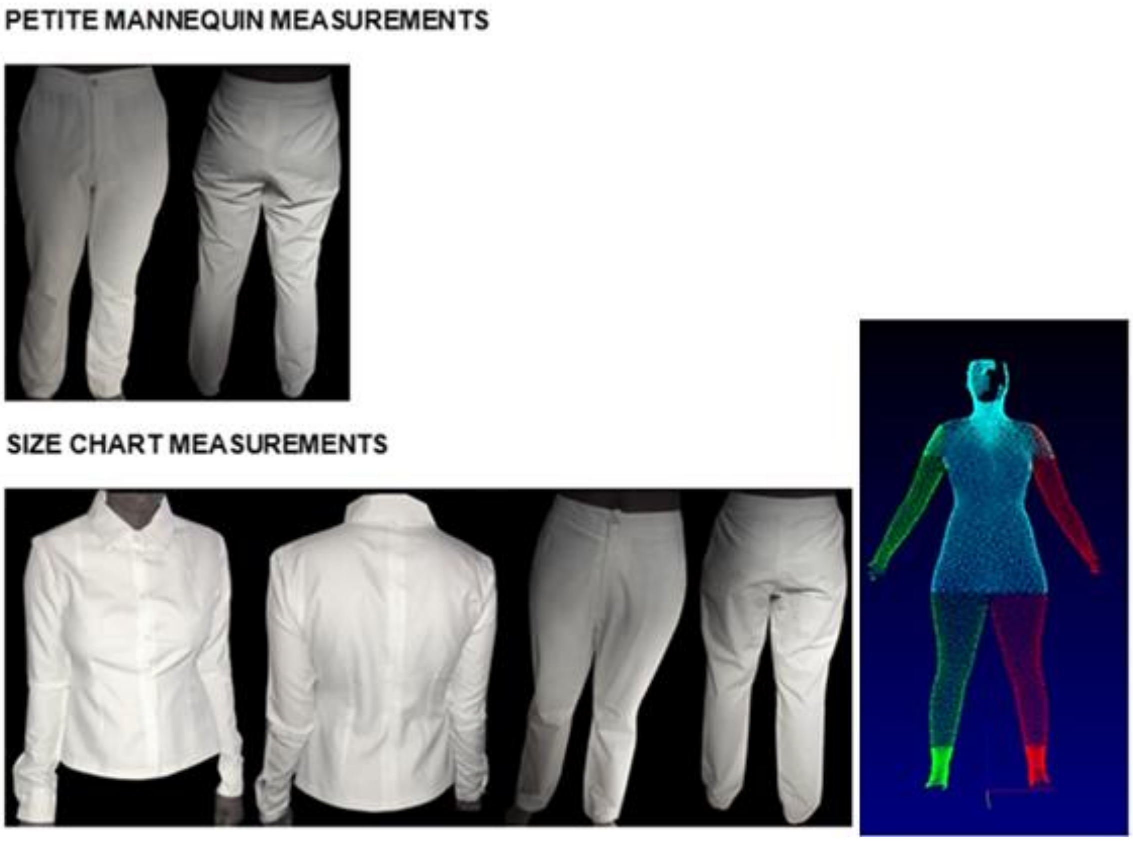


Figure 5.12: The prototype shirt and trouser garments fitted on subject 9 and the subject's 3D full body scan

5.5.10.1 Subject 9 mannequin size 10/34 shirt fit test evaluations

The shirt created from the mannequin's measurements did not fit subject 9, therefore the shirt could not be evaluated. Evaluator 1 observed the shirt to be too small; whilst evaluator 2 stated that the subject's upper arm was big for the evaluated shirt; hence the shirt could not fit. The subject's bicep measurement was 6 cm, whereas the elbow and armscye measurement were both 4 cm bigger than the mannequin's measurements (refer to appendix L9 for the upper body measurements).

The above-mentioned measurement differences were more than the 2 cm size interval allocated to size the bicep and elbow measurements from one size to the next in the size 10/34 size chart developed in this study (see Table 4.32).

5.5.10.2 Subject 9 size chart size 10/34 shirt fit test evaluations

The shirt was considered by evaluator 1 to have folds at the arm area; evaluator 2 stated that she observed minor pulls in the shirt but did not specify where in the shirt. The sleeve length was stated to fit long by both evaluators; the size 10/34 size chart sleeve length measurement (refer to appendix L9 for the upper body measurements) used to manufacture the prototype shirt was 3 cm longer than the subject's sleeve length measurement. Evaluator 2 indicated that the sleeve fit on the bicep was too tight, pulling and restricting movement. Evaluator 1 additionally stated that comfortability and movement in the shirt was constrained at the biceps, while the rest of the fit on the shirt was observed to be of good quality. The subject's bicep measurement was 5 cm, bigger than the mannequin's measurements; nonetheless, the rest of the arm girth measurements permitted the subject to fit into the shirt. Evaluator 1 observed the bust area to fit well, the subject's bust measurement was similar to the size 10/34 size chart bust measurement. Evaluator 2 considered the closure alignment to be well aligned. Evaluator 2 stated that the darts were well positioned and fitted well on the shirt garment.

5.5.10.3 Subject 9 mannequin size 10/34 trouser fit test evaluations

Evaluator 2 considered the overall fit of the trouser to be comfortable, even though, it was a little big and bulging at the back. The subject's upper waist to hip body proportion measurements, when compared to the mannequin's upper waist to hip measurement ratios, may influence how the trouser sits on the subject's body. The subject's size 10/34 size chart lower waist measurement was 7 cm smaller than the mannequin's lower waist measurement. The subject's size 10/34 size chart high hip measurement was 4 cm smaller than the high hip measurement of the mannequin and her size 10/34 size chart hip measurement was 2 cm smaller than the mannequin's measurements (refer to appendix L9 for the lower body measurements). Additionally, evaluator 2 indicated that the darts on the trouser were well positioned and produced a good fit.

The length of the trouser was considered to be a good length by evaluator 1, the subject's inseam measurement was 1 cm shorter and the outseam measurement was 2 cm shorter than the mannequin's measurements. Evaluator 2 further suggested that the length would fit better if the subject wore heels.

5.5.10.4 Subject 9 size chart size 10/34 trouser fit test evaluations

Evaluator 1 considered the compatibility and ease of the trouser to fit well albeit slightly loosely. The subject's lower waist and high hip measurements were observed to be smaller but more compatible to the size 10/34 size chart measurements (refer to appendix L9 for the lower body measurements). Evaluator 1 further stated that the trouser fit was better when compared to the fit of the trouser created using the mannequin's measurements. The fit on the thigh area was considered to be loose by evaluator 2, the subject's top thigh measurement was 4 cm smaller and mid-thigh measurement was 6 cm smaller than the size 10/34 thigh measurements. Furthermore, evaluator 2 indicated that the darts in the trouser to be well positioned and fit well on the wearer's body.

Subject 9 commented that the shirt fitted her well. The subject further added that the trouser created using the size chart measurements fitted her body well, according to her fit preference; the lower waist and hip fitted her well, but the rest of the trouser garment was slightly loose.

5.6 CONCLUSION

The findings from the shirt and trouser garment fit test evaluations showed that the two fit evaluators considered the test garments developed from the experimental subject's size 10/34 size chart measurements to offer an improved overall quality of fit compared to the quality of fit attained from the size 10/34 mannequin's measurements. Most of the shirt and trouser garments fitted in this study were rated to have a good-moderate quality of fit. Fit problems were observed and indicated in all the evaluated shirt and trouser garments. Garments that were too large formed an unflattering appearance, whereas garments that were too small restricted comfort and movement. The sleeve circumference dimensions such as the bicep, elbow and some wrist areas were tight on most of the subjects indicating that more ease should be added. This could indicate a deficiency in the correlation between bust girth measurements with the sleeve arm girth measurements. Surprisingly, the correlation coefficient between the bust and the bicep was 0.79 and the bust and elbow was 0.75, indicating high correlations; whilst the bust and wrist correlation was low (0.36, refer to Table 4.4). This shows that this is an area of improvement that is required in the size chart. The fit of the trouser girth areas had wrinkles because most of the length measurements were long for the subjects. This could indicate a deficiency in the correlation between the thigh, knee and ankle measurements with the trouser length (inseam and outseam) measurements and suggest that the trouser garment's leg length should be made shorter.

The shirt sleeve lengths in the analysed size 10/34 subjects and size 10/34 mannequin garments created for this study were found to be long; however, the mannequin's measurements sleeve length was longer than the sleeve length of the shirt garment created using the size 10/34 subjects. The crotch length was also observed to be longer in both analysed garments. The bust areas in most of the evaluated shirt garments were considered to be either gaping or, for some subjects, close-fitting. This could be attributed to the placement of the buttons influenced by the position of the bust in some of the shirt closure locations. The results on the quality of fit of most of the trousers were indicated to be a loose fit which showed that less ease was required in the trouser circumference measurements such as the thigh, knee and ankle areas. Most of the darts, especially for the size 10/34 chart size measurements were considered to be well-positioned, pointing in the right direction and sitting well on the subjects' bodies. The length measurements in both the shirt sleeve and trouser garment indicate inaccuracies in the correlations between the key (primary) body dimensions and the secondary body dimensions. The correlation between the inseam and outseam measurements were 0.45, which does not indicate a good correlation. This could indicate that the scanner does not pick up these measurements. It is suggested that the length measurements of the shirt and trouser garments could be improved by conducting a study on a larger petite women's sample.

The quality of fit on most of the trouser garments created using the mannequin's measurements was not considered to be satisfactory on the subject's bodies, despite the fact that the circumference measurements (lower waist, high hip, hip, thigh, knee and ankle areas) in the trouser garment were smaller than those of the trouser garment created using the size 10/34 size chart measurements (see Table 4.35). The shape of the size 10/34 mannequin was classified in section 4.5 as a pear body shape profile. Although the shape profile of the mannequin was similar to that of the subjects, the body proportions and height measurements differed. The elongated crotch length back and crotch length front measurements may have an impact on the trouser length measurements and the way the trouser garment fits of the subjects' pear shape bodies. The front and back crotch length measurements in the trouser garments created using the mannequin's measurements were established to be longer (see Table 4.34) when compared to the front and back crotch length measurements of the trouser garment created using the size 10/34 size chart measurements. As a result, the fit of the trouser presented a "dropped" effect and did not sit in the correct body landmarks of the subjects' causing bulking and creases in the garment.

From the results, it is evident that the fit of the shirt and trouser garments was affected by the height and body dimensions of the subjects (see Table 5.1). Because the nature of this study is exploratory; despite being considered to have improved quality of fit, the shirt garment length of the size 10/34 size chart measurements produced garment was found to be shorter than that of the length of the shirt garment created using the mannequin measurements, indicating that the upper proportion ratios of the size 10/34 mannequin was longer than that of the analysed 180 3D full body scanned pear shaped subjects. Furthermore, as stated in section 4.7, objective 5; the findings from the completed psychographic questionnaire indicated that South African petite women are shorter. As a result, the fit of their shirt sleeve lengths and the trouser garment lengths were mostly indicated by the subjects to be too long. This shows a deficiency in the correlations between the key body dimensions and the shirt sleeve and trouser garment length measurements; indicating that further analysis is required, possibly on a bigger sample to improve the fit of the shirt and trouser garment lengths. However, the overall fit of the evaluated shirt and trouser garment lengths was found to fit better for the garments created using the size 10/34 size chart measurements.

In future, the researcher recommends adjusting the garment length measurements after conducting garment fit test evaluations. According to Boorady (2011:346), pattern alterations are necessary after conducting garment fit test evaluations to improve the quality of the tested garment's fit. Boorady (2011) further suggests adjusting the garments to have them function properly after altering the pattern as an added requirement. However, the purpose of the study was to test the fit of the garments created from the established 3D full body scanned measurements; therefore, further measures to adjust the garments were not applicable for this study.

Additionally, it was observed by the researcher that the subjects that had smaller body silhouettes and were on the smaller end of the size 10/34 size chart measurements such as subject 1 (see Figure 5.4) experienced more garment fit problems, especially in the trouser garments. The trouser garment created using the size 10/34 size chart measurements was a little baggy and more wrinkles were observed in the garment created using the size 10/34 mannequin measurements. Subjects with bigger biceps such as subject 3, bigger bust measurements and a fuller abdomen area, such as subject 5 experienced more fit problems in the shirt garment. This suggests further studies on the different types of petite women's body silhouettes and body proportions relative to garment sizing and fit.

In conclusion, the overall quality of fit of the shirt and trouser garments created from the size 10/34 size chart measurements had a better fit than the garments produced from the size 10/34 mannequin measurements. The size 10/34 mannequin measurements (Table 5.1) were observed to be less than the size 10/34 size chart measurements and the measurements of the subject's actual body measurements. The fact that the mannequin measurements were less than the subject's measurements suggested that the fit of the shirt and trouser garments created from the mannequin measurements might not be as good, as the garments were made to fit the mannequin.

The accuracy of fit for the shirt and trouser garments produced using the size chart measurements was based only on the size 10/34 size range because this was the most commonly perceived and encountered body size for the shirt and almost the most commonly perceived size for the trousers with the sample of subjects. Furthermore, the availability of the 3D full body scanned size 10/34 mannequin enabled the size 10/34 chart measurements to be compared with those of a mannequin currently used commercially in the design and manufacture of garments for size 10/34 South African subjects. The greater accuracy of the size 10/34 size chart measurements compared with the size 10/34 mannequin measurements was validated by the fit test rating scales (see Table 5.2 and Table 5.3) which presented high rating values from both the garment fit evaluators in most of the garments created using the size 10/34 size chart measurements.

The findings from the garment fit test evaluation rating scale analysis showed that the shirt and trouser garments created using the size 10/34 measurements from the size chart data provided the subjects with a better quality of fit than the shirt and trouser garments created using the size 10/34 mannequin measurements that is currently available for commercial use when making garments for South Afrian petite women. This demonstrates the necessity of collecting raw data and using a population's actual measurements when developing size charts for garment production. However, deficiencies where observed in some areas where the fit of the garments was generally not satisfactory, such as the shirt garment length, bicep elbow, wrist and sleeve length measurements; the trousers crotch length, thigh, knee, ankle, inseam and outseam length measurements. The standard deviations of the above-mentioned measurements were observed to be greater for certain sizes in the size charts than others, indicating that the correlations between the key (primary) body dimension and the seconday body dimension variables may not have been good. This could indicate limitations in the scanner as the scanner could not pick up the landmarks correctly or consistently, especially in the length measurements. This is another source of error that could be due to variations in the pear body shape profiles. Therefore, it may be neccesary for further analysis on a larger sample, to assist in a more accurate and efficient sizing system that provides better fitting garments.

It is acknowledged that the evaluation was only performed for size10/34 subjects, which is limitation of the study. It is recommended that further evaluation should be done for the smaller and larger size ranges.

CHAPTER 6

CONCLUSIONS, IMPLICATIONS, LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

6.1 INTRODUCTION

This chapter summarises the results obtained from the study on "Evaluating garment sizing and fit for petite women using 3D full body scanned anthropometric data". This chapter concludes the dissertation by briefly reviewing the research purpose of this study and the methods applied to collect, analyse and evaluate the data. Conclusions are presented pertaining to the research questions posed and objectives set as indicated in section 1.3 and Chapter 4. The implications of the findings are considered and possible contributions to the existing systems of garment sizing for petite women is suggested, together with recommendations to assist the South African garment retail industry. Finally, the limitations of the study are acknowledged, and further studies relating to garment fit are proposed. The researcher's personal reflections of the findings and results are also included in this chapter.

6.2 SUMMARY OF THE RESEARCH METHODOLOGY

The motivation for this study was to gain some insight into garment fit issues experienced by petite South African women. This was especially regarding their experiences and challenges encountered in purchasing currently available ready-to-wear shirt and trouser garments. A principal issue was the accuracy and relevance of size charts and mannequins currently available for use in the manufacturing of garments for petite South African women. To evaluate this and other fit issues, 200 petite subjects' 3D full body scanned measurements were collected, using a $(TC)^2$ NX16 3D full body scanner. The demographic profiles of the subjects included their ethnicity, height, weight and age. The psychographic profile of the subject's perceptions regarding their body shapes and body proportions together with evaluations and purchasing behaviours regarding their shirt and trouser garments were also collected and analysed using quantitative and qualitative methods; however, most of the data analysis consisted of a quantitative approach.

There are two influences on the fit issues, namely: the quantification of fit, which used calculations of the subjects' height and weight measurements, collected using an Adam's® medical scale to determine the subject's height and weight range. As well as the calculations of the 3D full body scanned measurements to develop the upper and lower body dimensions size charts for manufacturing prototype shirt and trouser garments.

The average height measurement of the 200 petite subjects' sample was 157 cm and their body weights were between 38 kg - 125 kg. Nonetheless, the comparison of the subjects' weight measurements with garment sizing and fit was beyond the scope of this study. The perception of fit consisted mainly of data that contained the expert's opinions and evaluated data on the quality of fit on the evaluated shirt and trouser garments. The perception also included the subjects' opinions gathered from a psychographic questionnaire comprising of open-ended and closed-ended questions. The closed-ended questions provided data for the subjects' demographics such as their ethnicity, height, weight and age distributions. The open-ended questions provided data for the psychographic profiles of the subjects' perceptions of their body shapes and body proportions, together with evaluations and purchasing behaviour regarding their shirt and trouser garments. The responses comprised each subject's perceptions, experiences and challenges faced when purchasing currently available, ready-to-wear shirt and trouser garments.

The key conclusions of this study which address the research questions posed and the research objectives found in section 1.3, and are as follows:

6.3 KEY CONCLUSIONS FOR THE OBJECTIVES IN THIS STUDY

6.3.1 The body measurements and body shapes of the 200, 3D full body scanned petite subjects

The first research objective was to analyse the 3D scanned body measurements and the body shapes of the 200, 3D full body scanned petite women subjects collected in this study.

The majority of the 200 petite women subjects' body shapes, represented by 90% (n=180) of the 3D scanned subjects, were found to be pear shaped. Other shapes that were extracted from the 200, 3D full body scanned data included the straight 12% (n=24), inverted triangular 3.5% (n=7), and the hourglass 2.5% (n=5). There was a cross over in certain body scans, 16 of the scanned subjects' body shapes were categorised between two body shape profiles. As a result, the data resulted in a total of 216 body shape representations, instead of the exact 200 petite women subjects' sampled number.

The 3D full body scanned data for the subjects with the pear body shape profile 90% (n=180) were further used for data analysis to fulfil the other objectives of this study. The pear body shape profile was prevalent in 87% (n=157) of the Black ethnic group, followed by the Whites with 9% (n=15), then the Coloureds with 3% (n=6) and the Indian ethnic group with 1% (n=2). Nonetheless, the subsequent data analysis and the development of the upper and lower body dimensions size charts were inclusive of all the ethnic groups.
Recent South African academic studies by Muthambi (2012), Ola-Afolayan and Mastamet-Mason (2013), and Makhanya *et al.* (2014) along with a petite study conducted by Barona-McRoberts (2005:27) in the United States of America have also shown that female consumers were becoming more triangular/pear shaped.

South African petite women have pear body shape profiles which consist of a wider hip area than at the bust and shoulders. It is recommended that South African mannequin manufacturers consider creating mannequins that have a curvier shape profile.
Although, the mannequin's 3D full body scanned bust, upper waist and hip measurement relationship analysis (refer to section 4.5) suggested that the mannequin was also pear body shaped; visual analysis of the mannequin observed a crossover shape between the hourglass body shape and pear body shape profiles. Garment manufacturers and designers should specifically target and cater for the pear body shape as a niche market by incorporating garment sizing, fit measurements and design styles which are suitable for the triangular /pear body shape profile.

6.3.2 The developed experimental upper and lower body dimensions size charts from the 3D full body scanned petite subject's measurements.

The second research objective was to develop the experimental upper and lower body dimensions size charts based on the body measurements corresponding to the most prevalent body shape of the petite women subjects represented in this study. The most prevalent body shape was identified as the pear body shape pertaining to 90% (n=180) subjects. All the ethnic groups were represented in the size charts.

The methodology that was used to transform the 3D full body scanned anthropometric data into experimental upper and lower body dimensions size chart specifications was as follows:

The experimental upper (for shirt garments) and lower (for trouser garments) body dimensions size charts were compiled using the results of the below-mentioned arranged steps. The appropriate data consisting of the 180 3D full body scanned subjects' pear body shape profile measurements was selected for statistical analysis. The size charts were developed by statistically analysing the 3D full body scanned anthropometric data of the subjects gathered in this study using a $(TC)^2$ NX16 3D full body scanner.
Microsoft Excel and the IBM SPSS Statistics 24 2016 were used to analyse the 3D full body scanned data collected for this study. The upper and the lower body dimensions were analysed separately. A total of 14 upper body dimensions were established for developing prototype shirt garments and 13 lower body dimensions were established for developing prototype trouser garments. Multivariate data analysis based on PCA was used to analyse the 3D full body scanned data to gain several understandings into the characteristics of the data (refer to section 4.3 for the PCA of the upper and lower body dimensions).

The size charts for the upper and lower body dimensions were developed using the data analysed in the PCA. The equations (see section 4.4) were derived, using regression analysis, using the identified key (primary) body dimensions to predict the secondary body dimensions and allocate the number of size ranges, as well as calculate the increments in the measurements for the size intervals in the upper and lower body dimensions size charts. A total of 11 size ranges consisting of the sizes 6/30 to 26/50 were established to accommodate the analysed 3D full body scanned subjects' measurements; covering 98% (n=177) for the upper body and 97% (n=175) for the lower body of the 180, 3D full body scanned petite pear shaped women's sample.

The methodology used in this study may prove to be useful for developing size charts for garment sizing in the garment manufacturing sector.

6.3.3 Comparing the collected 3D full body scanned petite women subject's upper and lower body dimensions size chart measurements with previously published size charts for petite women

The third research objective was to compare the collected 3D full body scanned petite women subject's upper and lower body dimensions size chart measurements derived from this study with previously published size charts for petite women by Defty (1988:17-18), Winks (1990:74-76), and Bailey (2010:23) as well as the 3D full body scanned fit mannequin's measurements to illustrate the key differences between the developed size chart measurements and the measurements of the previously published size charts for petite women.

In the absence of representative anthropometric data of South African petite women, measurements were derived from a 3D full body scanned size 10/34 mannequin that was available at the UNISA Florida Campus, Department of Consumer Science.

The size 10/34 mannequin was developed by a well-known South African mannequin manufacturing company to represent the standard body measurements used in the South African ready-to-wear garment industry. The mannequin measurements were the only currently available sizing specifications to use since there are no other petite 3D scan data measurements in South Africa with which to compare the 3D scanned data of the subjects collected in this study. Hence, the mannequin's measurements, developed for a standard sample size 10/34 size range were considered to be representative. According to Millam (2016) sizing in the apparel industry is based on a standard sample size 10/34.

The size 10/34 upper and lower body dimensions size chart measurements and the 3D full body scanned mannequin measurements, were compared with Defty's (1988:17-18) and Winks' (1990:74-76) published South African petite size charts. Bailey's (2010:23) published size chart measurement specifications were not applicable for comparison in this study as it consisted of petite sizes 2/26, 4/28 and 6/30. The size measurements were below the range of the size 10/34 size range measurements established in this study.

The subjects' average height defined in this study was 157 cm. The average height range of both the 3D full body scanned mannequin and the average height range established by Winks (1990:74-76) was 160 cm, whilst Defty's (1988:17-18) average height was established to be 153 cm. Defty (1988:17-18) did not specify which ethnic groups and body shapes were used to develop her size chart. Winks' (1990:74-76) data were collected using White, Black and Coloured ethnic groups. Three body shapes, namely A, M and H with body size distribution measurement distinctions were established from Winks' (1990: 76) data. Each body shape having different ranges of body size measurements (see the different body shapes and size distribution chart in Table 4.43). The third body size distribution range from the M body shape best matched the size 10/34 body measurements developed from the subjects' upper and lower body dimensions size charts developed in this study.

The comparison between the size 10/34 size chart measurements and that of Defty's (1988:17-18) and Winks' (1990:74-76) size charts was limited since the researchers only listed a few measurements in their size charts that corresponded with the measurement specifications derived for the upper and lower body dimensions size charts in this study. Four body measurements; namely: the height, bust, waist and hip from Defty's (1988:17-18) and only three body measurements; namely: the height, bust and hip from Winks' (1990:74-76) studies (see Table 4.43) were applicable for comparison with body measurements derived for this study. The significant measurement differences and similarities were established within the compared size charts.

The implications of the measurement differences in terms of garment fit, if garment manufacturers were to use the older size charts by Defty's (1988:17-18) and Winks (1990:74-76) are elaborated below.

In response to the research question, it is difficult to explicitly state how relevant Defty's (1988:17-18) and Winks' (1990:74-76) size charts currently are by comparison with the size charts developed in this study because of the limited comparable data that they contain. On the evidence of bust and hip measurements alone, the subjects' size 10/34 bust measurements were the same as Winks' and Defty's bust measurements. Therefore, it may be inferred that bust fit would be similar for the shirt garments. The fit of the trouser garments at the hip would be similar if Winks' data was used to make the trouser garment because Winks' hip measurement was only 1 cm smaller than the subjects' size 10/34 hip measurement. Defty's hip measurement was 3 cm smaller than the subjects' size 10/34 hip measurement. Therefore, manufacturing the trouser garment using Defty's hip measurement may affect the fit of the garment on the subjects' body, resulting in a slightly tight fit in the hip area.

6.3.4 Investigating the petite subject's perceptions of their body shapes and proportions, together with their upper body and lower body garment evaluations and purchasing behaviour.

The fourth research objective was to evaluate the extent to which the subjects were satisfied with their shirt and trouser garment fit along with the challenges they face when purchasing the currently available ready-to-wear shirt and trouser garments sold in South Africa. The subjects' personal perceptions and preferences were analysed to identify what they regarded as important when they considered the sizing and fit of their ready-to-wear shirt and trouser garments.

Section 4.7 presents the subject's perceptions of their body shapes and experiences with their currently sold ready-to-wear shirt and trouser garments. The findings from the psychographic questionnaire showed that 16% (n=29) of the 180 pear shaped subjects stated that they were satisfied with their current ready-to-wear garment sizes; 84% (n=151) of the subjects stated that they were not satisfied.

Not all the subjects stated that they experienced problems with the fit of their currently available shirt garments, but those were in the majority (see Table 4.42 and Table 4.43). The subjects indicated that they found the ready-to-wear shirt garments to typically have a low neckline, loose collar, to be loose across the shoulders, too loose around their hips, too tight across the back, bust and around their upper waist area having a long sleeve length.The shirt garment length had equal representations of being either too short or too long depending on the style of the garment. The subjects' perceptions on the fit of currently sold ready-to-wear trousers were considered to be too tight around the lower waist, hips and thighs. The crotch length and the trouser length were indicated to be too long.

The subjects' body proportions may have an influence on how the fit of the ready-to-wear shirt and trouser garments fit on their bodies. Section 4.7 show that an equal number of 35% (n=63) of the subjects indicated that they perceived themselves to either have a long torso/short legs or an evenly proportioned body, which was more than the 29% (n=53) that stated that they have a body proportion of a short torso/long legs and only 1% (n=1) of the subjects was not sure which body proportion she has.
The subjects' perceived proportions were further compared with the subjects' measurements derived from the 3D full body scanner, using bust to upper waist and hip to upper waist ratios to compare their body proportions. The 3D full body scanned data showed that 82% (n=147) of the subjects had a short torso with long legs body proportions, while 15% (n=27) of the subjects had a long torso with short legs body proportions. The remaining 3% (n=6) had evenly proportioned body proportions. The above-mentioned body proportions are illustrated in Chapter 1, section 1.1. This shows a deviation in the subjects' compared body proportions, indicating that not a lot of subjects were aware of their body proportions to be able to select garments that are designed to enhance their body proportions.

According to Kasambala (2013:8), female consumers experience different types of fitting problems because of their varied body shapes which may influence their garment preferences. The subjects who had the pear body shape profiles indicated that they experience minimal fit problems in certain parts of their bodies when wearing their ready-to-wear shirt garments. The ready-to-wear trousers were stated as the most challenging in offering a better fit on their bodies as the trouser would fit their upper waist, lower waist (15cm below the upper waist, at the lower waistline between the upper waist and high hip area) but the fit would be tight on their hip area. As a result, they end up having to buy bigger sizes to accommodate their hip measurements and having to alter the upper waist and lower waist to obtain a better fit. The findings of this study are supported by

Alexander *et al.* (2005:52) and Kasambala *et al.* (2015:8) who established in their studies that pear body shaped women are more likely to report fit problems at both the upper and lower waist, hip and thigh areas.

The subjects revealed that they purchased their ready-to-wear shirt and trouser garments at selected retailer outlets. The low-end and middle-end stores were amongst the most preferred stores that the subjects selected to purchase their garments. 87% (n=166) preferred purchasing their garments by physically going to the retail stores, 7% (n=14) through the internet, 2% (n=3) through catalogues. Interestingly, 4% (n=8) selected the "others" option where they stated that they either make their own clothes or get a dressmaker to make their clothes and only one of the subjects mentioned that her mother buys her clothes because she does not like shopping for clothes.

The subjects stated that their purchasing decisions are influenced mainly by the name of the brand, followed by the latest trends, style/design, appearance of the garment, then the garment sizing measurements, comfort and quality. The findings show that various retail stores create garments catering for consumers with different lifestyles and income, etc. The importance of a garment's brand name could suggest that the subjects some sort of personal value for instance, associate the brand with a certain level of garment quality and could also suggest associations to a certain level of the upcoming middle class who can afford to buy branded garments; 66% (n=94) of the subjects in this study indicated that they were from the working class category. Garments that are perceived to have higher quality increase the customer's purchase decision and provide the selected brand with a competitive advantage over other brand competitors (Coury, 2015:12). A noticeable purchasing consumption in fashionable, trendy garments is perceived as "latest trends, style/design" was regarded as the second and third important influences of the subjects' purchasing decisions which may also epitomize this brand buying motive. The price and, interestingly, the fit of the garment were regarded as the least priority; this may be attributed to the 84% (n=151) of the 180 sampled subjects (as indicated in section 4.7) who anticipated having to alter their garments after purchasing to maintain a better fit. Some of the subjects included the colour of the garment, durability and exclusivity as the determining factor for their purchasing decisions.

Majority of the subjects indicated that they preferred wearing close-fitting shirt garments 33% (n=60) and trouser garments 41% (n=78). According to Pisut and Connell, (2007:376) and Alexander *et al*. (2005:59), there is a significant connection that exists between body shape and garment fit preferences in relation to body cathexis. The preference for close-fitting garments could be a reflection in the present fashion trends for shirt and trouser garments being sold in the retail stores. However, correlations between the subjects' body shapes, garment size measurements and the motives behind their garment fit preferences were beyond the scope of this study and therefore were not considered; this is further recommended for future studies.

Given the reasons behind the subject's perceptions of their body shapes and experiences they encounter when shopping for their ready-to-wear shirt and trouser garments, it is noted that there is some variability in the market of shirt and trouser garments for South African petite female consumers. This can be the result of some garment sizing and manufacturing issues that require further investigation.

6.3.5 Constructing basic pattern blocks for shirt and trousers patterns using the 3D full body scanned petite women subject's data for the developed experimental size charts and the 3D scanned petite tailoring mannequin measurements; to aid the manufacturing of the prototype shirt and trouser garments for the fit test evaluations.

The fifth research objective was to develop shirt and trouser patterns from the data collected in this study to aid the construction of the prototype shirt and trouser garments. The shirt and trouser pattern blocks were sized according to the subjects' size 10/34 size range measurements taken from the experimental upper and lower body dimensions size charts developed using 3D full body scanned data and from the 3D full body scanned size 10/34 mannequin specifications; thereafter, manufacture prototype shirt and trouser garments for the fit test evaluations.

The manufactured shirt and trouser garments were evaluated by fit evaluators to assess the quality of the shirt and trouser garments using three rating scale categories, namely: of 'good fit', 'moderate fit', and 'poor fit'. The fit rating scales were analysed by the researcher and thereafter conclusions were reported from the results. The results from the overall fit quality of the fit rating scales and the evaluated data of the fit test evaluations (see sections 5.4.2 and 5.5 for findings) showed that the test garments manufactured from the subjects' size 10/34 size range measurements obtained from the experimental upper and lower body size charts developed in this study were found to have an overall better quality of fit than the shirt and trouser garments manufactured with the size 10/34 mannequin measurements. Because the nature of this study is exploratory, despite being considered to have improved quality of fit, the prototype shirt garment's length was considered slightly short and the lengths of the sleeves too long. The shirt width measurements were considered by the fit evaluators to fit well on both of the assessed shirt garments; however, the bust area on both of the analysed shirts was gaping in majority of the subjects and the sleeve was considered to be tight in most of the evaluated garments. The prototype trouser's crotch length measurement was considered to be long. However, the overall length of the trouser garment manufactured from the size 10/34 size chart measurements was better than the mannequin's measurement, which was too long. Based on the results from the overall fit of the evaluated trouser garments, it is suggested that South African mannequin manufacturers should consider creating mannequins with shortened crotch length measurements. The trouser width measurements were considered to be slightly bigger on most of the garments manufactured using the size chart measurements; regardless, the overall fit of the trouser garments manufactured using the size chart measurements was evaluated to fit better than the trousers produced from the mannequin's measurements on the majority of the assessed subjects.

