BODY MORPHOTYPE AND 3-D SCANNED E-TAPE ANTHROPOMETRIC MEASURES FOR MEN IN GAUTENG

by

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submitted in accordance with the requirements for
the degree of

MASTER OF CONSUMER SCIENCE

in the

DEPARTMENT OF LIFE AND CONSUMER SCIENCES
COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

at the

UNIVERSITY OF SOUTH AFRICA

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February 2023

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Body morphotype and 3-D scanned e-tape anthropometric measures for men in Gauteng

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I declare that the above dissertation 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.

I further declare that I submitted the dissertation to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

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ACKNOWLEDGEMENTS

First, I am thankful to God for giving me the opportunity to learn new skills throughout this study. I would also like to express my deepest appreciation to the following persons who have helped and supported me during my studies.

- To Dr Reena Pandarum my supervisor, for her patience, detailed constructive feedback, support and encouragement throughout the dissertation writing journey. The time and effort you have invested in me for the past three years is greatly appreciated.

- To Prof Peter Njuho my co-supervisor, for his expert insights and guidance in reviewing the statistical analysis.

- To Ms Busi Tabo, for granting me access to the electronic tape (e-tape) anthropometric dataset for use in this study.

- To the University of South Africa (UNISA), for financial support during the entire study.

- To my mother Mrs Iris Mnyaiza, for her support and encouraging me to further my studies.

- To my siblings Mr Sifiso, Sicelo and Siphamandla, the late Ms Nombuso and Mr Mduduzi Mnyaiza for your endless support during this journey.

ABSTRACT

Advances in the clothing sector began from the 1980s when a three dimensional (3-D) full-body scanner was developed to obtain anthropometric body measurement data accurately, quickly and non-intrusively. However, sizing systems currently in use in South Africa are outdated and still based on traditionally extracted anthropometric measurements of the 'ideal' body type. In this study the aim is to classify the dominant male body morphotype and develop anthropometric size charts for men residing in Gauteng, South Africa, based on 3-D anthropometric body scan measurements.

The research study used secondary data (Tabo, 2020) e-tape anthropometric dataset of 270 men residing in Pretoria and Johannesburg, Gauteng, South Africa, aged 18 to 56 years. Principal Component Analysis (PCA) and K-Means Cluster Analysis were used to identify the key body dimensions and to classify the dominant men's body morphotype emerging from prevalent cluster categories. Furthermore, a combination of PCA and Regression Analysis was used to identify the key control e-tape measurements for the development of an anthropometric size chart.

The PCA and K-Means Cluster Analysis identified the rectangle (n=123, 45.5%) as being the dominant body morphotype from a sample of 270 men. Thereafter, the inches (inch) and centimetres (cm) based anthropometric size chart for the upper and lower body, aligned with a South African commercial men's tailoring mannequin manufacturer, was established as chest size of 37 inch to 41 inch for upper body, and waist size of 30 inch to waist size 36 inch for the lower body.

For the upper body, the men's tailoring mannequin shoulder to shoulder width of 47 cm was 11 cm larger than the shoulder- to- shoulder width of 36 cm for the men of a Rectangle morphotype. For the lower body, the men's tailoring mannequin thigh girth of 60 cm was 10 cm larger than the thigh girth of 50 cm for the men of a Rectangle morphotype, and the out-seam 110 cm was 13 cm longer than the out-seam 97 cm for men of a Rectangle morphotype.

The findings of the study, therefore, suggest that menswear clothing manufacturers in South Africa need to revise size charts to reflect the current body morphotype anthropometric measurements.

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DEFINITIONS

Anthropometrist: An individual who measures the size and proportions of the human body (Moss *et al*., 2021).

Body morphotype: The body outline of the scanned image in this study was defined as a morphotype because the anthropometric measurements extracted using a 3-D full-body scanner were found to be different from those of the traditional anthropometric measurements extracted using a dressmaker’s tape measure or callipers (Pandarum *et al*., 2020).

e-tape anthropometric measurements: Are body measurements that are extracted digitally using technology such as a 3-D full-body scanner (Phasha *et al*., 2020, Pandarum *et al*., 2020).

Traditional anthropometric measurements: Are body measurements that are extracted manually using body measurement tools such as a dressmaker’s tape measure (Yan *et al*., 2020; Zakaria & Gupta, 2020).

LIST OF ACRONYMS

[TC]^2	:	Textile Clothing and Technology Corporation
3-D	:	Three-Dimensional
BMI	:	Body Mass Index
BVI	:	Body Volume Index
CAESAR	:	Civilian America and European Surface Anthropometry
cm	:	Centimetres
COVID-19	:	Coronavirus Disease of 2019
e-tape	:	Electronic tape
inch	:	Inches
ISO	:	International Organisation for Standardisation
kg	:	Kilograms
KMO	:	Kaiser Meyer Olkin
mep	:	Measurement Extraction Programme
PC (s)	:	Principal Component (s)
PCA	:	Principal Component Analysis
PMP	:	Phase Measurement Profilometry
RTW	:	Ready-To-Wear
SABS	:	South African Bureau of Standards
SANS	:	South African National Standards
SMME	:	Small and Medium-Sized Enterprises
SPSS	:	Statistical Package for the Social Sciences
UNISA	:	University of South Africa
USA	:	United States of America

CHAPTER ONE

OVERVIEW OF THE STUDY

1.1 INTRODUCTION

Men shopping for apparel has led to the growth in local manufacturers and retailers expanding the male ready-to-wear (RTW) clothing ranges due to the financial returns and growth of the market (Van Rensburg *et al*., 2023). However, sizing systems currently in use in South Africa are outdated and based on traditionally extracted anthropometric measurements of the 'ideal' body type (Muthambi *et al*., 2016:2).

Clothing manufacturers and designers in South Africa extract anthropometric measurements from a men's tailoring mannequin of an 'Ideal' body type to draft patterns and to test the fit of the RTW garments for their target with different body types (Ola-Afolayan *et al*., 2021:52). Tailoring mannequins, also referred as dress forms, are used by clothing manufacturers and designers to draft basic patterns to create clothing and to test how a particular sample garment will fit on the body type of the intended wearer (De Klerk *et al*., 2014:86). The RTW clothing garments intended to fit heterogenous men in South Africa are tested for the fit on the tailoring mannequin. The tailoring mannequins are developed from an anthropometrical dataset of muscular/lean body dimension ratios of the 'ideal' male (Mchiza *et al*., 2015:8). Therefore, men with diverse body types and body dimension ratios that are different from the commercially available 'ideal' tailoring mannequin in South Africa, may experience fit incongruities with RTW retail garments (Ola-Afolayan *et al*., 2021:52).

Hsu and Ying-Zhou (2013:211), Mchiza *et al*. (2015:10) and Varte *et al*. (2017:32) further report that garment fit problems experienced by men globally, lead to approximately five to ten % of garments store returns because of the dissatisfaction with the quality the RTW clothing fit. Jadezweni (2020:1) and Wasserman (2020:1) attribute this to the lack of accurate standardised representative e-tape anthropometric datasets and, as a result, inconsistent sizing systems are adapted by retailers for South African men. As an example, a size 32 formal/casual trouser at Woolworths report an average waist measurement of 83 cm, while at H&M an 80 cm, and 81 cm at Mr Price. Song and Ashdown (2010:266), and Gupta and Zakaria (2014:256), concur, saying that RTW garment manufacturers and retailers select anthropometric measurements of a standard fit tailoring mannequin's body type, and grade proportionally up or down from these standardised anthropometric measurements to develop size charts and size ranges for their target market. Therefore, men of a different body type, with different anthropometric measurements to those of the tailoring mannequin manufacturers, experience difficulties in finding RTW garments that fit well (Žuraj *et al*., 2017:356). Furthermore, this indicates that clothing manufacturers develop size charts without updating the tailoring mannequin anthropometric measurements to reflect the current anthropometric measurements and the dominant body type of South African men (Jadezweni, 2020).

In the field of clothing in South Africa, studies related to body type and size have been conducted extensively for women (Makhanya *et al*., 2014; Muthambi *et al*., 2016; Pandarum *et al*., 2017; Phasha *et al*., 2020).The only known studies exploring male body types in South Africa have been conducted by Reardon and Govender (2011), Martin and Govender (2013) and Body-dynamics (2016). However, these qualitative studies considered body types from a subjective socio-cultural viewpoint. Studies investigating the dominant body type and its sizes for updating size charts objectively using the quantitative approach have never been conducted.

Therefore, the primary aim of this study is to analyse e-tape anthropometric measurements from a secondary anthropometric dataset (Tabo, 2020) for men residing in Gauteng. The study initially classified the dominant body morphotype arising in the secondary dataset of 270 men. Thereafter, the anthropometric size charts were developed for the dominant male body morphotype that arose in that dataset.

1.2 PROBLEM STATEMENT

Literature indicates that men become frustrated with the lack of consistency of fit and sizing of RTW brands (Wilson, 2016:7). Dominant factors that contribute to the fit and sizing issues experienced by men in South Africa include the lack of consistency in sizing across RTW garments, and non-standardised sizing systems developed on the 'ideal' body type of men of western descent. Furthermore, sizing systems are based on average anthropometric measurements of the primary body dimension such as the chest, waist and hip girths, that results in unrealistic sizes of a standard body (Narang, 2014:43). Hence, this study aims to address the gaps in the literature for men's morphotypes and anthropometric size charts from a sample of men residing in South Africa.

1.3 RESEARCH OBJECTIVES OF THE STUDY

This study aims to classify the dominant male body morphotype and develop anthropometric size charts for men residing in Gauteng, South Africa. The following research objectives and questions are formulated for the study:

1.3.1 Objective 1

To classify the dominant body morphotype arising in the secondary dataset of 270 men.

1.3.2 Objective 2

To develop upper and lower anthropometric size charts from the dominant male body morphotype that was identified from objective 1.

1.3.3 Objective 3

To compare the upper and lower body anthropometric measurements for men of a dominant morphotype with those from the current men's tailoring mannequin of a similar body size by Figure-Forms mannequin manufacturing company in South Africa.

Question 1

What is the dominant body morphotype for men that can be established based on analysis of 3-D anthropometric measurements?

Question 2

What are the size ranges of key 3-D anthropometric measurements of the upper and lower body of the dominant body morphotype for men?

Question 3

How 3-D anthropometric measurements of the dominant body morphotype for men compare to that of Figure-Forms tailoring mannequin manufacturer?

1.4 RESEARCH DESIGN

A convenience and purposive non-probability sampling method of the exploratory quantitative research design was applied to fulfil the objectives of this study. These research sampling methods, and the research design, are fully described in section 3.2 of Chapter 3 in this study.

The primary data collected by Tabo (2020) was used as secondary data in this study. The dataset consisted of the demographic questionnaires with their matching set of 3-D scans of anthropometric measures. The demographic information in this study was used to ensure that the results are interpreted in relation to profiles of men whose 3-D scans were extracted in the dataset to fulfil the objectives of this study. These objectives were to classify the dominant male body morphotype and to develop anthropometric size charts.

Initially, the body morphotype categories of the 270 men were classified using the Principal Component Analysis (PCA) and K-Means Cluster Analysis methods. These methods clustered the e-tape anthropometric dataset into homogeneous groups to establish the dominant male body morphotype arising in the dataset. The prevalent body morphotype that fall into each cluster was provided a name based on the commonly used geometric classifications as a Rectangle, Oval, Triangle and Trapezoid. Thereafter, the body dimensions of the morphotype that emerged as being the dominant in the clusters were analysed using PCA and regression analysis to develop the upper and lower body anthropometric size charts. Thereafter, the upper body and lower body anthropometric measurements of the men of a dominant morphotype were compared with those from a men’s tailoring mannequin of a similar body size by Figure-Forms, a South African mannequin manufacturing company. This mannequin manufacturing company was willing to share the anthropometric data for the purpose of this study.

1.5 SIGNIFICANCE OF THE STUDY

Based on the potential findings of this study, it will provide the South African clothing sector, manufacturers, retailers, and standardisation bodies with updated and current anthropometric data of the dominant male body dimensions, morphotype and body frame sizes to update their current sizing and fit databases. The researcher anticipates that the dominant body morphotype, and the subsequent anthropometric size charts, will assist the formal clothing sector, SMME's and standardisation bodies to improve garment sizing and fit systems for men.

1.6 RESEARCH LAYOUT

The layout of the dissertation was proposed based on the objectives of the study and was presented as follows:

Chapter 1 introduction

Chapter 1 presents the introduction of the study. In this chapter the background to justify the aim and scope of the study was discussed. The research problem, research objectives, research design and significance of the study are also presented in this chapter.

Chapter 2 literature review

Chapter 2 presents the literature review. This chapter reviews the existing theories that were reviewed to find information that is relevant for the justification of the aim of the study. The literature on sizing systems, body types, anthropometric data collection methods and tailoring mannequins are reviewed.

Chapter 3 methodology

Chapter 3 discusses the methodology of the study. In this chapter the research design, the sampling methods, data collection methods, data analysis, data quality and ethical considerations of the study are presented.

Chapter 4 findings

Chapter 4 presents the dissertation findings. The profile of the sample was discussed, the process of the data analysis of the e-tape measurements for classification of the dominant body morphotype and to develop size charts are discussed, together with the interpretation and discussion of the findings.

Chapter 5 conclusions

Chapter 5 summarises the results and conclusions of the study that resulted from the reflection of the objectives of the study. The contributions to the study, limitations, and the recommendations for future studies in clothing and apparel fit are also highlighted.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

There is a plethora of reported anthropometric studies on women's body types and sizes in South Africa (Ola-Afolayan & Mastamet-Mason, 2013; Makhanya *et al*., 2014; Muthambi *et al*., 2016; Pandarum *et al*., 2017; Phasha *et al*., 2020). Reported studies for men, however, are limited. Sizing systems currently in use in South Africa have been developed using the traditional methods of the past such as extracting anthropometric measurements of the 'ideal' body type using dressmaker's tape measures and callipers to fit a population with different body types (Muthambi *et al*., 2016:2). The local clothing industry adapt foreign systems that originated from national, traditional anthropometric surveys that were conducted in developed countries (Ola-Afolayan & Mastamet-Mason, 2013:202-203). These adapted sizing systems, consisting of the body dimensions of the population from western countries, are currently in use to provide fit in the retail and manufacturing sector. However, the use of these might prove inadequate in addressing fit issues of approximately 40 % of men in South Africa who are reported to be obese with a protruding stomach, enlarged breast tissue and thin legs (Body-dynamics, 2016). Therefore, the purpose of this study is to explore and classify the dominant body morphotype category of men in South Africa, and thereafter develop the anthropometric size charts.

This chapter focus on the methodology that has been applied in the literature to develop sizing systems. The methodology consists of five stages that will be discussed throughout the literature review. Thereafter, a brief discussion on the use of tailoring mannequins to evaluate garment fit follows. Finally, the main, relevant points arising from the review of the literature are summarised.

2.2 SIZING SYSTEM/SIZE CHARTS

A sizing system is a series of size charts consisting of the key anthropometric dimensions used to classify population into different body type categories (Shin *et al*., 2011:47; Petrova & Ashdown, 2012:268). Mpampa *et al.* (2010:52) and Vithanage *et al*. (2013:32), conducted anthropometric studies to develop a sizing system using different methodologies. However, the methodology to develop a sizing system according to Varte *et al.* (2017:30) and Xia and Istook (2017:236), the approach consists of five steps. An explanation of each is that in the first step, anthropometric data of the target market for manufacturers and retailers is collected or accessed in a database. The second step involves the division of collected or accessed anthropometric data into body type categories based on key body dimensions. These key body dimensions are also used to determine the size ranges of the sizing system in the third step. Thereafter, in the fourth step, the values of secondary key body dimensions are calculated. Finally, the sizes in the sizing system are communicated. The methodology to develop a sizing focusing on the five steps mentioned above will be discussed in the next sections below.

2.2.1 Anthropometric data of the target market for manufacturers and retailers

The clothing industry manufacturers and retailers are always striving to design garments with a good fit for the wearers' body. However, this is often not easy to achieve without a clear understanding of a wearers' body types and sizes (Gupta & Zakaria, 2014:35). At the beginning of the anthropometric data collection process to design garments with a good fit, the targeted or 'ideal' wearer's body dimensions need to be systematically measured to determine anthropometric data that is representative (Varte *et al*., 2017:30). The collection of the anthropometric data that represents the sample of the targeted population for garment design is also known as anthropometry. Anthropometry is a reliable scientific method dealing with the collection of body measurements to identify the relationships between the dimension of the bones, muscle, and fat tissue for understanding the physical classification of the human body type and the range of body size (Alubel *et al*., 2017:1; Chisosa & Muzenda, 2020:99; Gleadall-Siddall *et al*., 2020:337; Lee *et al*., 2020:2; Yadav & Chanana, 2020:16).

Anthropometry produces a series of quantitative human body measurements that are used to evaluate the composition of the body type and size and are collectively known as anthropometric data sets (Alubel *et al*., 2017:1). Body dimensions are components of the anthropometric data set that consist of length, girth, and depths; measurements that are used to classify body type categories of the wearers and to formulate standard sizes that provide a good fit to those wearers' figure types (Gupta & Zakaria, 2014:35; Kausher & Srivastava, 2016:138; Xia & Istook, 2017:236).

The South African National Standard (SANS) organisation in South Africa published the clothing standard SANS 8559:1&2 in 2019. The SANS 8559:1&2 clothing standard is taken as a guide for the extraction and evaluation of the anthropometric data to describe and select those body dimensions that are viewed as vital in the construction of the garments. The standard only guides the manufacturers, retailers and researchers about the methods that are available to collect and extract the anthropometric body dimensions (De Klerk *et al*., 2014:88). Specific details on how to select a suitable method for anthropometric data collection using these clothing standards are lacking (Gill, 2015:17). Therefore, in the past and currently, clothing industry manufacturers and retailers apply their own standardised methods to collect and analyse the anthropometric data to develop anthropometric size charts (Xia & Istook, 2017:246). Anthropometric data collection methods that have been used in the past, and currently in the clothing industry to provide well-fitting garments, are discussed in the next section.

2.2.2 Different anthropometric data collection methods/tools

During the second half of the 20th century, body type and size researchers began to generate anthropometric body measurements from the international and national anthropometric survey data sets that were collected with guidelines from sizing standards published in different countries (Xia & Istook, 2017:236; Kim *et al*., 2019:1). The anthropometric body measurement researchers at these times used manual anthropometric data collection tools and methods to collect limited linear human body measurement data (Zakaria & Gupta, 2020:14). However, at the beginning of the 21st century, the researchers included 3-D scan e-tape anthropometric data collection tools and methods to collect human body data that can be used to identify a variety of human body types and sizes. These anthropometric data collection tools and methods have led to an increase in both public and proprietary anthropometric population data sets that are analysed by the researchers to understand the human body types and sizes (Gill, 2015:16).

2.2.3 Manual anthropometric data collection

Manual anthropometric data collection in the research studies can be described as the process of the extraction of human body measurements in the pre-defined body surface landmarks points using manual measurement tools such as dress maker's tape measures, anthropometers, callipers and medical scales (Heymsfield *et al*., 2018:8; Diprose *et al*., 2020:371; Gleadall-Sidall *et al*., 2020:337; Yan *et al*., 2020:1; Zakaria & Gupta, 2020:5). Manual anthropometric data collection tools provide one-dimensional (1-D) linear body measurements to the researchers intending to describe and classify the human body type and size (Cottle, 2012:2; Balach *et al*., 2020:56; Zakaria & Gupta, 2020:3). One-dimensional body measurements are usually insufficient to evaluate human variations that define body type, size and proportions that are essential for clothing pattern development (Alubel *et al.*, 2017:1; Balach *et al*., 2020:56; Carufel & Bye, 2020:2). In today's apparel industry, garment pattern making is a vital procedure of manufacturing well-fitting garments (Wang *et al*., 2019:1). However, human body dimensions that are important in the provision of well-fitting clothes, such as the width and depth of the armscye are not easily determined using traditional manual measurement tools that capture linear measurements (Gupta & Zakaria, 2014:42).

According to Apeagyei (2010:64), Gill (2015:2) and Dianat *et al*. (2018:1705), observer error is another issue in the collection of manual anthropometric data measurements, usually caused by imprecision in a landmark location, incorrect positioning of the subject and inaccurate application of the measuring tool. A trained anthropometrist/fieldworker is needed to collect accurate, consistent, reliable, and valid manual anthropometric data (Cottle, 2012:9; De Klerk *et al*., 2014:89; Petrak *et al*., 2015:150; Lescay *et al*., 2016:51; Moss *et al*., 2021:1). Having a trained anthropometrist in the manual anthropometric data collection process would reduce the observer error; the process, however, is time-consuming and challenging to apply in large-scale anthropometric data collection studies (Petrak *et al*., 2015:150; Brolin, 2016:3; Koepke *et al*., 2017:1; Wang *et al*., 2019:2; Zakaria & Gupta, 2020:29).

2.2.4 3-D scan e-tape anthropometric data collection

Generally, body scanning can be described as the technology that is employed to capture the 3-D surface of the human body utilising structured light projection (Gill, 2015:17). The structured light in the 3-D scanning tool projects and facilitates rapid identification of complex views of human body girth dimensions, length dimensions, dimension volumes and surface area measurements (Cottle, 2012:2; Gleadall-Siddal *et al*., 2020:337).

Since the 1980s, body scanning technologies have been used in conjunction with traditional anthropometric methods to measure human body dimensions to provide better-fitting clothes worldwide (Elnour, 2015:47; Pandarum & Yu, 2015:200; Heymsfield *et al*., 2018:1; Zakaria & Gupta, 2020:29). Otieno (2013:55) describes 3-D full-body scanners as advanced body measuring technology because of the variety of scanners that are available for the collection of anthropometric data in the clothing industry.

There are different types of 3-D full-body scanners available on the market today, with the main purpose of scientifically extracting anthropometric data and digitizing 3-D human body models. The 3-D full-body scanners with distinct features and advantages include a Virtus Smart body scanner, Symcad body scanner, Cyberware body scanner and, the Textile Clothing Technology Corporation $[TC]^2$ NX-16 3-D full-body scanner. A Virtus Smart body scanner offers a contactless measurement of the human body in 8-20 seconds (Vitronic, 2020). The scanner produces e-tape measurements that can be reproducible for use in the clothing industry. The cameras, with a structured light-stripe method, capture a 3-D image of the subject with more than 140 precise e-tape measurements that can help manufacturers who want to provide the consumers with well-fitting clothes (Human solutions, 2015). The Symcad body scanner projects a white structured light with markers and is usually fitted with four sensors that capture a full-body scan of the subject in less than 8-10 seconds (Varte *et al*., 2017:31). The Cyberware scanning machine scans a human body in 17 seconds (Yumpu, 2020). Laser structured lights from the cameras are reflected from the body of a subject, combining the body units into a complete 3-D model of the subject's body (Faust and Carrier, 2014;41). The $[TC]^2$ NX-16 3-D full-body scanner (used in this study), uses optical lenses to develop a 3-D body image. The e-tape measurements in the $[TC]^2$ NX-16 3-D full-body scanner system are extracted by the Phase Measurement Profilometry (PMP) method (Zeraatkar & Khalili, 2020:3). In the body scanning process, the PMP method employs a white structured light to develop a 3-D point cloud image with more than 140 e-tape measurements (Bougourd & Treleaven, 2010:332; Lau *et al*., 2017) in 8 seconds (Apeagyei, 2010:60). A series of cameras captures the body image of the subject from the reflection of the white structured light (Song & Ashdown, 2010:270). The images captured consist of between 20,000 and 300,000 processed data points (Lescay *et al*., 2016:51). The $[TC]^2$ NX-16 3-D full-body scanner produces results by the rapid capturing of high-resolution digital 3-D point cloud images that are displayed on a monitor connected to the scanner operating system (Pandarum *et al*., 2011:3; Cottle, 2012: ii; Heymsfield *et al*., 2018:2). Furthermore, the landmarks extracted using scanning technology can be replicated and are reproduceable (Apeagyei, 2010:59; Löffler-Wirth *et al*., 2016:2; Varte *et al*., 2017:37; Pandarum *et al*., 2020:3).

It can thus be concluded from the literature that 3-D full-body scanners are contactless, fast, and accurate methods that facilitate the process of the collection of large accurate anthropometric body scan datasets within a short period of time (Gupta & Zakaria, 2014:43; Zakaria & Gupta, 2020:29). Large anthropometric data sets, because of 3-D full-body scanners, are available in various countries and are currently used to predict body types and to generate accurate data for the creation of efficient size charts (Pandarum *et al*., 2020:2). However, the 3-D body scanning technology has not been widely adopted in the clothing sector in South Africa (Pandarum *et al*., 2011:1; Koepke *et al*., 2017:3).

Internationally, Civilian American and European Surface Anthropometric Resource (CAESAR), SizeUK and SizeUSA anthropometric data collection surveys, collected large volumes of anthropometric data to evaluate human body measurements that can be used to identify the body types and sizes of the population. The reproducible data from these surveys were anticipated to provide up to date 3-D models of human bodies to predict body types and sizes that are representative of the population (Apeagyei, 2010:59; Li *et al*., 2015:1).

The CAESAR anthropometric data collection project was conducted between 1998-2000 using a Cyberware body scanner (Scataglini & Gunther, 2019:8). In the project's database, a dataset of more than 4400 male and female civilians from the United States of America (USA), the Netherlands and Italy was collected (Heymsfield *et al*., 2018:7; Yan *et al*., 2020:2; Zakaria & Gupta, 2020:6). The collection of the most updated additional portion of over 10 000 male and female American civilians in the SizeUSA, followed in 2000-2003 in the United States (US) using a $[TC]^2$ full-body scanner (Shin *et al*., 2011:47; Heymsfield *et al*., 2018:7). In 2003-2004 the SizeKorea anthropometric data collection survey was conducted to create a 3-D digital human database of 19700 Korean civilians (Kim *et al*., 2019:1586). The SizeUK in 2009 collected the anthropometric data of 5500 males and 5500 females (16-76 years) in Britain using a $[TC]^2$ full-body scanner (Scataglini & Gunther, 2019:10). This anthropometric data collection project developed the first large-scale anthropometric national 3-D digital human database to provide solutions in the fit and sizing issues encountered by various UK populations (Apeagyei, 2010:58-59; Bougourd & Treleaven, 2010:327). Although these surveys provided a fee-based anthropometric dataset that is open for use in the body type and sizing research for adults, they cannot be analysed to identify the dominant body type and size charts in South Africa since they consist of the body dimensions representing the population of their own countries. According to Capelassi *et al*. (2017:2), body dimension measurements differ from one country to another, due to factors such as nutrition and population ethnic group (Beshah *et al*., 2014:52). In certain applications, such as the design of clothing, an efficient product-user fit can be best obtained only when a complete 3-D profile of representative subjects is available from the target population (Gupta & Zakaria, 2014:43) Therefore to develop size charts anticipated to meet clothing fit requirements for South African menswear clothing industry, only nationally collected anthropometric data sets can be applied.

In South Africa, universities such as the University of South Africa (UNISA), the Cape Peninsula University and the University of Pretoria are currently using the 3-D scanning technology to collect the e-tape anthropometric data that is mostly used in their teaching and student research. The anthropometric data sets in these academic institutions, according to Pandarum and Yu (2015:195), mostly consist of focused and generic, but limited anthropometric data of South African women. However, Tabo's (2020) secondary data set, used to address the objectives of this study, represents the small anthropometric data of 270 men that was captured at the University of South Africa using a $[TC]^2$ NX-16 3-D full-body scanner.

A South African retailer, Woolworths, partnered with an international market leader in body scanning Alvanon in 2014, and conducted the first national 3-D anthropometric survey for male and female consumers in South Africa using a full-body scanner (Bizcommunity, 2014). The findings of the Woolworths study are considered proprietary and have never been published in the public domain. Therefore, the age and ethnicity of approximately 6000 men and women who participated in this study are unknown. In the study, 24 % of the participants were men. To date, this is the only large-scale 3-D anthropometric data collection survey that is known to have been conducted in South Africa. However, the data collected cannot be accessed for the in-depth analysis to classify the dominant body type and sizes, or to compare menswear size charts that might reveal factors that underlie fit problems.

2.2.5 Classification of body type categories using key body dimensions

Key body dimensions are fundamental determinants in the classification of body type categories of the population (Zhang, 2020:269). Key body dimensions are anthropometric dimensions that correlate with other body dimensions of the human body (Narang, 2014:28). In a sizing system development process, these body dimensions are selected and calculated to divide a cluster of the population into homogeneous subgroups (Narang, 2014:41; Kausher & Srivastava, 2016:137). The members that belong to a specific homogeneous subgroup consist of similar ratios of the key body dimensions (Narang, 2014:45). Therefore, they are classified as a body type category that is different from other subgroups (Zhang, 2020:270). Divided in this way, it is possible to provide well-fitting garments to the most prevalent homogeneous subgroups using a size chart with the least number of size ranges (Vithanage *et al*., 2015:482; Varte *et al*., 2017:37; Carufel & Bye, 2020:2-3).

2.2.5.1 Selection and calculation of the key body dimensions of the population

According to Gupta and Zakaria (2014:42), a set of the key body dimensions derived from accurate anthropometric data serve as a point of reference to match classified body type categories to the correct sizes. Anthropometric data collected using a 3-D full-body scanner provide a large dataset of the population body dimensions (Koepke *et al*., 2017:3). Therefore, the anthropometric data set need to be statistically analysed to determine the key body dimensions amongst the body dimensions to identify body type categories of the population (Gupta & Zakaria, 2014:43).

After body type categories of the population have been identified, their key body dimensions are also used to assign the correct sizes that are best suitable for their body types (Petrova & Ashdown, 2012:238). In this process, these key body dimensions are called control dimensions because they are also fundamental to provide a garment with a good fit. Faust and Carrier (2014:60) and Narang (2014:28) suggest that to create a garment with a good fit, the designers should select a pair of control body dimensions. In previous studies, anthropometric researchers found that there is no control dimension that is related to both horizontal and vertical body measurements (Mpampa *et al*., 2010:51). Therefore, control body dimensions that are in different planes describe the sizes of the population better than those extracted in a single plane (Petrova & Ashdown, 2012:236). For example, if a hip girth dimension shows correspondence with an in-seam length dimension, they can therefore be selected as the most important to include in establishing sizes for the trousers.

As highlighted in the previous sections, 3-D full-body scanners provide researchers with large volumes of anthropometric data (Koepke *et al*., 2017:3; Gupta & Zakaria, 2014:44). Therefore, advanced statistical methods need to be used to reduce e-tape measurements derived from the 3-D point cloud images into significant variables. A statistical method, referred to as (PCA), is commonly applied to identify the key and control body dimensions that are relevant for the set-up of body type categories and body sizes (Heymsfield *et al*., 2018:7).

The relationships between the body dimensions in the PCA method are determined by the correlation coefficient associations between measurements (Ahmed, 2014:2; Alubel *et al*., 2017:2). Correlation co-efficient determines those variables that have a high degree of correlation which are estimated to provide the possibility of achieving a higher degree of fit satisfaction to a maximum number of the population using a smaller number of sizes (Brolin, 2016:2; Schober *et al*., 2018:1763; Balach *et al*., 2020:57; Yadav & Chanana, 2020:17). During the variable correlation test, it has been observed that vertical body dimensions have a strong correlation with each other, while horizontal body dimensions show a strong correlation with each other (Tiwari & Anand, 2016:3). The waist girth, hip girth, and knee width are examples of horizontal body dimensions and, shoulder length, abdomen front length, front armscye to elbow distance are the examples of vertical body dimensions (Beshah *et al*., 2014:53). The values used in the determination of correlations between the dimensions and identifying key parameters are usually based on the BS 7231 standard. The standard specifies that, if the correlation coefficient is less than 0.4, then there is no relationship; a correlation coefficient between 0.6-0.75 is a mild relationship; and a correlation coefficient more than 0.76, shows a strong or high relationship (Adu-Boakye *et al*., 2012:5; Alubel *et al*., 2017:2; Yadav & Chanana, 2020:17).