Deficiencies where observed in some body dimensions for the size 10/34 subject measurements, when compared to the size 10/34 size chart measurements. The sleeve circumference dimensions such as the bicep, elbow and some wrist areas were tight, indicating that more ease should be added. This could indicate a deficiency in the correlation between bust girth measurements with the sleeve arm girth measurements. Deficiencies were also observed between the trouser garment girth measurements such as the thigh, knee and ankle with the trouser garment length (inseam and outseam) measurements, where the girth areas had wrinkles because most of the length measurements were long for the subject.

Analysis on a larger sample is suggested, to provide an improvement on the correlations between the key (primary) body dimensions and the secodary body dimensions, to further assist in an efficient sizing system that provides better fitting garments. Although, minor wrinkles were observed in some of the subjects' upper trouser area when conducting the fit test evaluations, the waist to hip girth measurement correlations of the size 10/34 size chart measurements seem to produce a better fit. The subjects indicated in section 4.7 that they end up having to purchase larger ready-to-wear trouser sizes to accommodate their hip measurements, having to alter the upper waist and lower waist to obtain a better fit. Furthermore, some of the subject's girth and length measurements when compared with the size 10/34 size chart size range measurements shifted to another size range. It is suggested that a larger sample size needs to be carried out to improve the accuracy of some of the measurements in the developed upper and lower body dimensions size charts. The overall findings in this study demonstrate the challenges with the quality of fit of the South African petite women's ready-to-wear shirt and trouser garments produced from garment sizes based on the tailoring mannequin considered in this study. It is suggested that improvements should be made to offer South African petite women with better fitting shirt and trouser garments.

In conclusion, this study is the first study that has 3D scanned petite South African women and the first to develop upper and lower body dimensions size charts based on the scanned data. It is also the first study that has canvassed the opinions and preferences of petite South African women in terms of their body shapes and sizes and the issues that they experience when purchasing garments. The findings in response to the research questions posed provided sufficient data to address the objectives in which this study was designed. It is challenging to obtain an entirely satisfactory garment sizing in a size chart for all the individuals in a population because of the variety of the body shapes and proportions. Based on the tested garments manufactured using the size 10/34 size range, adjustment of the measurements in the body dimensions that seemed to be deficient such as the shirt garment length, sleeve length, bicep, elbow and wrist measurements; the trousers crotch length, inseam length, outseam length, thigh, knee and ankle measurements are required to assist in a more accurate and efficient sizing system that provides better fitting garments. The standard deviations of the above-mentioned measurements were observed to be greater for certain sizes in the size charts than others.

6.4 CONTRIBUTION OF THE STUDY TO GARMENT SIZING AND FIT RESEARCH

The importance of this study is its influence on the theory and methodology within the field of garment sizing and fit for South African petite women. The construction of the size 10/34 prototype shirt and trouser garments manufactured using the developed experimental size charts for the upper and lower body dimensions provided insight into the relevance and accuracy of the size charts. The results from this study provided improvement to the fit and sizing of shirt and trouser garments since the results provided useful insight into the limitations of the petite mannequin. This study not only advances the development of size charts for South African petite women using quantitative methods. Qualitative data collection methods were also undertaken in the form of a survey to provide understanding to the extent that South African petite women are satisfied with the sizing and fit of the ready-to-wear of shirt and trouser garments currently offered in retail stores in South Africa. Furthermore, it has created awareness of the various petite consumers' body shapes, and the shirt and trouser sizing and fit issues that South African petite women are experiencing to date. It was envisioned that this might assist South African garment manufacturers and retailers in understanding and interpreting the petite women's consumer's preferences and viewpoints regarding their body shapes and challenges they encounter when shopping for ready-to-wear shirt and trouser garments currently offered in retail stores. That way they can provide better fitting shirt and trouser garments.

This study will contribute to the limited amount of published studies on "garment sizing and fit" for South African petite women to improve the fit of South African petite women's ready-to-wear garments. Additionally, the data will be available to students, garment manufacturers and retailers in South Africa.

6.5 IMPLICATIONS AND LIMITATIONS OF THE STUDY

In this study, the limitations can be identified in terms of the sample and the measuring instrument and the output of the analysed data. The most obvious limitation is that only 200 petite women aged between 20-54 from the African, White, Coloured and Indian ethnic groups with a height range of 163 cm and below was included in this study. This means that caution must be exercised in generalising the results to the broader South

African population. The purposive sample of subjects came from the Gauteng (Pretoria and Johannesburg) area, with a predominance of 87% (n=157), Black subjects from the analysed 180 petite pear shape sample. As a result, the population sample was not large enough to accommodate a representative number of the subjects in all the ethnic groups. Although, garments are not made specifically for ethnic groups, it would have been preferred to obtain a population sample that accommodated all the ethnic groups, to get a reflection of how the size charts might compare in relation to their varied body shapes. Nonetheless, the sample in this study addressed the purpose of the study.
With regard to the measuring instruments, a $(TC)^2$ NX16 3D full body scanner, an Adam's® medical scale and a demographic questionnaire were used to collect data in this study. The limitations of the 3D full body scanner were observed in the identification of the body landmarks by the scanner software.

From the subjects that were scanned, 12 of the subjects' bust surfaces were not captured by the 3D full body scanner (see section 4.2). As a result, the missing areas (holes) were filled using "MeshLab" 2016 software. The trouser garment manufactured using the crotch length body landmarks extracted in the scanner were observed to fit too long on the majority of the subjects' body; indicating that the accuracy of the crotch length measurements might not have been accurately identified by the scanner software.

There were large discrepancies between the predicted/visually observed shapes (see Table 2.1) and the self-perceived body shapes (see Table 4.2). Nonetheless, the most commonly perceived body shape profile, namely; the triangular /pear/spoon body shape 41% (n=83) concurred with the most represented body shape profile extracted from the subjects' 3D full body scanned data, namely; the pear body shape 90% (n=180). This shows that, although not by a large number, there are some subjects who are aware and have realistic perceptions about their body shapes. The study was limited to a subcategory of the South African population since the anthropometric data used in the development of the experimental upper and lower body dimensions size charts fell between the sizes 6/30 to 26/50. The patterns constructed, and the produced garments were limited to shirt and trouser garments using the size 10/34 size chart measurements and the size 10/34 mannequin measurements. The other size ranges were not considered to offer the unit of garment fit analysis as it was not within the scope of the study. However, further evaluations of the other size ranges in the developed upper and lower body dimensions size charts, possibly manufacturing prototype shirt and trouser garments to fit the size ranges and undertaking further garment fit evaluations will be necessary to be able to fully assess the accuracy and relevance of the developed size charts in this study.

The quality of garment fit was attained from and limited to the produced size 10/34 shirt and trouser test garments evaluated on nine subjects with appropriate body size measurements. There were 11% (n=22) of the 180 pear shaped subjects who fell into the size 10/34 size range. From the 22 size 10/34 subjects, 39% (n=14) indicated that they were willing to assist with the garment fit test evaluations. However, only 39% (n=9) of the 14 subjects that were willing to assist with the garment fit test evaluations were available. Therefore, a non-representative sample was used to evaluate the quality of fit of the test garments; nonetheless, the selected sample addressed the purpose of the study.

Irrespective of the afore-mentioned limitations of this study, the implications of the findings of this study should not be regarded as insignificant but by implication, the findings of the study cannot be generalised among the general South African petite female population.

6.6 RECOMMENDATIONS

It is evident from the literature reviewed in this study that Academic researchers should collect data on a population sample of interest, and thereafter use that sample's data to make scientific predictions about the population. This study was based on investigating garment sizing and fit of petite female consumers residing in the Gauteng (Pretoria and Johannesburg) area by evaluating their 3D full body scanned data and developing experimental upper and lower body size chart for creating prototype shirt and trouser garments.

A $(TC)^2$ NX16 3D full body scanner was used to collect data in this study, since there is not much sizing and fit research conducted using modern technology. The use of the 3D full body scanner to collect data in this study was proven to be effective. However, the use of improved 3D full body scanners is recommended so that the 3D full body scanner

can capture data for people with bigger sizes without having missing body landmarks (holes) caused by shaded areas and skinfolds and accurate crotch length measurements. As presented in section 4.1, MeshLab 2016 software was used to fill missing bust areas of twelve of the subjects scanned for this study, since the body scanner did not capture the bust area.
It was observable that filling missing holes is time consuming and requires precision. Nonetheless when filling the missing bust area holes for the twelve subjects in this study, the researcher ensured that the output surfaces of the filled bust areas preserved their pear body shape profiles.

The conceptual framework model established in Figure 1.2 section 1.5 suggests that there are particular elements contributed by anthropometric data and body shape that cause petite consumers to experience garment sizing and fit problems, which could be used as a contribution to assist garment manufacturers and retailers in improving the problems of shirt and trouser garment sizing and fit. The findings from the subject's demographic data in section 4.7 and the findings from the garment fit test evaluations suggest that the South African petite women are shorter; hence the fit of their shirt and trouser garment lengths were mostly too long. Based on the findings of this study, it is recommended that the South African garment manufacturing industry focus on developing a sizing system that accommodates petite garment measurements, body proportions and shape variations by understanding the unique needs of their target market.

The subjects stated in the psychographic questionnaire that, due to the inconsistency and unreliability of the sizing and labelling of currently available ready-to-wear shirt and trouser garments, they find themselves having to purchase different sizes from different retail stores (see Figure 4.12, Figure 4.13, Figure 4.14 and Figure 4.15 for the perceived size ranges plotted against the size ranges predicted by the size charts). The subjects indicated that they purchase their garments in various sections offered in store, namely the average women's section 61% (n=118), the petite section 17% (n=33), the plus-size women's section 14% (n=27), the kiddies section/children's department 7% (n=13) and 1% (n=2) of the subjects stated that they purchase their garments in any department. This results in the subjects having to unavoidably try on their ready-to-wear shirt and trouser garments before purchasing them, which is time consuming. Nonetheless, even

having to try on the garments, an overall number of subjects 84% (n=151) specified that they alter their garments after purchasing, leaving only 16% (n=29) of the subjects who stated that they were satisfied with their current ready-to-wear garment sizes and do not have to alter them after purchasing.
Hence, it is advisable for garment manufacturers and designers to adopt a distinctive set of size charts for the upper and lower body dimensions that are known to be suitable for various petite women's body shapes which manufacturers could use for consistency in garment sizing and fit to benefit both the garment retailers and petite female consumers. It is also recommended that garment retailers consider offering special alteration services for their petite customers seeing that most of them altered their shirt and trouser garments after purchasing, which indicates that garment alterations seems to play a significant role of adjusting the fit of their ill-fitting shirt and trouser garments for them to achieve their desired quality of fit.

This study proved that identifying the target population's actual anthropometric measurements and classifying the body shapes is important when developing size charts, as this is an essential component for improving garment fit and increase customer satisfaction.

6.7 FURTHER STUDIES

Garment sizing and fit is a very broad topic and there is great potential for future studies in this area in South Africa. There is no accessible garment sizing system in the public domain that is readily available for the South African garment manufacturers to use when creating garments for petite women. The findings of the study suggest that the collection of actual anthropometric body measurements using 3D full body scanners has the potential of contributing to better fitting garments. As a result, improvements in the quality of fit of ready-to-wear shirt and trouser garments for South African petite women may be anticipated in areas such as the sleeve length as the subjects indicated in section 4.7 that the fit of their currently sold ready-to-wear shirt sleeve lengths were long; and their currently sold ready-to-wear trouser waist to hip fit was not satisfactory for them as they end up having to alter the trouser garment to achieve their desired fit.

The depth of studying different body shapes for different ethnic groups and developing the prototype fit test garments in all the size ranges from the developed experimental upper and lower body size charts has not been fully explored. Future studies should explore studying the different body shapes identified for the South African petite women and evaluate garment fit for each size range identified in the experimental shirt and trouser size charts, as it is clear from the findings of this study that body shapes among other factors affect garment sizing and fit. In a country such as South Africa, the population consists of a diverse society of various ethnic groups and different body shapes; and the findings of the study warrant repeating the study and developing experimental upper and lower body size charts with other body shapes found within the South African petite women population, such research has potential of accomodating various body shapes and improving the overall quality of fit attained from ready-to-wear shirt and trouser garments in South Africa, thus leading to increased levels of consumer satisfaction. However, a large population is recommended to generate an acceptable sample size for each ethnic group and body shapes.

The prototype shirt and trouser test garments were designed to accommodate the 10/34 size attained from the experimental upper and lower body size chart specifications for South African petite women with pear shape body profiles and by implication, the garment fit test garments manufactured in this study fundamentally offered the unit of analysis with improved quality fit. The other size ranges from the developed experimental upper and lower body size charts were not considered to offer the unit of garment fit analysis as it was not within the scope of the study. Further studies are recommended to evaluate the developed upper and lower body dimension size charts for the smaller and larger size ranges, than the size 10/34. It is also recommended to look at more depth into critical areas in the developed size charts where the fit issues were observed, such as the bicep, elbow, wrist, sleeve length and the garment length in shirt garment; the trouser crotch length, thigh, knee, ankle, inseam and outseam length measurements. Additionally, creating shirt and trouser garments in the smaller and larger garment size ranges with a representative sample is recommended in future for evaluating the quality of the fit in the shirt and trouser test garments in order to generalise the findings.

It is further recommended that the proposed experimental upper and lower body size charts for South African petite females with pear body shape to be transferred to garment manufacturers and retailers using guidelines by the ISO to provide consumers with improved satisfaction with the quality of ready-to-wear shirt and trouser garments and to aid clear communication of garment sizing. Tables 4.46 and 4.47 presented how the currently available shirt and trouser garments fit on certain parts of the subject's bodies. The results showed that the number of the subjects who indicated that they experienced fit problems with their currently available shirt and trouser garments when added together, were greater than the number of subjects who indicated that they do not have problems. A scope for further research is recommended regarding the correlations of the subjects' responses to their body measurements.

The findings of the study show the necessity for conducting a study on a representative antropometric data of the South African petite women population. Further studies could compare body shapes, garment size measurements and the motives behind their garment fit preferences of subjects.

Having said all of this, this is the first study to specifically 3D full body scan petite South African women, develop and evaluate a set of size charts based on the scanned data and assess their opinions and preferences. Therefore it represents a significant contribution towards gaining a greater insight into garment fit issues for this group of South African women.

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APPENDIX A: INVITATION LETTER

INVITATION TO TAKE PART IN A 3D FULL BODY SCANNING SIZING & FIT STUDY FOR SOUTH AFRICAN FEMALE CONSUMERS

Dear Participant

My name is Marion Phasha. I'm a student completing a Master's Degree in the Department of Life and Consumer Sciences situated on the Science Campus, University of South Africa (UNISA). I am currently embarking on a 3D full body scanning study for South African women (aged 18-55), on the Science Campus.

I would like to invite you to take part in this study. Please NOTE that the data is collected anonymously and no personal details are attached to your 3D scan. As a token of my appreciation you will be able to take away a colour copy of your scan including your body measurements. A raffle will be drawn at the end of the study where two lucky subjects will share a prize of R500.
Scanning will be conducted in your *undergarments that may **not** be **black or navy blue*** in colour. Should you have any queries on this, please contact Marion Phasha on (078) 2177689 or phashamarion@gmail.com , respectively.

This research uses a 3D full body Scanner to capture the body landmark measurement points of the whole body in 6 seconds to capture the data. The method is quick, non-intrusive and uses white light (like those found in your offices and homes) to capture the 3D scan and is, therefore, safe to your health. A medical scale will also be used to measure your body height and your weight. The measurements will be taken privately by a trained professional.

The data collected is for developing a size chart to improve the sizing and fit of South African women's ready-to-wear clothing. The study intends to provide relevant up-to-date petite female body dimensions, size information and also present statistical analysis on South African female anthropometric demographics in Gauteng (Johannesburg and Pretoria).

Please RSVP on the above-mentioned contact details

We are planning to arrange transport for female subjects who will need transport to and from the campus. Pick-up places will be prearranged at a central place best suited for the majority of subjects situated in a specific area**.**

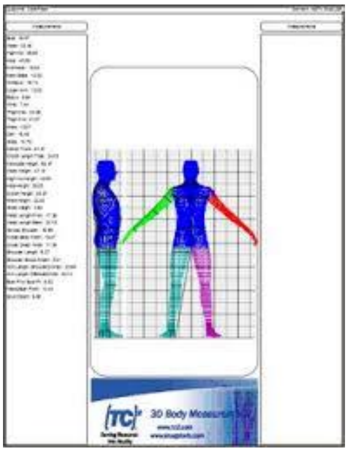
Scanning will take place on the Science Campus in Florida, Roodepoort in Block B, Room 249. We have obtained permission from SENRIC and Ethical clearance to conduct this study.

To view a video clip of the scanning process, click on the following link:

http://www.tc2.com/index_3dbodyscan.html.

Below, see an example of the 3D full Body scanner and the output. The output gives out information on your body measurements and shape analysis. We will also give you guidance information on how to dress for your body shape.

Example of the scanning machine



Example of the data output

Please complete the consent and demographic form beforehand if possible. REMEMBER to bring the Consent and the Demographic form with you. The scanning will take place from 9am until 3pm.

Should you have any inquiries please contact me on the contact details provided above.

Kind Regards

Marion Phasha

(Masters Student- Department of Life and Consumer Science**)**

UNISA university of south africa

APPENDIX B: CONSENT FORM

TITLE OF RESEARCH PROJECT: EVALUATING GARMENT SIZING AND FIT FOR PETITE WOMEN USING 3D BODY SCANNED ANTHROPOMETRIC DATA.

Dear Respondent

South Africa has varied female consumers with different body shapes and proportions. The purpose of this study is to conduct a petite female sizing and fit study to identify their varied body dimensions with the aim of acquiring accurate and up-to-date data using a 3D full body scanner and a tape measure measurement for developing a petite women's size chart. You are therefore kindly requested to give your input by answering the questionnaire and grant permission to be scanned and measured.

Your participation is voluntary. You have the right to be a part of the study, choose not to participate or to stop participating at any time without penalty. There are no right or wrong answers. The information you will provide will strictly remain confidential and anonymous, it will only be used for research purposes.

You will not directly benefit by participating in the study, however this study will indirectly benefit you as a participant in the form of providing information that can be used to improve the sizing and fit of petite women's clothing.

If you have any questions at any time about the study, you may contact the researcher at the email phashamarion@gmail.com or my supervisor at pandak@unisa.ac.za .

CONSENT

I, have read the above information relating to the research and have also heard the verbal version, and declare that I understand it.

Signature of participant..

Signed at …………………………………….. on ……………………………………………….

WITNESSES

1 ....

2 ....

APPENDIX C: ETHICAL CLEARANCE LETTER

UNISA university of south africa

CAES RESEARCH ETHICS REVIEW COMMITTEE

Date: 26/11/2015

Ref #: **2015/CAES/116**
Name of applicant: **Ms MM Phasha**
Student #: **54178924**

Dear Ms Phasha,

Decision: Ethics Approval

Proposal: Evaluation of garment sizing and fit: Petite females using 3D body scanned and manually measured anthropometric data

Supervisor: Ms K Pandarum

Qualification: Postgraduate degree

Thank you for the application for research ethics clearance by the CAES Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the project.

Please note point 4 below for further action.

The application was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Research Ethics Review Committee on 26 November 2015.

The proposed research may now commence with the proviso that:

1) *The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.*
2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Research Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable*

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.

4) *There is a new consent form available on the college website that the researcher must use. The various sections must be populated with the particulars of the project and submitted to the Committee.*

Note:

The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the CAES RERC.

Kind regards,

Signature
CAES RERC Chair: Prof EL Kempen

Signature
CAES Executive Dean: Prof MJ Linington

Note conditions

Approval template 2014

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

APPENDIX D: DATA COLLECTING DEMOGRAPHIC AND PSYCHOGRAPHIC QUESTIONNAIRE FOR PETITE WOMEN'S SIZING AND FIT STUDY

For office use only	
Date:	
Scan Reference No:	Sf:

A. DEMOGRAPHIC INFORMATION

Please complete Sections A – E of this form BY TICKING MARKING THE RELEVANT BOX WITH AN'X' ORENCIRCLING OR ENCIRCLING YOUR CHOICE. NOTE that the information that is provided will be treated as strictly confidential.

1. **Date of birth:** YYYY/MM/DD

2. **Marital Status:**

1	2	3	4	5	6	7	8
Single	Married	Divorced	Separated	Widowed	Living Together	Traditional Marriage	Other Specify:

3. **Ethnic Group:**

1	2	3	4
African	Coloured	Indian	White

4. **Highest Level of Education:**

1	2	3	4	5	6
None	Primary School	Std. 6-9/ Gr. 8-11	Std. 10/ Gr. 12 (Matric)	Undergraduate Tertiary Education	Postgraduate Tertiary Education

5. **Place of residence:**

1	2	3
Pretoria	Johannesburg	Other/state the city

B. MARKETING INFORMATION

The following questions are related to your choice of clothes. Please choose one from the option/s below.

6. How do you usually purchase your clothes? Please encircle the relevant option(s).

1) Physically going to the shops
2) Through catalogues
3) Through internet/online shopping
4) Other(s) please specify:…..

7. In the space next to the ready-to-wear garment listed below, please indicate the retail outlet (from the retail outlets listed above) you think supplies garments that provide the best fit for your body.

Retail outlet(s)	
Zara	1
Topshop	2
Truworths	3
Woolworths	4
Edgars	5
Identity	6
Legit	7
Mr Price	8
Other(s) Please specify:	9

8. From which section in a retail store do you normally purchase your garments? Please encircle the relevant option.

1) The average women's section
2) The petite women's section
3) The plus-size women's section
4) The kiddies section/ children's department
5) Other(s) please specify: …..

C. GARMENT SIZING AND FIT

The following questions are related to your experiences and preferences when sizing and fitting garments. Please answer all the questions.

9. Do you have concerns with ready-to-wear clothing that is currently being sold at retail outlets in South Africa? Please encircle the relevant number.

YES	1	NO	2

If yes, please specify your concerns by encircling the relevant number. Give a brief explanation if you have encircled 1, 2 and 3.

	1	2	3	If you have indicated a problem, please give
1) **Neckline**	Too	Too low	No problem	
2) **Collar**	Too	Too	No problem	
3) **Across shoulders**	Too tight	Too loose	No problem	
4) **Across back**	Too	Too	No problem	
5) **Across bust**	Too	Too	No problem	
6) **Around waist**	Too	Too	No problem	
7) **Around hips**	Too	Too	No problem	
8) **Sleeve - Around upper arm**	Too tight	Too loose	No problem	
9) **Sleeve length**	Too	Too	No problem	
10) **Garment length**	Too short	Too long	No problem	
11) **Skirts- Around waist**	Too tight	Too loose	No problem	
12) **Skirts – Around hips**	Too tight	Too loose	No problem	
13) **Skirts – Around thighs**	Too tight	Too loose	No problem	
14) **Skirts- Length of skirt**	Too short	Too long	No problem	
15) **Trouser- Around lower waist**	Too tight	Too loose	No problem	

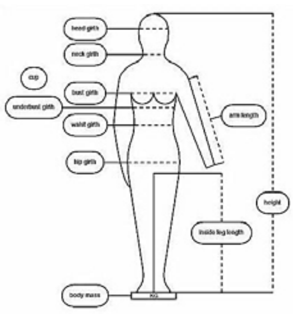
Continued on the next page

16) **Trouser – Around hips**	Too tight	Too loose	No problem	
17) **Trouser – Around thighs**	Too tight	Too loose	No problem	
18) **Trouser – Crotch length**	Too short	Too long	No problem	
19) **Trouser – Length**	Too short	Too long	No problem	

10. Which of the options listed below do you consider to be a priority when purchasing your clothing from retail outlets? Please rate the options from 1 to 9 (in order of your preference) from the most important (1) to the least important (9)

Criteria	Your Rating (in order of preference from 1-9)
1) Price	
2) Garment sizing	
3) Fit	
4) Comfort	
5) Quality	
6) Appearance	
7) Garment brand name	
8) Style / Design	
9) Latest trends	
10) Other(s) Specify:	

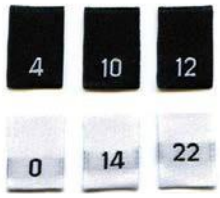
11. Which of the following information would you prefer to see on the garment label to guide you when purchasing clothing? Please encircle the most relevant number.



1) Model pictogram sizing **2) Hang tags**

SOURCES: http://www.mobilefish.com/services/en13402_pictogram/en13402_pictogram.php
https://www.pinterest.com/pin/367395282075730289/

Continued on the next page



3) Number size labels labelling

4) A l p h a b e t symbols size

SOURCES: http://www.allthingslabels.com/size-labels-size-tabs-s/40.htm
http://www.aliexpress.com/store/product/Clothes-trademark-size-signs-ca-design-standard-customized-hang-brand-production-woven- label-woven-printed-labels/318353_528150963.html

D. WOMEN"S CLOTHING

The following questions are related to your experiences and preferences when purchasing women's clothing. Please answer all the questions.

From the tables below choose the retail garment sizes(s) you would typically purchase in respect of each garment type that is indicated: Please encircle the relevant size (you may choose more than one size if applicable; If so, please write the garment type against the preferred size)

12. Women's shirts

Shirt sizes	
2/26	1
4/28	2
6/30	3
8/32	4
10/34	5
12/36	6
14/38	7
16/40	8
18/42	9
Other. Specify:	10

13. Women's trousers

Skirts/ trouser	
2/26	1
4/28	2
6/30	3
8/32	4
10/34	5
12/36	6
14/38	7
16/40	8
18/42	9
Other. Specify:	10

14. Do you select the same size garment/s at the different retail outlets? Please encircle the relevant number. (Here we are asking you if you are for example a size 10 in all clothing outlets/stores)

YES	1	NO	2

If no, can you please tell us why you think that this is so

……

……

15. Please rate the availability on the range of your garment sizes in retail outlets. Please encircle the number that is relevant to you below.

Excellent	1	Good	2	Average	3	Fair	4	Poor	5

Please tell us why you have chosen that particular option

……

……

16. Indicate your fit preferences for the garments listed below by encircling the relevant number that you prefer to wear.

Garment	Figure hugging	Close fitting	Semi-fitted	Loose fitting	Very loose fitting	Not applicable
1)**Shirts**	1	2	3	4	5	6
2) **Trousers**	1	2	3	4	5	6

17. What percentage of a retail-bought garment do you alter to fit properly? Please encircle the relevant number?

0%	1
Up to 25%	2
Up to 50%	3
Up to 75%	4
Up to 100%	5

E. BODY CATHEXIS AND SHAPES

The following questions are related to your perception of your body shape and proportions. Please answer all the questions.

18. On a scale of 1 to 5, where 1 *is extremely satisfied* and 5 *extremely dissatisfied,* please rate your satisfaction or dissatisfaction with your body parts by ticking the relevant column.

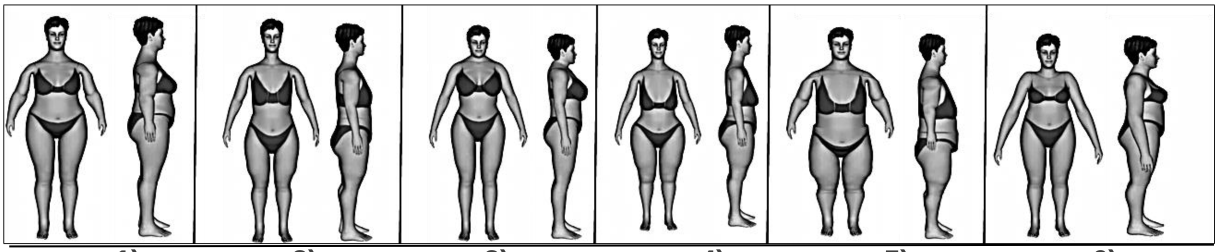
	1 Extremely Satisfied	2 Somewhat Satisfied	3 Satisfied	4 Mostly Dissatisfied	5 Extremely Dissatisfied
1) **Overall Height**					
2) **Overall Body weight**					
3) **Posture**					
4) **Head**					
5) **Upper body**					
6) **Lower body**					
7) **Face**					
8) **Neck**					
9) **Shoulder**					
10) **Arm length**					
11) **Upper arm girth**					

Continued on the next page

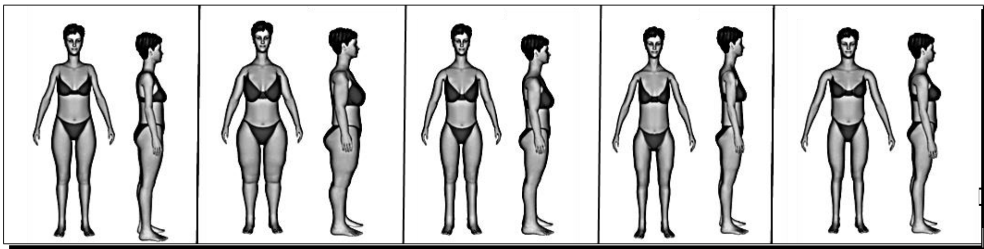
	1 Extremely Satisfied	2 Somewhat Satisfied	3 Satisfied	4 Mostly Dissatisfied	5 Extremely Dissatisfied
12) **Bust**					
13) **Upper waist**					
14) **Torso proportions**					
15) **Hips**					
16) **Thighs**					
17) **Knee**					
18) **Calves**					
19) **Legs**					
20) **Leg length**					
21) **Feet**					

19. Please look at the body shapes below and choose the one that best represents your body's silhouette.

Please encircle the relevant number.



1) **2)** **3)** **4)** **5)** **6)**



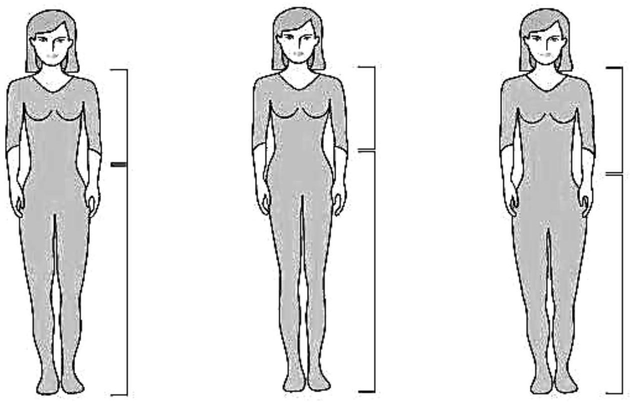
I DON'T KNOW

7) **8)** **9)** **10)** **11)** **12)**

Adapted from the Bernina MyLabel CAD programme using captured3D full body scans

20. Please look at the body shapes below and choose the one that best represents your body's proportions.

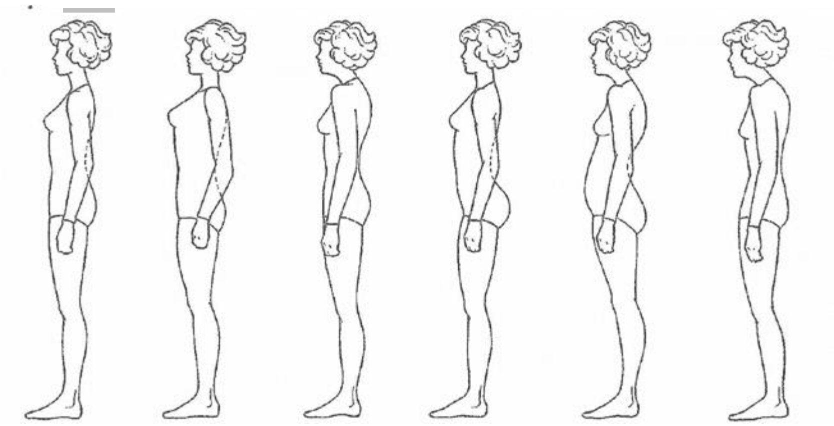
Please encircle the relevant number.



1) **2)** **3)**

Alterations Needed (2010)

21. Please look at the figure types below and choose the one that best represents your posture. Please encircle the relevant number.



1) **2)** **3)** **4)** **5)** **6)**

Liechty, Rasband and Pottberg-Steineckert (2010)

22. Any other comments that will assist us with this study:

…...

....

23. Will you be willing to assist us with the fit test evaluations of the garments developed from this study?

YES	1	NO	2

If yes, please provide us with your contact details below:

Telephone number:

…...

Cell number:

…...

Email address: …..

THANK YOU FOR TAKING PART IN THE STUDY.

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F. MANUAL ANTHROPOMETRIC MEASUREMENTS

The following measurements will be taken, using an Adams medical scale in kilograms (kg) and in centimetres (cm).

24. Weight (kg) | | | | |
25. Height (cm) | | | | |

26. **General comments**: Measurers comments on any factors which could have influenced measurements taken manually.

....

....

....

APPENDIX E: LETTER OF APPRECIATION

Department of Life
And Consumer Science
Private bag X6
Florida
South Africa
1710

Dear Subject/Participant

The Researcher would like to thank you for participating in this study, and as a token of my appreciation find attached, a colour copy of your scan with your body measurements. The analysed data will be used for post-graduate research within the Consumer Sciences Department at UNISA.