In India, the Varte *et al*. (2017) study used PCA and a correlation coefficient to analyse the key body dimensions of e-tape measurements of 2,719 men to develop a size chart using a Telmat (SYMCAD™) 3-D body scanner. The selection of only those values of the key body dimensions that correlated with each other from different planes to update the sizing system, showed an improvement to the previous size charts for the Indian male population. However, there is an absence of reported scientific publications of men in South Africa using correlation research methods such as PCA to identify the key body dimensions essential for clothing production purposes. The PCA method was applied by the Varte *et al*. (2017) study to improve the outdated size charts in their country, including other methods that are used to predict body types that are further discussed in section 2.2.2 below.

Mchiza *et al*. (2015:8) state that RTW clothing manufacturers mass-produce garments using a sizing system and patterns with normatively proportioned key body dimensions. In the mass production of the garments, a standard size chart with the key body dimensions of the 'ideal' body type, with the characteristics of lean and well-toned muscular body build, is selected for garment production (Chattaraman *et al*., 2013; Narang, 2014:17). Men, with dimensions different to the body dimensions of the 'ideal' body, experience fit problems such as wearing garments that are not comfortable and do not drape well (Saeidi, 2018:34). Varte *et al*. (2017;31) mention that garment manufacturers who develop size charts using a pair of key body measurements of the target market, provide a range of RTW clothing with a good fit. Therefore, a well-developed sizing system will be defined by providing garments with a good fit for the dominant body type of the country's population (Narang, 2014:140). Therefore, for a country to produce garments with a good fit, a cross-section data of the population needs to be measured to establish an updated sizing system (Elnour, 2015:47; Pandarum & Yu, 2015:198).

The SANS 8559:1&2 standard of body measurements in South Africa, published by South African Bureau of Standards (SABS), acts as the guideline to determine the key body measurements that can be used to classify body types and sizes for pattern and garment manufacturing. However, the current sizing systems are based on values of the key body dimensions of the retailer's target market that do not fully capture every size and body type in the consumer population. These sizing systems do not consider that consumers with the same body height and body weight can have different body types. Therefore, the South African population experience garment fit problems because the garment standards are voluntary, and retailers and manufacturers continue to adapt size charts to suit fit needs of their target customer body type (Pandarum *et al.*, 2017:42). This prompted this study to use pre-collected e-tape anthropometric data to predict the dominant body morphotype to develop a size chart of the South African men.

2.2.6 Classification methods/techniques for body types

Various methods have been used by academic researchers to predict female body types (Simmons *et al.,* 2004a, b.; Connell *et al.,* 2006; Pandarum *et al.,* 2020), and male body types (Shin *et al*., 2011; Wilson, 2016; Saeidi, 2018; Lee *et al.,* 2020), for different applications including apparel design. In these studies, body type categories were classified using visual analysis methods, drop value analysis methods and various statistical methods. The visual analysis method involves the visual assessments of the front, back and sides of human body to predict body type categories. Drop values are established by assessing most often found relationships between the key body dimension ratios of chest, waist, and hip girths to define body types (Shin *et al.*, 2011:47; Yan *et al*., 2020:1). The drop value is the difference between the calculations of the girth values of upper body dimension (chest) and lower body dimension (hip) (Bougourd & Treleaven, 2010:333; Cottle, 2012:3; Petrova & Ashdown, 2012:268; Narang, 2014:41). The following discussion presents the academic studies that applied the visual analysis, drop value and statistical methods, to predict both women's body types and men's body types.

According to Saeidi (2018:42), the first visual classification to predict body types was conducted in the field of psychology by an American psychologist named William Sheldon in 1940. In his study, photographs of 4,000 young male college students were visually analysed from the front, the sides and the back. The visual classification method was applied approximately eight decades ago and provided a simple use of scale based photographic techniques and callipers to capture body dimensions for classification of the human body (Balach *et al*., 2020:56). The subjective application of the method showed lower variations between girth anthropometric measurements to predict male body types. Therefore, only three body types, namely, the Ectomorph (tall/thin), Mesomorph (lean/muscular) and Endomorph (short/fat) were classified. Currently, with the technology that exists, classifying body types into only three categories is not enough, therefore further methods need to be explored to represent more variations in body types.

Connell *et al*. (2006) assessed proportional values of front and side silhouettes to determine body type categories as visualised in 42 body scans of women aged 20-55 years derived using a $[TC]^2$ full-body scanner. In this study, the authors developed the Body Shape Analysis Scale (BSAS©) with a nine-scale method that could be applied through software to analyse body variations in 3-D scanned data. BSAS© scale showed greater variations of women, and, therefore, predicted an expanded number of body type categories than Sheldon's (1940) study. Four prevalent body type categories generated in this study were the Inverted Triangle, Hourglass, Rectangle and Pear body types.

Simmons *et al*. (2004a, b.) visually analysed 3-D point cloud images of a scan data set derived of 253 women from a $[TC]^2$ full-body scanner. The researchers also applied mathematical algorithm formulas based on the Female Figure Identification Technique (FFIT) for Apparel© software method that was developed in the study to predict body types. The algorithm, consisting of the ratios of bust, waist, hip, stomach, and abdomen girth were used to predict body type categories of the subjects' 3-D cloud point images. Thereafter, the algorithm method was classified into nine body type categories: Diamond, Inverted Triangle, Hourglass, Bottom Hourglass, Top Hourglass, Rectangle, Spoon, Triangle and, Oval.

Both Connell *et al*. (2006) and Simmons *et al*. (2004a, b) showed improved performance over the photographic visual method used by Sheldon (1940) to predict body types for women. However, these studies focused on the BSAS© scale rating algorithm applied in software and the FFIT for Apparel© algorithm. A shortcoming of these methods, however, is that a clear discussion on how the rules were used for dividing the key body dimensions to predict definitions of a variety of body type categories, is lacking. Therefore, the methods raise the challenge as to how the algorithms can be modified and applied as a dominant body type classifier of South African men in this study.

A further study conducted by Pandarum *et al*. (2020) extended the Simmons *et al*. (2004a, b) method by developing a mathematical model called it the New Normative Model (NNM). The 3-D scans of 341 women were initially classified by a panel of experts on the commonly known horizontal classification of body types such as Hourglass, Rectangle, Spoon, Oval, Inverted Triangle, Triangle and Diamond. Thereafter, a detailed NNM mathematical model with the values derived from the calculations of drop value ratios was developed to predict body type categories, and the experts all agreed on the initial body classifications. The study explained the rules that were followed to develop an algorithm to predict body types, therefore it can be easily modified and applied to men.

The application of statistical methods, such as multivariate PCA, Factor and Cluster Analysis have been used by researchers to assist in classifying both upper body types (Shin *et al*., 2011; Wilson, 2016) and lower body types (Saeidi, 2018; Lee *et al*., 2020), of men. John-Anthony and Demirkiran (2014:6) define multivariate analysis as a statistical method that is applied when working with multiple variables in a study. Cluster Analysis is the statistical tool that divides a set of the key body dimensions of individuals in groups (clusters), in such a way that subjects of the same cluster have more similar key body dimensions to each other than to those in other groups (Cottle, 2012:9).

Shin *et al*. (2011) initially applied the multivariate factor analysis method to 25 body dimensions to predict a relevant set of dimensions to determine upper body types of 3686 men from the SizeUSA database. Four sets of factors were found: girth factor, height- length factor, torso- length factor and degree factor. Thereafter, drop values between chest and waist girth, hip and waist girth and hip and chest girth were computed from clusters with higher factor loading scores. Body types were classified into Slim body type category, similar to the Ectomorph, Heavy type category with characteristics of both Endomorphy and Mesomorphy, Slant Inverted Triangle type category with minor traces of Ectomorph and Mesomorph, and Short Round Top type category, similar to Endomorph.

Wilson (2016) combined Visual analysis, Drop values and Cluster Analysis methods to predict upper body types of 788 3-D scans of men between the ages of 26 and 35 years using the SizeUSA data set. The researcher used five drop values and ratios from the primary girth measurements (chest, waist, high hip, and hip) to divide measurements into two clusters. One set of clusters was used as a training set and the other set was used for validation**.** Based on the result from the training set, a new body type identification software was developed in Microsoft Excel called MSIT (Male Shape Identification Technique) for apparel was developed. Four geometric body type category clusters were identified; these body types were Oval (Portly, Corpulent), Rectangle (Stout), Trapezoid (Regular) and Inverted Trapezoid (Athletic). In addition to the use of Sheldon's (1940) somatotype for a male figure, the use of geometric shapes has become an additional way to classify male body type categories (Wilson, 2016:18-19). Therefore, they are discussed in detail in section 2.2.7 below.

Similar methods were later applied and modified for lower body type categories by Saeidi (2018) using 1,420 3-D body scans of men between the ages of 18 and 35 years that were selected from [TC]^2 SizeUSA data set. In this study, 15-20 lower body dimensions such as front and back arc, widths and front/back were characterized using factor analysis. Factor analysis predicted the key body dimensions that affect the fit of the garments designed for a lower body, such as trousers. In conjunction with the factor analysis method the author also used Cluster Analysis to categorize both the silhouette and profile of the lower body. Three body type groups, group A (Flat-Straight/Ectomorph) was characterised by the lowest girth factor loading, lower seat angle, group B (Moderate Curvy-Straight/Mesomorph) consisted of a medium group factor loading with intermediate back seat angle, and group C (Curvy /Endomorph) with the highest girth factor loading, and with higher factor loadings of back measurements than group A and B.

Further study by Lee *et al*. (2020) used a combination of the multivariate PCA statistical method and the Cluster Analysis method to classify lower body types of 625 3-D scans of obese men (36-64 years) from the SizeKorea data set. Body dimensions related to lower body torso used for PCA analysis were 31 drops, two heights, two lengths and four angles included for more specific categorization of both the silhouette and profile of the lower body. Ten principal components (PCs) representing distinctive silhouettes and profiles of lower body types were extracted. The PCs were interpreted as follows: abdomen prominence, thigh to knee profile, upper buttocks prominence, waist to hip drop, thigh to knee silhouette, lower body tilt angle, waist to crotch length, vertical height, abdomen to crotch height and lower buttocks slope. The PCA, in conjunction with Cluster Analysis, identified three clusters of body type categories with a flat abdomen but prominent buttocks, a developed abdomen and buttocks with vertical thighs and drooped buttocks with tilted thighs.

Shin *et al*. (2011), Wilson, (2016), Saeidi, (2018) and Lee *et al*. (2020) addressed the application of various methods with the same objective of predicting body type categories of men in their countries. However, to date, there is no study that has been reported to apply these methods to predict the dominant body type of men in South Africa.

2.2.7 Male body types classifications

Wilson (2016), Capthatt, (2020), Centeno, (2020) and Mountain khakis, (2020), classified the male body type categories by comparing body types to geometric shape; namely, Trapezoid, Rectangle, Oval, Triangle, and inverted Triangle body type. These male body type categories described hereafter have long been prevalent in the apparel industry for women but are only recently beginning to be explored for men.

2.2.7.1 Trapezoid body type

The Trapezoid body type is a body type that can be easily dressed. According to Armstrong (2013:35), a variety of menswear styles are produced with this ‘ideal’ male body type in mind. The author reasons that the clothing industry selects Trapezoid body types on male models when they consider standardised sizes that would fit men (Martinez, 2019). Therefore, men of this body type category have a broad selection of clothing styles to choose from. The characteristics of men with a Trapezoid body type consist of a well-proportioned body type with a medium to narrow waist and hip girth, as well as broad shoulders and chest girth (see Figure 2.1).

Although most male garment styles seem to be based on a Trapezoid body type, it is the second rarest of all body type categories (Armstrong, 2013). Hancock (2017), states that approximately 13 % of men fall into the Trapezoid body type category. As a result, clothing styles designed with the fit for men who have this body type may not fit men with other body type categories.

Figure 2.1: Adapted illustration of Trapezoid body type (Martinez, 2019)

2.2.7.2 Rectangle body type

The Rectangle body type in men can be described by the appearance of the rectangular upper body torso (see Figure 2.2). Men with this body type category are well-proportioned between the chest and hip body parts (Hancock, 2017). The waist appears smaller or about the same width with the chest and hip (Armstrong, 2013; Wilson, 2016:55). Martinez (2019) emphasises that it is easier for stylists to dress men of this type.

Figure 2.2: Adapted illustration of Rectangle body type (Martinez, 2019)

2.2.7.3 Oval body type

The Oval body type tends to appear in men with a rounder prominent stomach (Martinez, 2019). This is the most predominant body type category among men in the United Kingdom (Hancock, 2017). Men of Oval body type consist of slim upper body parts such as shoulders and chest (see Figure 2.3). Along with these body parts, the waist is wide, while the hips are narrow (Armstrong, 2013).

Figure 2.3: Adapted illustration of Oval body type (Martinez, 2019)

2.2.7.4 Triangle body type

Triangle body type appears in men who carry more weight in the lower torso and have a chest that is narrower than their hips (Armstrong, 2013; Martinez, 2019). A wider waist and narrow shoulder body part are evident in this body type category (see Figure 2.4). The body type resembles the triangular geometric type.

Figure 2.4: Adapted illustration of Triangle body type (Martinez, 2019)

2.2.7.5 Inverted Triangle body type

The Inverted Triangle body type is top-heavy with the characteristics of having wide shoulders, broad chest, developed arms and shoulder muscles (see Figure 2.5). The waist and hips on men with this body type category are narrow compared to the upper body (Armstrong, 2013). This body type is common among men who are athletic (Martinez, 2019).

Figure 2.5: Adapted illustration of Inverted Triangle body type (Martinez, 2019)

2.2.8 Determining size ranges for the development of a sizing system

In the development of a sizing system, several sizes should be allocated in such a way that a specified portion of the population is covered. The term size range is often associated with the sizes that are estimated to cover a certain range of the population in the size chart creation process (Beshah *et al*., 2014:53). The percentage of the population covered by the sizing system is called the accommodation rate (Varte *et al*., 2017:34). As highlighted earlier in the literature, an efficient and optimal sizing system is one that offers a good fit to maximum body type categories of the retailers' target market with a fewer number of size ranges (Sindicich & Black, 2011:44; Beshah *et al*., 2014:53; Gupta & Zakaria, 2014:264; Varte *et al*., 2017:30). In a sizing system, only sizes that can lead to production of a garment that represents the sizes of most of the population need to be selected for manufacturing. According to Xia and Istook (2017:237), an acceptable production accommodation rate should be between 65% and 85%. Therefore, if the rate has been achieved in the process, at least only 15-35 % of the population may not be able to find the right size.

In the process of determining size ranges that accommodate a larger proportion of the population in the sizing system the mean, standard deviation (SD), minimum and maximum values of the ranges and size interval need to be established. The process involves the demarcation of the extreme values from the frequency table (Varte *et al*., 2017:34). The mean values and the standard deviation are established as essential approaches to create size steps for the size chart, and to determine outliers (Abdullah *et al*., 2017:468). Outliers are the values that are below the values of the smallest or the largest of the size range (Alubel *et al*., 2017:2).

The values of the mean and standard deviation are also applied to categorise size ranges. To categorise size ranges, Alubel *et al*. (2017:2) and Yadav and Chanana (2020:18) suggest that a one standard deviation (1SD) and two standard deviations (2SD) values are added to the mean to obtain two values that are higher than the mean. Thereafter, (-1SD) and (-2SD) values are subtracted from the mean sequentially to obtain two values that were less than the mean.

The mean value is the most widely used value for size steps, and it is equivalent to the average size of every size chart (Xia & Istook, 2017:238). If an average size of a size chart for example is 32, by subtracting one standard deviation and two standard deviation values (-1SD and -2SD) from the mean, size 31 and 30 are obtained.

The size interval is the value of the differences between sizes from the key body dimensions of the group members of each size group (Petrova & Ashdown, 2012:268). The size code in the sizing system is also determined by the size ranges based on the size intervals. Size intervals divide ranges of each size based on the key body dimensions (Xia & Istook, 2017:238).

Key body dimensions of the size charts are used to identify secondary key body dimensions using a mathematical method called regression analysis. According to Ahmed (2014:2) and Ali and Younas (2021:116), regression is the mathematical method that is used to determine the statistical relationship between two or more variables. The regression analysis method estimates body measurements from one size to the next size by examining the relationships between the key and secondary variables to determine size ranges and size intervals for a size chart (Vithanage *et al*., 2015:485).

A selection from both the girth and the length variables, applying the regression analysis is recommended to identify secondary key body dimensions that represent the population in the size chart (Ahmed, 2014:2). This is also important to ensure that only primary key body dimensions that have a strong relationship with other secondary key body dimensions are selected. Primary key body measurements also predict secondary dimensions that are also essential on the clothing, including the allocation of the number of size ranges, as well as for calculating the increments in the measurements for the size intervals (Xia & Istook, 2017:238).

2.2.9 Calculation of secondary control dimensions for a sizing system

Gupta and Zakaria (2014:96) define secondary body dimensions as the dimensions that are used together with primary dimensions to define the body size of an individual as a whole. The secondary body dimension values are mostly calculated, identified, and tabulated in the sizing system after the identification and grouping of the key primary body dimensions (Petrova & Ashdown, 2012:268; Vithanage *et al*., 2015:485). Patterns for manufacturing clothing cannot be drawn only with the key primary body dimensions, therefore, key secondary body dimensions are also necessary to describe the detail of a body type (Xia & Istook, 2017:238).

Regression analysis is also used to predict secondary body dimensions for a size chart. According to Xia and Istook (2017:238), secondary body dimensions are estimated based on the key primary body dimensions. For example, if a chest girth dimension was identified as a primary key body dimension for men's upper body, other body dimensions that are associated with an upper body, such as the neck girth, are regressed with the primary key body dimension. Those dimensions that strongly correlate with the primary key dimension are selected as secondary key body dimensions.

2.2.10 Communication of the sizing system

According to Pandarum and Yu (2015:197), clothing size refers to the garment label that usually appears on the RTW garments that are sold in retail stores. The most important criteria that people use to select the garment size that fits their body type is by looking at the size chart ranges of the garment that are usually provided in the store websites and in catalogues (Gupta & Zakaria, 2014:256). The number of sizes within this range are usually selected from a size chart that was developed to satisfy the sizing needs of the manufacturer's target consumer (Ola-Afolayan & Mastamet-Mason, 2013:205; Gupta & Zakaria, 2014:274). Therefore consumers use the clothing labels that are attached to the RTW garments as a guide to finding the correct size that fits their body type.

Shin *et al*. (2011:46) state that menswear size labelling charts in the garments are usually depicted in a metric system based on the centimetres of length or girth of the key body dimensions including neck, arm, chest, waist and leg. Garment sizing labels are also illustrated by the letter codes such as L (large), M (medium) and S (small) in a men's basic shirt derived from chest girths, and the number codes such as 32, 34 and 36 suggest the imperial system of body dimensions that originated from the inch measure of waist girth for a basic trouser (Gupta & Zakaria, 2014;263). Consumers anticipate that these labels provide information about whom those garments would fit. For example, one would expect a jacket with a chest measurement of 44 inch to be labelled with a size code (44) to provide fit. But these expectations are not always fulfilled by manufacturers and retailers since they are not obliged to label their clothes according to the country's anthropometric measurement standards (Nkambule, 2010:22; Gupta & Zakaria, 2014:262). Furthermore, Faust and Carrier (2014:134), Gupta & Zakaria (2014:262) and Hoegg *et al*. (2014:72), state that manufacturers and retailers label their garments using vanity sizing. Vanity sizing is a marketing method whereby a garment is labelled with a smaller size label than its actual size (Nkambule, 2010:26; Faust & Carrier, 2014:24).

The labelling system is confusing to men, and they spend more time trying on the garments in a store's fitting room to find the right size that fits (Faust & Carrier, 2014:24; Alubel *et al*., 2017:1; Labat & Ryan, 2019:522). However, to address the fit and sizing problems and eliminate the confusion because of vanity sizing, Pandarum and Yu (2015:199) suggest that countries worldwide need to update the sizing system so that the key body measurements in the labelling system are a true reflection of the body types of the country's population. Therefore, the study analysed a current 3-D anthropometric secondary data set to develop a size chart for South African men.

2.3 TAILORING MANNEQUINS IN THE CLOTHING INDUSTRY TO TEST THE FIT OF GARMENTS

Despite the availability of improved various types of tailoring mannequins to evaluate the fit of RTW clothing, men are still experiencing garment fit issues. Tailoring mannequins are the models that are used by small, medium, and large clothing manufacturers to evaluate how the garments will fit the targeted human body type of a specific size (Do & Choi, 2016:708). In most cases, the standard tailoring mannequins for men are manufactured as a half-body torso without the head, arms and legs (Xie & Zhong, 2020:937). However, they are also developed as either the full-body torso with detachable arms, or the lower half of the body with detachable legs. The clothing manufacturers choose standard tailoring mannequins such as the full-body torso, or the lower half of the body, to evaluate the fit of their RTW garment designs and proportions because they can maintain a consistent set of anthropometric measurements better than using the live human fit model (Song & Ashdown, 2010:264). The set of anthropometric measurements derived in these standard tailoring mannequins are used to address fit problems and to develop upper and lower body size charts for specific target populations. According to Joseph-Armstrong (2014:35), currently, these standard tailoring mannequins are manufactured using the body type of an 'ideal' proportionate human model whose body dimensions do not match the distinct body types of the target markets. Therefore, the standard tailoring mannequins produced in this way do not provide well-fitting RTW garments.

In recent years, tailoring mannequin manufacturers and academics in countries such as Japan and South Africa attempted to develop tailoring mannequins that resemble the human body better than the standard tailoring mannequins. The tailoring mannequin manufacturers in these countries mostly extract the common girth measurements of the chest, waist, and hip in their target markets (Hsu & Ying-Zhou, 2013:211; Hu *et al*., 2018:159). Although these girth measurements may appear to be similar in two individuals, including the body lengths such as the thigh length or angles such as the buttocks angle, their body types may be defined differently. Therefore, the lengths and angles of the body dimensions also need to be considered as the basis for the manufacturing of tailoring mannequins to provide an accurate garment fit.

According to Hu *et al*. (2018:162), parametric tailoring mannequins are one of the commonly produced human-like mannequins by the clothing industry to provide fit because its type can be flexibly changed to fit a variety of consumers sizes. However, these tailoring mannequins are only reliable when the body dimensions related to lengths, widths, and angles are considered rather than relying on only girth dimensions (Do & Choi, 2016:708) This highlights that although the body sizes of the humans might be equal, their body types and dimensions might not be the same.

The Digital Human Laboratory in Japan collaborated with the Bunka Fashion College to produce two tailoring mannequins that resemble the human type such as the Japanese tailoring mannequins and Tuka tailoring mannequins. The Japanese tailoring mannequins were produced to detect gradual continuous changes in body types and sizes of the students at Bunka college over the years (Hu *et al*., 2018:163). These tailoring mannequins are different from the standard tailoring mannequin in terms of the armhole dimensions. The shape of the armhole depicts a 'wonky triangle' compared to the rectangular armhole in the standard tailoring mannequin. Joseph-Armstrong (2014:30) reports that a 'wonky triangle' adjusts the arms to hang down in a natural position rather than in a straight down position because of the rectangular armhole. Furthermore, the Tuka tailoring mannequins are manufactured using materials that looks similar to human skin. These mannequins, unlike the standard tailoring mannequins, resemble the muscles of the live human model and produce better flexibility during the test of the fit of sample garments.

In South Africa, Millam (2021), a senior manager of Figure-Forms, a South African mannequin manufacturer reports that currently their mannequins are produced following the anthropometric measurements of the target market from the clothing industry to evaluate fit accurately in clothing garments.

Despite the application of all these efforts to develop human-like tailoring mannequins in the clothing industry, clothing fit remains unsatisfactory in terms of body types, dimensions, and sizes of the population. The garment fit satisfaction can only be provided through the development of tailoring mannequins that represent the target population's body types (Joseph-Armstrong, 2014:35). However, this is not the case in South Africa where the RTW clothing that is intended to fit men, does not conform to the dominant body type of the South African men's population. Song and Ashdown (2010) support the idea of developing an improved human-like tailoring mannequin rather than using standard tailoring mannequins that still lack a realistic detail of the adiposity of the heterogenous body types of humans. Therefore, in South Africa, the classification of the dominant body type category of men and their size using e-tape measurements, could play a vital role in developing tailoring mannequins that provide well-fitting RTW garments.

2.4 SUMMARY

The existing literature that was reviewed, found that, despite the availability of technology such as 3-D full-body scanners in South Africa, there is a lack of an e-tape anthropometric dataset that is representative of the distinct body types of men. However, it was evident that the accurate representative e-tape anthropometric datasets in other countries have been applied to develop improved size charts that are more efficient in providing the garments that fit. Hence, this study sought to address the gaps in the literature.

The next chapter provides the research design, highlighting the methods, tools and procedures that were used to identify, process, and analyse the information that was relevant to fulfil the purpose and objectives of this study.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

The purpose of the research methodology is to describe and indicate how the study was executed. The research methodology in this men's study consists of all the research approaches and methods that were adopted to fulfil the objectives of the study outlined in chapter 1, section 1.3 of this dissertation.

This chapter begins by describing the research design, data collection methods and instruments that were selected for the study. A research design can be described as a succession of approaches that are incorporated when the researcher collects and analyses data to fulfil the objectives of a study (Walliman, 2011:30). Thereafter, the population sampling procedures are described and the instruments that were used to collect the secondary e-tape anthropometric dataset used in this study are discussed in detail. The discussion then proceeds to the data analysis methods and highlights how validity and reliability were employed to ensure repeatability. Lastly, the ethical considerations are discussed.

3.2 RESEARCH DESIGN

Due to stringent rules and regulations of the COVID-19 pandemic regarding human movement, secondary data sources consisting of scientifically and professionally collected, 3-D anthropometric data was chosen as a viable option to meet the objectives of this study. The primary data that was used as secondary data in this study was collected by Tabo (2020) from the years 2019 to 2020 using a combination of instruments such as a demographic questionnaire and a [TC]^2 NX-16 3-D full-body scanner situated on UNISA, Florida, Science Campus in Johannesburg. The study design was exploratory in nature. Research studies are often viewed as exploratory when the investigation of the problem is in a preliminary stage (Pandey & Pandey, 2015:9). This is the case in this study since there is little research information that is reported to have analysed 3-D anthropometric body dimensions to classify the dominant men's body morphotype category and to develop a men's size chart. Therefore, the purpose of selecting and applying the exploratory design for this study was to gain new insight on how an e-tape anthropometric dataset from a 3-D full-body scanner of men in South Africa can be statistically analysed to develop a size chart.

To address the objectives of the present study, a quantitative method was adopted. De Franzo (2011), describes that the quantitative research method data can be analysed, quantified, and expressed in numerical forms. The researcher initially adopted and applied a descriptive quantitative method to quantify the information from textual to numerical form to identify characteristics of the demographic sample profile of the subjects. Thereafter and inferential quantitative method was used to identify the key body dimensions measurements required to classify the dominant body morphotype and those necessary to develop an anthropometric body size chart. These key e-tape anthropometric measurements for the men of a dominant morphotype were also compared to those that were traditionally extracted from the men's tailoring mannequin of a similar body size from the Figure-Forms mannequin manufacturing company in South Africa.

3.2.1 Sampling

According to Gravelle and Rogers (2014:150), usually, research studies cannot be obtained from the larger population, instead, sampling units are often selected. Sampling units are those subjects that provide relevant information that represent the characteristics of a larger population (Buelens *et al*., 2018:19). Therefore, in this section sampling methods that were used by the primary researcher (Tabo, 2020) are described.

Tabo's (2020) study sampled 286 male subjects aged 18 to 56 years old from Gauteng (Johannesburg and Pretoria) using convenience and purposive non-probability sampling methods. Convenience sampling is a method whereby the subjects are selected on their immediate availability to participate in the research study (Walliman, 2011:32). The purposive sampling method allows the researcher to identify the subjects based on what information is needed to meet the study objectives (Buelens *et al*., 2018:19).

The use of a convenience sampling method assisted the primary researcher to approach and invite men across Gauteng in South Africa to voluntarily participate for 3-D body scanning at UNISA Florida Science Campus.

However, in this study, only 270 male scans were selected; males who had completed all the questions in the demographic form aged 18 to 56 years old, and from ‘all walks of life’ residing in Gauteng for further analysis to meet the objectives of this study. These men were represented by the African (74%), Coloured (12%), Indian (3%) and White (11%) ethnic groups.

3.2.2 Data collection instruments

During the data collection process, a researcher has several methods to choose from. The choice of selecting one method over the other depends on the objectives of the study (Kumar, 2011:25). Walliman (2011:34) emphasises that in every research study, the relationship between the chosen data collection method and the research objectives must be clearly justified and explained as discussed in sections 3.2.2.1 to 3.2.2.2.

3.2.2.1 The questionnaire

A questionnaire is a research instrument that can be used to collect the demographic measurements as well as other characteristics of the subjects. These subjects’ characteristics are, for example, age, gender, or population ethnic group (Wilson, 2016). The 270 questionnaires taken from Tabo (2020) consisted of closed and open ended questions that consisted of the age, body weight, body height distributions, marital status, population ethnic group and place of residence in section A of Appendix A. Section B of Appendix A of the questionnaire represent the psychographic (market information) of the male subjects, which included their preferred way of purchasing RTW clothing, the retail outlets they purchase their RTW garments from, and their fit preference of specific RTW garment types. Furthermore, in this section, problems that male subjects had with RTW garments, their current retail RTW garments sizes, perceived self-reported body types that represent their body’s silhouette, body parts that described their body morphotypes, as well as their body weight and body height, were identified. The demographic information in this study was analysed to allow the findings to be interpreted in relation to the profile of the 270 subjects.

3.2.2.2 Primary data used as a secondary data in this study that was collected using the [TC]² NX-16 3-D full-body scanner

A secondary set of point cloud scans and their derived e-tape measurements of the 270 male subjects were categorised into different body morphotype clusters to classify a dominant body morphotype arising in the e-tape anthropometric dataset to develop the anthropometric body size chart. As mentioned previously, the subject's e-tape measurements were captured by Tabo (2020) using the [TC]² NX-16 3-D full-body scanner at the UNISA Florida Campus (see Figure 3.1). Pandarum and Yu (2015:199) state that an advantage of using 3-D full-body scanners, such as the [TC]² NX-16 3-D full-body scanner to collect anthropometric data, is the ability to rapidly measure and provide high quality human body scans. Pandarum *et al*. (2011) emphasise that capturing high quality body scans consistently depends on the appropriate selection of underwear that is worn during the 3-D scanning process. Therefore, all men that participated in Tabo's (2020) [TC]² NX-16 3-D full-body scanning process were asked to wear light grey form-fitting activewear garments such as leggings provided by the researcher during 3-D scan data collections. Dark colours such as black or navy blue were avoided as they mask some key body dimensions that are critical in the development of size charts of the subjects, such as the crotch body part (Pandarum *et al*., 2017:3; Styku, 2020).