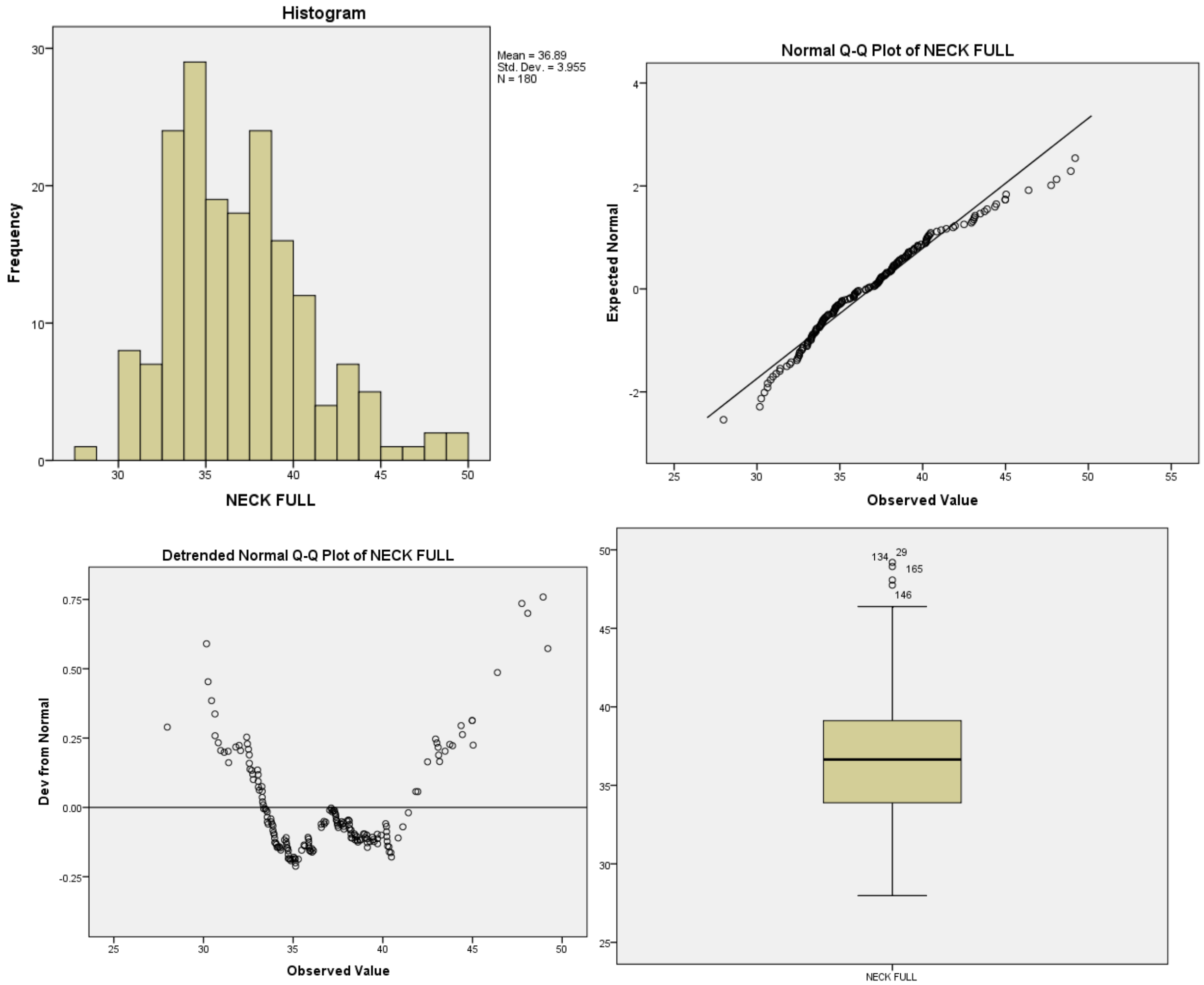
Kind Regards

Marion Phasha

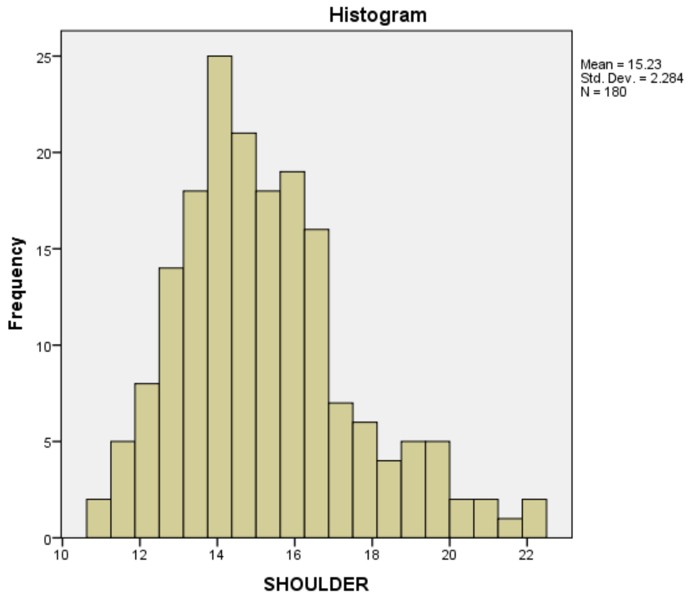
(Consumer Science Research Masters student)

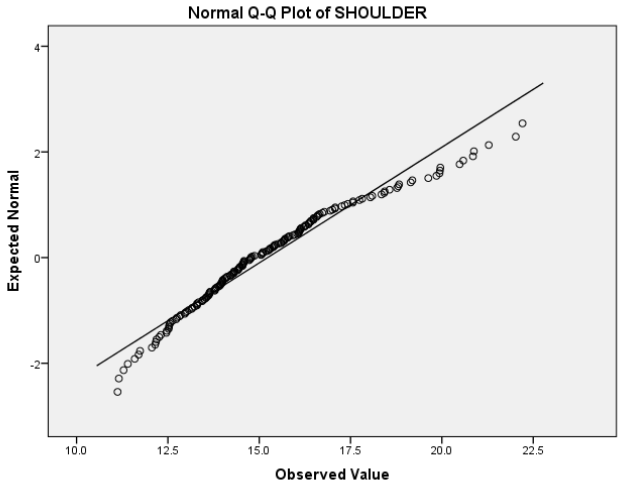
APPENDIX F: EXAMPLES OF THE BOX PLOTS, HISTOGRAMS AND DATA DISTRIBUTIONS OF THE 3D FULL BODY SCANNED PETITE SUBJECTS' UPPER PEAR BODY DIMENSIONS

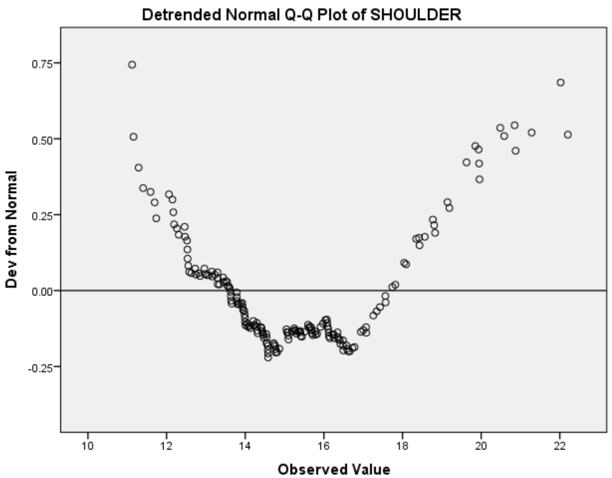
NECK FULL

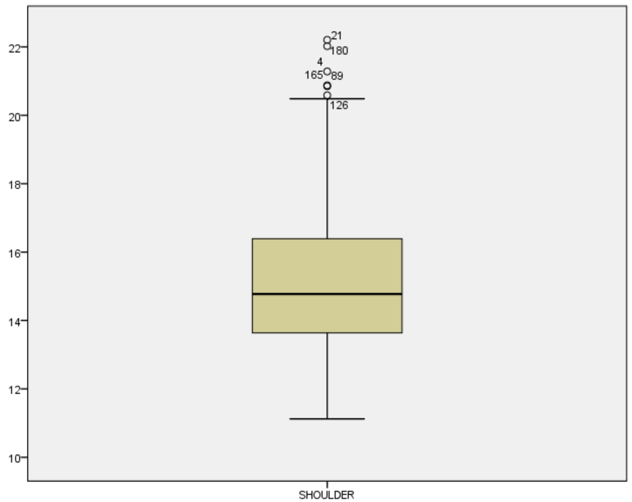


SHOULDER

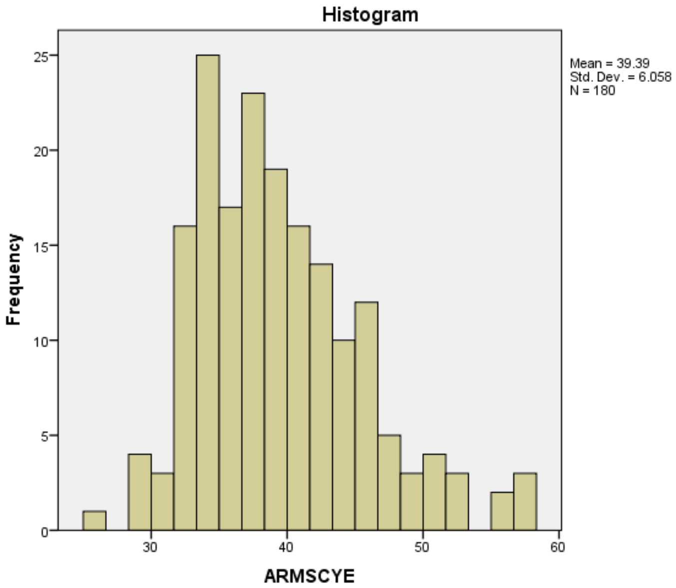

Histogram
Mean = 15.23
Std. Dev. = 2.284
N = 180
Frequency
SHOULDER

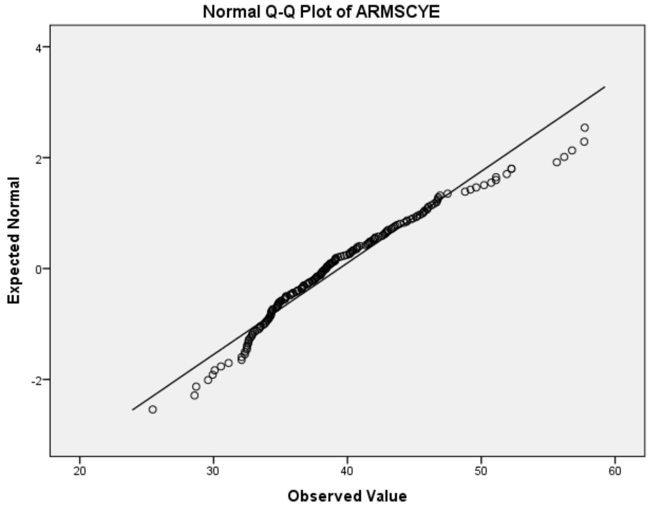

Normal Q-Q Plot of SHOULDER
Expected Normal
Observed Value

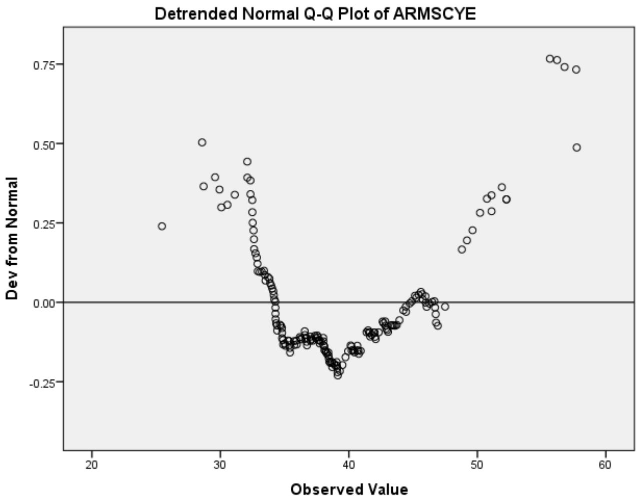

Detrended Normal Q-Q Plot of SHOULDER
Dev from Normal
Observed Value

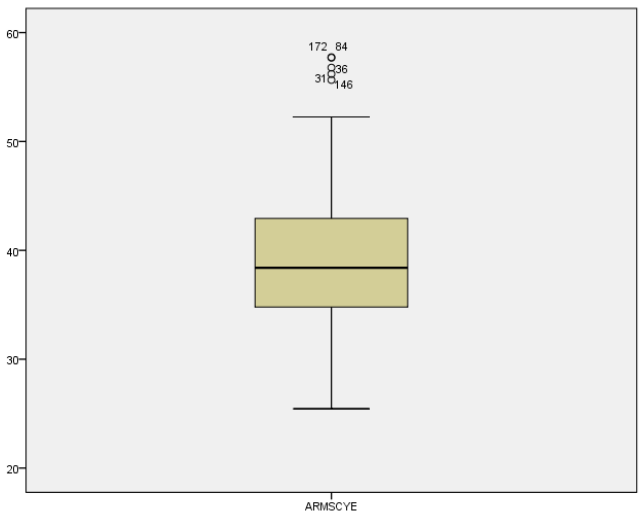

21
180
4
165
89
126
SHOULDER

ARMSCYE

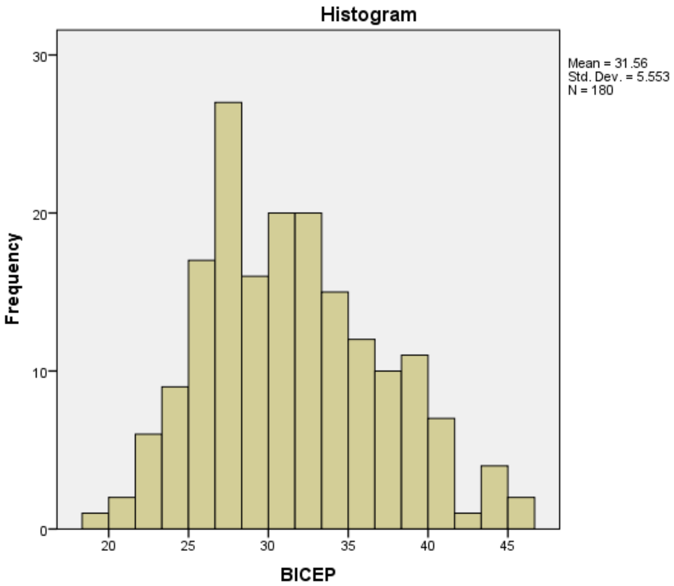

Histogram
Mean = 39.39
Std. Dev. = 6.058
N = 180
Frequency
ARMSCYE

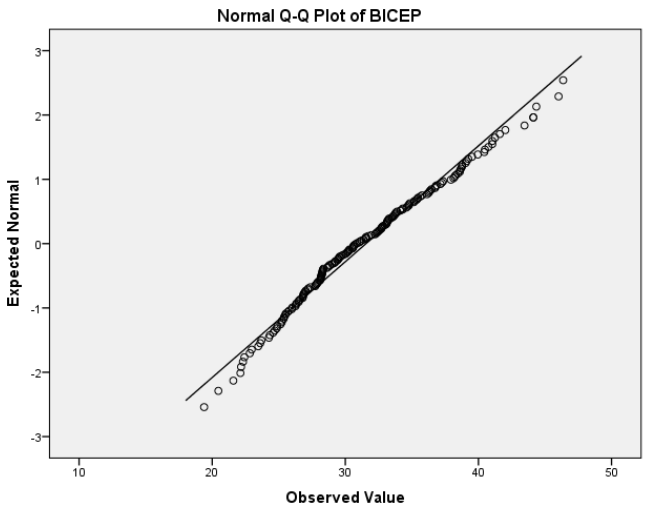

Normal Q-Q Plot of ARMSCYE
Expected Normal
Observed Value

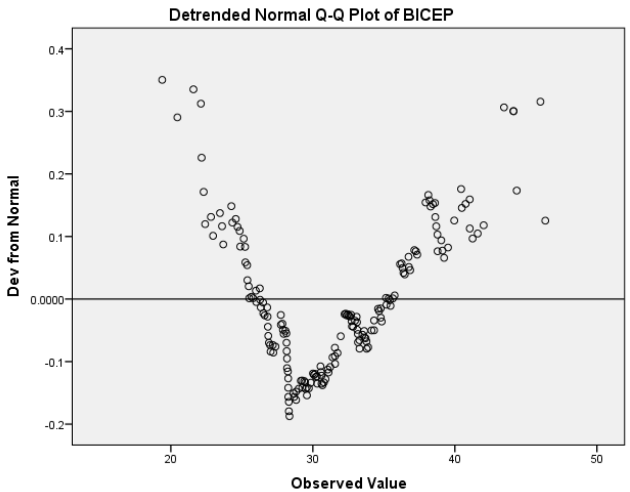

Detrended Normal Q-Q Plot of ARMSCYE
Dev from Normal
Observed Value

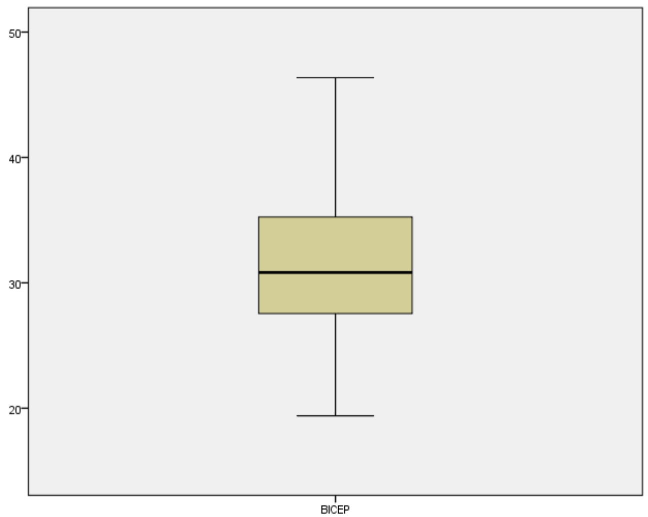

172
84
36
31
146
ARMSCYE

BICEP

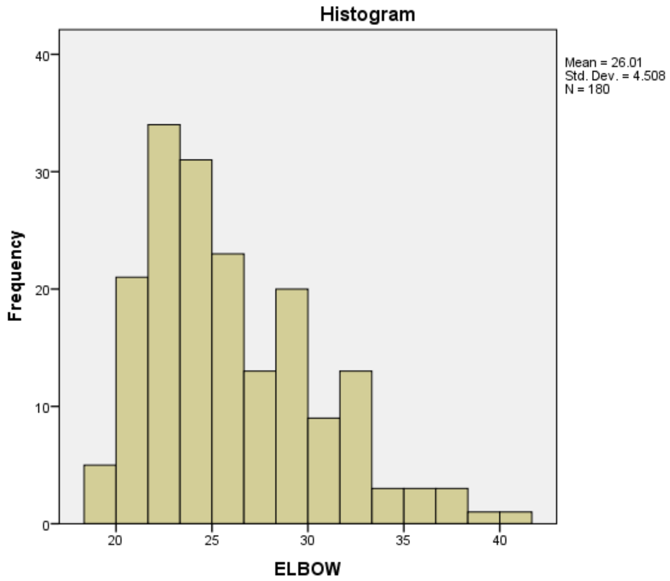

Histogram
Mean = 31.56
Std. Dev. = 5.553
N = 180
Frequency
30
20
10
0
20
25
30
35
40
45
BICEP


Normal Q-Q Plot of BICEP
Expected Normal
3
2
1
0
-1
-2
-3
10
20
30
40
50
Observed Value

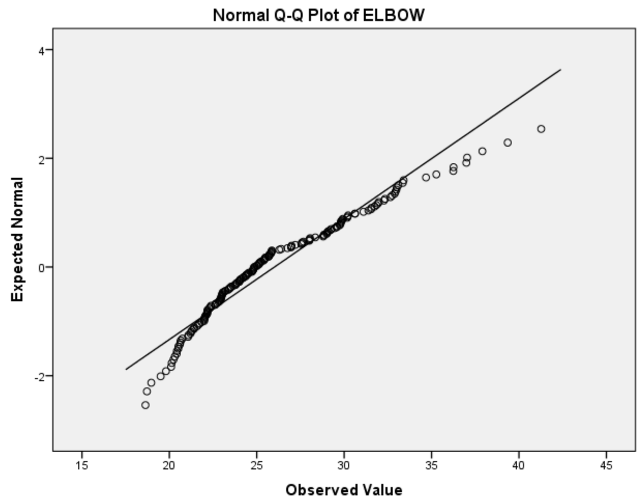

Detrended Normal Q-Q Plot of BICEP
Dev from Normal
0.4
0.3
0.2
0.1
0.0000
-0.1
-0.2
20
30
40
50
Observed Value


50
40
30
20
BICEP

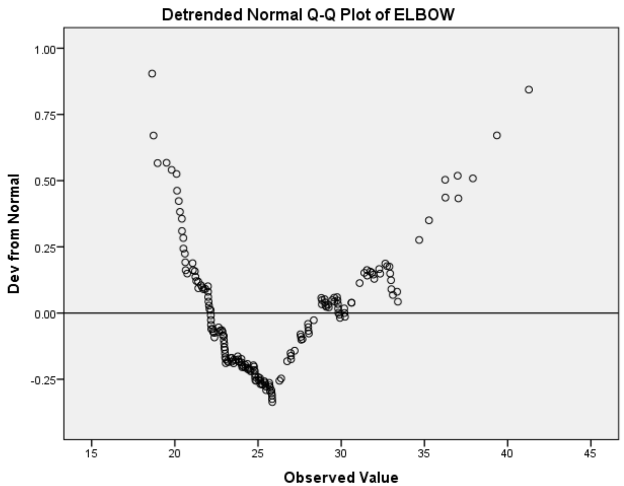
ELBOW



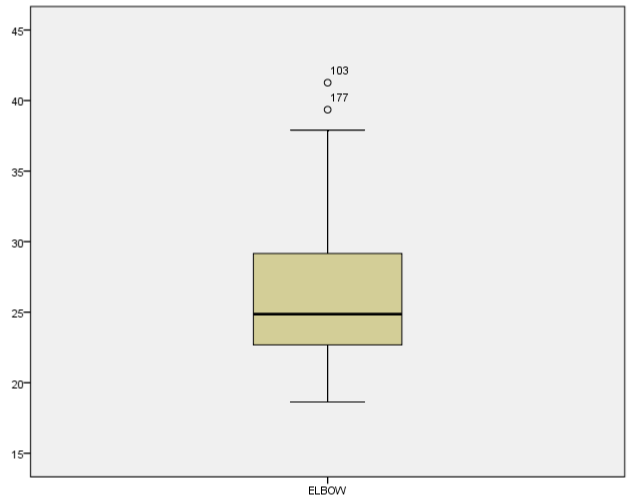
Histogram
Mean = 26.01
Std. Dev. = 4.508
N = 180
Frequency
ELBOW



Normal Q-Q Plot of ELBOW
Expected Normal
Observed Value

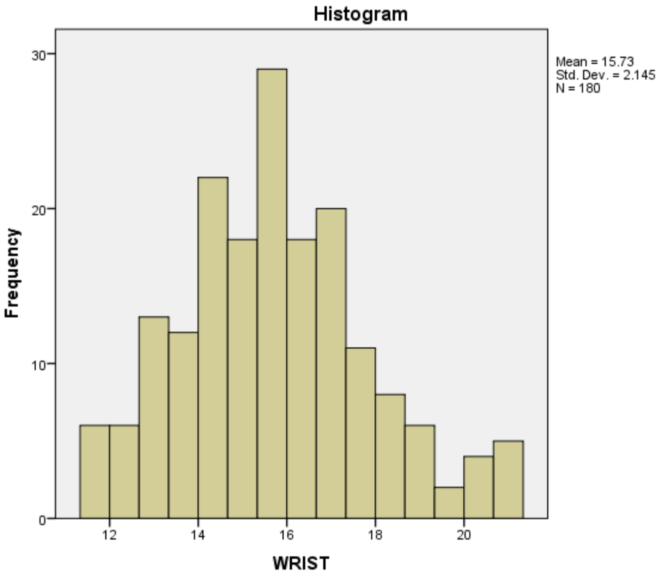


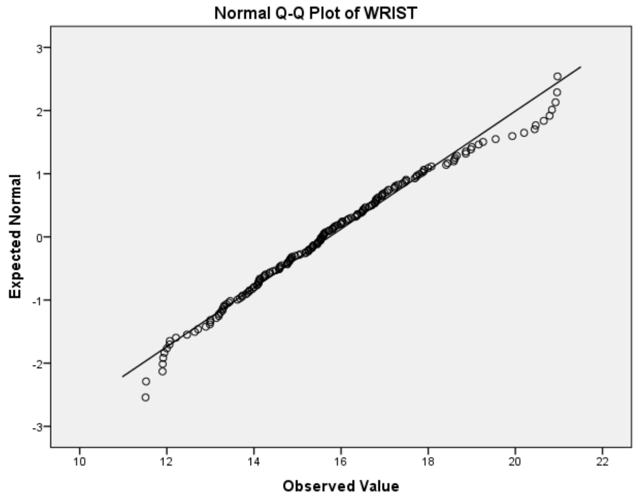
Detrended Normal Q-Q Plot of ELBOW
Dev from Normal
Observed Value

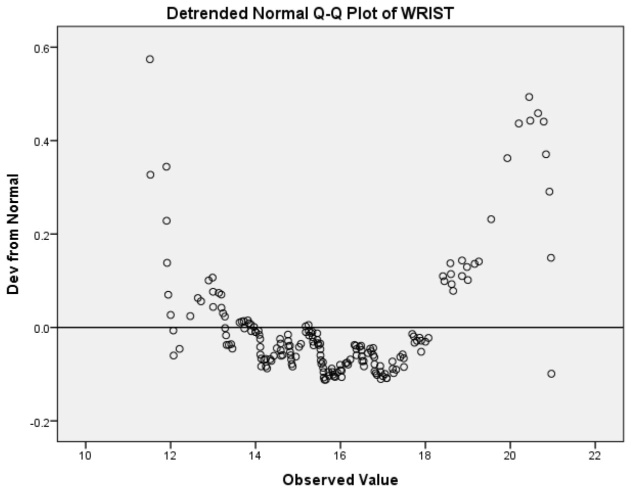


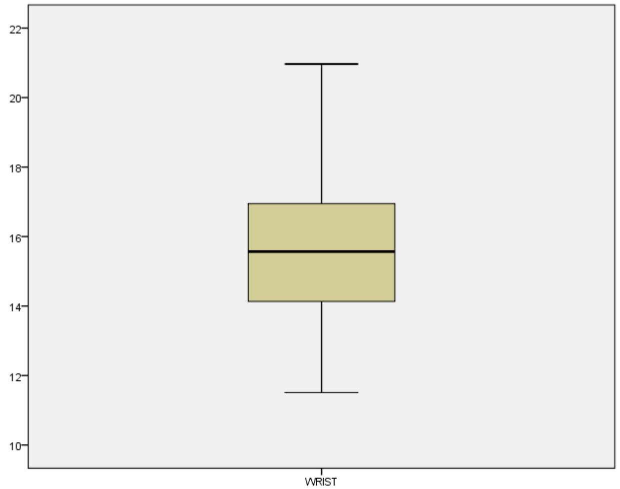
103
177
ELBOW

WRIST

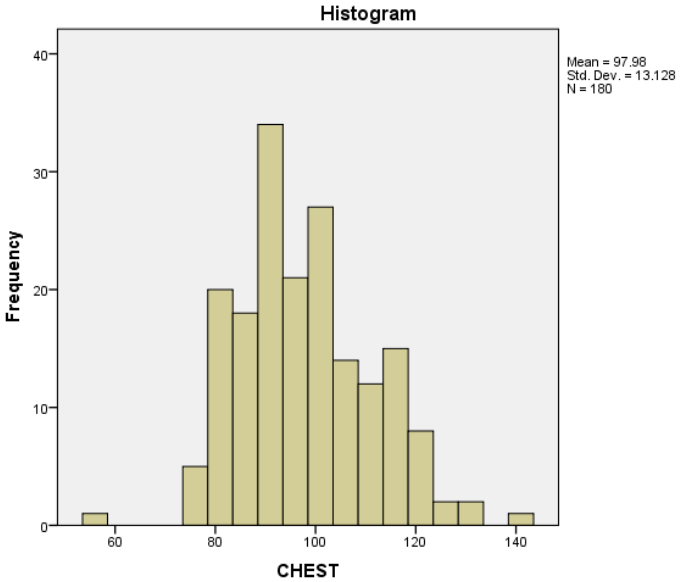

Histogram
Mean = 15.73
Std. Dev. = 2.145
N = 180
Frequency
WRIST


Normal Q-Q Plot of WRIST
Expected Normal
Observed Value

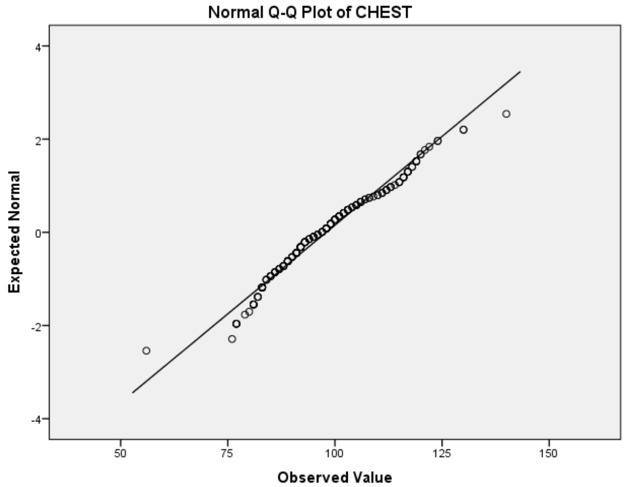

Detrended Normal Q-Q Plot of WRIST
Dev from Normal
Observed Value


WRIST

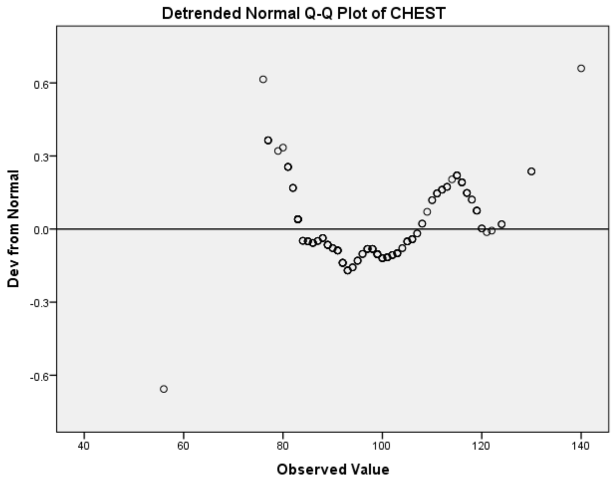
CHEST



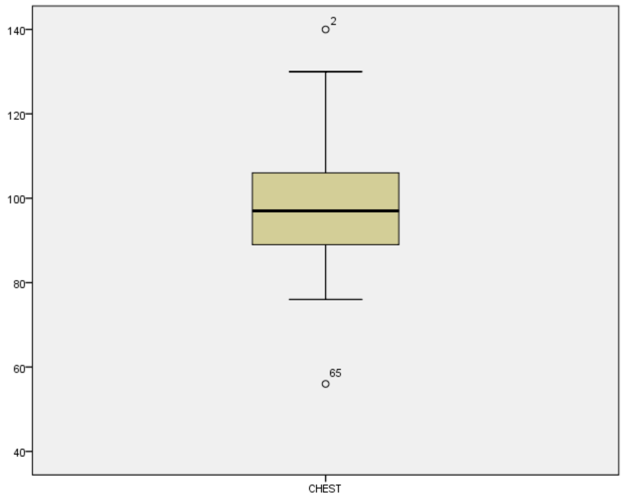
Histogram
Mean = 97.98
Std. Dev. = 13.128
N = 180
Frequency
CHEST



Normal Q-Q Plot of CHEST
Expected Normal
Observed Value

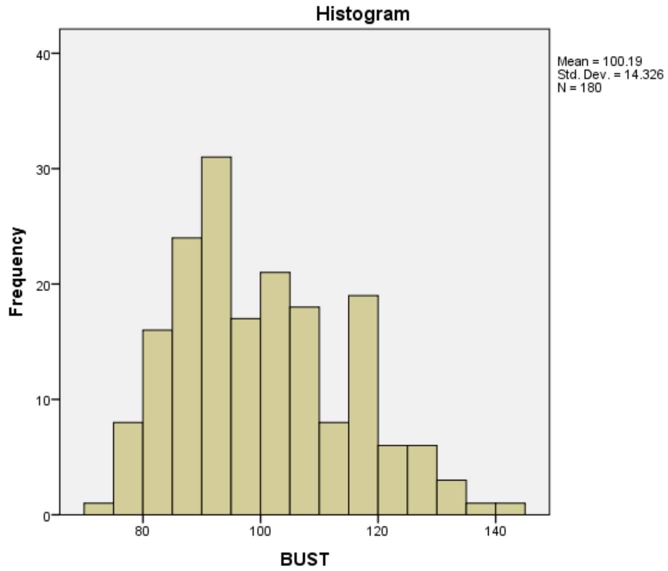


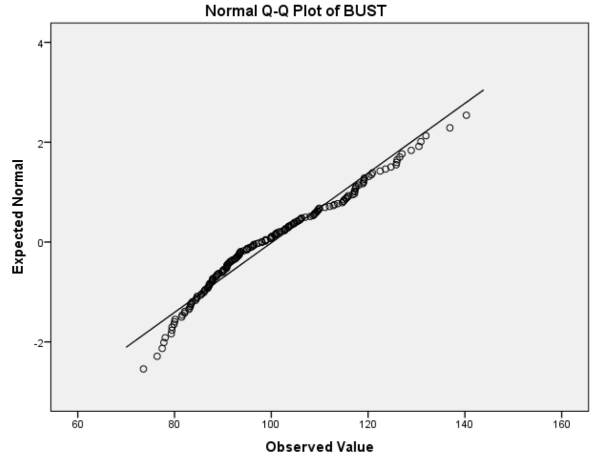
Detrended Normal Q-Q Plot of CHEST
Dev from Normal
Observed Value