Figure 3.1: Image of the inside of [TC]^2 NX-16 3-D full-body scanner and the monitor situated on the UNISA, Florida Campus

The body position and body posture of the subject, according to Varte *et al*. (2017:30) and Koepke *et al*. (2017), also influences the quality of the e-tape measurements in the scanning process. Therefore, to ensure consistency in the positioning of the body posture/stance during the scanning process, subjects should stand on the foot prints that are marked on the floor of the scanning cubicle. This is done to minimise the number of e-tape measurements that would have to be discarded because of poor-quality scans. In the scanning process, Wang *et al*. (2019:4) and Yan *et al*. (2020:3) state that the subjects should be in a standing body position. Furthermore, Pandarum *et al*. (2011:3) mention that the subject's scanning position must be in the Frankfurt plane, i.e., the feet are parallel to each other, 350 mm apart. The arms of the subject are outstretched, with hands holding on to the fixed handrails 1,100 mm apart, with the right thumb over the right handle to press the button that begins the 3-D scanning process (Varte *et al*., 2017:30; Diprose *et al*., 2020:372). In Tabo's (2020) study, these scanning guidelines were followed by every subject throughout the scanning process. The subjects were scanned thrice to minimise any anomalies caused by slight movements of the subject during the scan generation process.

3.3 DATA ANALYSIS AND INTERPRETATION

The researcher of this study began quantitative data analysis process by manually entering the 270 demographic questionnaire responses received from Tabo's (2020) e-tape anthropometric dataset into a Microsoft Office Excel spreadsheet. The e-tape measurements of the 270 men were extracted using a user define software in the [TC]^2 NX-16 software interface according to the ISO 8559-1 (2017) and the SANS 8559-1 (2019), then batch-processed into a separate Excel Spreadsheet. The data was cleaned to identify any missing values of each variable to ensure that only the data with complete values was used in the further statistical analysis. Statistical Package for the Social Sciences (SPSS) version 27 software was employed for statistical analysis and interpretation of all the dataset. This SPSS version 27 software was chosen because it is user-friendly and can easily deal with either basic or complex calculations and presentation of the analysed data (Walliman, 2011:42).

Thereafter, descriptive statistics on the demographic questionnaire and e-tape anthropometric dataset summarised the demographic and psychographic characteristics and e-tape measurements for men. The descriptive statistics, such as order statistics (minimum or maximum), central tendency (mean), dispersion (standard deviation), number of sampled men, percentages distributions and 95 % confidence intervals were used to create tables and figure representations of the statistical summaries of the findings.

The minimum and maximum score data analysis is a method used to determine the lowest and the highest range distributions of the collected data (Walliman, 2011:90). Therefore, in this study, the minimum and maximum minimum values were calculated to represent the lowest and highest values of the results from responses of the age, body weight and body height of the demographic questionnaire, and to allocate the number of size ranges to cover the maximum number of the dominant body morphotype for men. The lower bound of the 95% confidence intervals were subtracted from the upper bound of the e-tape anthropometric dataset to determine the size intervals of the upper and lower primary and secondary anthropometric dimensions for size charts.

The mean can be described as an arithmetic average of a set of scores (Walliman, 2011:90). It expresses a central value (toward the middle) that characterizes all the other values of the data (Kaliyadan & Kulkarni, 2019:84). Mean, in this study, was calculated to determine the average values of the age, body weight and body height of men in this study. The mean was also used to establish the central value of the primary and secondary key anthropometric dimensions that were established as a medium size of the upper and lower body size charts for the dominant body morphotype of men. The standard deviation (SD) can be described as measures of the dispersion of scores in a distribution (Akaranga & Makau, 2016:6). The standard deviation determines variations of data distributions from each value of the body dimensions (Sullivan, 2011:16; Haradhan, 2017:78). Standard deviation in this study was used to determine the distance of the values of the age, body weight and body height around the mean and to determine variations of data distributions for an upper and lower bound of each value of the upper and lower body dimensions. For example, a lower value of standard deviation, after the calculations, indicated that the dataset was spread over a small range around the mean (Elo *et al*., 2014:5). A larger value of the standard deviation indicated that the data set was spread over a large range around the mean (Mengual-Macellne *et al*., 2015:4).

The researcher calculated the number of sampled men and percentages to analyse the demographic and psychographic dataset of the questionnaire to draw conclusions that were summarised in tables and figures. These tables and figures were included to aid the visual interpretation of the results derived from the descriptive statistics. The tables and bar chart figures were used to present data for nominal variables such as age, marital status and population ethnic group and ratio scaling.

Thereafter inferential data analysis was applied using a multivariate statistical analysis approach since the 3-D dataset consisted of more than one body dimension. According to Mengual-Macellne *et al*. (2015:3), multivariate analysis is the most appropriate method to apply to a data set that consists of multiple variables. The PCA and Cluster Analysis methods were used in this study to determine the key body dimensions that are essential to define the dominant body morphotype and sizes of men in this study. Opaleye *et al*. (2019:30) state that PCA is a powerful method to be used to identify the key body dimensions such as in-seam, waist, thigh, hip, and bottom girth that are important in the development of a size chart. In this study, PCA was applied in reducing the dimensionality and addressing the multicollinearity problem. The strength of the relationships between the key body dimensions was determined. The researcher explored and identified those key variables that are essential for classifying the dominant body morphotype and applied regression analysis to identify those measurements that were combined with the key variables in anthropometric size chart development (Kaliyadan & Kulkarni, 2019:10). Furthermore, Cluster Analysis was applied to allocate PCs of men's anthropometric dimensions that were similar into homogeneous cluster groups (Mengual-Macellne *et al*., 2015:4). Thereafter, the dominant body morphotype of men emerged from the cluster group with the largest number of men.

3.4 DATA QUALITY

Reliability and validity are important strategies when examining the quality of data. According to Kumar (2011:42), reliability and validity are useful concepts in a quantitative approach as they guide the researcher in choosing the most relevant ways to conduct the study. These concepts are essential during the assessment of how credible a study is (Elo *et al*., 2014:5). Thus, for a research study to be recognised and trusted, it depends on the validity or reliability of the data (Kumar, 2011:37). Therefore, studies with a clear discussion of validity and reliability have a limited chance of providing deceiving data (Akaranga & Makau, 2016:7).

3.4.1 Validity and reliability

Leung (2015:325) and Haradhan (2017:69) state that validity is an evaluation of how the instrument can measure what it has been designed to measure. Tabo (2020) piloted the questionnaire with a focus group of ten male participants. Suggestions and recommendations for improvement were gathered from the participants and integrated with the recommendations from the study supervisors prior to being distributed to the subjects for data collection.

To determine the reliability of the research data, the sources need to be carefully scrutinised. Scrutiny of the sources promotes confidence to the researcher as it is likely that the phenomena under the study was recorded accurately (Walliman, 2011:47). This can be done by examining the consistency and repeatability of the research findings if the study was to be conducted again in the same setting (Sullivan, 2011:21; Haradhan, 2017:71).

Tabo's (2020) 3-D scans were collected using the South African National Standards (SANS) SANS 8559-1 body landmark positioning protocols programmed into the $[TC]^2$ NX-16 3-D full-body scanner software interface. This standard guided the researcher in setting the user-defined measurement extraction programme (mep) that consistently extracts the e-tape body measurement of each scan, thus ensuring reliability, repeatability, and reproducibility of the e-tape measurement data.

3.5 ETHICAL CONSIDERATIONS OF THE STUDY

According to Kumar (2011:45), ethics refers to motivations of considering what is taken as being morally accepted in all decisions the researcher makes during the research process. Secondary e-tape anthropometric dataset was analysed in this study to fulfil the objectives that were not the same as those of the original researcher. However, before the data analyses process started, an ethical application describing how the researcher will uphold ethical issues related to the use of secondary was submitted to the research ethics committee of UNISA. Therefore, to conduct this study a further ethical clearance (2021/CAES_HREC/058 in Appendix B) certificate to Tabo's ethical clearance (2018/SSR-ERC/023) was granted to conduct the present study.

Prior to the data collection process of the primary anthropometric data set, Tabo, (2020) obtained informed consent from the subjects who participated. Subjects who participated in Tabo's (2020) research project signed the consent form to provide the agreement for further analysis and use of their anthropometric information (see an example in Appendix C).

Moreover, in Tabo's (2020) study, anonymity and confidentiality of the subjects were addressed by using sequential numbers to de-identify subjects' personal information, both in the questionnaire and 3-D scan anthropometric measurement data set as indicated in Tabo's (2020) Ethical Clearance 2018/SSR-ERC/023 certificate. The subjects' records are currently kept secure in locked cabinets and in an online database that is password protected at the University of South Africa in the 3-D Scanner Laboratory on the Florida Science Campus. The point cloud scans in (rbd) and the anthropometric e-tape measurements is access controlled by a dongle that is only available from the 3-D Scanner Research Theme Leader. Therefore, in this study, the researcher upheld anonymity and confidentiality towards the subjects as agreed in Tabo’s (2020) ethical clearance, and in a further ethical clearance (2021/CAES_HREC/058) obtained for this study to use the secondary dataset.

CHAPTER FOUR

FINDINGS AND INTERPRETATION

4.1 INTRODUCTION

In this chapter, the data of the 270 men's demographic questionnaires (Tabo, 2020) are analysed to define the profiles of men. The purpose of analysing the demographic information in this study was to ensure that the results are interpreted in relation to these profiles.

In Appendix A, section A provided the demographic data for open and closed questions such as age, body weight, body height, marital status and ethnic group that are presented in section 4.2 of this chapter. Section B provided the data of the psychographic (market) information of the men's preferred way of purchasing RTW clothes, the retail outlets where they purchase and their fit preferences with the various RTW garments that are presented in section 4.3 of this chapter. Thereafter the results of the three objectives are presented, namely, to classify the dominant body morphotype of the men emerging in the dataset for the 270 men. The second objective was to develop upper and lower body anthropometric size charts for the dominant male body morphotype emerging in this study. The third objective compared the upper and lower body anthropometric measurements developed for men of a dominant body morphotype with those that were traditionally extracted from the men's tailoring mannequin from the South African mannequin manufacturer of similar body size.

4.2 DEMOGRAPHIC PROFILE

A report of the demographic profile using the number of subjects and percentages (rounded off to the nearest whole number) is presented in Table 4.1.

Table 4.1: Demographic profile of male subjects (n=270)

Continuous data					
Demographic variables	**Minimum**	**Maximum**	**Mean**	**Standard deviation**	**95% confidence interval**
Age (years)	18	56	32	9.0	30.4 to 32.6
Body weight (kg)	45	133	70	15.0	67.8 to 71.2
Body height (cm)	155	188	172	7.0	171.2 to 172.3
Categorical data					
Marital status		**Number of subjects**		**Percentage (%)**	
Single		189		70	
Married		65		24	
Divorced		5		2	
Separated		6		2	
Widowed		5		2	
Population ethnic group		**Number of subjects**		**Percentage (%)**	
Africans		200		74	
Coloureds		32		12	
Whites		30		11	
Indians		8		3	

Table 4.1 shows that the distribution of the 270 male subjects’ age ranged from 18 to 56 years. The body weight category of the men fell within the range of 45 kg to 133 kg, and their body height ranged from 155 cm to 188 cm with a mean body weight of 70 kg, and a standard deviation of 15.0. The mean body height was 172 cm with a standard deviation of 7.0. The results also highlighted that these male subjects were mostly Black Africans (74%), followed by Coloureds (12%), White (11%) and lastly Indian (3%).

The findings indicate that the mean (average) age of men in this study was 32 years. The Faber (2013) study conducted in the United States of America reported similar results; however, this contrasted with a Chinese study reported by Du *et al*. (2017) where the average body weight and body height of the men were 63 kg and 169.3 cm respectively. These men are smaller and shorter than the average men in this study. Therefore, this indicates that men in South Africa may experience tight and short fitting from ready-to-wear basic shirt and trouser garments that are size- based on the size charts based on the American or Chinese standards.

4.3 PSYCHOGRAPHIC (MARKET) PROFILE OF THE MALE SUBJECTS

Following, are the findings of the psychographic (market) profile using the number of subjects and percentages (rounded off to the nearest whole number) presented in Appendix D.

The findings indicate that male subjects have strong preference for either visiting retail outlets physically (74%) or shopping using the internet (12%), rather than catalogues (4%) and other ways (10%) for shopping. Similarly, Devi and Prasad (2011), Manish and Sima's (2012) studies concur that male consumers prefer visiting retail outlets physically. Another study conducted by Rudansky-Kloppers (2017) found that the internet usage by men has increased by 49 %, meaning that online shopping in South Africa is increasing. The findings of this study should be considered by the retailers who need to strengthen their product and service offerings to remain ahead of their competitors.

For their preferred stores, 44% mentioned that they purchase long sleeve shirts from retailers such as Exact, followed by 31% who preferred Markham. Truworths was preferred by 18% of the men, and 7% preferred Woolworths. In contrast, 35% selected Exact as their most preferred store for purchasing short sleeve shirts, Markham 30%, followed by Truworths 23%, and Woolworths 12%.

Furthermore, the selection of stores men preferred to purchase from for t-shirts, jackets and short trousers were higher at Exact (36%, 31% and 39% respectively) except for trousers, pull-overs and jerseys where Markham was preferred the most by 34%, 37% and 33% respectively. Therefore, the findings indicate that Exact and Markham were the most preferred retail outlets for purchasing RTW garments for men.

These findings are similar to the results from the study conducted by Makgopa (2018) which indicated Markham as being one of the most preferred retail outlets by men. However, Exact was identified as being the least preferred retail outlet for RTW garment shopping. The difference between the findings of this study and that of Makgopa's (2012) study may be attributed by the unique characteristics that consumers consider important when deciding on the retail outlet to shop in. This is supported by the findings of Medrano *et al.* (2016), who identified characteristics such as personal relationship with store personnel, convenience, variety of products and services and price as being the most important for consumers when selecting the retail outlet from which to purchase products. Therefore, the results indicate that Exact and Markham had been offering products and services with unique characteristics that serve the RTW garment needs of men residing in Gauteng better than the other retail outlets. However, the percentage might be different under COVID-19 restrictions where consumers are also using online stores.

The findings from the demographic questionnaire for the RTW garment fit preferences (Tabo, 2020) indicate that slim-fitting and semi-fitted categories were the most popular choices for men. The results further indicated that very few men opted for the loose-fitting category in their garment choices. In South Africa, a possible explanation of these findings could be that fashion media strategies emphasise young and muscular body morphotype of men as being the ideal. Chattaraman *et al*. (2013) mention that fashion media use male models who promote muscle-gaining by dieting and exercising. Therefore, the preference of slim-fitting and semi-fitted garment categories by men in this study may be influenced by a desire to achieve the body silhouette of an 'ideal' body morphotype as portrayed by the media (Chattaraman *et al*., 2013)

Figure 4.1 and Figure 4.2 represents fit problems experienced on the shirt and trouser garment.

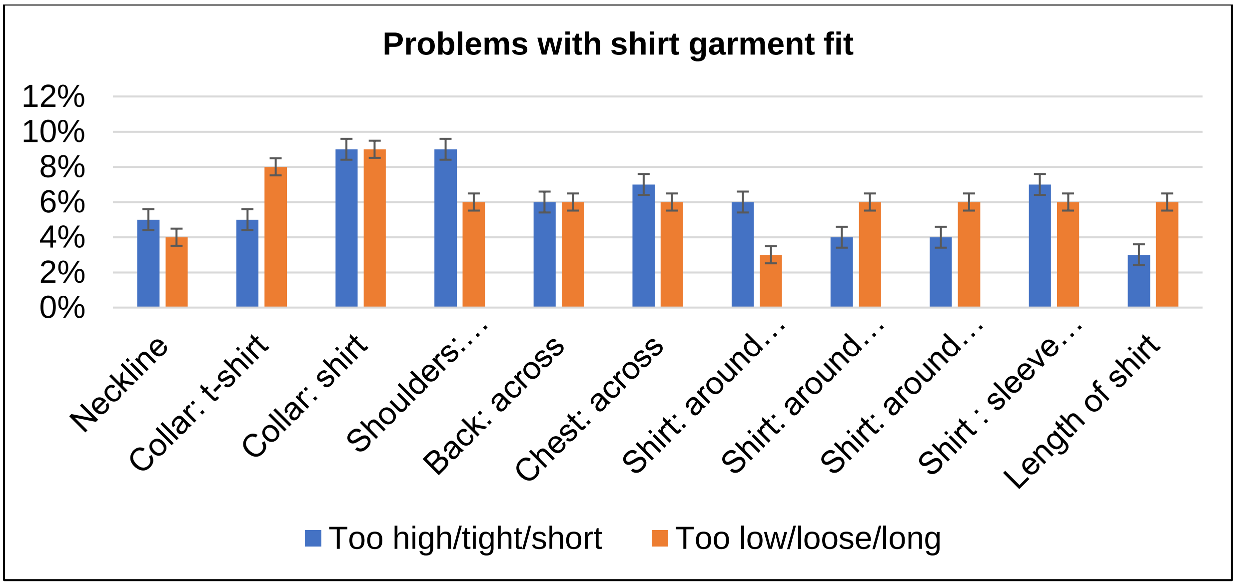


Figure 4.1: Fit problems experienced on the shirt

As indicated in Figure 4.1, the men reported fit problems with the shirt collar (such as it is too high 9% and too long 9%), T-shirt collar (too long 9%), across the shoulders (too high 9%), across the chest (too high 7%) and on the shirt sleeve (too short 7%). The least reported problem was of the shirt being too short in general (3%), and the shirt being too loose (3%) around the waist. From these subjective findings it is clear that men experienced most fit problems in the neck, across the shoulders, across the chest and on the shirt sleeve for an upper body part. Therefore, clothing manufacturers and designers need to consider actual anthropometric measurements such as neck height (front and back), shoulder-to-shoulder width as established in this study to improve fit

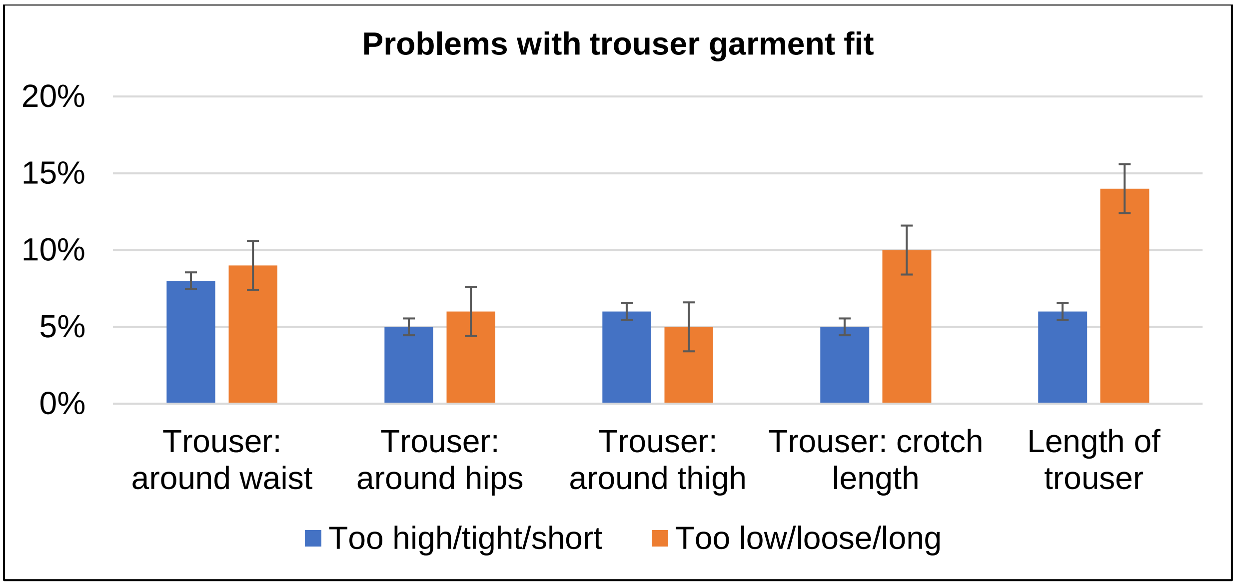


Figure 4.2: Fit problems experienced on the trouser

For the lower body garment, the trouser length being too long was encountered the most (14%). In contrast, the trouser crotch length fit problem (too tight) around the waist was encountered the least (5%). From these subjective findings it is clear that men experienced most fit problems in the hem of the trouser for the lower body part. Therefore, clothing manufacturers and designers need to consider actual anthropometric measurements such inseam and out-seam as established in this study to improve fit.

Figure 4.3 represents the men who reported no fit problems on shirt and trouser.

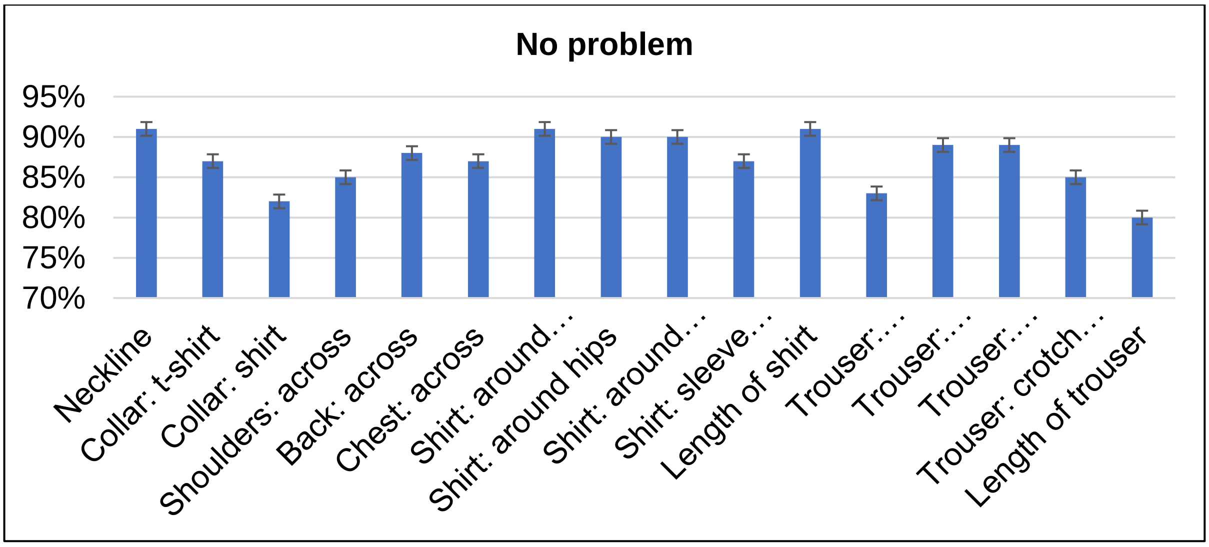


Figure 4.3: The men who reported no fit problems on parts of the shirt and trouser

Although the majority (91%) of the men subjectively reported no fit problems for the neckline, shirt around the waist and general length of shirt garment fit. An explanation of this is that slim-fitting RTW garments, which was the most preferred choice for these men are currently manufactured with fabrics that are blended with spandex to ensure stretch and comfort (Brooksworth *et al*., 2022). Therefore, clothing manufacturers and designers need to work more objectively using 3-D scanned measurements such those established in this study to improve fit.

Figure 4.4 and Figure 4.5 below illustrate the self-reported retail bought garment sizes for shirts and trousers.

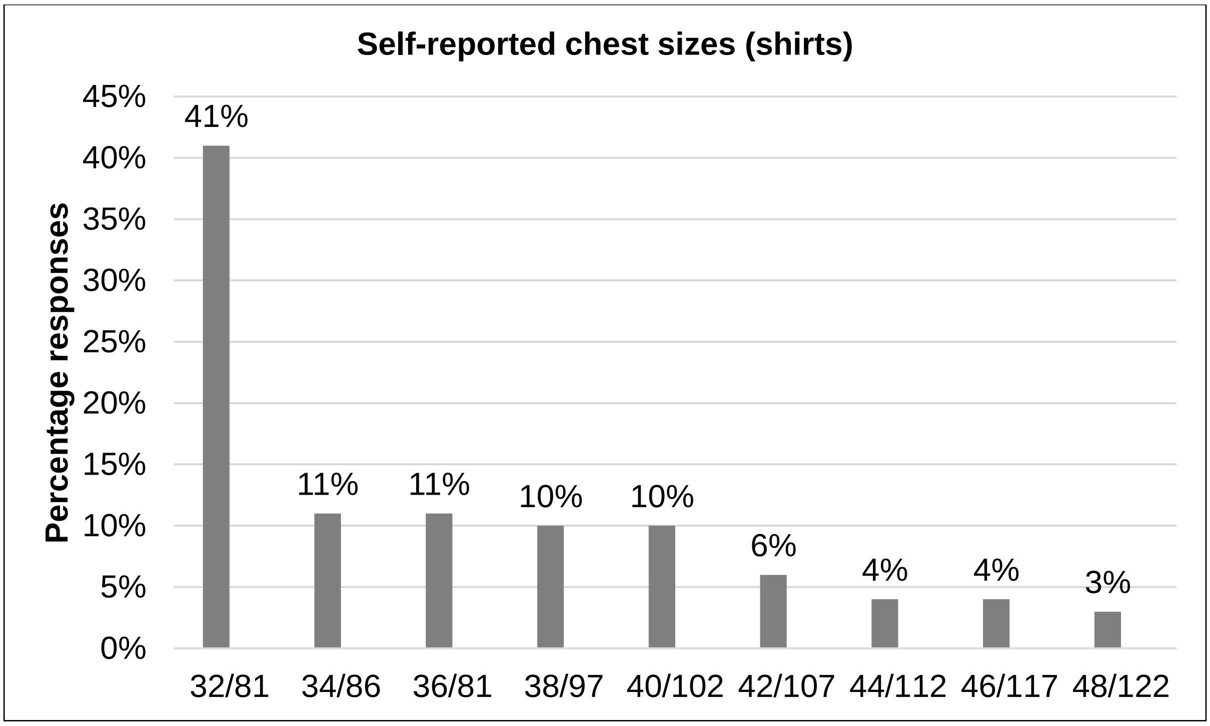


Figure 4.4: Self-reported shirt sizes of male subjects

Figure 4.4 indicates that 41 % of the men perceive their RTW shirt sizes to be a chest measurement of 32 inch/81 cm. In contrast, a chest measurement of 48 inch/122 cm (3%) was the least perceived RTW sizes for shirts.

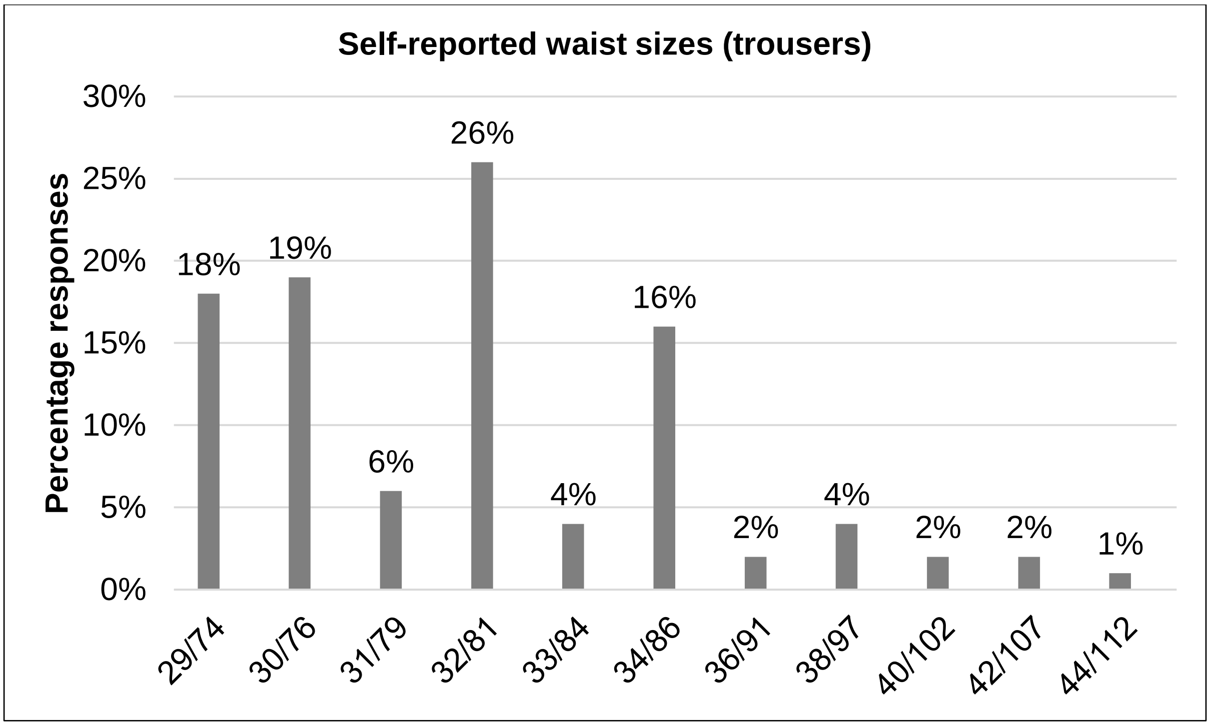


Figure 4.5: Self-reported trouser sizes of male subjects

Figure 4.5 shows that 26 % of the men perceive their RTW trouser sizes to be a waist measurement of 32 inch/81 cm. In contrast, the least perceived RTW trouser size waist measurement was 44 inch/112 cm (1%).

A chest size of 32 inch/81 cm is equivalent to an alpha letter size of small (S) and a waist size of 32 inch/81 cm is equivalent of an alpha letter size of large (L) (Gupta & Zakaria, 2014:212). However, the findings imply that men subjectively perceived their chest size to be similar to their waist size, hence, there will be more demand for ready-to-wear clothing styles that fit the same around the chest and the waist. Therefore, more efforts to develop anthropometric size charts objectively as it was done in this study are needed to assist clothing manufacturers and designers manufacture clothing with a better fit for men.

Figure 4.6 below presents the percentages of the perceived self-reported body morphotypes of the male subjects.

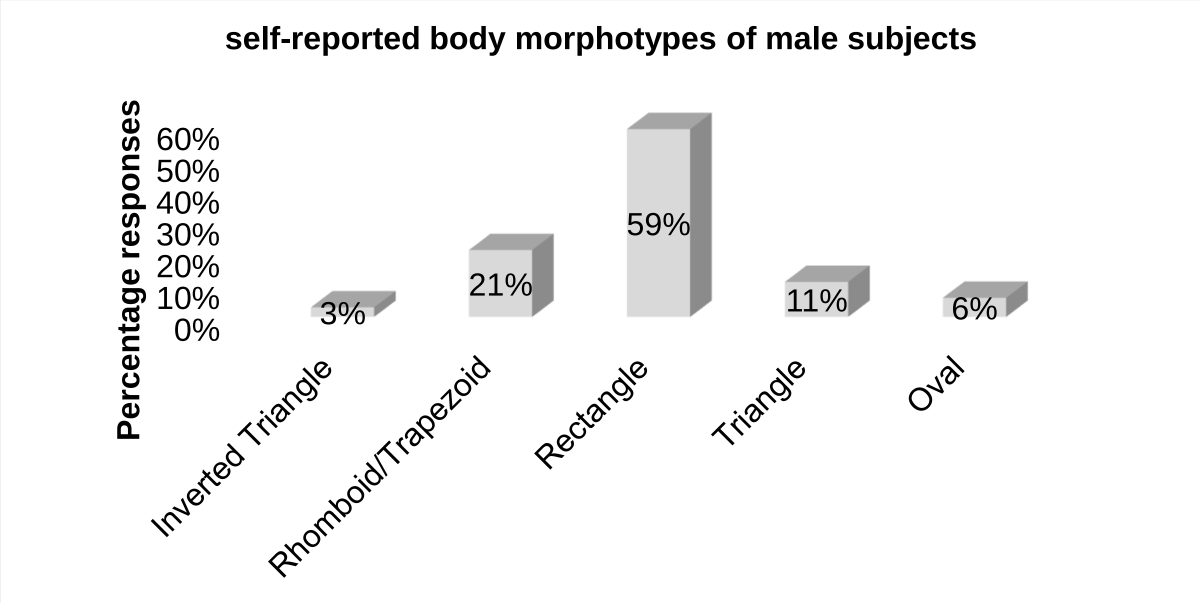


Figure 4.6: Self-reported body morphotypes of male subjects (n=270)

In Figure 4.6, the findings indicate that 59 % of men in this study perceived themselves as a Rectangle body morphotype, and 21 % a Rhomboid/Trapezoid body morphotype. The least perceived body morphotype was the Oval (6%) followed by the Inverted Triangle (3%). According to Wilson (2016:55), men with the Rectangle body morphotype are defined by leaner chest and hip that have approximately the same size measurements, with the waist that is smaller than the chest and hip. Furthermore, the Rhomboid/Trapezoid body morphotype considered that the ‘ideal’ body morphotype in men consists of muscular, broad chest and shoulders with medium or narrow waist and hip (Wilson, 2016:19; Martinez, 2019). However, the findings imply that this is not the case in South Africa, whereby men subjectively perceive themselves as Rectangle. Therefore, there is a need for clothing manufacturers and designers to consider objective approaches such as the one that was applied in this study to identify the dominant body morphotypes of men in their target markets. Figure 4.7 below presents the percentages of the self-reported body parts of the male subjects.