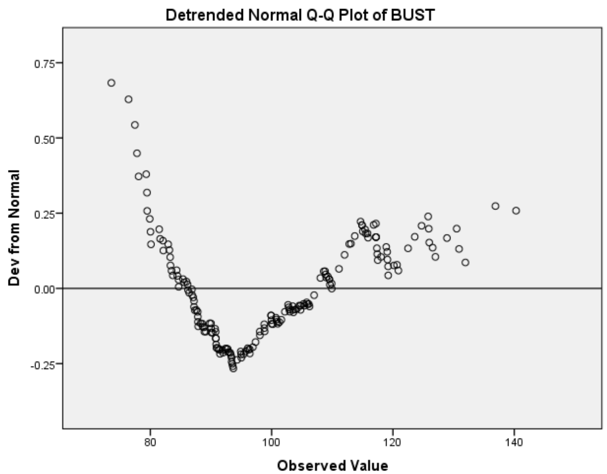


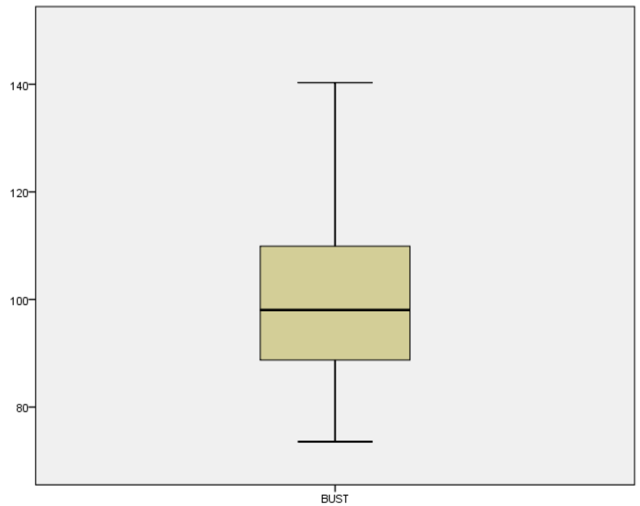
2
65
CHEST

BUST

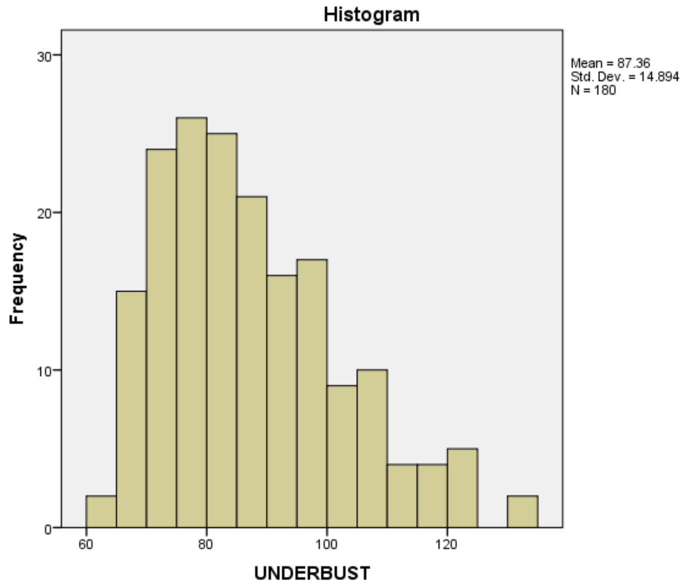

Histogram
Mean = 100.19
Std. Dev. = 14.326
N = 180
Frequency
BUST

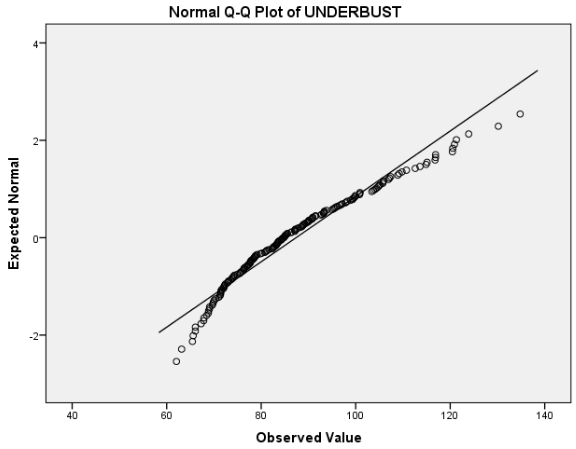

Normal Q-Q Plot of BUST
Expected Normal
Observed Value

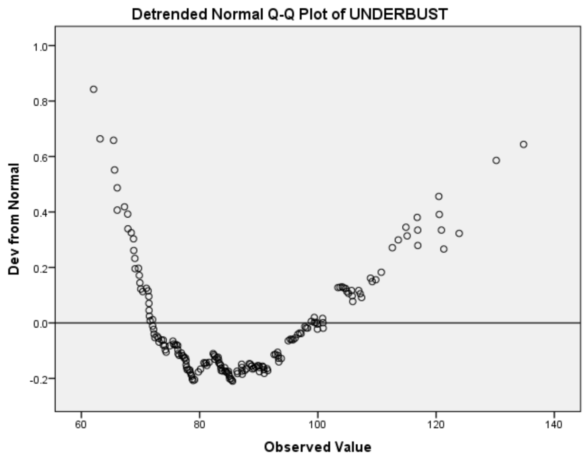

Detrended Normal Q-Q Plot of BUST
Dev from Normal
Observed Value

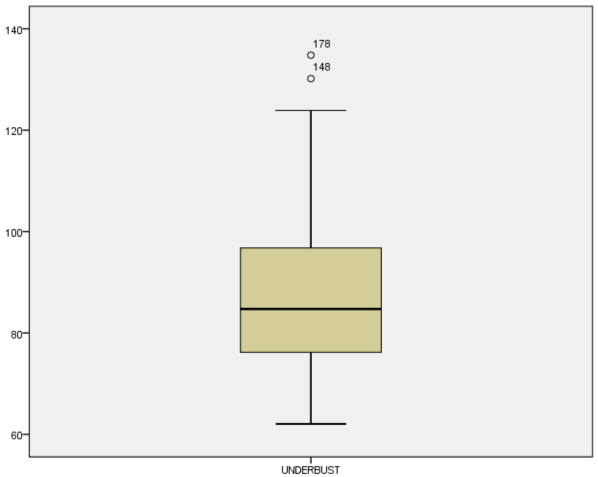

BUST

UNDERBUST

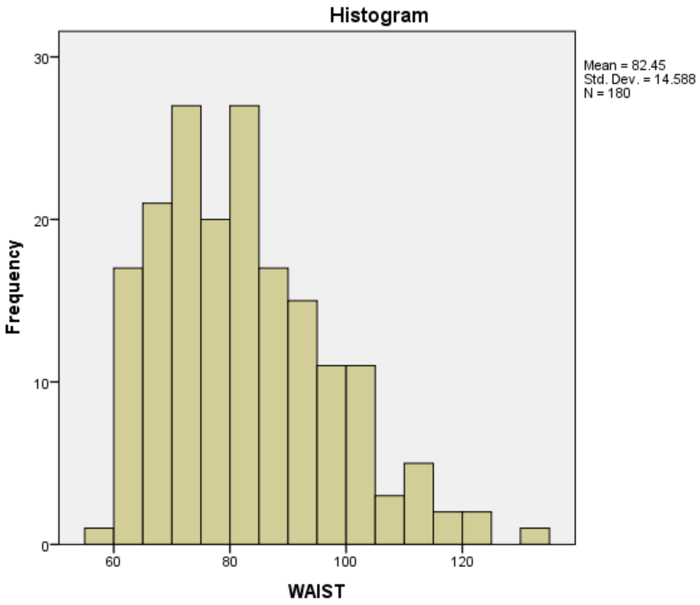

Histogram
Mean = 87.36
Std. Dev. = 14.894
N = 180
Frequency
30
20
10
0
60
80
100
120
UNDERBUST

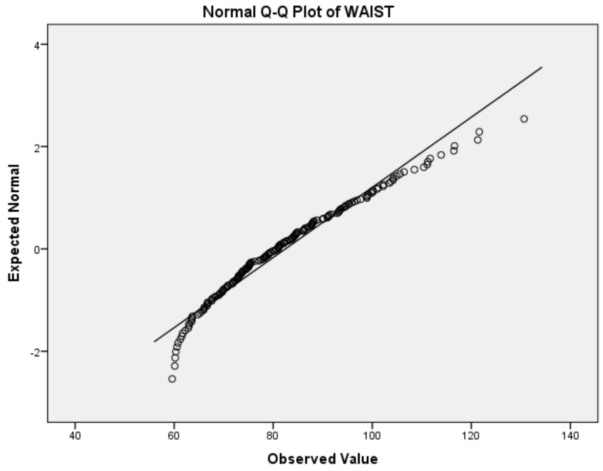

Normal Q-Q Plot of UNDERBUST
Expected Normal
4
2
0
-2
40
60
80
100
120
140
Observed Value

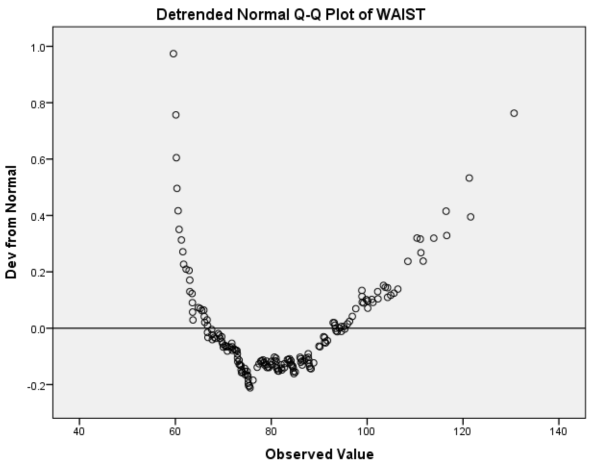

Detrended Normal Q-Q Plot of UNDERBUST
Dev from Normal
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
60
80
100
120
140
Observed Value

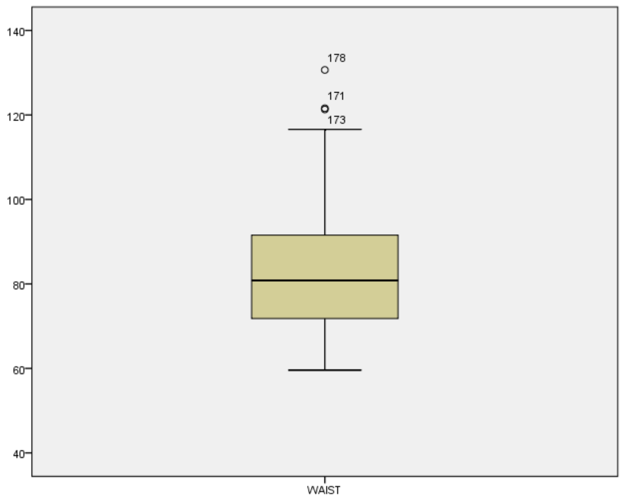

140
120
100
80
60
178
148
UNDERBUST

UPPER WAIST

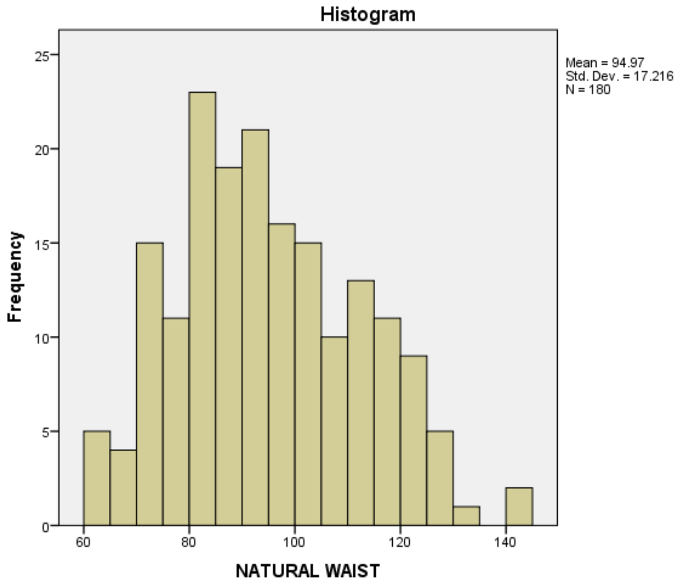

Histogram
Mean = 82.45
Std. Dev. = 14.588
N = 180
Frequency
WAIST
30
20
10
0
60
80
100
120


Normal Q-Q Plot of WAIST
Expected Normal
Observed Value

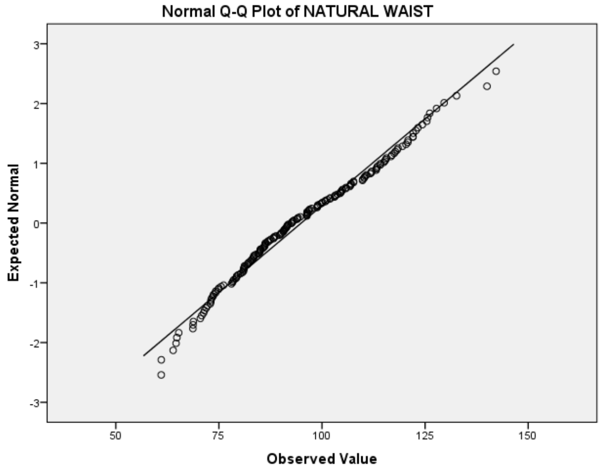

Detrended Normal Q-Q Plot of WAIST
Dev from Normal
Observed Value


178
171
173
WAIST

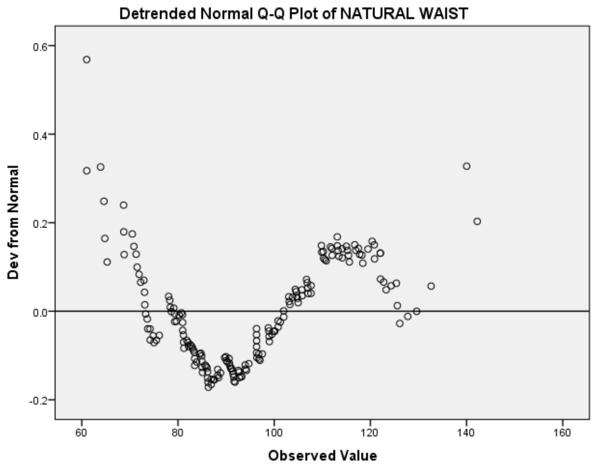
LOWER WAIST



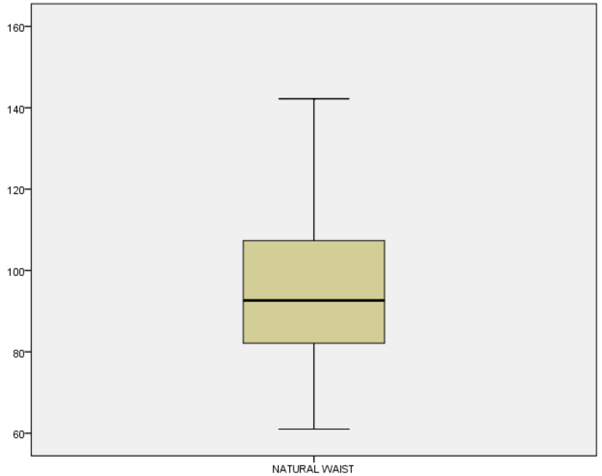
Histogram
Mean = 94.97
Std. Dev. = 17.216
N = 180
Frequency
NATURAL WAIST



Normal Q-Q Plot of NATURAL WAIST
Expected Normal
Observed Value

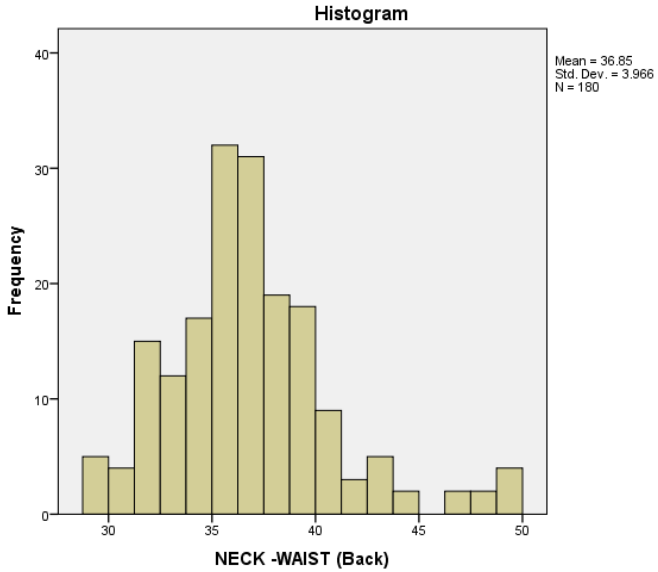


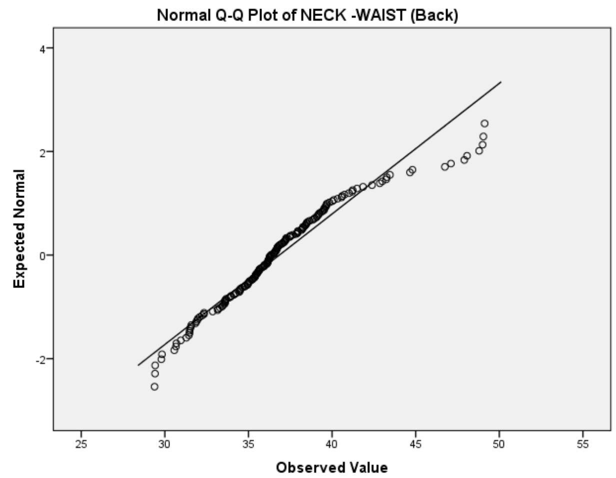
Detrended Normal Q-Q Plot of NATURAL WAIST
Dev from Normal
Observed Value

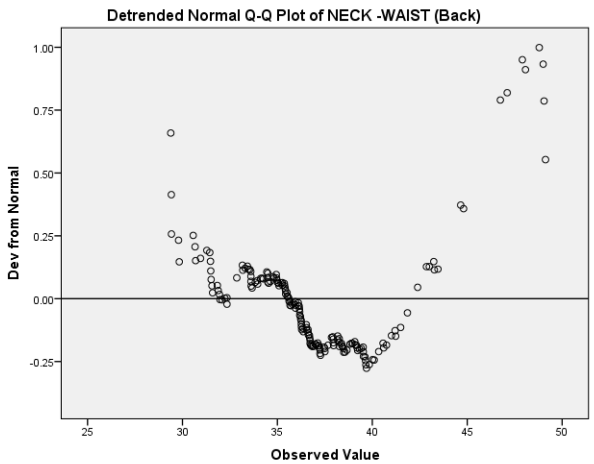


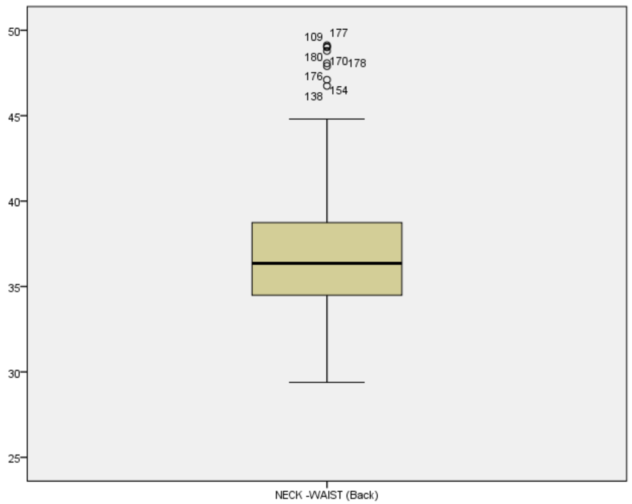
NATURAL WAIST

NECK to UPPER WAIST (Back)

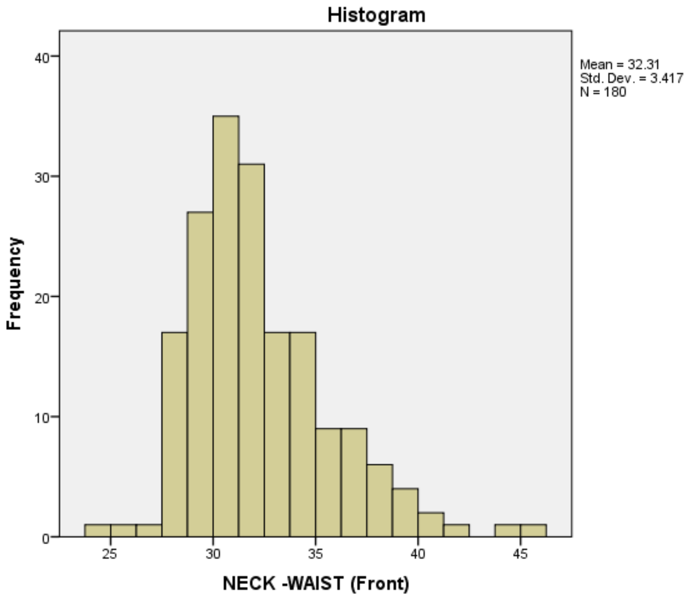


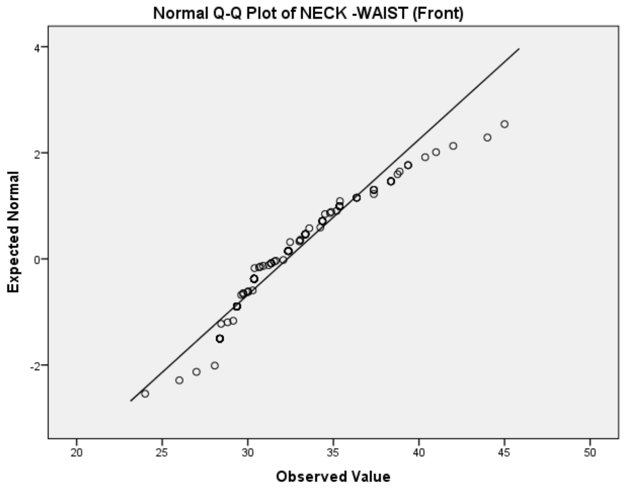


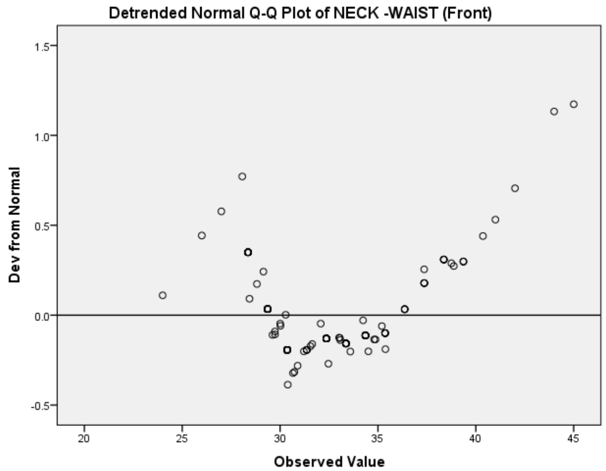


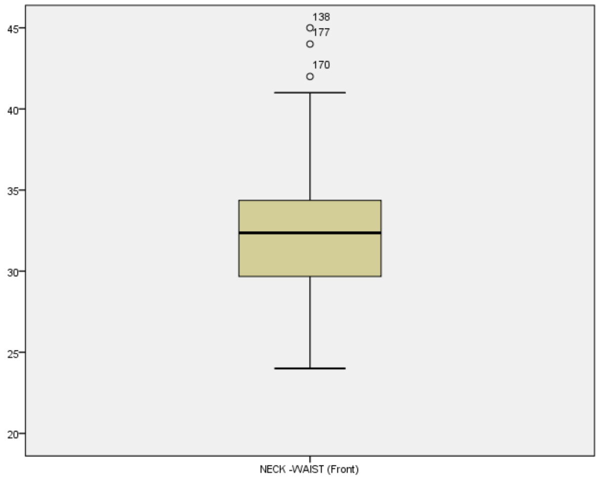


NECK to UPPER WAIST (Front)

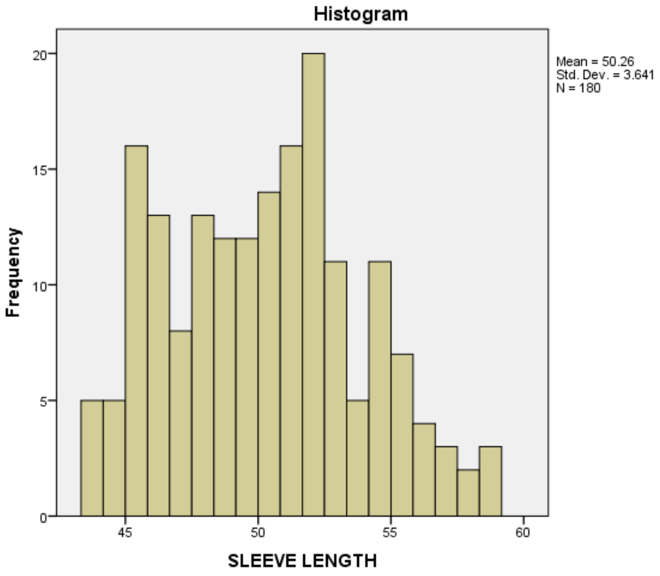


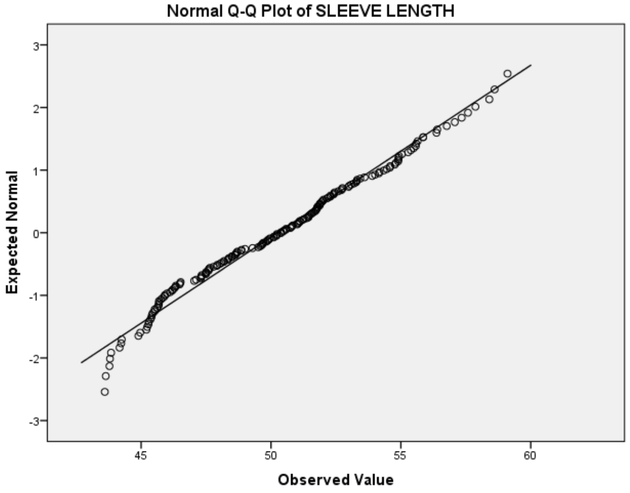


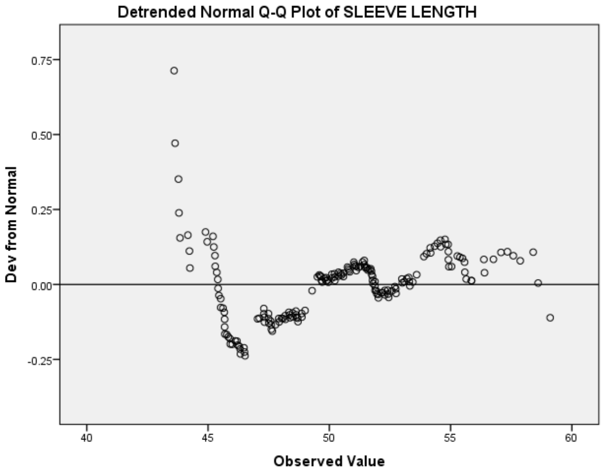


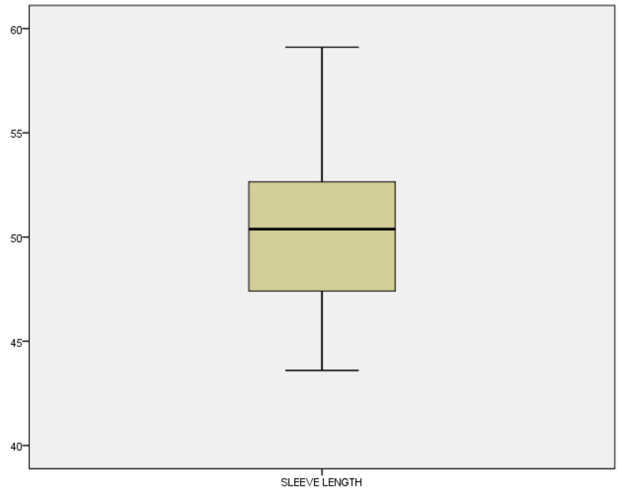


SLEEVE LENGTH



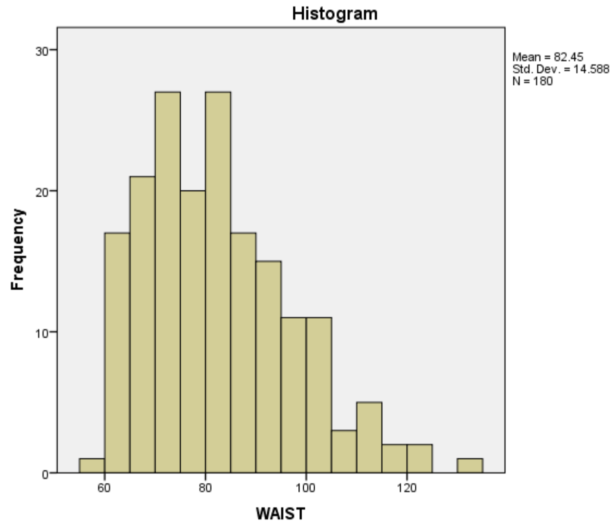


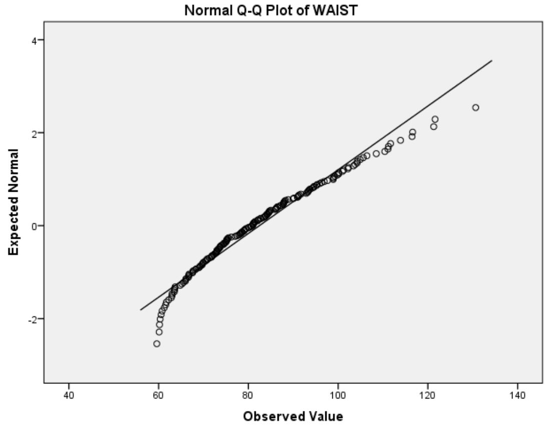


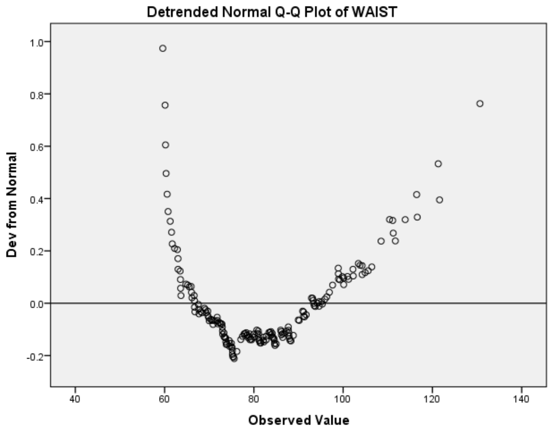


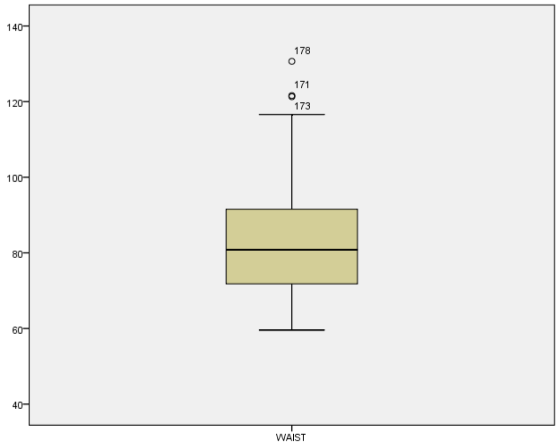
APPENDIX G: EXAMPLES OF THE BOX PLOTS, HISTOGRAMS AND DATA DISTRIBUTIONS OF THE 3D FULL BODY SCANNED PETITE SUBJECTS' LOWER PEAR BODY DIMENSIONS

UPPER WAIST

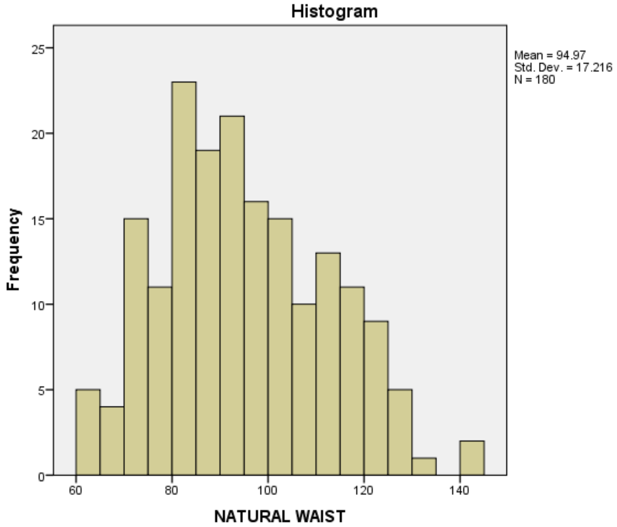


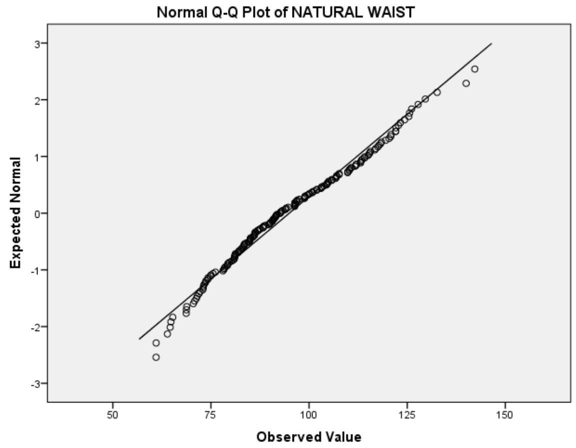


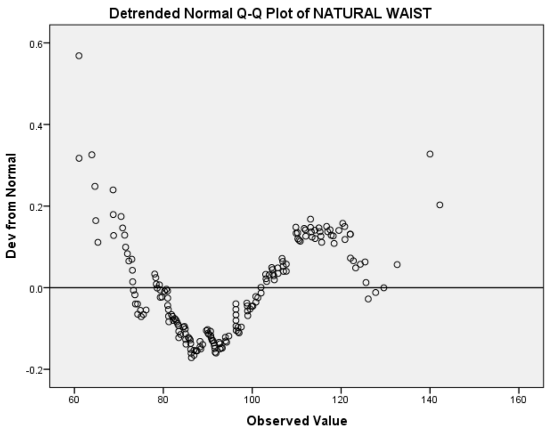


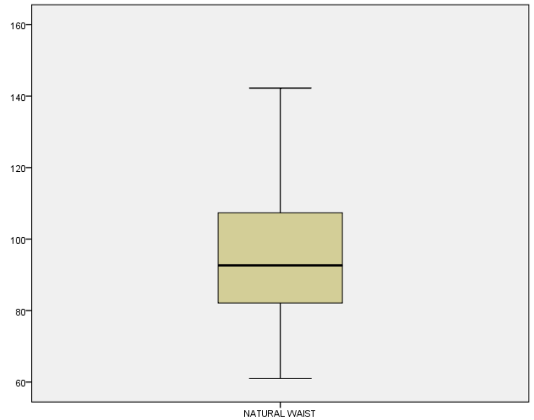


LOWER WAIST

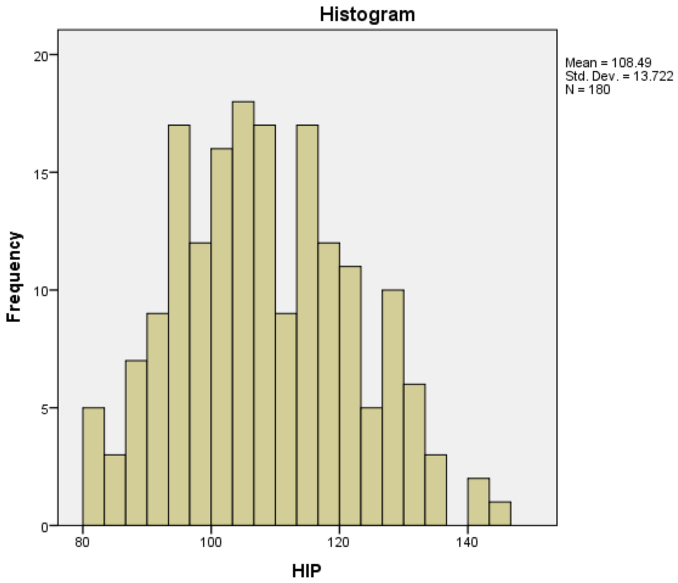

Histogram
Mean = 94.97
Std. Dev. = 17.216
N = 180
Frequency
NATURAL WAIST


Normal Q-Q Plot of NATURAL WAIST
Expected Normal
Observed Value

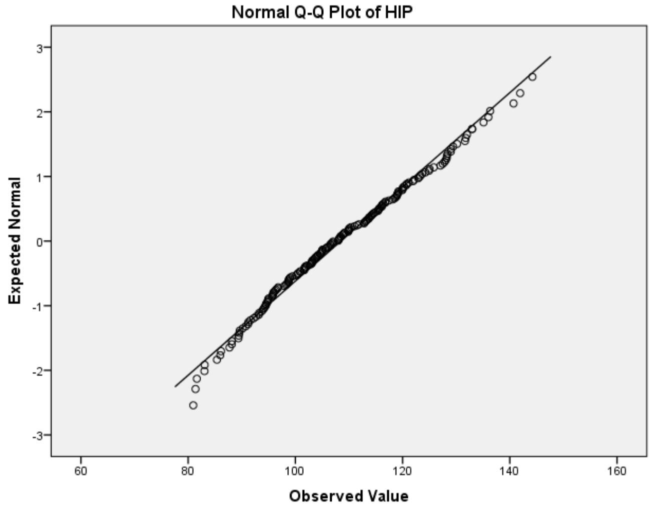

Detrended Normal Q-Q Plot of NATURAL WAIST
Dev from Normal
Observed Value


NATURAL WAIST

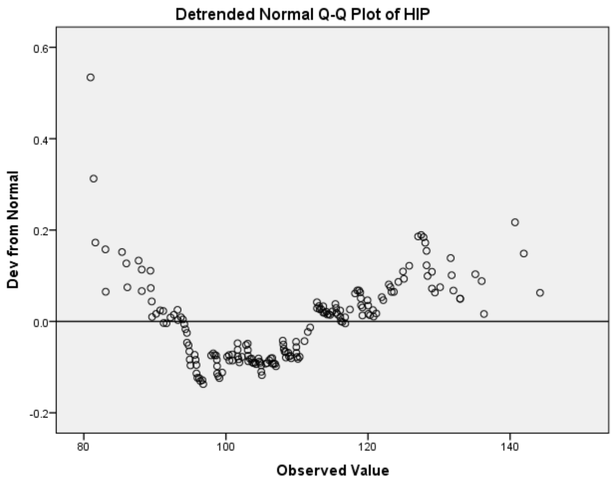
HIP



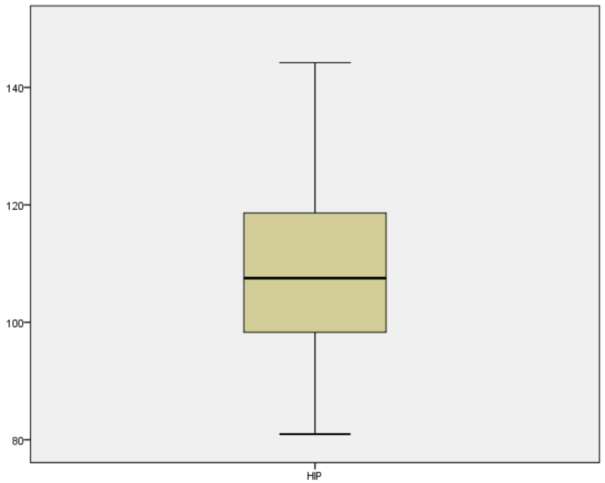
Histogram
Mean = 108.49
Std. Dev. = 13.722
N = 180
Frequency
HIP



Normal Q-Q Plot of HIP
Expected Normal
Observed Value

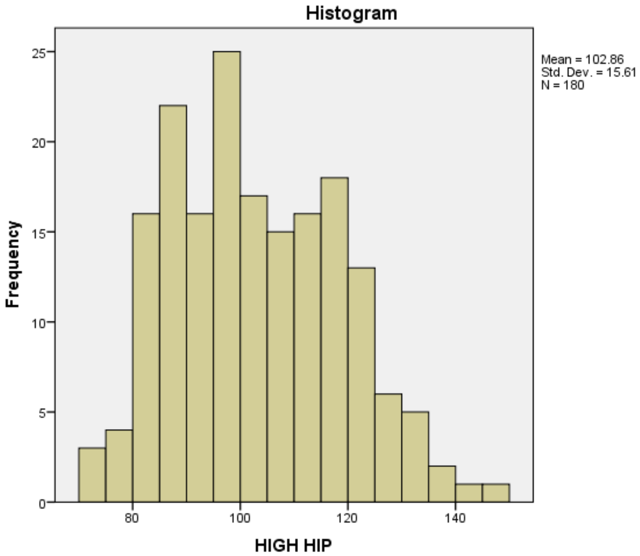


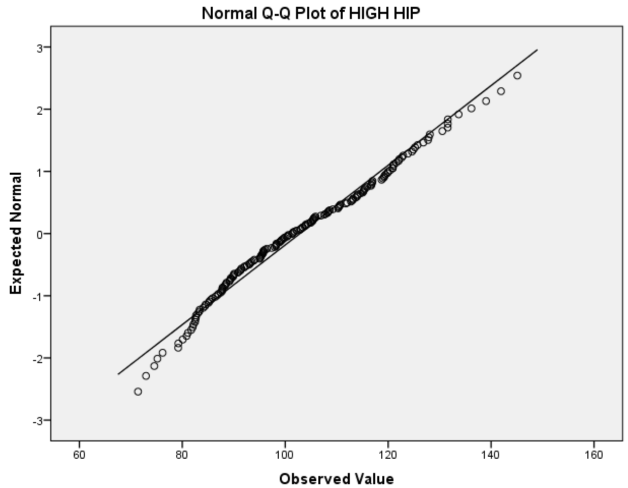
Detrended Normal Q-Q Plot of HIP
Dev from Normal
Observed Value

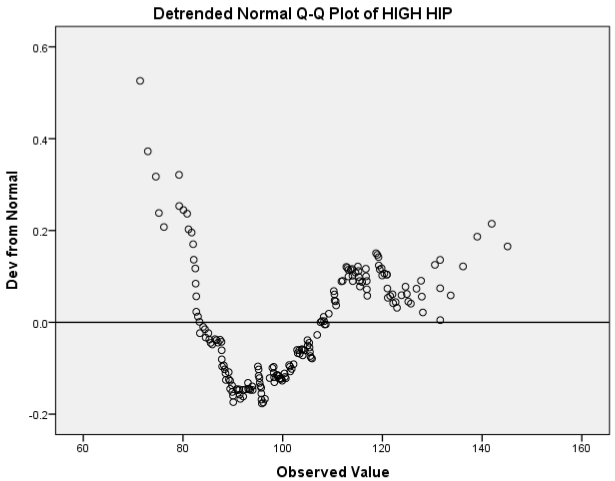


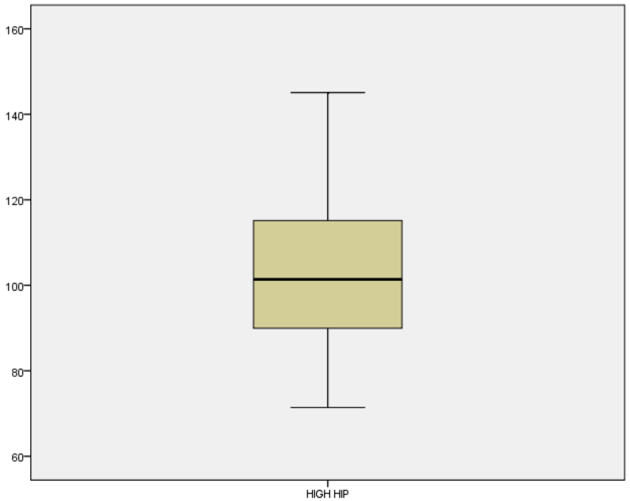
HIP

HIGH HIP

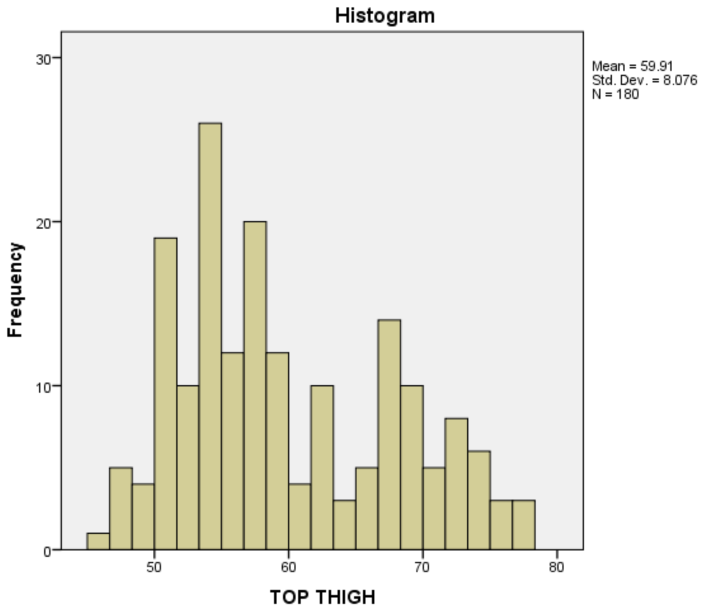

Histogram
Mean = 102.86
Std. Dev. = 15.61
N = 180
Frequency
HIGH HIP

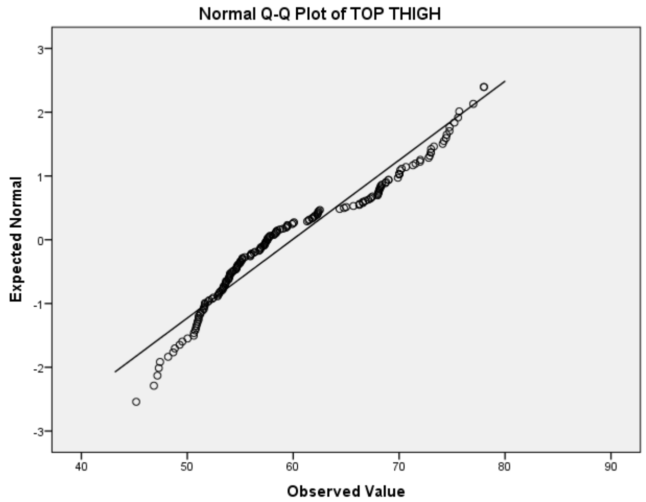

Normal Q-Q Plot of HIGH HIP
Expected Normal
Observed Value

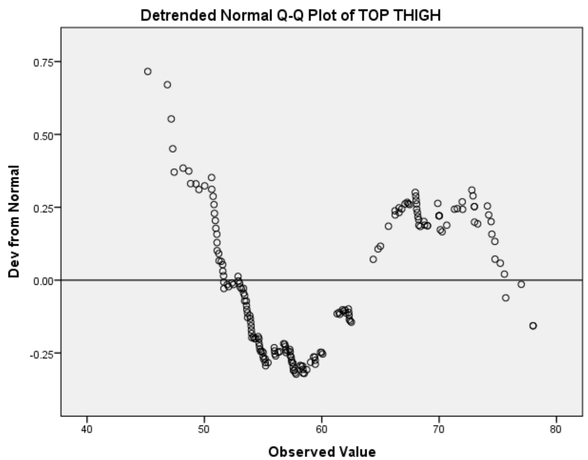

Detrended Normal Q-Q Plot of HIGH HIP
Dev from Normal
Observed Value

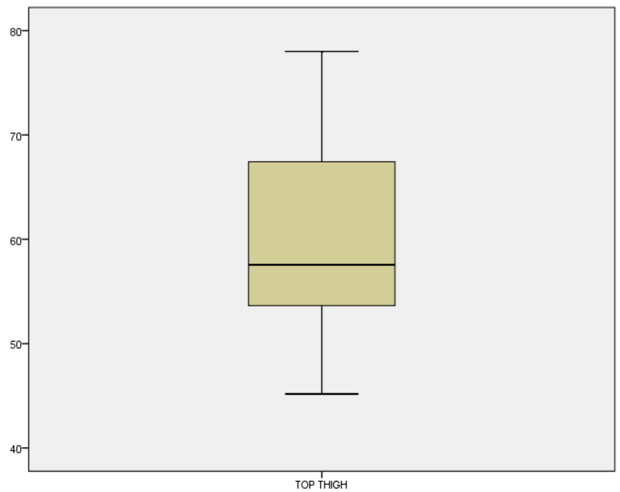

HIGH HIP

TOP THIGH

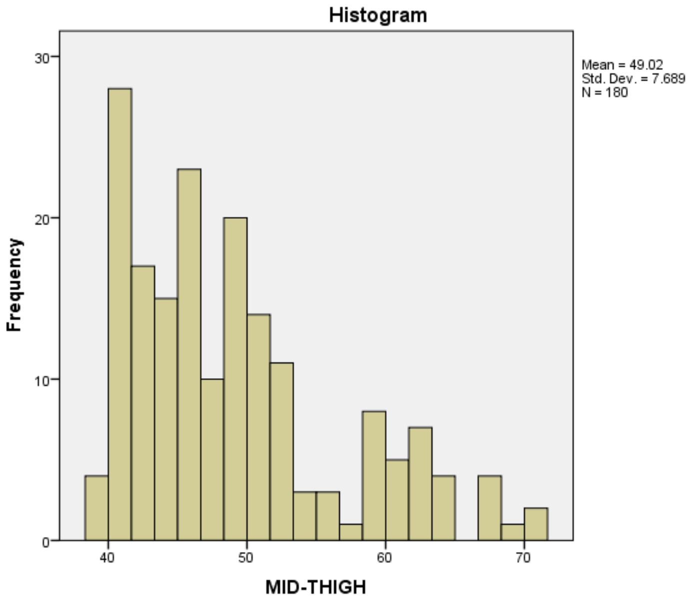

Histogram
Mean = 59.91
Std. Dev. = 8.076
N = 180
Frequency
TOP THIGH
0
10
20
30
50
60
70
80


Normal Q-Q Plot of TOP THIGH
Expected Normal
Observed Value

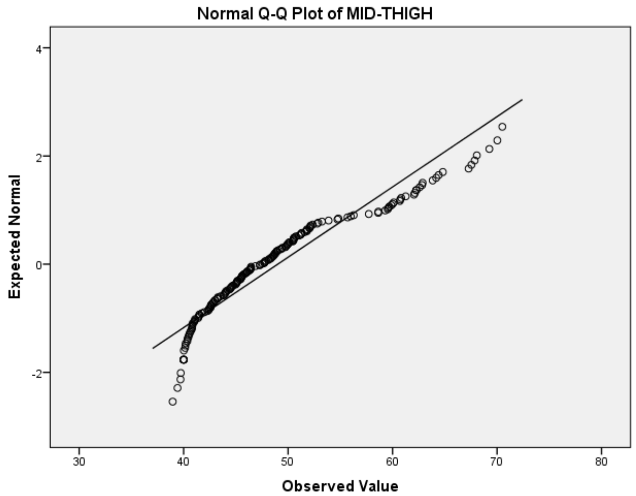

Detrended Normal Q-Q Plot of TOP THIGH
Dev from Normal
Observed Value


TOP THIGH

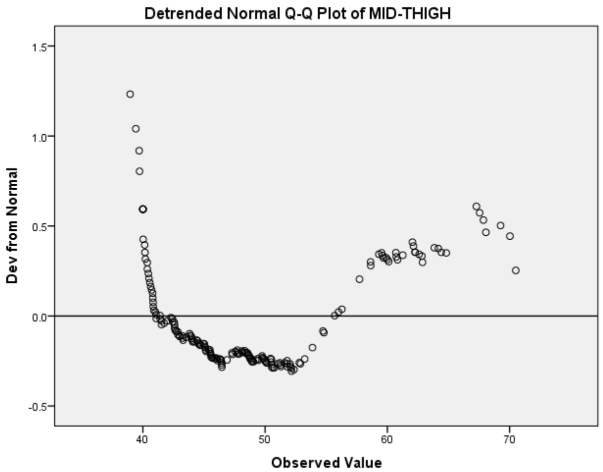
MID-THIGH



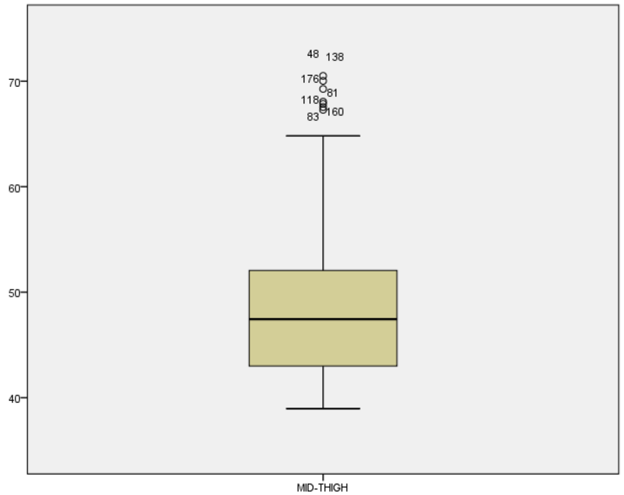
Histogram
Mean = 49.02
Std. Dev. = 7.689
N = 180
Frequency
0
10
20
30
40
50
60
70
MID-THIGH



Normal Q-Q Plot of MID-THIGH
Expected Normal
4
2
0
-2
30
40
50
60
70
80
Observed Value

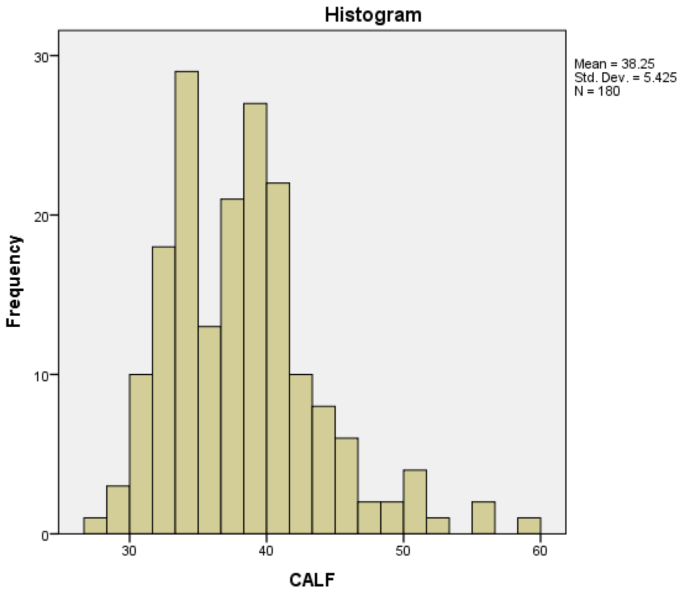


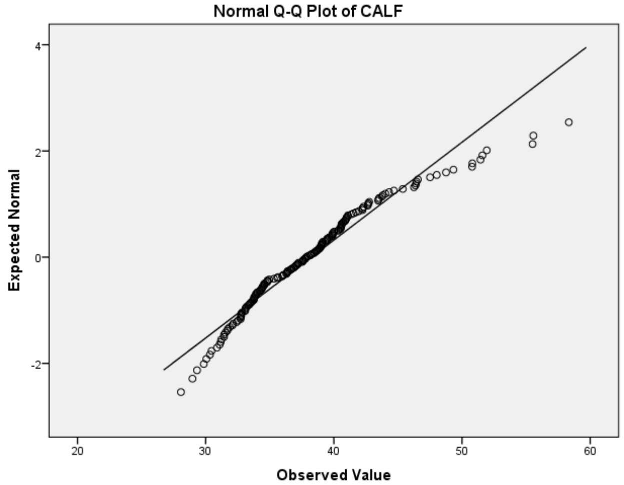
Detrended Normal Q-Q Plot of MID-THIGH
Dev from Normal
1.5
1.0
0.5
0.0
-0.5
40
50
60
70
Observed Value

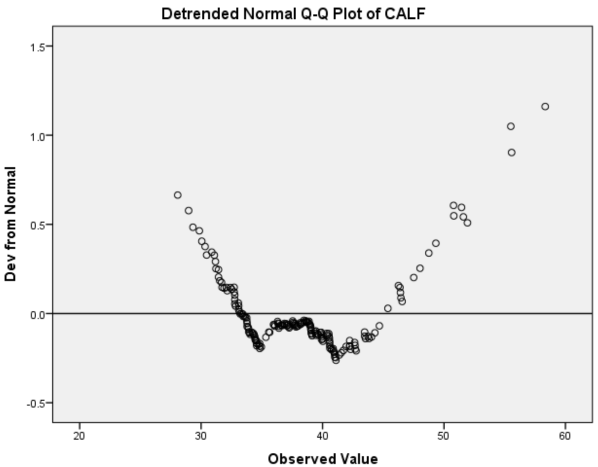


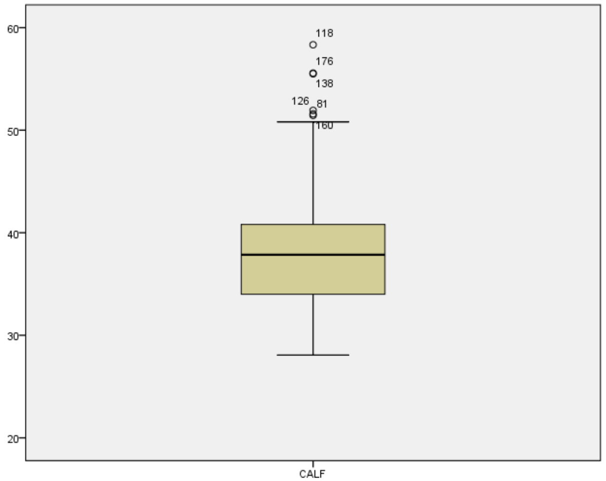
48
138
176
81
118
160
83
70
60
50
40
MID-THIGH

CALF

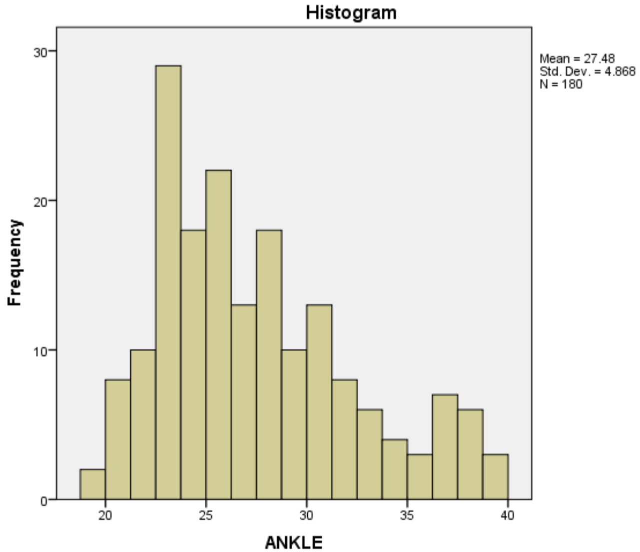

Histogram
Mean = 38.25
Std. Dev. = 5.425
N = 180
Frequency
CALF


Normal Q-Q Plot of CALF
Expected Normal
Observed Value

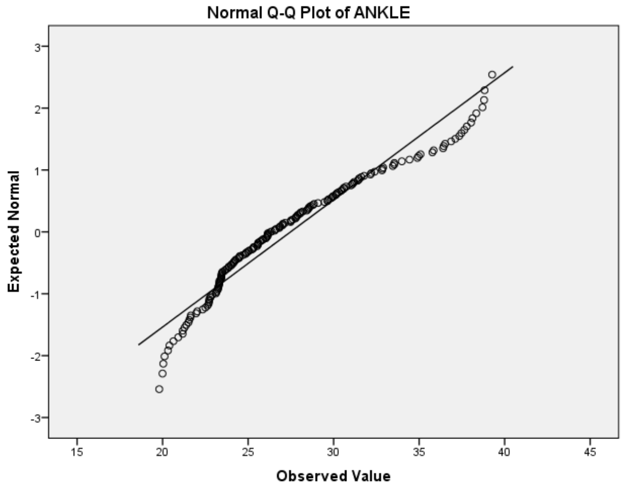

Detrended Normal Q-Q Plot of CALF
Dev from Normal
Observed Value


118
176
138
126
81
160
CALF

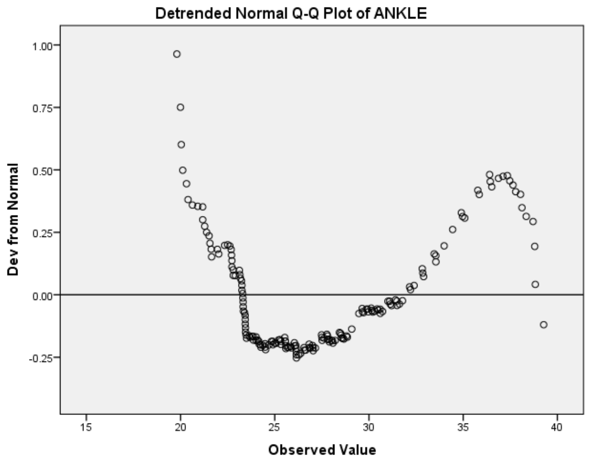
ANKLE



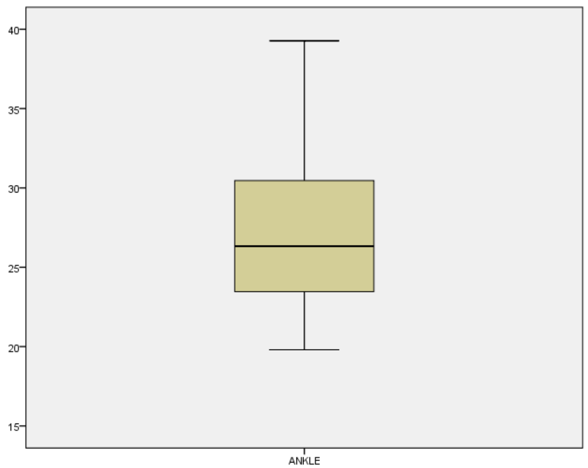
Histogram
Mean = 27.48
Std. Dev. = 4.868
N = 180
Frequency
ANKLE



Normal Q-Q Plot of ANKLE
Expected Normal
Observed Value

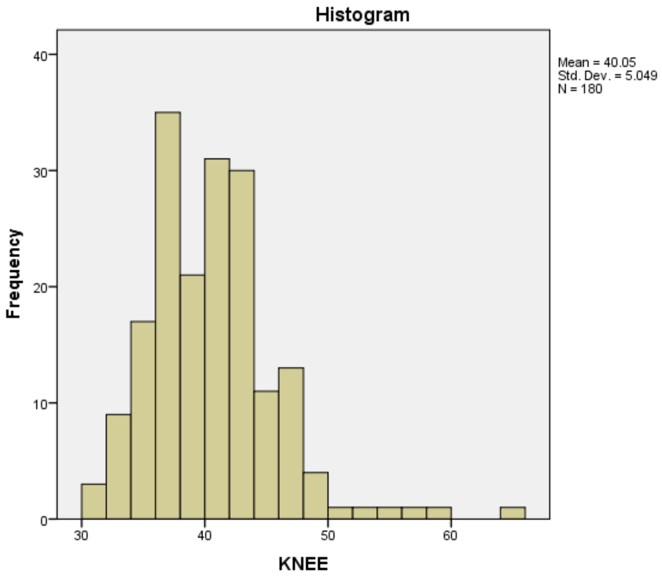


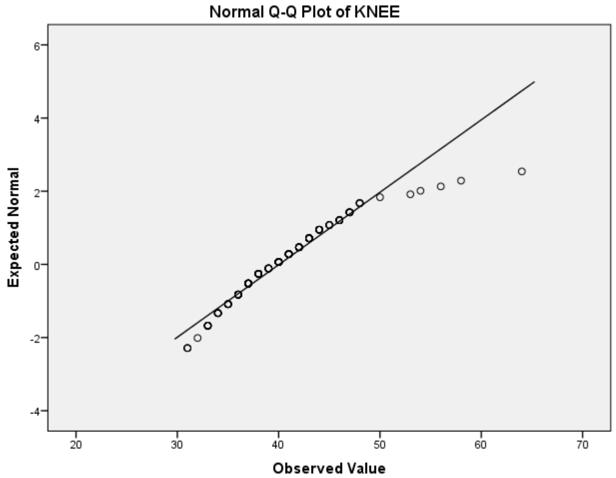
Detrended Normal Q-Q Plot of ANKLE
Dev from Normal
Observed Value

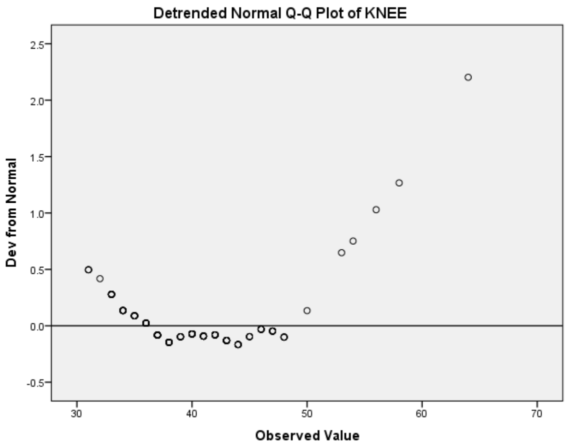


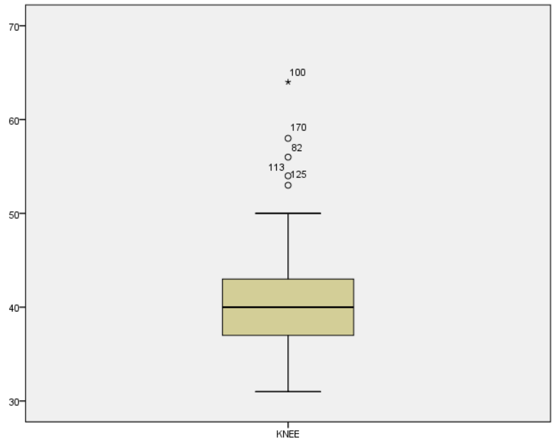
ANKLE

KNEE

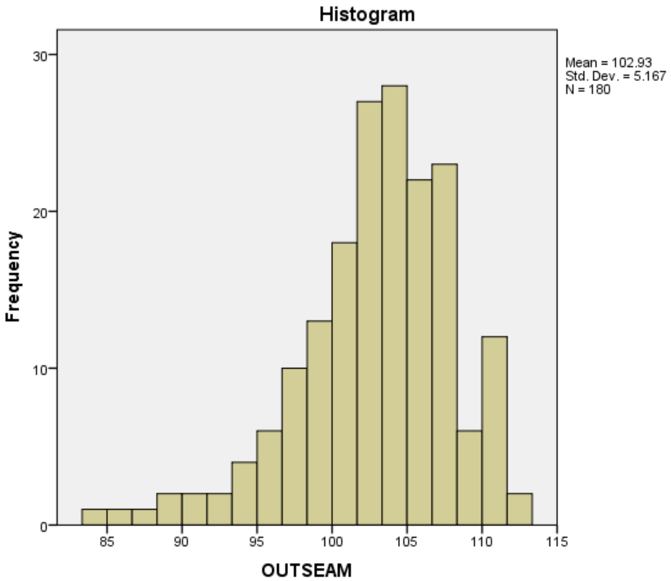

Histogram
Mean = 40.05
Std. Dev. = 5.049
N = 180
Frequency
0
10
20
30
40
30
40
50
60
KNEE