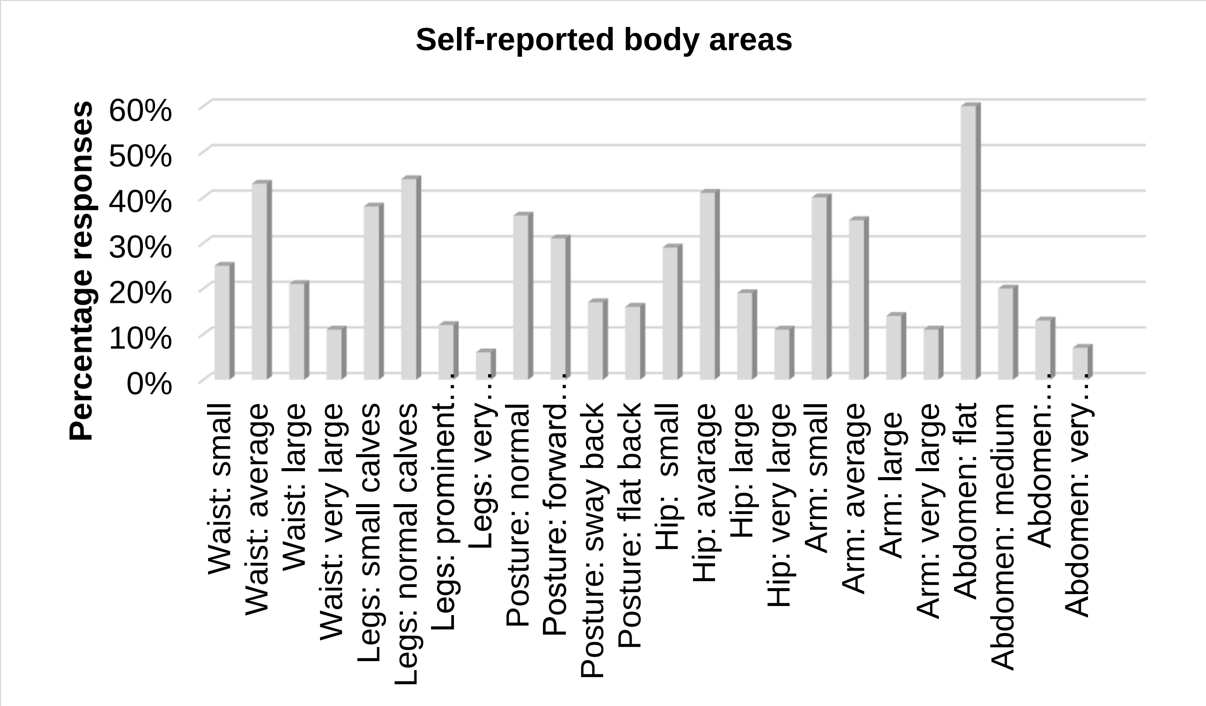


Figure 4.7: Self-reported body parts of the male subjects (n=270)

In terms of the waist girth most male subjects report an average waist size of 86 cm (43%), followed by a small waist of 79 cm (25%), large waist of 94 cm (21%) and very large waist of 102 cm (11%). From their viewpoint of their legs, 44 % cent of the male subjects perceived themselves as having legs with normal calves, followed by small calves (38%), prominent calves (12%), and very prominent calves (6%).

Regarding their body posture, the largest distribution of male subjects reported having a normal body posture (36%), followed by forward head body posture (31%), sway back body posture (17%) and flat back body posture (16%). Body posture is an important factor that is considered when the patterns for creating clothes are drafted. According to Sheperis *et al*. (2019:28), if a pattern for a garment, such as the basic shirt, is drafted based on the person with a body type of a normal balanced body posture, the pattern should also be evaluated to accommodate other body postures of the same body type such as that of the sway back to avoid altering the pattern during the late stages of clothing manufacturing.

These men were also reported to have average hip (41%) followed by small hip (29%), large hip (19%) and very large hip (11%). In terms of the arms most male subjects perceive themselves as having small arms (40%), followed closely by average arms

(35%), whilst the least perceived body parts were large arms (14%), and very large arms (11%). Concerning the abdomen, most of the male subjects perceived themselves as having a flat abdomen (60%), followed by a medium abdomen (20%), thereafter a prominent abdomen (13%) and very prominent abdomen (7%).

The men (33%) perceived themselves having a flat seat (also referred to as the buttock), followed by those with a prominent seat (26%), medium seat (21%) and very prominent seat (20%).

In terms of their perceived chest size 43 % of the subjects perceived themselves as having an average chest, followed by a large chest (24%), whilst the least perceived (23%) and 10% were the small and very large chest respectively.

The findings indicate that most men perceived themselves as having an average-sized chest, waist and hip girths. These men also reported smaller arms, normal leg-calves with a flat abdomen and seat. Therefore, the subjective knowledge related to the perceptions of men about their body parts may help manufacturers and retailers to understand the parts of the body in which fit problems are mostly experienced. Therefore, they could use 3-D body scanned anthropometric measurers of these body areas to update their size charts more objectively as it was done in this study to provide garments that fit well.

4.4 THE DOMINANT BODY MORPHOTYPE CLASSIFICATION FOR MEN IN THIS STUDY

The first objective of the study was to classify the dominant body morphotype of the men arising from the dataset of 270 men. The body measurements were extracted from the e-tape anthropometric dataset from the $[TC]^2$ NX-16 3-D full-body scanner. The approach was to initially apply Principal Component Analysis (PCA) covariance matrix to 72 e-tape measurements to determine the key body dimensions that are essential to categorise the dominant body morphotype of the men. Thereafter the K-Means Cluster Analysis was performed to group these key body dimensions into clusters to determine the cluster with the largest number of men identified as the dominant body morphotype.

4.4.1 Applying Principal component analysis to identify the key body dimensions for the dominant male body morphotype

PCA determined by the covariance matrix resulted in 42, e-tape measurements that are essential key vertical (height and length) and horizontal (girth and width) body measurements required to define the different clusters of body morphotype categories. The height and length body measurements consisted of the neck height (front and back), chest height, stomach height, thigh height, right calf height, left calf height, left knee height, hip height, right ankle height outside and left in-seam. The left waist to hip, right back waist to crotch level, left shoulder to elbow, overarm height, left front side neck to armscye level, right shoulder length, right thigh length, left shoulder to waist back, right shoulder to waist back, left shirt sleeve, left coat out-sleeve, right coat in-sleeve, left out-seam and buttocks angle were also selected.

The identified girth and width body measurements were the left forearm girth, left bicep girth, left leg surface, left thigh girth, waist girth, hip girth, left calf girth, chest girth, abdomen girth, right knee girth, left knee girth, left ankle girth and horizontal body measurements of the abdomen front, waist front, chest front, shoulder to shoulder width and across chest horizontal.

Thereafter the Kaiser-Meyer-Olkin (KMO) and Bartlett's test were conducted to predict if all the 42, e-tape dimensions were suitable for PCA analysis. According to Chang and Schulz (2018:4), the value of the KMO measure between 0.7 and 0.8 indicate that the body dimensions determined by the PCA are suitable for analysis. Bartlett's test measure must be less than 0.05 to predict the dataset that is suitable for a PCA analysis. In this study the KMO measure and Bartlett's test measure were 0.8 and 0.00, respectively. Hence, all 42 body dimensions were deemed suitable for PCA analysis.

The PCA Covariance matrix grouped the body dimensions into the fewest principal components (PCs) to determine the key body dimensions. To determine the number of the PCs to be retained, three criteria, namely, the scree plot (in Appendix E), percentage of variance criterion (in Table 4.2) and component matrix (in Appendix F) were considered. The Scree plot criterion graph visualised the number of PCs that should be retained based on the Eigen value. According to Amao (2018:1), Chuerubim and Da Silva (2018:1028), the PCs that have Eigen values greater than one in the scree plot criterion graph are retained when determining the key body dimensions. Furthermore, the number of PCs to retain in the scree plot criterion graph were also determined by the breakpoint (curve) resembling an 'elbow' morphotype that is commonly considered as a cut-off area (Gupta & Zakaria 2014:106; Kleinlugtenbelt *et al*., 2018:28; Schulze & Boscardin 2018:11; Sheperis *et al*., 2019:28).

Table 4.2 shows the percentages of the total variance criterion explained by each PC that was retained for the selection of the key body dimensions for the classification of body morphotypes for the 270 men.

Table 4.2: The total variance explained by each PC for the e-tape body dimensions required for the classification of male body morphotypes.

Total variance explained			
Component	**Initial Eigenvalues**		
	Total	**% of variance**	**Cumulative %**
PC1	5.8	26.3	26.3
PC2	1.8	8.1	34.4
PC3	1.4	6.2	40.6
PC4	1.3	5.8	46.4
PC5	1.2	5.6	52.0

Table 4.2 shows that a large proportion (26.3%) of the variance in the e-tape anthropometric dataset was explained by the first component (PC1), followed by 8.1 % in the second component (PC2), 6.2 % by the third component (PC3), 5.8 % by the fourth component (PC4), and 5.6 % by the fifth component (PC5). The five PCs explained that at least 50 % of the total variance were chosen as significant (Gupta & Zakaria, 2014:107) and retained for further analysis, as they explained a cumulative percentage of 52.0 % of the e-tape body dimensions.

Based on the results from the scree plot criterion, and the table of total variance, the next step in the analysis, namely the component matrix was determined (in Appendix F) to identify all the factor loadings for each vertical and horizontal body dimension in each of the five principal components. The vertical body dimensions are related to the length and height, and the horizontal body dimensions to the girth and width of the dominant body morphotype. The factor loading scores indicate how strong the e-tape anthropometric dimensions correlate with each principal component (Gupta & Zakaria, 2014:4). Therefore, the 42 vertical and horizontal body dimensions that demonstrated factor loadings greater than 0.40 highlighted (in Appendix F) are explained as follows.

PC1 was primarily dominated by the body height measures of the neck (front and back height), chest height, stomach height, thigh height, right calf height, left calf height, left knee height. The body lengths of the in-seam left, left waist to hip and right back waist to crotch level. The body girth measures identified the left forearm girth and left bicep girth. Therefore, this component has been named the height, length, and girth factor.

The PC2 was primarily dominated by body girth measures such as the left leg surface, left thigh girth, waist girth, hip girth, left calf girth and chest girth. The body length and height of the left shoulder to elbow, overarm height, left front side neck to armscye level, waist front height, right coat in-sleeve and the width of chest front. PC2 was termed girth, length, height, and width factor.

The PC3 was dominated by the body height measures such as the hip height and the body length measures of the right shoulder length, right thigh length and body width of shoulder- to- shoulder width. The body girth measures of the left knee girth. This component was named the height, length, width, and girth factor.

The PC4 was dominated by body length and body height measures such as the right coat in-sleeve, right shoulder length, right ankle height outside, left out-seam, left coat out-sleeve, left shirt sleeve. The body width of shoulder- to- shoulder width, the body girth of the left ankle girth and angle of the buttocks. The component was named length, height, width, girth, and angle factor.

PC5 was dominated by body girth measurers of the right knee girth, abdomen girth, body length for the left shoulder to waist back, right shoulder to waist back and body width of across chest horizontal, abdomen front. This component was termed girth, length, and width factor.

Based on these (PC1 to PC5) key body dimensions, Cluster Analysis was performed to determine the distinct clusters that defined the 270 men's body morphotypes.

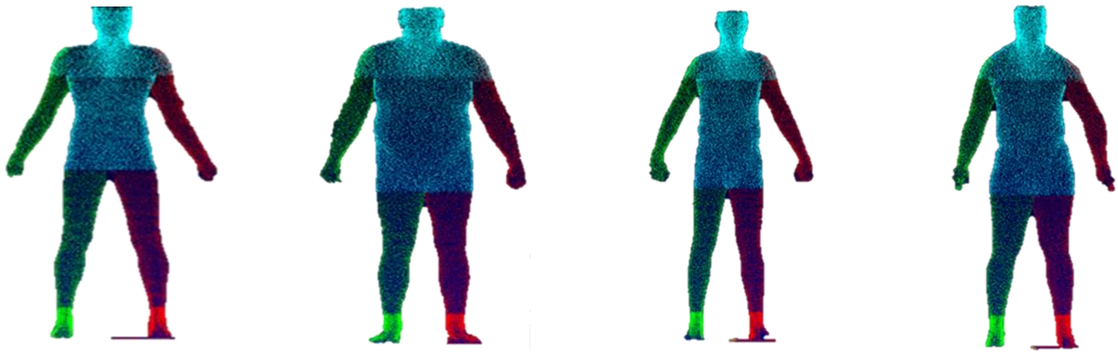
4.4.2 Using Cluster Analysis to categorise the dominant body morphotype of the men

To classify the dominant body morphotype category of the men, K-means Cluster Analysis was conducted in SPSS version 27 software using PC scores of the factors for PC1 to PC5 extracted from the PCA analysis (in Appendix G). The scores of the height, length, girth, width, and buttocks angle factor loadings were loaded as independent variables to classify the dominant body morphotype category of men. The K-Means Cluster Analysis divided the key body measurements into clusters to distinguish one body morphotype from the other (Cottle, 2012:9). Therefore, the first step in the analysis was to identify the number of clusters that explain the men's body morphotype categories.

To identify the number of clusters, four cluster model was initially evaluated.

In the four-cluster model (n=47,17,4%; n=55, 20.4%; n=45,16.6%; n=123, 45.5%), men were almost evenly distributed in three clusters with a fourth cluster clearly defined as dominant. Therefore, four-cluster model were selected as the most appropriate to classify the dominant body morphotype category for the men in this study.

The four-cluster model that classified each body morphotype category cluster statistically by observing and comparing the scores of the body dimensions within each distinct cluster was based on the results of the K-means method (such as (0.176; 0.178) in Appendix G). From these findings, four body morphotype clusters namely the Trapezoid (n=47,17.4%), Triangle (n=45, 16.6%), Oval (n=55, 20.4%) and the Rectangle (n=123, 45.5%) were identified. The dominant body morphotype of men that exist within each cluster are illustrated in Figure 4.8.



(1) Trapezoid (2) Oval (3) Rectangle (4) Triangle

Figure 4.8: Trapezoid, Oval, Rectangle and Triangle men's body morphotypes

From the anthropometric characteristics of the length, height, girth, width and buttocks angle factor loadings, the men in Cluster 1 were classified as the Trapezoid body morphotype. This body morphotype category had neither a too long nor too short neck (0.176; 0.178), stomach (0.134) nor a longer chest (0.176) in terms of height. The men in this category tended to be short from the side of the neck point to the armscye level at the front, and long in length from the shoulder to the waist at the back. These men were short from the waist at the back to crotch level, and long at the hip height part; however, they had the shortest lower body part in terms of the thigh height, knee height, calf height, and the in-seam and out-seam. The men exhibited a broad chest and a narrow abdomen front with prominent buttocks. The chest dimension was broader than their waist and the hip girths (see Figure 4.8). The hip was smaller than the chest but larger than the waist. Overall, these men tend to be leaner around the thighs, the knees, the ankles, with prominent biceps and a large forearm.