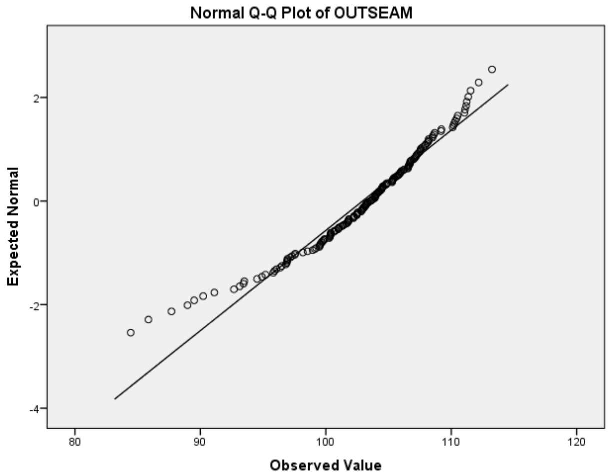

Normal Q-Q Plot of KNEE
Expected Normal
6
4
2
0
-2
-4
20
30
40
50
60
70
Observed Value

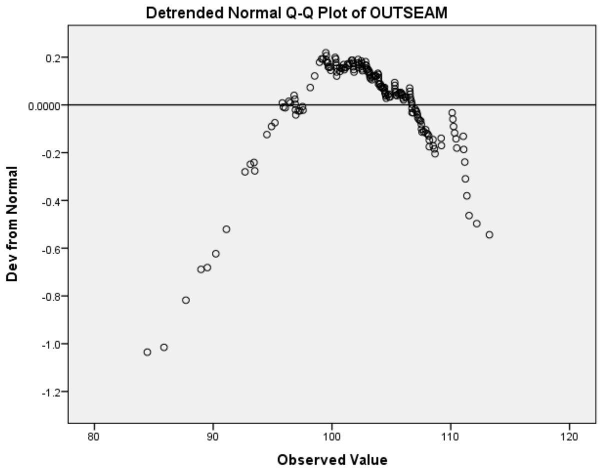

Detrended Normal Q-Q Plot of KNEE
Dev from Normal
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
30
40
50
60
70
Observed Value

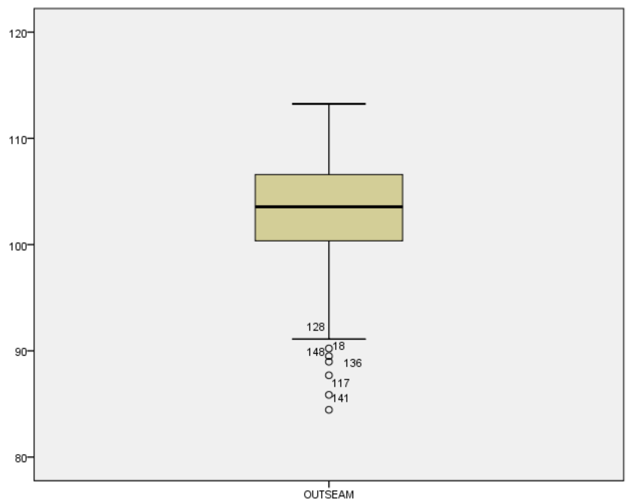

70
60
50
40
30
100
170
82
113
125
KNEE

OUTSEAM

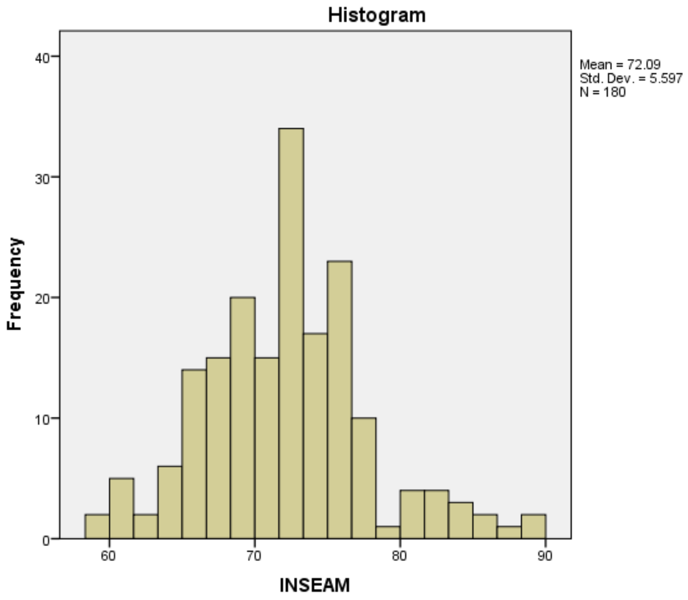

Histogram
Mean = 102.93
Std. Dev. = 5.167
N = 180
Frequency
30
20
10
0
85
90
95
100
105
110
115
OUTSEAM

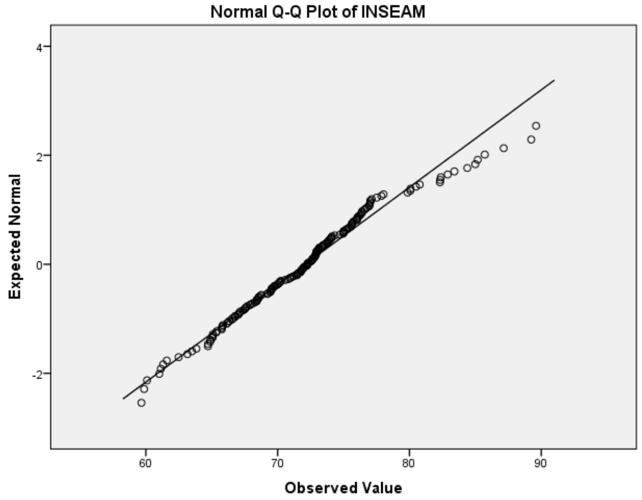

Normal Q-Q Plot of OUTSEAM
Expected Normal
2
0
-2
-4
80
90
100
110
120
Observed Value

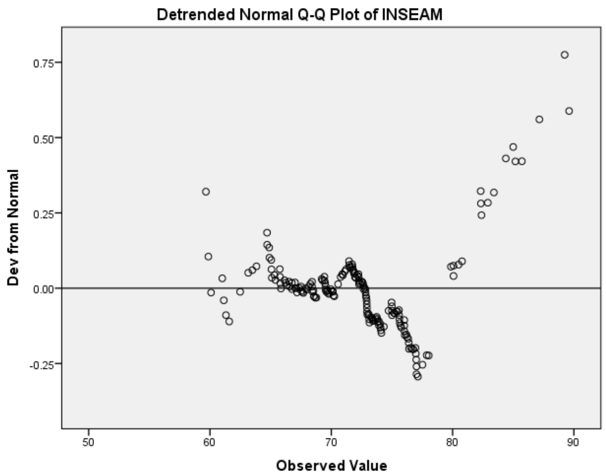

Detrended Normal Q-Q Plot of OUTSEAM
Dev from Normal
0.2
0.0000
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
80
90
100
110
120
Observed Value

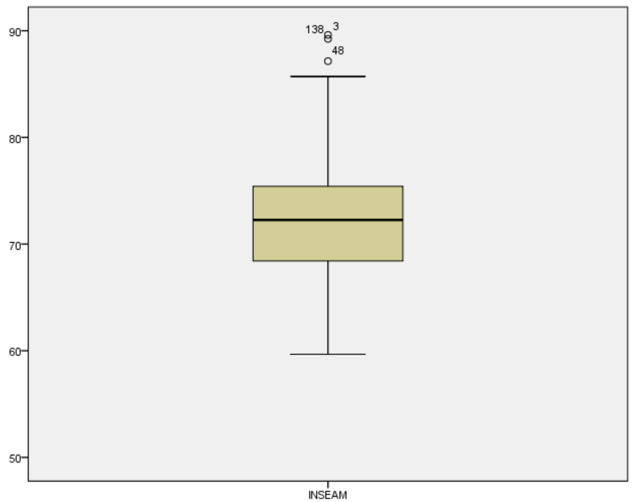

120
110
100
90
80
128
148
18
136
117
141
OUTSEAM

INSEAM

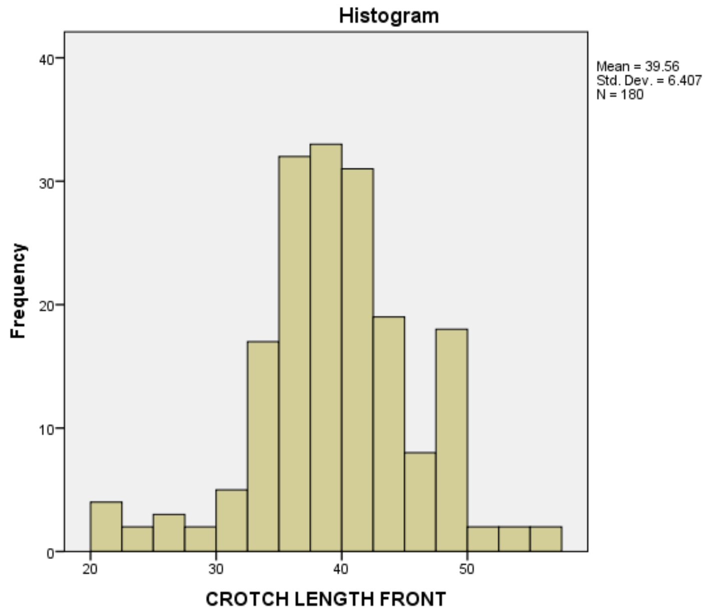

Histogram
Mean = 72.09
Std. Dev. = 5.597
N = 180
Frequency
INSEAM
0
10
20
30
40
60
70
80
90

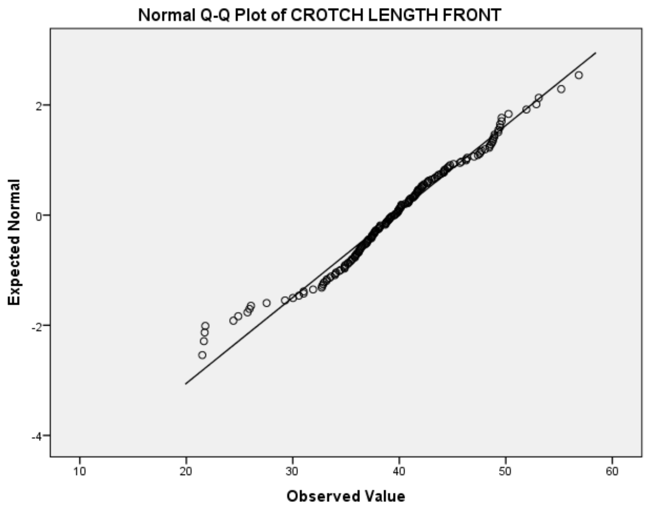

Normal Q-Q Plot of INSEAM
Expected Normal
Observed Value
4
2
0
-2
60
70
80
90

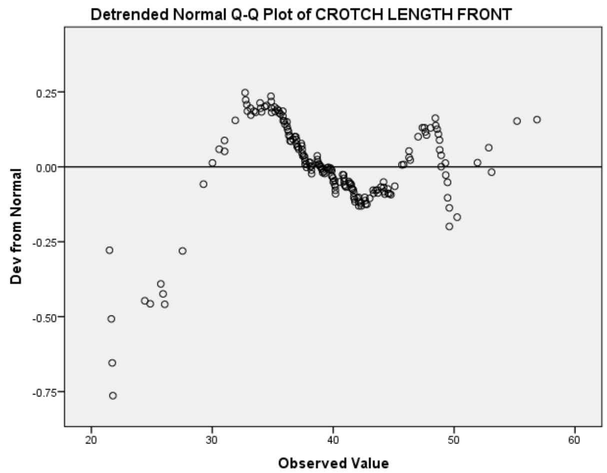

Detrended Normal Q-Q Plot of INSEAM
Dev from Normal
Observed Value
0.75
0.50
0.25
0.00
-0.25
50
60
70
80
90

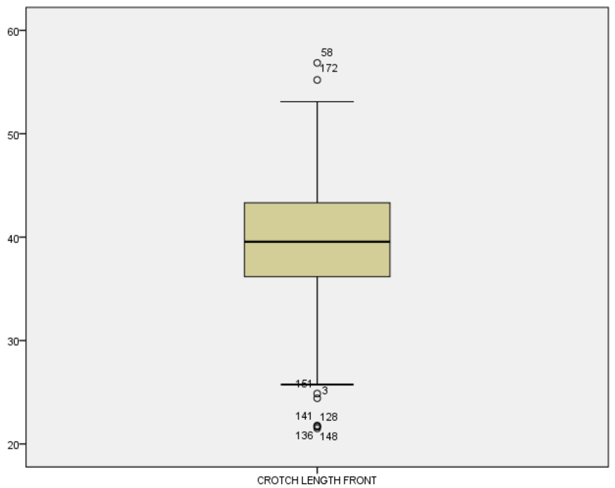

138
3
48
90
80
70
60
50
INSEAM

CROTCH LENGTH FRONT

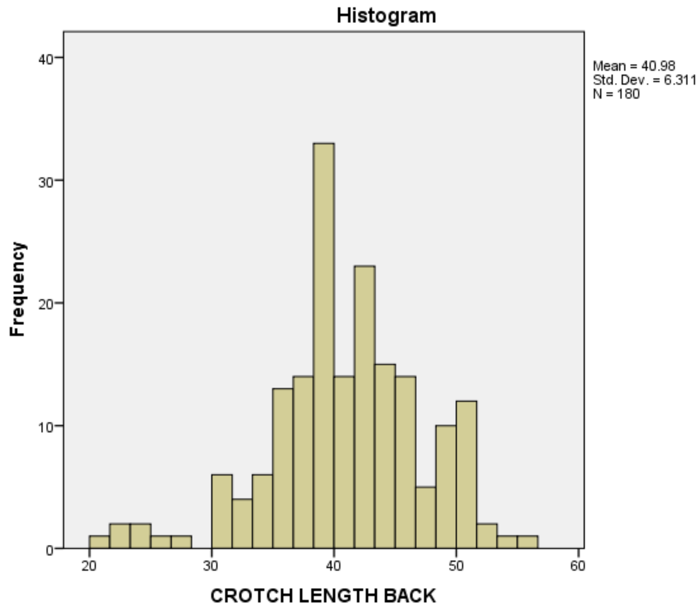


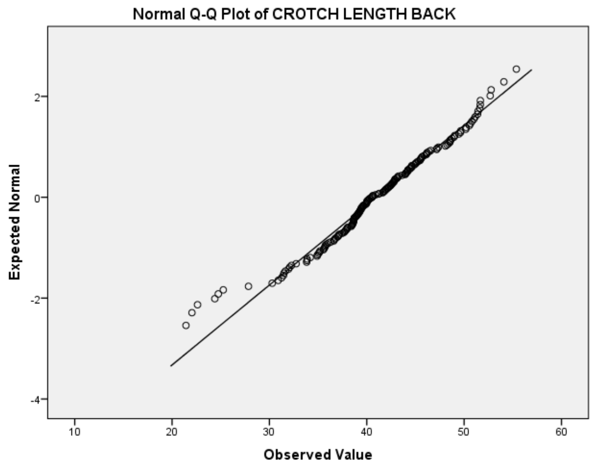


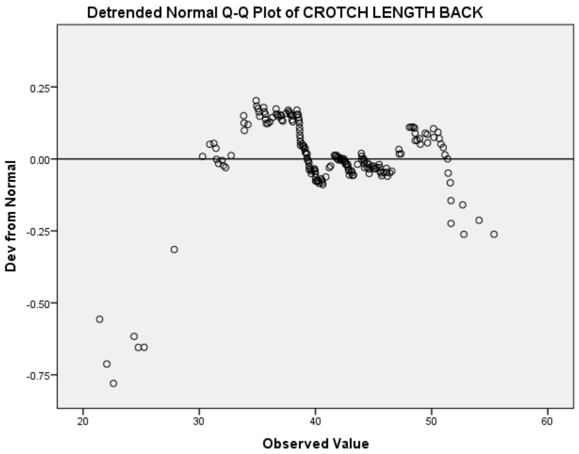


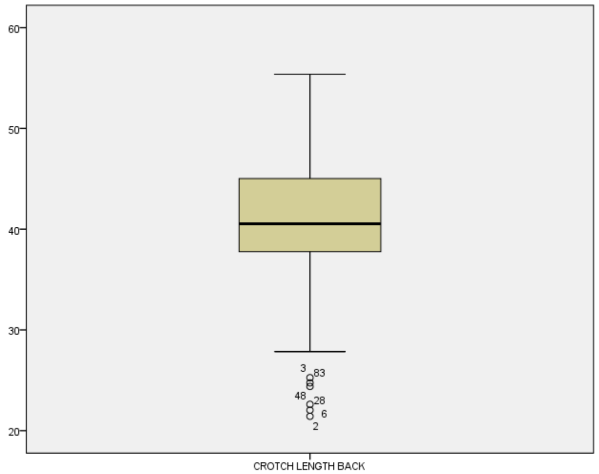


CROTCH LENGTH BACK









APPENDIX H: AN EXAMPLE OF THE REGRESSION CALCULATIONS FOR ALLOCATING THE SIZE RANGES IN THE SIZE CHARTS

The upper waist and bust were used as the key (independent variables) body dimensions and the chest as the secondary (dependent variable) body dimension for allocating the size range in the size chart for the upper body girth related body dimensions. The average measurements for the key body dimensions were the upper waist: 82 cm and bust: 100 cm (see Appendix H1 below for an example of the calculations).

Appendix H1: Calculations for allocating the average measurement for the chest secondary body dimension

CORREL =21.073+(0.246*D5)+(0.565*D6)

upper body regression2

	A	B	C	D	E	F	G	H	I	J	K
1								MIN	MAX		
2			Constant	Upper waist	Bust			60	131	Upper waist	6
3		Chest	21.073	0.246	0.565			74	140	Bust	6
4		Underbust	-6.691	0.405	0.605			56	140	Chest	
5			upper waist	82	6						
6			bust	100							
7	Chest	(0.565*D6)		1.5	3.4		5				
8	Underbust	87		2.4	3.6		6				

The formula for calculating the average measurements for the secondary body dimensions (an example, of the chest measurement calculations is shown as: =21.073 (constant)+ (0.246*82 (upper waist)) + (0.565*100 (bust)) = 97.745, which was rounded up to 98. As a result, the average measurement for the chest body dimension was 98cm.

To obtain the size interval for the chest measurements, the following calculations were used: =E5*0.246 (upper waist) + =E5*0.565 (bust) = 4.9 rounded up to 5, which was used as the final size interval for the chest measurements (see Appendix H2 below for an example of the calculations).

Appendix H2: Calculations for allocating the size interval for the chest secondary body dimension

D7 =E5*0.246

upper body regression2

	A	B	C	D	E	F	G
1							
2			Constant	Upper waist	Bust		
3		Chest	21.073	0.246	0.565		
4		Underbust	-6.691	0.405	0.605		
5			upper waist	**82**	6		
6			bust	**100**			
7	Chest	98		1.5	3.4		5
8	Underbust	87		2.4	3.6		6

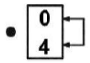
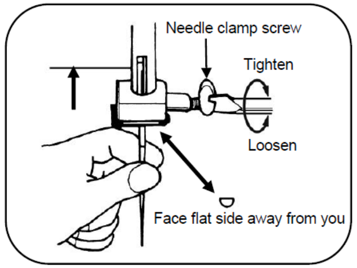
E7 =E5*0.565

upper body regression2

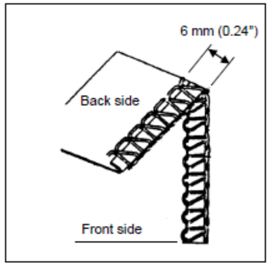
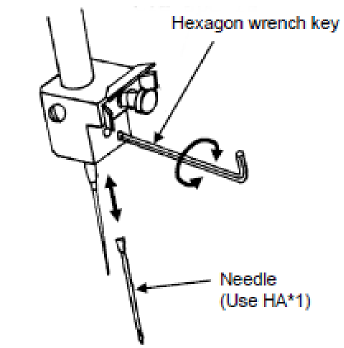
	A	B	C	D	E	F	G
1							
2			Constant	Upper waist	Bust		
3		Chest	21.073	0.246	0.565		
4		Underbust	-6.691	0.405	0.605		
5			upper waist	**82**	6		
6			bust	**100**			
7	Chest	98		1.5	3.4		5
8	Underbust	87		2.4	3.6		6

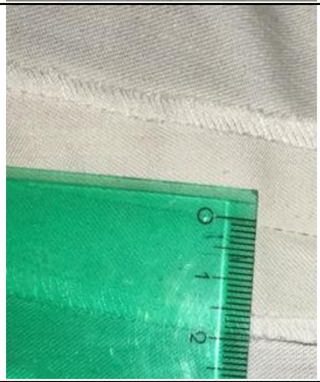
APPENDIX I: TECHNICAL SPECIFICATIONS AND PARAMETERS ASSOCIATED WITH MANUFACTURING THE PROTOTYPE SHIRT AND TROUSER GARMENTS

Shown below are the technical specifications consisting of the structure of procedures used to assemble the shirt and trouser garments manufactured in this study; the parameters are also specified for the assembling process, adapted from the ISO 4916:1991 stitch type standards; the Empisal dress maker 270D free arm sewing machine and the Empisal model S4D free arm overlocker sewing machine instruction manuals.

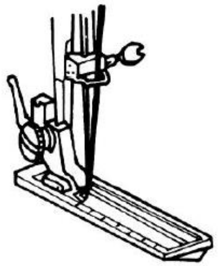
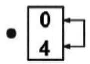
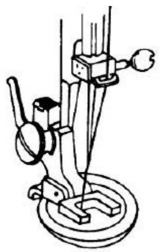
EQUIPMENTS USED TO MANUFACTURE THE PROTOTYPE SHIRT AND TROUSER GARMENTS					
Operation	**Seam Construction**	**Stitch Type**	**Equipment**	**Image**	**Parameters to be specified**
The sewing machine used	The entire shirt garment seam construction	Plain straight stitch 301 ---- 	EMPISAL: Dress maker 270D 		**Seam Type:** flat-seaming **Stitch density**: 0-4 stitch length machine adjustment, producing 10-12 stitches per inch **Needle type & size:** 70/10 universal slightly round-point needle. 70 = European size 10 = American size

Continued on the next page

The over locker used	Fabric edges of the entire shirt garment	504 Overedge 	EMPISAL: Model S4D 		**Seam Type:** flat-seaming, narrow over lock **Stitch density:** 2.0 - 3.5 mm **Needle type & size:** HA×1 No.11-14 130/705H No. 80-90 Three threads were used instead of four. Only the left needle was used, the over locking width was 6mm (0.24).
Threads used	-	-	-		**Thread Type/size:** Seralon M120/1000m threads **Thread composition:** 100% polyester threads

FABRICS USED FOR MANUFACTURING THE PROTOTYPE SHIRT GARMENT					
Operation	**Seam Construction**		**Fabric**	**Image**	**Parameters to be specified**
Fabric used	-	-	Calico fabric: 190 grams per square metre (g/m²)		-
Fusing	Collar, front closure, sleeve cuffs	-	32 g/m² white non-woven fusing		**Fusing conditions:** Temp: 135 - 145℃ Pressure: 0.15 - 0.25kg Time: 12 – 18 seconds **Method of fusing:** Hand Iron, no steaming
Seam allowance	The entire shirt garment construction	-	-		2cm seam allowances were used for assembling the shirt garment pieces

FABRICS USED FOR MANUFACTURING THE PROTOTYPE TROUSER GARMENT					
Operation	**Seam Construction**	**Stitch Type**	**Equipment**		**Parameters to be specified**
Fabric used	Entire shirt garment construction	-	Calico fabric: 245 g/m²		-
Fusing	Trouser waistband	-	32 g/m² white non-woven fusing		**Fusing conditions:** Temp: 135 - 145℃ Pressure: 0.15 - 0.25kg Time: 12 – 18 seconds **Method of fusing:** Hand Iron, no steaming
Seam allowance	The entire trouser garment construction	-	-		2cm seam allowances were used for assembling the trouser garment pieces

EQUIPMENTS USED TO FINISH THE PROTOTYPE SHIRT AND TROUSER GARMENTS					
Operation	**Sewing Construction**	**Stitch Type**	**Equipment**		**Parameters to be specified**
Sewing button holes	Shirt: sleeve cuffs(x1 for each side) and front closure (x5) Trouser: Trouser waistband front closure (x1)	Buttonhole stitch pattern 	EMPISAL: Dress maker 270D 		**Button type/size:** Shirt: French Bevel 2 Hole Button, 10mm/ 16 ligne Trouser: French Bevel 2 Hole Button, 15mm/ 24 ligne **Seam Type:** flat-seaming **Stitch density:** 6 stitches (for each side). 0.25-1 stitch length machine adjustment
Sewing buttons	Shirt: sleeve cuffs (x1 button for each side) and front closure (x5 buttons) Trouser: waistband front closure (x1 button)	Plain straight stitch 301 ---- 	EMPISAL: Dress maker 270D 	 Shirt  Trouser	**Button type/size:** Shirt: French Bevel 4 Hole Button, 10mm/ 16 ligne Trouser: French Bevel 2 Hole Button, 15mm/ 24 ligne **Seam Type:** Inserting the machine needle to enter the holes of the button without any obstruction **Stitch density:** 7 stitches
Trim and inspect	-	-	Scissors	-	The manufactured prototype shirt and trouser garments were inspected, any faults occurring where corrected and hanging threads were trimmed using scissors. Thereafter, the garments were ironed using a steam iron for a crisp and finished look.

APPENDIX J: STANDARDS FOR THE GARMENT FIT TEST EVALUATIONS

SHIRT FIT TEST EVALUATIONS STANDARDS

	GOOD	MODERATE	POOR	COMMENTS: Evaluators
1. There is compatibility and ease in the garment (No pulls or tucks)				
2. The garment is steady and rests well on the body (No stretching or gathering)				
3. There is a smooth drape at the front of the garment (Not too tight, no creases)				
4. There is a smooth drape at the back of the garment (Not too tight, no creases)				
5. Garment collar lies smooth against base of the neck (Does not stretch or have gatherings)				
6. The shoulders lie flat and balanced (No pulling or rippling)				
7. The armholes do not constrict, have gatherings or pull away from the body				
8. The sleeves are accurately positioned, fits and hang well (Not too short or too long)				
9. The sleeve biceps area fits well (No pulls or gatherings)				
10. The sleeve elbow area fits well (No pulls or gatherings)				
11. The sleeve wrist area fits well (No pulls or gatherings)				
12. The bust area fits well with adequate ease (There are no gaps or pulling)				
13. The closure location is balanced (Buttons and buttonholes are correctly aligned)				
14. There is enough ease for closure (Not too tight or loose)				
15. Hems and finishes are parallel and smooth (No bulking)				
16. The garment is at the right length and is evenly hemmed (Not too short or too long)				
17. Is there comfortability and movement when wearing the garment?				
18. Can the wearer sit comfortably when wearing the garment?				

Adapted from Stamper *et al.* (2005), Liechty *et al.* (2010:54) and Marshall *et al.* (2012).

TROUSER FIT TEST EVALUATIONS STANDARDS

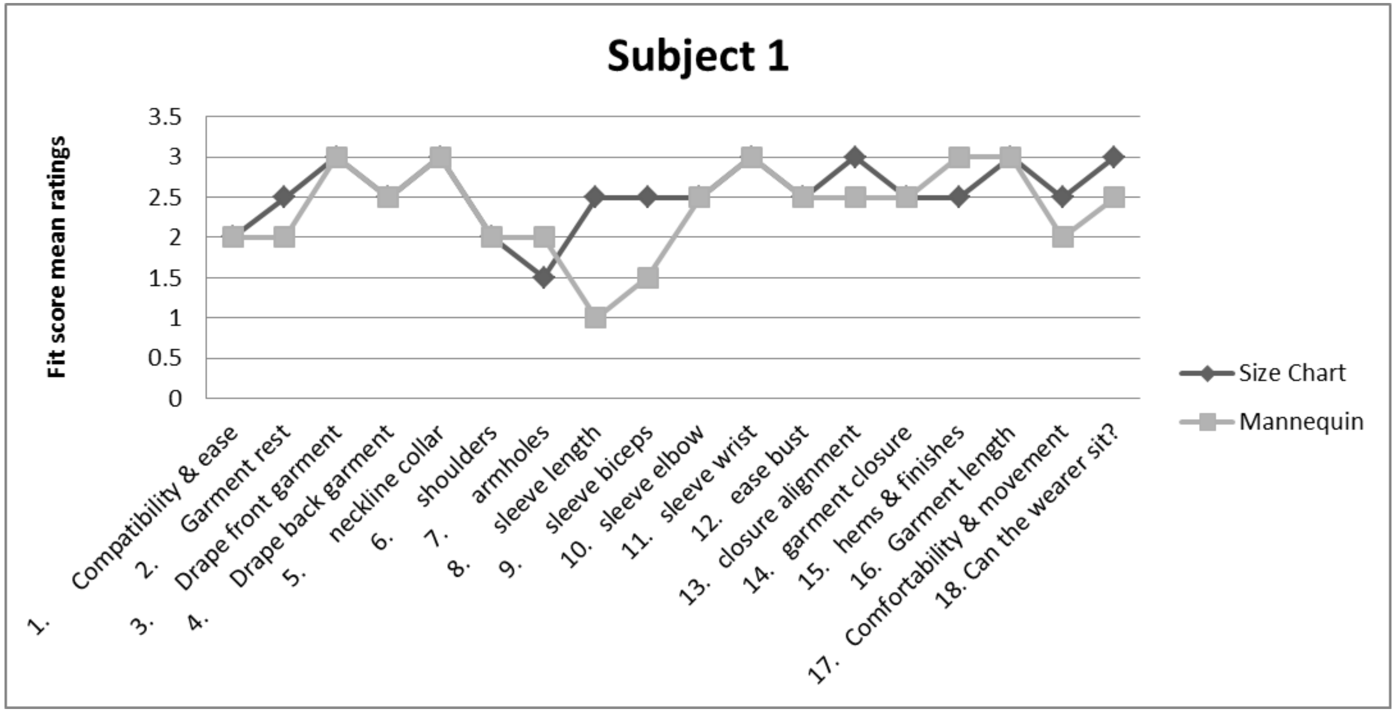
	GOOD	MODERATE	POOR	COMMENTS: <u>Evaluators</u>
1. There is compatibility and ease in the garment (No pulls or tucks)				
2. The garment is steady and rests well on the body (No stretching or gathering)				
3. The lower waist fits well (No pulls or gatherings).				
4. The hip fits well and accommodate the wearer's curves (There are no wrinkles or pulling)				
5. The crotch area fits well, there's enough ease for closure (No pulling or wrinkling)				
6. The garment fits well around the buttocks (No bulking or stretching)				
7. There is a smooth drape at the seat (Not too tight, no creases)				
8. The thigh area fits well (No pulls, wrinkles)				
9. The knee area fits well (No pulls, wrinkles)				
10. The ankle area fits well (No pulls, wrinkles)				
11. The inseam length is at the right length (Not too short or too long)				
12. The outseam length is at the right length (Not too short or too long)				
13. Hems and finishes are parallel and smooth (No bulking)				
14. There is enough ease for closure (Not too tight or too loose)				
15. The bottom of the garment is at the right length and is evenly hemmed (Not too short or too long)				
16. Is there comfortability and movement when wearing the garment?				
17. Can the wearer sit comfortably when wearing the garment?				

Adapted from Stamper *et al.* (2005), Liechty *et al.* (2010:54) and Marshall *et al.* (2012).

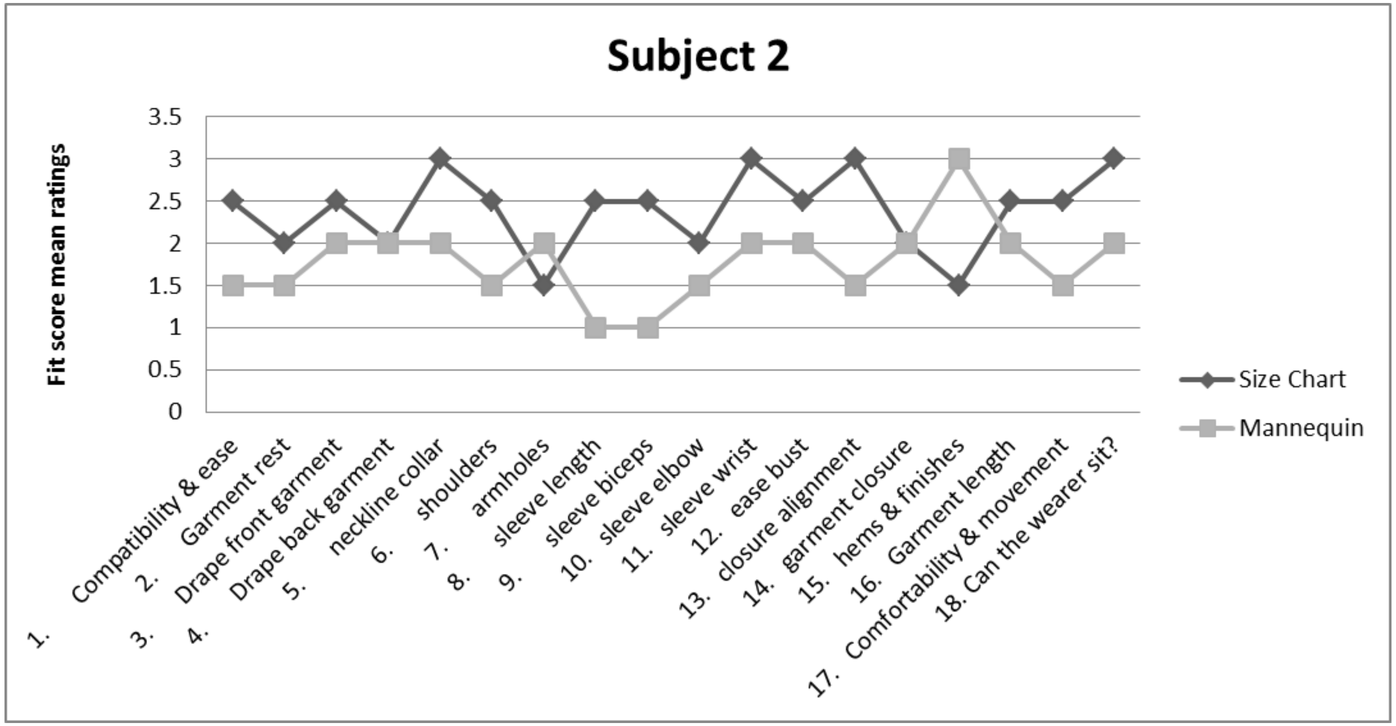
APPENDIX K: COMPARATIVE MEAN RATINGS FOR THE QUALITY OF THE SHIRTS AND TROUSERS GARMENT FIT EVALUATED ON EACH SUBJECT

THE COMPARATIVE MEAN RATINGS FOR THE SHIRT GARMENTS FOR EACH SUBJECT

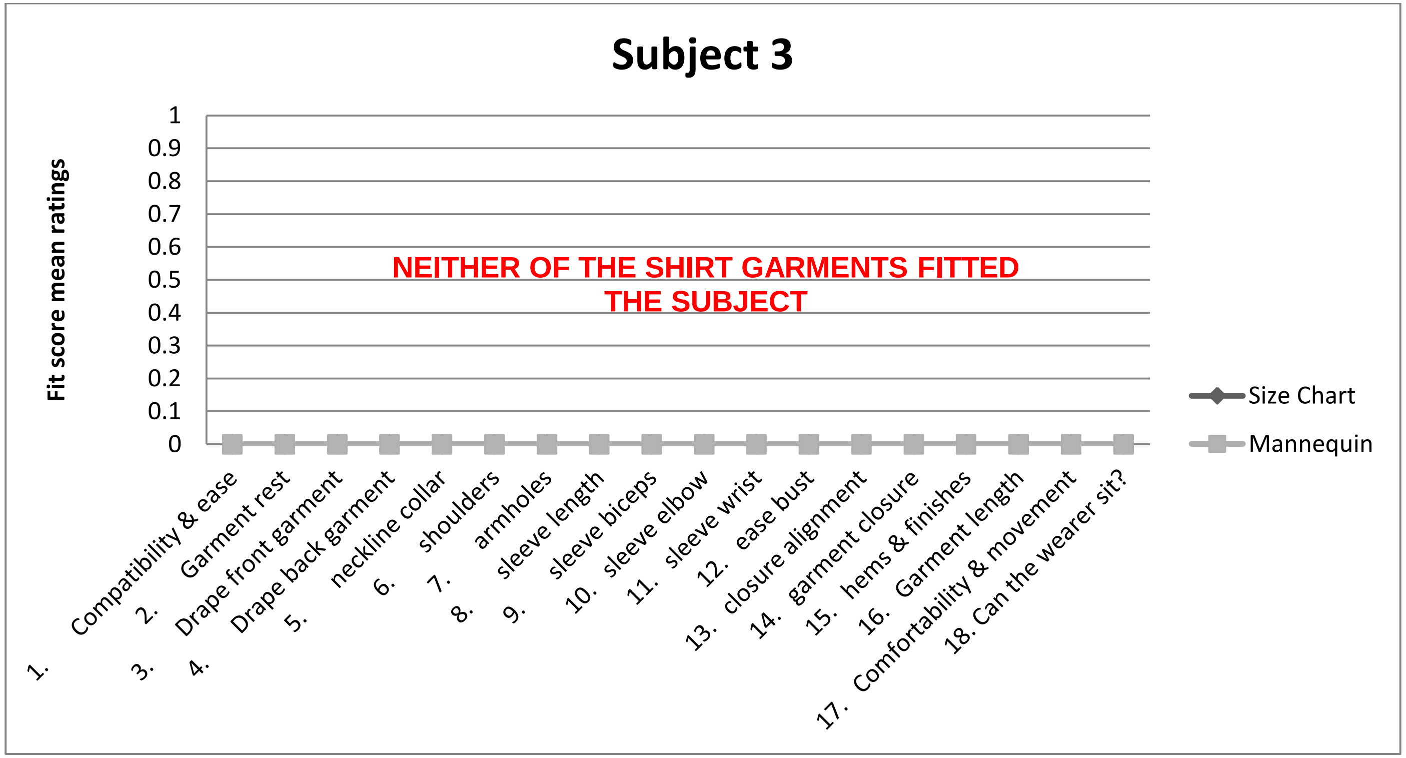
Appendix K1: The comparative mean ratings for the shirts quality of fit attained from subject 1.



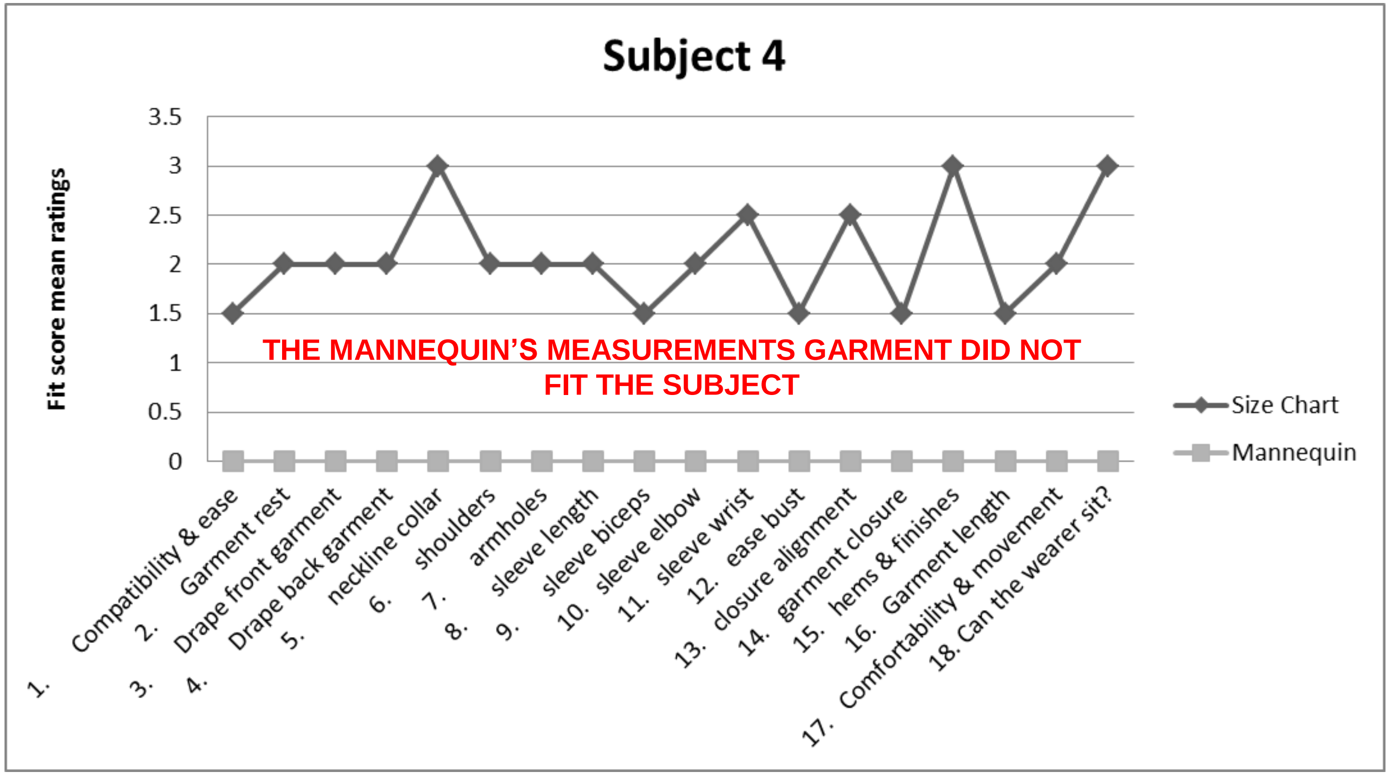
Appendix K2: The comparative mean ratings for the shirts quality of fit attained from subject 2.



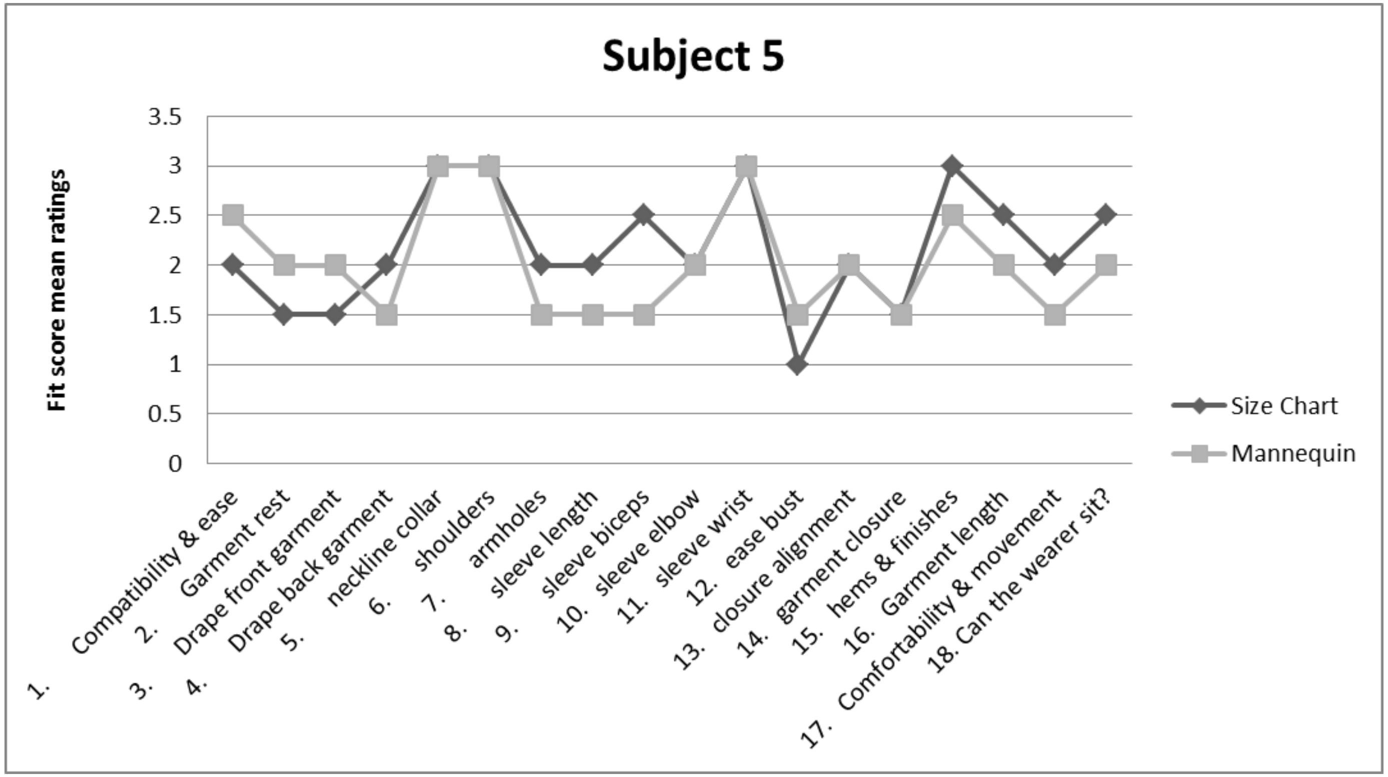
Appendix K3: The comparative mean ratings for the shirts quality of fit attained from subject 3.



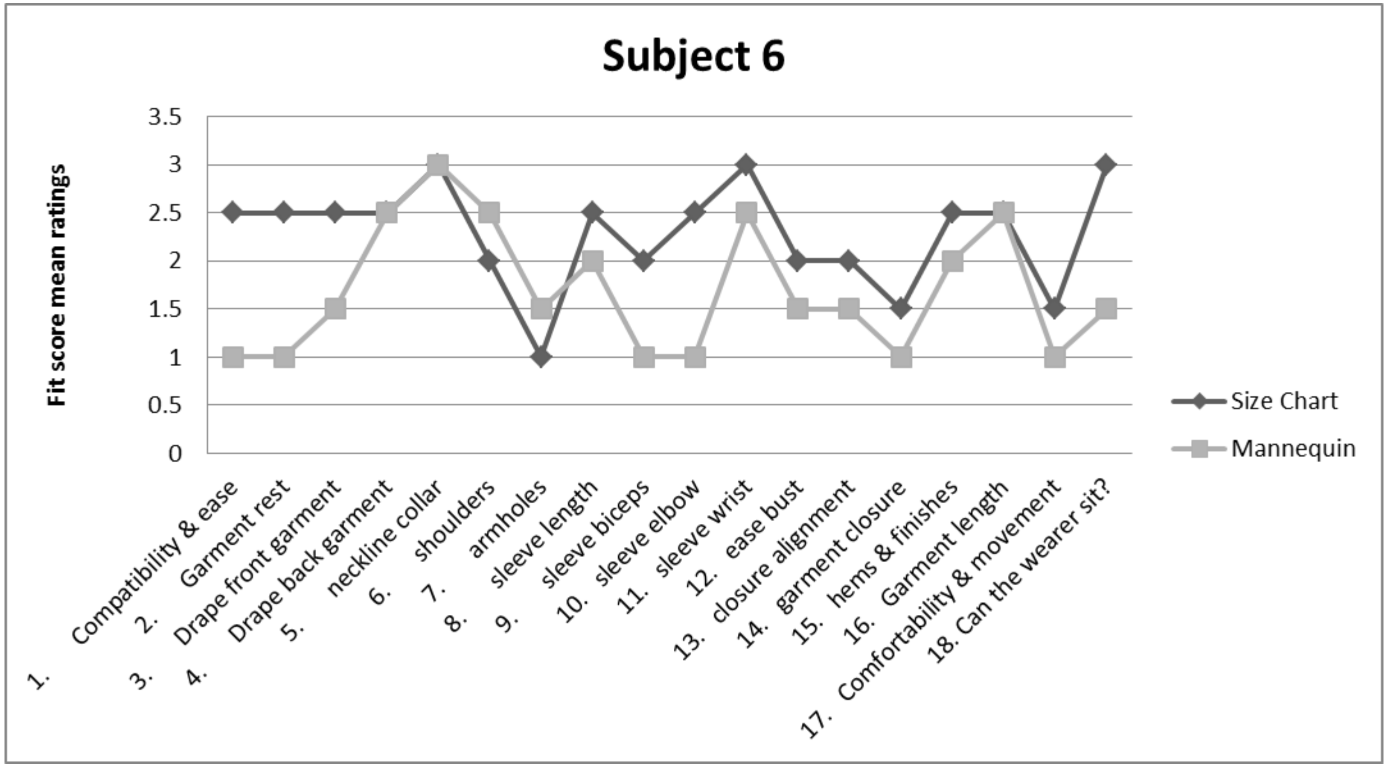
Appendix K4: The comparative mean ratings for the shirts quality of fit attained from subject 4.



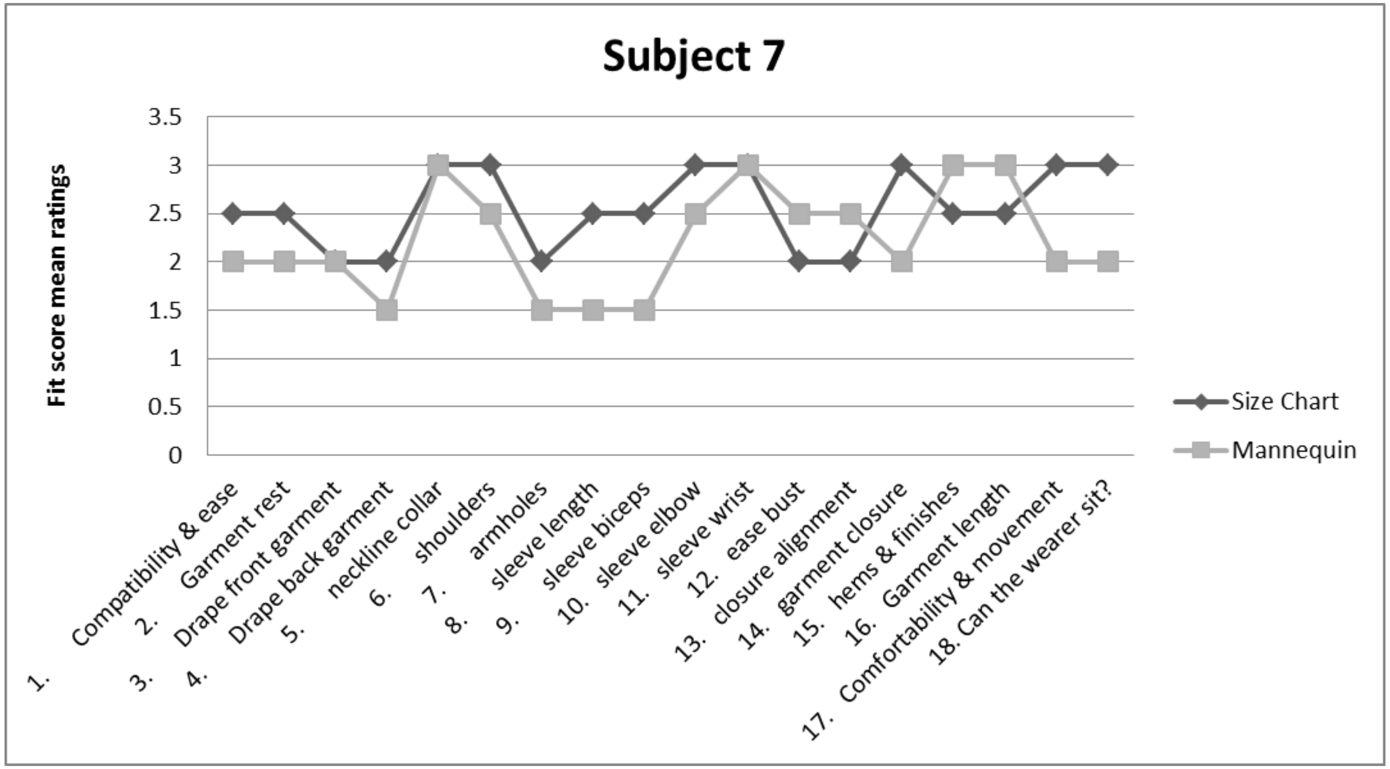
Appendix K5: The comparative mean ratings for the shirts quality of fit attained from subject 5.



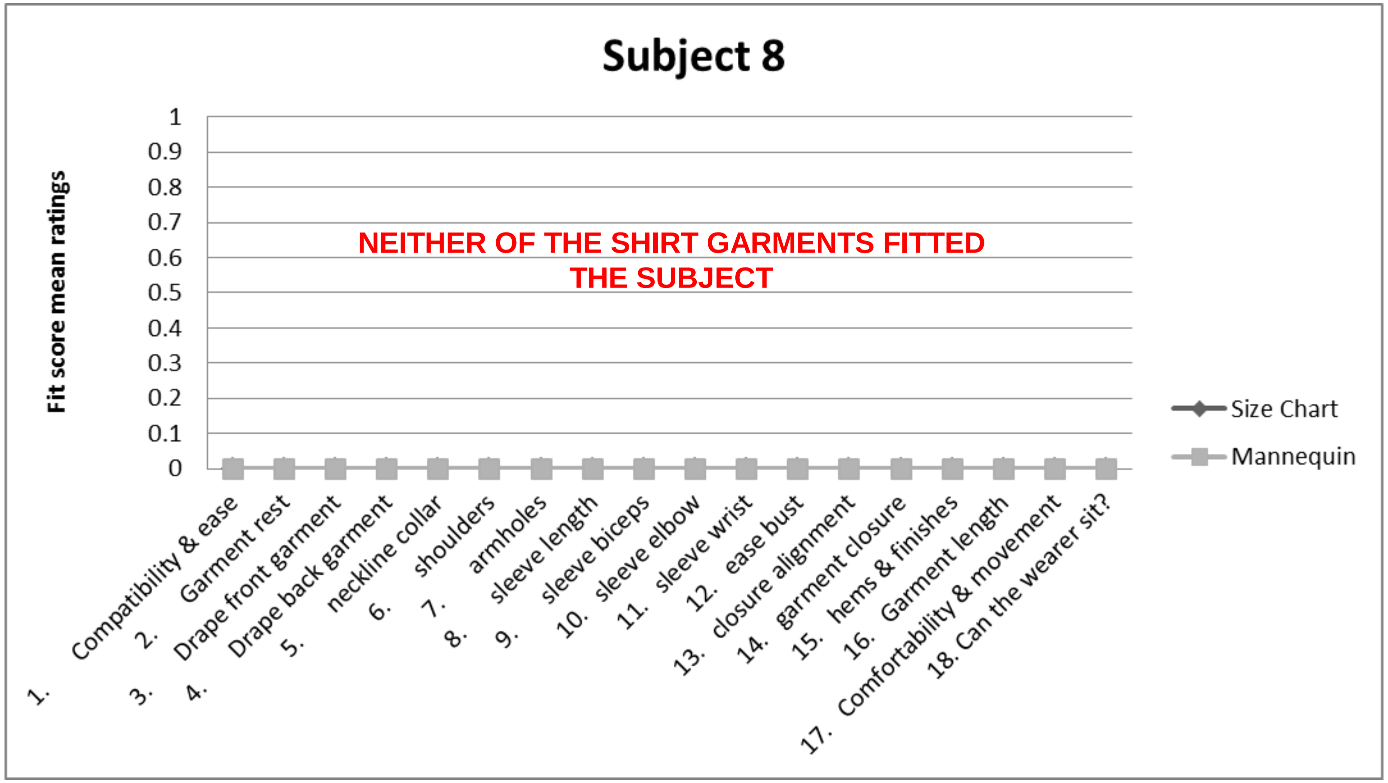
Appendix K6: The comparative mean ratings for the shirts quality of fit attained from subject 6.



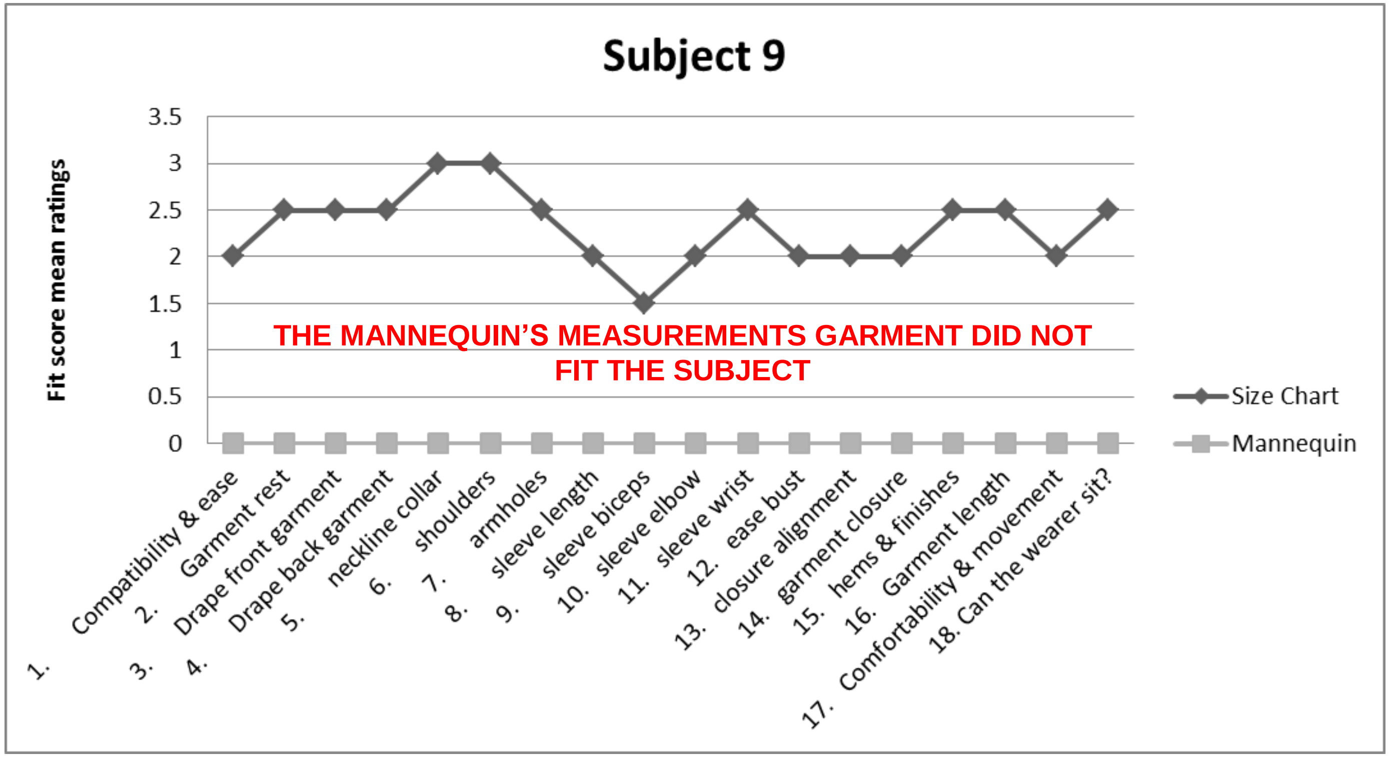
Appendix K7: The comparative mean ratings for the shirts quality of fit attained from subject 7.



Appendix K8: The comparative mean ratings for the shirts quality of fit attained from subject 8.

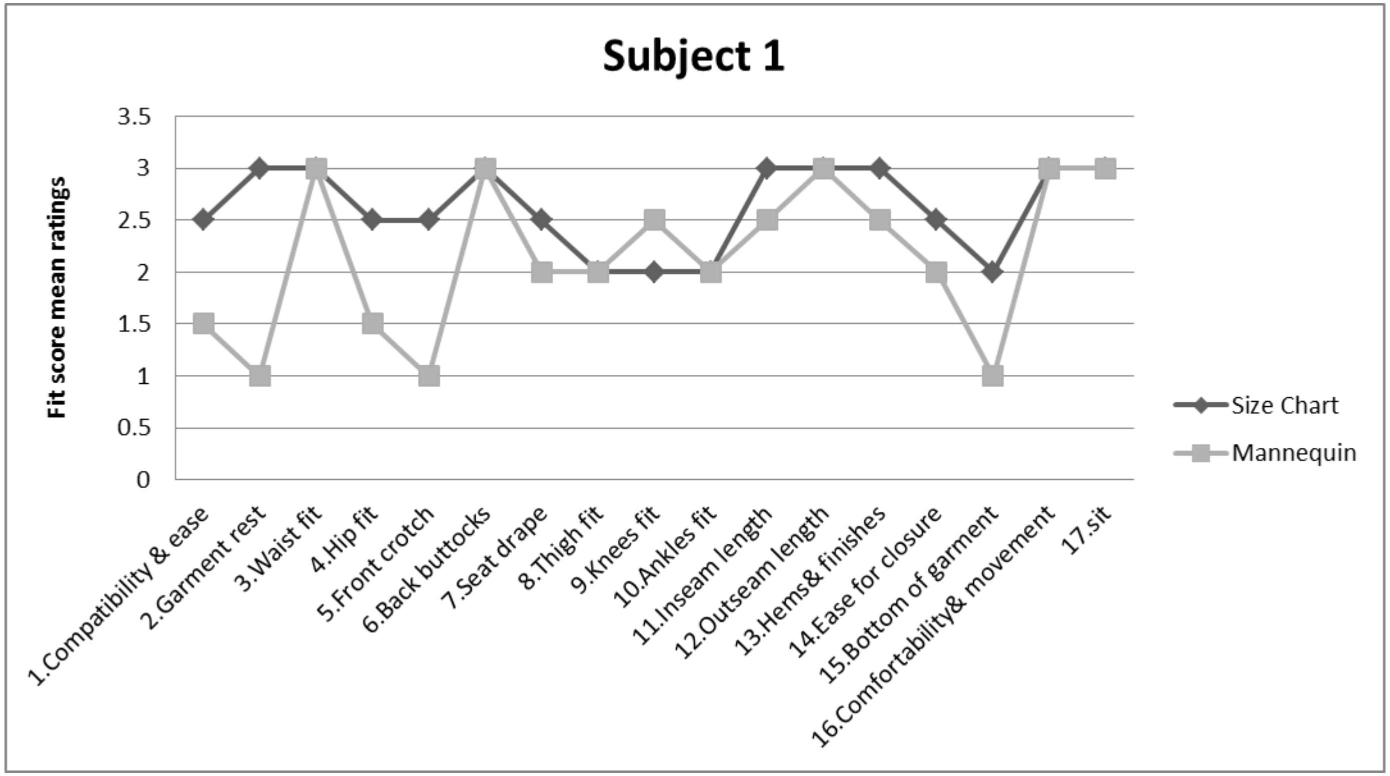


Appendix K9: The comparative mean ratings for the shirts quality of fit attained from subject 9.

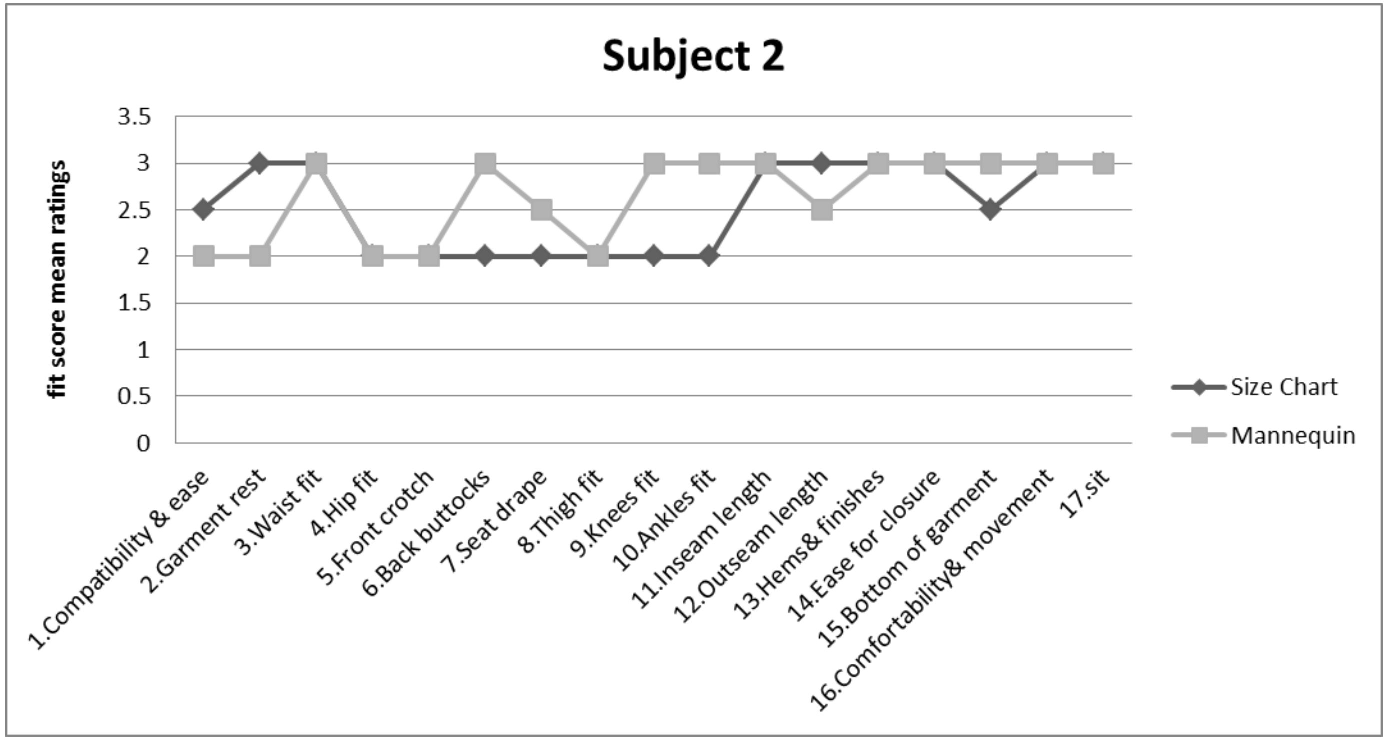


THE COMPARATIVE MEAN RATINGS FOR THE TROUSER GARMENTS FOR EACH SUBJECT

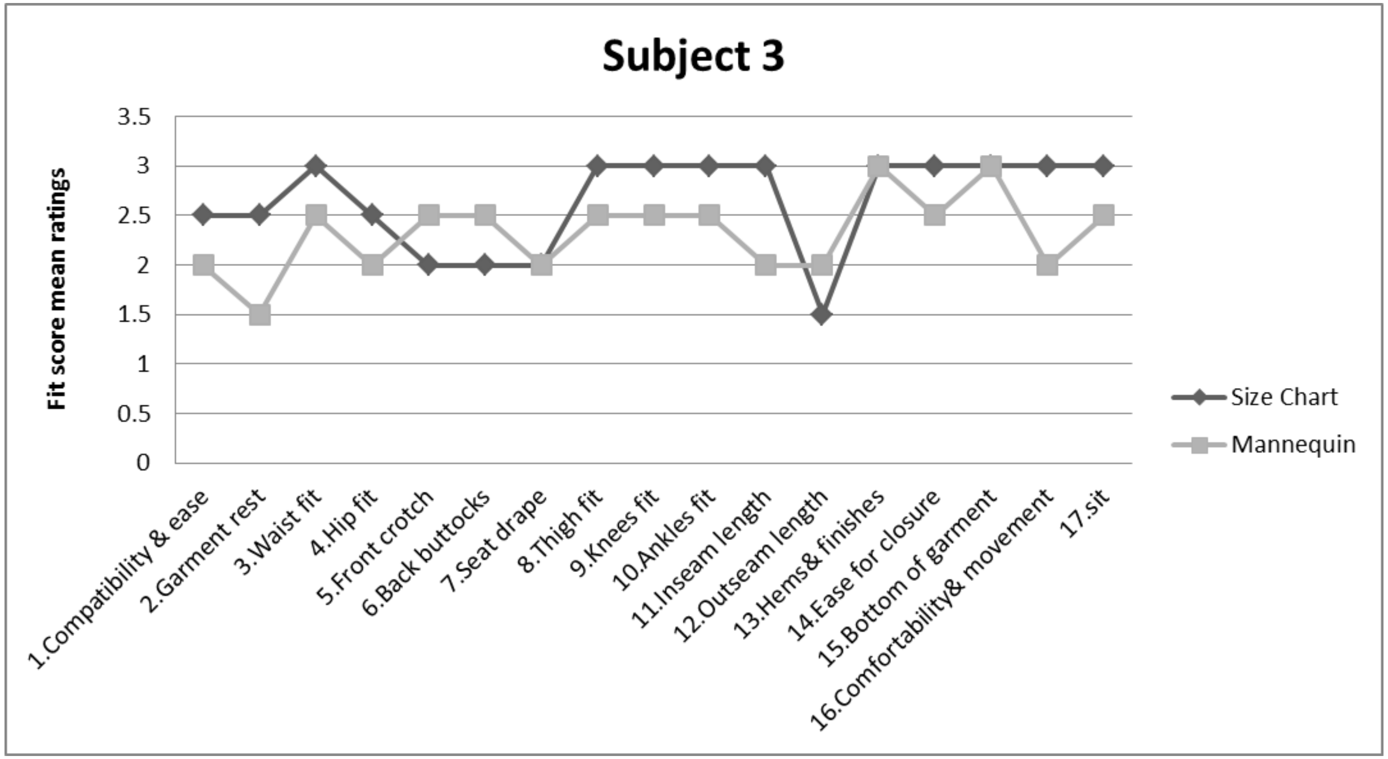
Appendix K10: The comparative mean ratings for the trousers quality of fit attained from subject 1.



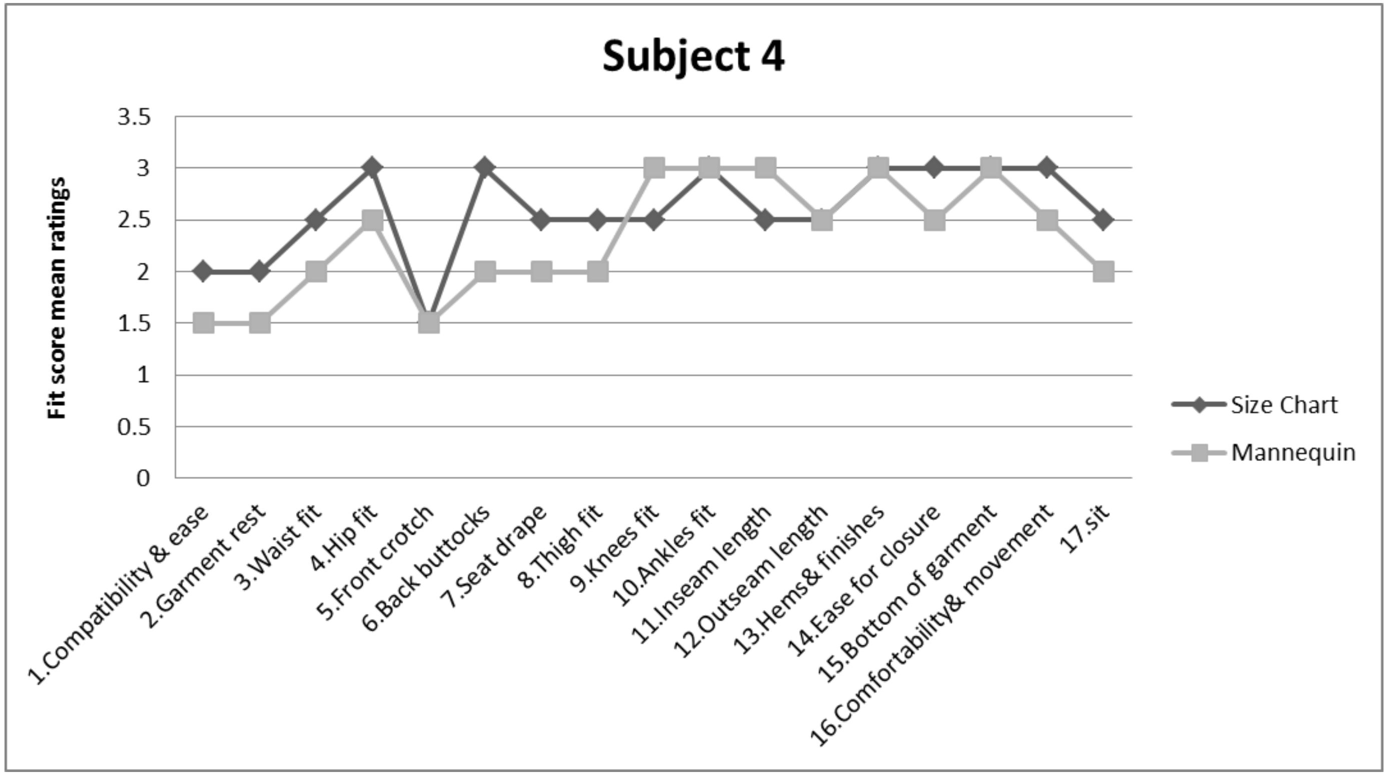
Appendix K11: The comparative mean ratings for the trousers quality of fit attained from subject 2.



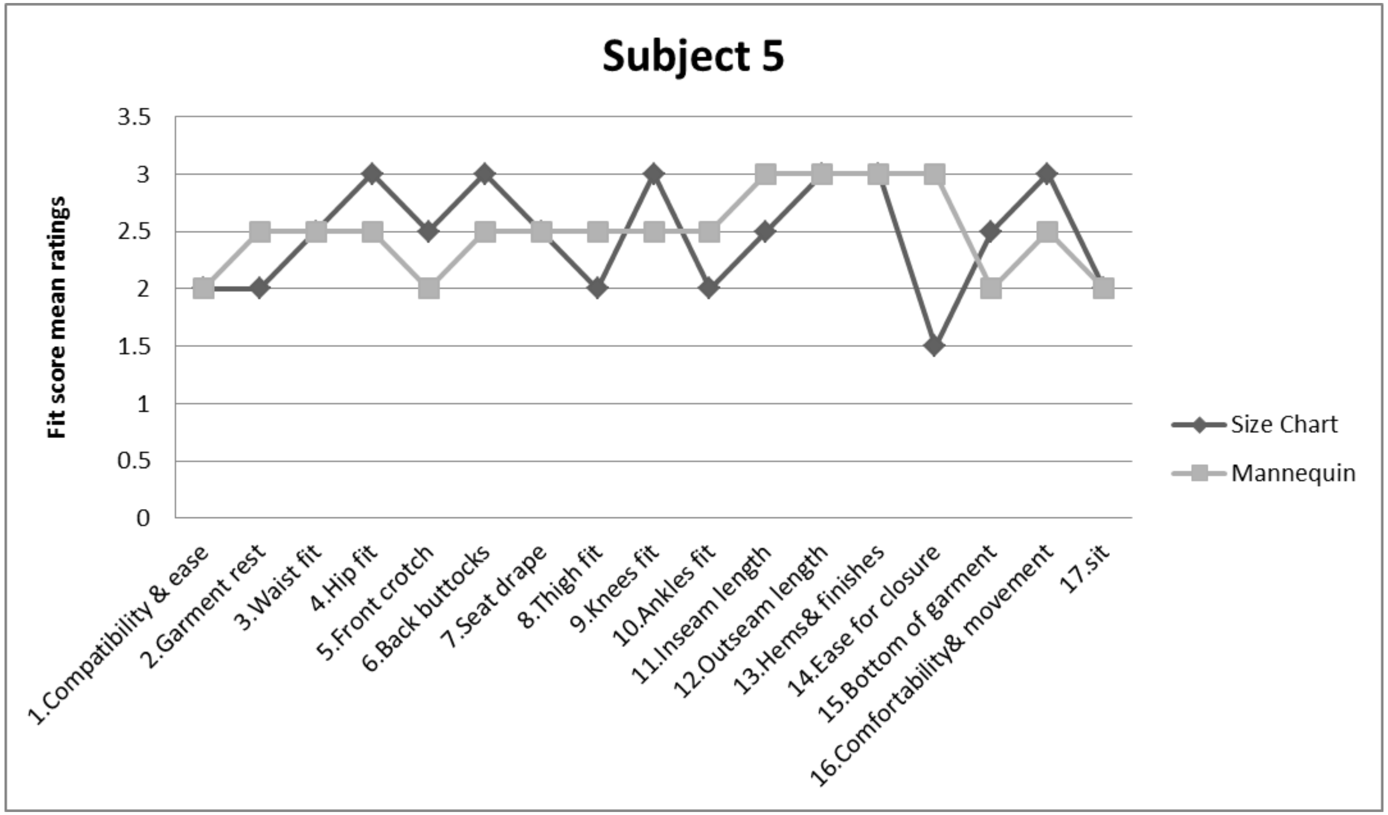
Appendix K12: The comparative mean ratings for the trousers quality of fit attained from subject 3.



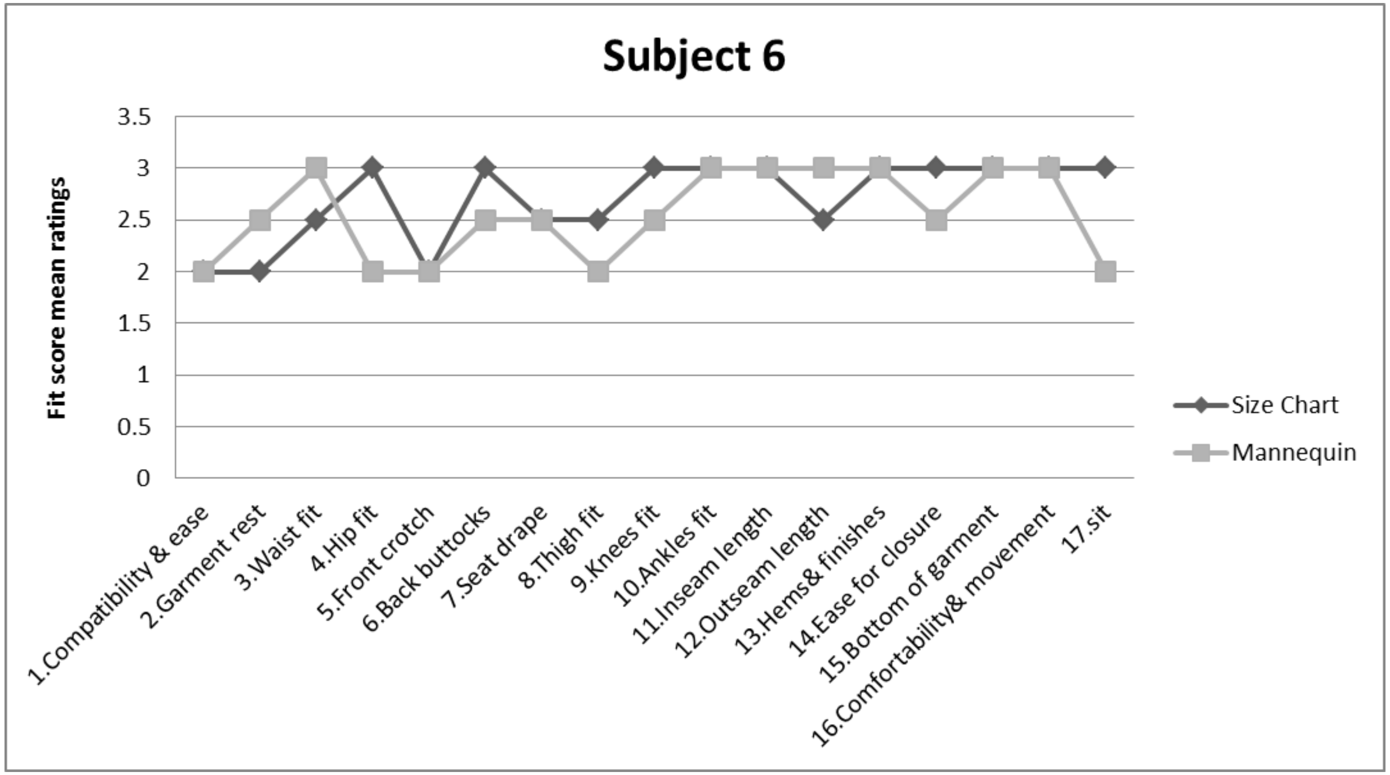
Appendix K13: The comparative mean ratings for the trousers quality of fit attained from subject 4.



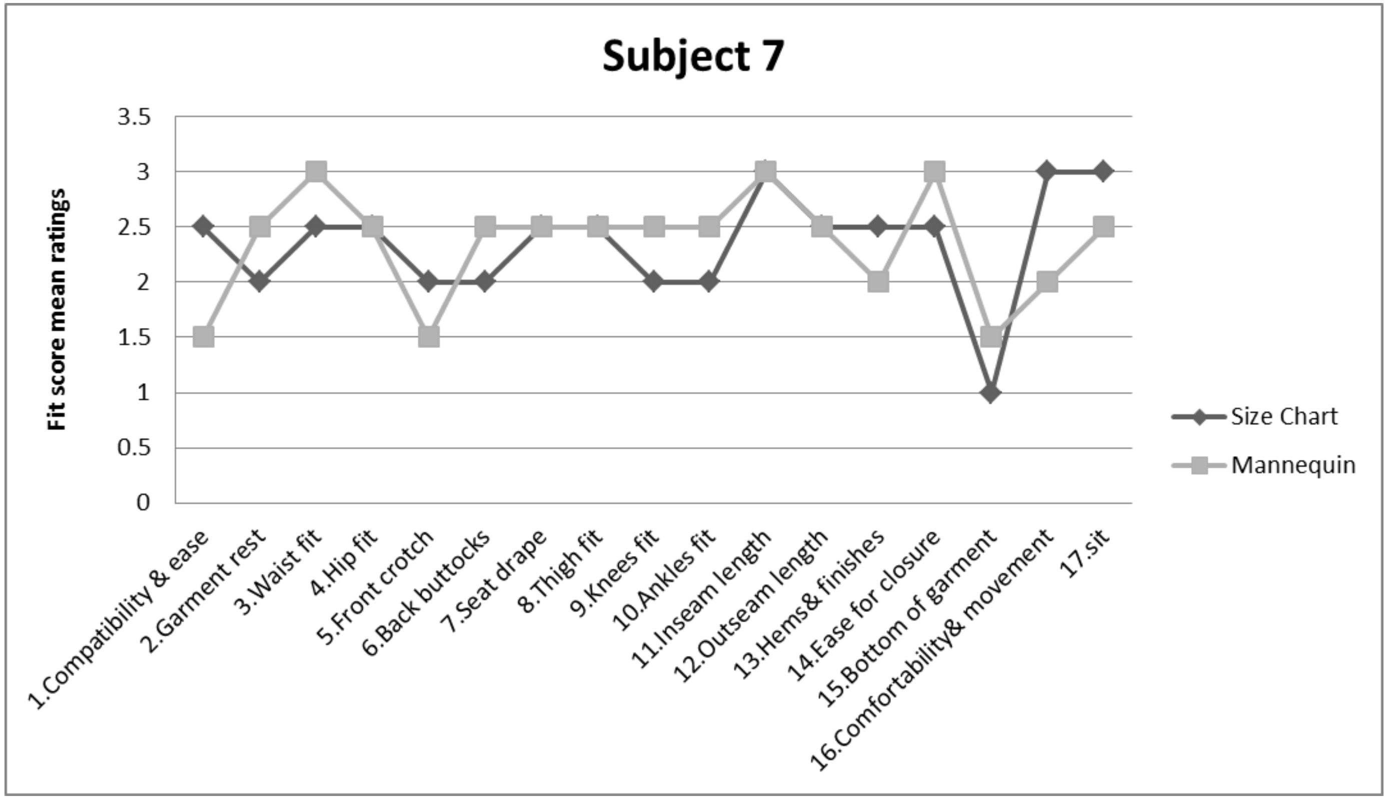
Appendix K14: The comparative mean ratings for the trousers quality of fit attained from subject 5.



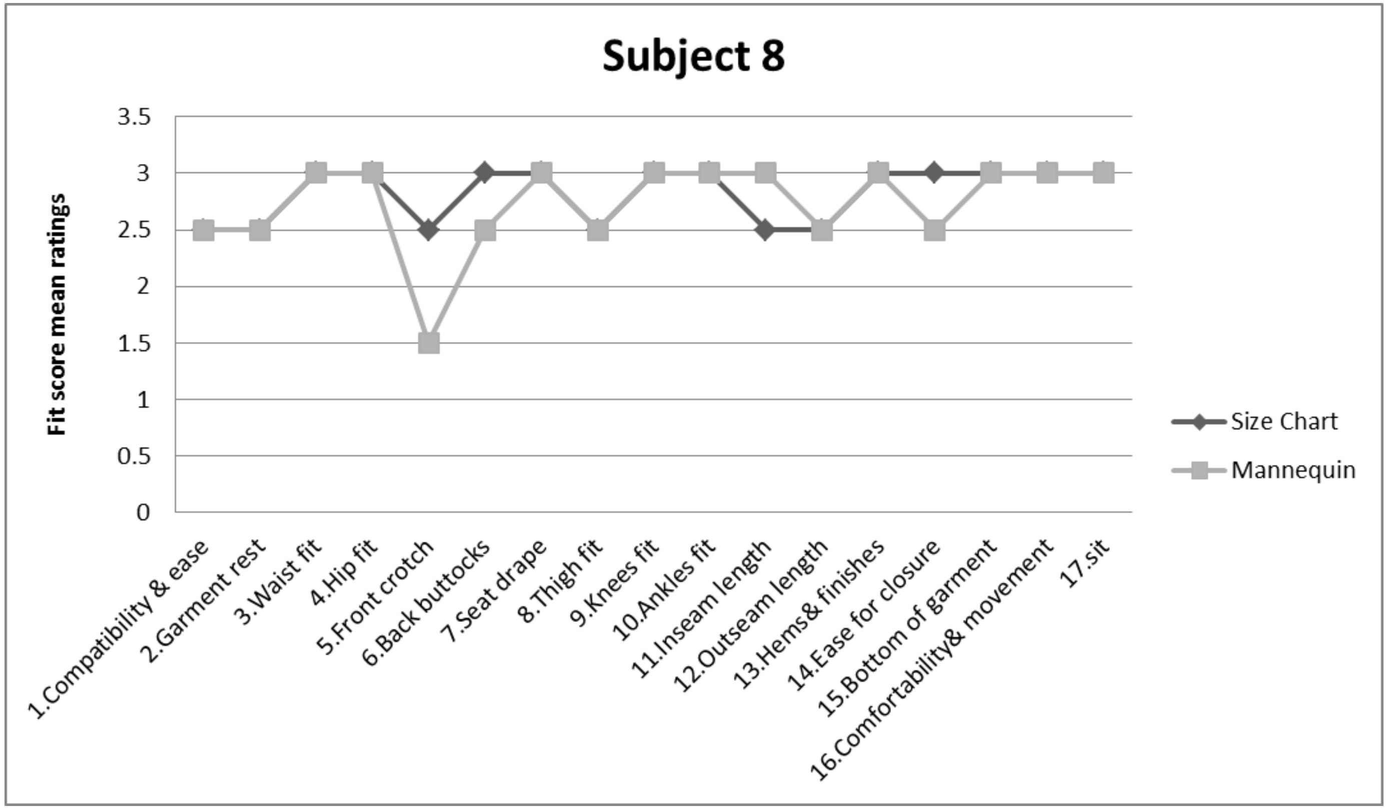
Appendix K15: The comparative mean ratings for the trousers quality of fit attained from subject 6.



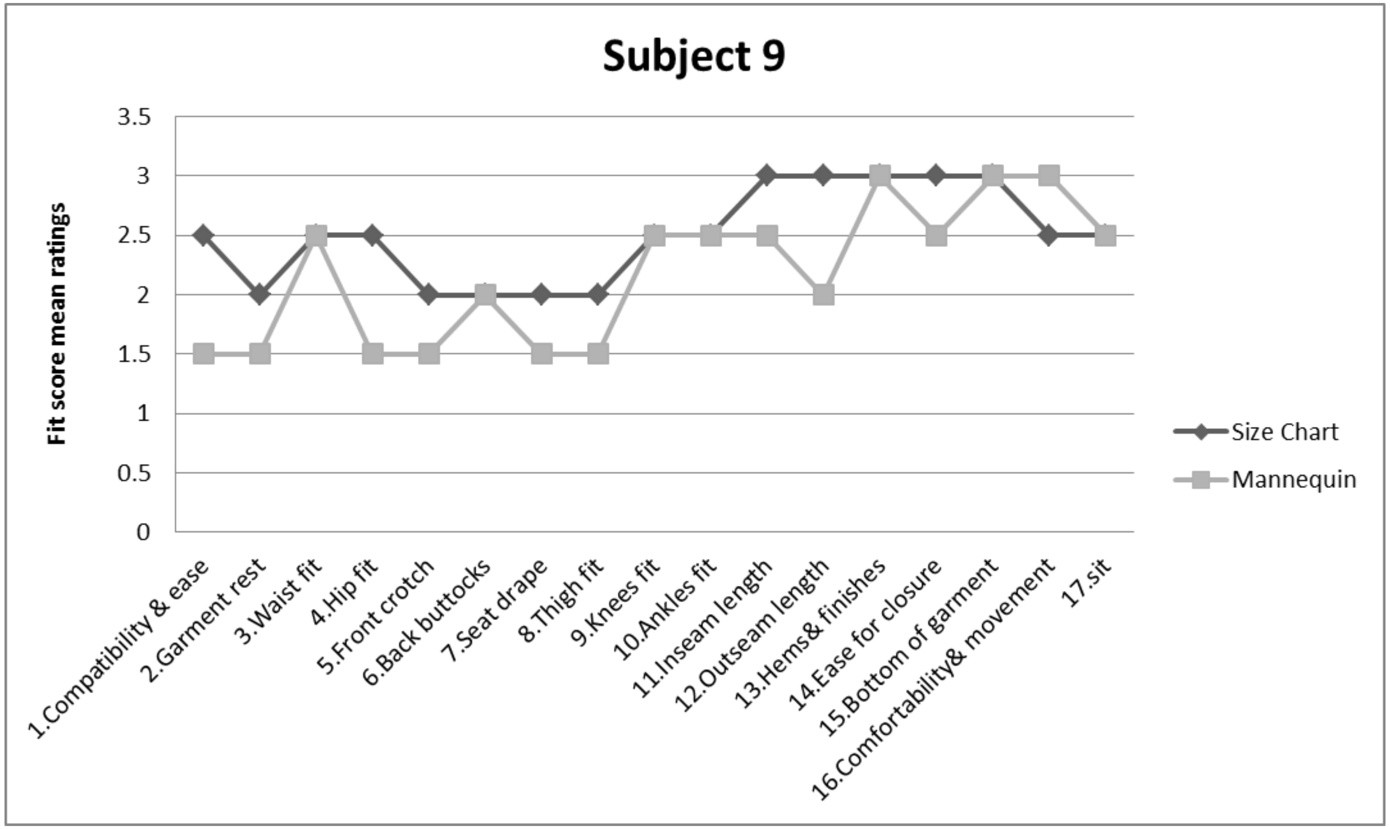
Appendix K16: The comparative mean ratings for the trousers quality of fit attained from subject 7.



Appendix K17: The comparative mean ratings for the trousers quality of fit attained from subject 8.



Appendix K18: The comparative mean ratings for the trousers quality of fit attained from subject 9.



Appendix L: Each subject’s 3D full body scanned measurements compared with the size 10/34 chart measurements and the size 10/34 measurements from the petite mannequin

Appendix L1: Measurement comparison for subject 1

Subject 1: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 1: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	87	86
Upper waist	70	63	69
Chest	88	85	87
Underbust	75	72	73
Lower waist	81	85	85
Bicep	28	30	27
Elbow	23	24	20
Neck full	35	35	34
Armscye	36	32	33
Neck to upper waist back	33	32	39
Neck to upper waist front	30	30	35
sleeve length	48	45	51
Shoulder	12	12	12
Wrist	16	14	15

Subject 1: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 1: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
[redacted]			
Upper waist	70	63	69
Lower waist	81	85	85
Hip	96	98	95
Top thigh	55	56	54
Mid-thigh	45	41	41
Calf	35	35	34
High hip	90	90	92
Ankle	26	23	25
Knee	41	38	39
Crotch length back	35	33	36
Crotch length front	34	33	36
Inseam	66	66	73
Outseam	100	96	102

Appendix L2: Measurement comparison for subject 2

Subject 2: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 2: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	89	86
Upper waist	70	73	69
Chest	88	88	87
Underbust	75	77	73
Lower waist	81	90	85
Bicep	28	30	27
Elbow	23	24	20
Neck full	35	35	34
Armscye	36	34	33
Neck to upper waist back	33	34	39
Neck to upper waist front	30	31	35
sleeve length	48	46	51
Shoulder	12	12	12
Wrist	16	15	15

Subject 2: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 2: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Upper waist	70	73	69
Lower waist	81	90	85
Hip	96	97	95
Top thigh	55	55	54
Mid-thigh	45	40	41
Calf	35	33	34
High hip	90	94	92
Ankle	26	23	25
Knee	41	36	39
Crotch length back	35	37	36
Crotch length front	34	35	36
Inseam	66	72	73
Outseam	100	99	102

Appendix L3: Measurement comparison for subject 3

Subject 3: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 3: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	90	86
Upper waist	70	70	69
Chest	88	87	87
Underbust	75	70	73
Lower waist	81	83	85
Bicep	28	35	27
Elbow	23	26	20
Neck full	35	34	34
Armscye	36	33	33
Neck to upper waist back	33	36	39
Neck to upper waist front	30	34	35
sleeve length	48	48	51
Shoulder	12	13	12
Wrist	16	16	15

Subject 3: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 3: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
[redacted]			
Upper waist	70	70	69
Lower waist	81	83	85
Hip	96	98	95
Top thigh	55	58	54
Mid-thigh	45	46	41
Calf	35	36	34
High hip	90	89	92
Ankle	26	25	25
Knee	41	39	39
Crotch length back	35	37	36
Crotch length front	34	39	36
Inseam	66	82	73
Outseam	100	100	102

Appendix L4: Measurement comparison for subject 4

Subject 4: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 4: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	92	86
Upper waist	70	74	69
Chest	88	89	87
Underbust	75	76	73
Lower waist	81	87	85
Bicep	28	31	27
Elbow	23	23	20
Neck full	35	33	34
Armscye	36	34	33
Neck to upper waist back	33	35	39
Neck to upper waist front	30	32	35
sleeve length	48	47	51
Shoulder	12	12	12
Wrist	16	14	15

Subject 4: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 4: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Upper waist	70	74	69
Lower waist	81	87	85
Hip	96	100	95
Top thigh	55	58	54
Mid-thigh	45	44	41
Calf	35	34	34
High hip	90	96	92
Ankle	26	20	25
Knee	41	39	39
Crotch length back	35	43	36
Crotch length front	34	38	36
Inseam	66	73	73
Outseam	100	100	102

Appendix L5: Measurement comparison for subject 5

Subject 5: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 5: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	92	86
Upper waist	70	76	69
Chest	88	89	87
Underbust	75	79	73
Lower waist	81	87	85
Bicep	28	30	27
Elbow	23	25	20
Neck full	35	32	34
Armscye	36	37	33
Neck to upper waist back	33	36	39
Neck to upper waist front	30	31	35
sleeve length	48	45	51
Shoulder	12	12	12
Wrist	16	15	15

Subject 5: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 5: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Upper waist	70	76	69
Lower waist	81	87	85
Hip	96	97	95
Top thigh	55	55	54
Mid-thigh	45	42	41
Calf	35	35	34
High hip	90	92	92
Ankle	26	24	25
Knee	41	36	39
Crotch length back	35	36	36
Crotch length front	34	37	36
Inseam	66	74	73
Outseam	100	98	102

Appendix L6: Measurement comparison for subject 6

Subject 6: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 6: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	90	86
Upper waist	70	72	69
Chest	88	86	87
Underbust	75	74	73
Lower waist	81	80	85
Bicep	28	31	27
Elbow	23	26	20
Neck full	35	33	34
Armscye	36	35	33
Neck to upper waist back	33	35	39
Neck to upper waist front	30	30	35
sleeve length	48	47	51
Shoulder	12	13	12
Wrist	16	15	15

Subject 6: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 6: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Upper waist	70	72	69
Lower waist	81	80	85
Hip	96	97	95
Top thigh	55	54	54
Mid-thigh	45	44	41
Calf	35	34	34
High hip	90	89	92
Ankle	26	26	25
Knee	41	37	39
Crotch length back	35	40	36
Crotch length front	34	39	36
Inseam	66	75	73
Outseam	100	101	102

Appendix L7: Measurement comparison for subject 7

Subject 7: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 7: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	89	86
Upper waist	70	75	69
Chest	88	87	87
Underbust	75	76	73
Lower waist	81	81	85
Bicep	28	30	27
Elbow	23	24	20
Neck full	35	31	34
Armscye	36	30	33
Neck to upper waist back	33	32	39
Neck to upper waist front	30	30	35
sleeve length	48	46	51
Shoulder	12	11	12
Wrist	16	15	15

Subject 7: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 7: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Upper waist	70	75	69
Lower waist	81	81	85
Hip	96	98	95
Top thigh	55	53	54
Mid-thigh	45	40	41
Calf	35	39	34
High hip	90	96	92
Ankle	26	26	25
Knee	41	40	39
Crotch length back	35	37	36
Crotch length front	34	36	36
Inseam	66	67	73
Outseam	100	98	102

Appendix L8: Measurement comparison for subject 8

Subject 8: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 8: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
[redacted]			
Bust	88	93	86
Upper waist	70	74	69
Chest	88	90	87
Underbust	75	79	73
Lower waist	81	91	85
Bicep	28	34	27
Elbow	23	26	20
Neck full	35	34	34
Armscye	36	38	33
Neck to upper waist back	33	40	39
Neck to upper waist front	30	33	35
sleeve length	48	48	51
Shoulder	12	13	12
Wrist	16	17	15

Subject 8: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	**Size 10/34 3D full body scanned petite women's measurements (in this study)**	**Subject 8: 3D full body scanned measurements**	**Size 10/34 3D full body scanned petite mannequin measurements**
Upper waist	70	74	69
Lower waist	81	91	85
Hip	96	100	95
Top thigh	55	56	54
Mid-thigh	45	45	41
Calf	35	36	34
High hip	90	98	92
Ankle	26	28	25
Knee	41	38	39
Crotch length back	35	34	36
Crotch length front	34	39	36
Inseam	66	68	73
Outseam	100	101	102

Appendix L9: Measurement comparison for subject 9

Subject 9: Upper body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 9: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Bust	88	88	86
Upper waist	70	66	69
Chest	88	86	87
Underbust	75	78	73
Lower waist	81	74	85
Bicep	28	33	27
Elbow	23	24	20
Neck full	35	33	34
Armscye	36	37	33
Neck to upper waist back	33	36	39
Neck to upper waist front	30	31	35
sleeve length	48	45	51
Shoulder	12	12	12
Wrist	16	14	15

Subject 9: Lower body measurement comparisons with the size 10/34 size chart measurements and the size 10/34 measurements from the petite mannequin.

Body dimensions	Size 10/34 3D full body scanned petite women's measurements (in this study)	Subject 9: 3D full body scanned measurements	Size 10/34 3D full body scanned petite mannequin measurements
Upper waist	70	66	69
Lower waist	81	74	85
Hip	96	97	95
Top thigh	55	51	54
Mid-thigh	45	39	41
Calf	35	32	34
High hip	90	88	92
Ankle	26	21	25
Knee	41	34	39
Crotch length back	35	39	36
Crotch length front	34	38	36
Inseam	66	72	73
Outseam	100	100	102