From the anthropometric characteristics of the length, height, girth, width, and buttocks angle factor loading, men in Cluster 2 were classified as an Oval body morphotype. This body morphotype category had the longest neck (0.491; 0.492), chest (0.475) and stomach (0.489) in terms of height. Men in this category exhibited the longest side of the neck point to the armscye level at the front, and shorter shoulder to the left waist part at the back. These men were longest from the waist at the back to crotch level, and shorter at the hip height part. The thigh height, the ankle height, the ankle height, the left in-seam, and the left out-seam were longer, except for the left knee height. Therefore, these men are longer on the lower body part. The men in this morphotype category exhibited broadest shoulders, chest, waist and abdomen based on the shoulder- to- shoulder width, chest front, waist front and abdomen front dimension (in Figure 4.8). The buttocks were the least prominent with the men exhibiting a larger waist girth than the chest and hip. Overall, these men were the largest in terms of their abdomen, the thighs, the knee, and the ankle, with prominent calves. Their arm length and legs length fell into the longer length category, with a large forearm but with a least prominent bicep.

Regarding the height, length, girth, width, and buttocks angle factor loading, men in Cluster 3 were classified as a Triangle. Men who fell in this body morphotype category had the shortest neck average (-2.114; -2.116), stomach (-0.174) and chest (-2.079) in terms of height. Men in this category exhibited the shortest side of the neck point to the armscye level at the front, and the longest at the left waist part at the back. These men were shortest from the waist at the back to crotch level, and shortest at the hip height part. The thigh height, the knee height and the ankle height were longer, with the shorter calf and the in-seam. Therefore, these men were longer on the lower body part. The men in this morphotype category exhibited narrow shoulders in terms of the shoulder- to- shoulder width dimension, with the most prominent buttock part. The men had a chest that is smaller than the hip part (see Figure 4.8). Overall, these men were large in the thigh and their ankles with a prominent calf. The legs were longer in the right thigh length, left knee height, except the calf height which was shorter.

In terms of height, length, girth, width, and buttocks angle factor loading, men in Cluster 4 were classified as a Rectangle. Men in this body morphotype category were taller than men in other morphotype categories in terms of the average neck height (front and back) of (0.467; 0.466), chest height of (0.467), the left front side neck to armscye level of (-0.088). Men in this category exhibited the longest lower body than all other body morphotype categories based on the average hip height of (0.114), thigh height of (0.492), left knee height of (0.300), calf height (right and left) of (0.460; 0.448), left waist to hip of (0.285) and the left in-seam of (0.492). These men were the leaner than all other body morphotypes categories, based on the average of chest girth (-0.272), waist girth (-0.259), hip girth (-0.274)., calf girth (-0.058), across chest horizontal width (-0.069) and waist front (-0.102) with the least prominent buttocks. The men in this morphotype category exhibited that the chest that is equal to the hip size (see Figure 4.8).

Therefore, it can be concluded that the dominant body morphotype (123; 45.5%) of the men in this study were classified as being a Rectangle morphotype. These 123 men (Cluster 4) exhibited similar chest and hip measurements.

Thereafter, to verify whether the men in Cluster 4 were also of a rectangle body morphotype visually, a set of nine full body scans illustrated in Appendix N were extracted based on the anthropometric measurements of the small, average, and large male rectangle subject from Cluster 4. These nine rectangular-shaped three-dimensional scans were sent to 15 clothing designers situated in Gauteng. The results of the visual analysis of the front views of the 3-D scans indicate that all 15 experts agreed that the men grouped within Cluster 4 fell into a rectangle body morphotype category.

Hence, the further discussion below is of the analysis and developments of anthropometric size charts for the dominant morphotype in the dataset, i.e., the rectangle. Also compared is the anthropometric measurements of the Rectangle morphotype when compared to that of a commercially available fitting mannequin of a similar body size that is used in South Africa.

4.5 DEVELOPMENT OF THE UPPER AND LOWER BODY ANTHROPOMETRIC MEN’S SIZE CHARTS

The second objective of the study was to develop upper and lower body anthropometric size charts for the 123 men that were classified as a Rectangle body morphotype out of a sample size of 270 men in K-Means Cluster Analysis. A set of 18 upper-body and 18 lower-body related measures were analysed separately to determine the key body measurements used to establish upper and lower body anthropometric size charts. Initially, the PCA covariance matrix method in SPSS version 27 software was applied to determine the key body measurements referred to as control dimensions used in the development of the anthropometric size charts. Thereafter, regression analysis predicted the secondary key body dimensions.

4.5.1 Principal component analysis for determining the upper and lower body control dimensions for the 123 men of a Rectangle morphotype

Varte *et al*. (2017:9) mention that control body dimensions are used as the reference when a consumer chooses a RTW garment size to fit their body well. Eight upper body-related dimensions, namely the left shirt sleeve, chest girth, neck girth, left bicep girth, shoulder to shoulder width, left elbow girth, right wrist girth and left forearm girth were determined using the PCA covariance matrix method. Thereafter, a set of 10 lower body dimensions, namely the left in-seam, left out-seam, hip height, front crotch length, waist girth, hip girth, left thigh girth, left calf girth, left knee girth, and left ankle girth were chosen.

The KMO and Bartlett's test of sphericity performed separately determined that all 8 upper body-related and 10 lower body related body dimensions were suitable to produce reliable PCA outputs (Chang & Schulz, 2018:4). The results of the KMO test for the upper related and lower body related dimensions measured a value of 0.80 that meant it was a good suitability score of each body dimension to produce reliable outputs. In terms of Bartlett's test, a value of 0.00 in both the upper and lower body measurements indicated that all the 8 and 10 body dimensions, respectively, were suitable to predict reliable upper-body and lower-body related outputs for the PCA analysis.

The PCA covariance matrix was thereafter applied to identify the PCs with the e-tape anthropometric dimensions that provided most of the information associated with the size-codes for the upper and lower body of the men of a Rectangle morphotype. The PCA outputs of the scree plot of the upper body related dimensions (in Appendix H) and lower body related dimensions (in Appendix I), table of total variance in Table 4.3 and Table 4.4 and the component matrix in Table 4.5 and Table 4.6, were analysed.

The scree plot graph of the upper body related dimensions determined four PCs components based on Eigenvalue value greater than one and the cut-off area named an 'elbow'. The scree plot graph of the lower body related dimensions determined five PCs based on Eigenvalue value greater than one and an 'elbow' cut-off area. The PCs below an Eigen value of one, and an 'elbow', were considered to be giving less information, therefore were not retained for further analysis.

The four PCs for an upper body and five PCs for a lower body of the men of a Rectangle morphotype were further analysed using the table of total variance to determine the percentages of the variance that is explained by each component. Table 4.3 and Table 4.4 present the number of the upper body and lower body components and their percentages of variances.

Table 4.3: The total variance explained for the e-tape body dimensions required for the size chart of an upper body for the men of a Rectangle morphotype.

Total variance explained			
Component	**Initial Eigenvalues**		
	Total	**% of variance**	**Cumulative %**
PC1	1.3	14.5	14.5
PC2	1.2	12.9	27.4
PC3	1.1	12.4	39.8
PC4	1.0	11.6	51.4

Table 4.3 indicated that the largest proportion (14.5%) of variance of the e-tape anthropometric dataset for an upper body was explained by the first component (PC1), followed closely by 12.9 % in the second component (PC2), 12.4 % by the third component (PC3), and 11.6 % by the fourth component (PC4). Therefore, four PCs for an upper body with a cumulative percentage of 51.4 % were retained for further analysis.

Table 4.4: The total variance explained for the e-tape body dimensions required for the size chart of the lower body for the men of a Rectangle morphotype.

Total variance explained			
Component	**Initial Eigenvalues**		
	Total	**% of variance**	**Cumulative %**
PC1	1.3	13.2	13.2
PC2	1.3	12.7	25.9
PC3	1.2	11.7	37.6
PC4	1.1	11.1	48.7
PC5	1.0	10.2	58.9

Table 4.4 indicates that the largest proportion (13.2%) of variance of the e-tape anthropometric dataset for the lower body was explained by the first component (PC1), followed closely by 12.7 % in the second component (PC2), 11.7 % by the third component (PC3), 11.1 % by the fourth component (PC4) and 10.2 % by the fifth component (PC5). Therefore, five PCs for the lower body with a cumulative percentage of 58.9 % were retained for further analysis.

Based on the results, four PCs for the upper body, and five PCs for the lower body were retained from the scree plot and the table of total variances output. The next step was to create a rotated component matrix. The rotated component matrix identifies the factor loadings of the e-tape measurements that explained the most essential information related for determining the size-codes for the men of a Rectangle morphotype. Factor loadings with scores greater than 0.40 were presented in Table 4.5 for an upper body, and Table 4.6 for the lower body. The values of the anthropometric measures that were extracted in these PCs were regarded as giving essential information to define the size of an individual, therefore, they were further analysed to determine the primary (independent key) and secondary (dependent key) body dimensions for a size chart for the men of a Rectangle morphotype in this study.

Table 4.5: The rotated component matrix for the identification of the primary (upper key) and secondary body dimensions of the size chart for the men of a Rectangle morphotype.

Component matrix				
Body dimensions	**Component**			
	PC1	**PC2**	**PC3**	**PC4**
Chest girth	0.014	0.032	0.057	**0.585**
Left shirt sleeve left	0.381	**0.636**	-0.119	0.031
Neck girth	-0.206	-0.114	**0.412**	-0.361
Left bicep girth	-0.054	0.314	**0.658**	0.100
Shoulder to shoulder width	**0.572**	**0.482**	0.234	0.023
Left elbow girth	**0.408**	0.109	0.007	**0.507**
Right wrist girth	0.010	**0.402**	**0.436**	**0.454**
Left forearm girth	**0.567**	0.114	0.217	0.306

The PCs (in bold face) with the body dimensions with the component factor loadings greater than 0.40 in Table 4.5 were explained as follows:

The PC1 was dominated by the horizontal body measure of shoulder- to- shoulder width and the girth measurers of the left elbow girth and left forearm girth. The PC2 was dominated by the vertical body measure of the left shirt sleeve, the horizontal body measure of the shoulder- to- shoulder width and girth measure of the right wrist girth. The PC3 was dominated by body girth measures of the neck girth, left bicep girth and right wrist girth. The PC4 was dominated by the girth measurers of the chest girth, left elbow girth and right wrist girth.

Table 4.6: The rotated component matrix for the identification of the primary (lower key) and secondary body dimensions of the size chart for the men of a Rectangle morphotype.

Component matrix					
Body dimensions	**Component**				
	PC1	**PC2**	**PC3**	**PC4**	**PC5**
Waist girth	**0.579**	0.163	**0.488**	0.198	-0.090
Hip girth	**0.472**	-0.235	**0.564**	0.251	0.019
Left in-seam	0.170	**0.477**	-0.290	0.173	-0.264
Left out-seam	0.227	**0.539**	0.005	**0.491**	0.109
Left thigh girth	0.347	0.242	**0.437**	**0.441**	-0.059
Left calf girth	**0.492**	0.047	**0.401**	0.083	0.184
Hip height	0.298	0.209	0.132	**0.623**	0.103
Left knee girth	-0.306	**0.583**	0.232	0.147	0.140
Left ankle girth	-0.346	**0.433**	0.277	0.352	0.351
Front crotch length	0.147	-0.190	-0.162	0.050	**0.859**

The PCs (in bold face) with the body dimensions with the component factor loadings greater than 0.40 in Table 4.6 were explained as follows:

The PC1 was dominated by the body girth measures of the waist girth, hip girth and left calf girth. The PC2 was dominated by vertical body measures of the left in-seam and left out-seam, and the body girth measures of left knee girth and left ankle girth. The PC3 was dominated by the body girth measures of the waist girth, hip girth, left thigh girth and left calf girth. The PC4 was dominated by the body girth measure of the left thigh girth and vertical body measures of the left out-seam, hip height. The PC5 was dominated by the vertical body measure of the front crotch length.

The upper and lower body dimensions, such as the chest girth, neck girth, left shirt sleeve, waist girth, hip girth and left in-seam were considered the primary (independent key) control dimensions of the upper and lower body anthropometric size charts. These six body dimensions are commonly adopted by the clothing designers as being essential independent variables guiding the allocation of sizes in clothing manufacturing (Gupta & Zakaria, 2014:113; Xia & Istook, 2017:241). The upper and lower body dimensions, namely, left bicep girth, shoulder to shoulder width, left elbow girth, right wrist girth, left forearm girth, left out-seam, left thigh girth, left calf girth, hip height, left knee girth, left ankle girth and front crotch length were considered dependent body dimensions of the anthropometric size charts. These 12 body dimensions are referred to as dependant variables, because they are commonly predicted as secondary key control body dimensions based on calculations between one or multiple independent body dimensions (Xia & Istook, 2017:239).

The next section explains the methods and procedures used to develop the upper and lower body anthropometric size charts, using the six primary (independent key) control body dimensions (chest girth, neck girth, left shirt sleeve, waist girth, hip girth and left in-seam) to predict the secondary (dependent key) control body dimensions among 12 selected dependent body measures (left bicep girth, shoulder to shoulder width, left elbow girth, right wrist girth, left forearm girth, left out-seam, left thigh girth, left calf girth, hip height, left knee girth, left ankle girth and front crotch length).

4.5.2 Method and procedure for developing the anthropometric size charts for men

Bivariate and multivariate linear regression analysis was conducted to predict the values of the secondary (dependent) body dimensions for the 123 men of a Rectangle morphotype. Before performing the regression analysis, selective descriptive statistics for six primary (independent key) and 12 dependent body dimensions was calculated to determine the minimum, maximum, the mean, standard deviation and 95 % upper bound and lower bound confidence interval for each body dimension. The minimum and maximum values were calculated to allocate the number of size ranges to cover the maximum number for the 123 men of a Rectangle morphotype, with a minimum number of sizes. The mean was calculated to determine central (average) values of the middle size for the upper and lower body anthropometric size charts, as suggested by Varte *et al*. (2017:32). The standard deviation and 95 % confidence interval was calculated to determine variations of data distributions, and an upper and lower bound of each value of the upper and lower body dimensions (Sullivan, 2011:16; Haradhan, 2017:78). Table 4.7 and Table 4.8 list the calculations of the minimum, maximum, the mean, standard deviation and 95 % confidence interval values for each upper and lower (independent and dependent) body dimensions.

Table 4.7: The minimum, maximum, the mean, standard deviation and 95 % confidence interval measurement values for the upper body dimensions

Descriptive statistics (n=123)					
Upper body dimensions (cm)	**Minimum**	**Maximum**	**Mean**	**Std. deviation**	**95% confidence interval**
Chest girth	79	139	99.13	9.66	97.97 to 100.28
Neck girth	15	56	40.51	3.46	40.09 to 40.92
Left shirt sleeve	45	104	87.38	6.48	86.61 to 88.16
Left bicep girth	22	44	30.09	3.86	29.63 to 30.55
Left elbow girth	20	32	25.31	2.19	25.05 to 25.57
Left forearm girth	21	34	26.09	2.22	25.83 to 26.36
Right wrist girth	6	20	16.26	1.47	16.08 to 16.43
Shoulder to shoulder width	26	54	41.11	4.75	40.54 to 41.68

Table 4.7 presents the descriptive statistic values of the three primary (independent key) control body dimensions and five dependent body dimensions that were predicted to determine secondary dimensions for the upper body anthropometric size charts. The mean values of the primary (independent key) control body dimensions highlighted in Table 4.7 were rounded up or down to the whole number. These values of the primary (upper independent key) control body dimensions were established by the chest girth 99 cm, neck girth 41 cm, and left shirt sleeve 87 cm.

The original mean values of the left bicep girth, left elbow girth, left forearm girth, right wrist girth and shoulder- to- shoulder width in Table 4.7 were not applied as the average values of the upper body anthropometric size charts, however, the new mean values were predicted later in step 2 of this chapter

Table 4.8: The minimum, maximum, the mean, standard deviation and 95% confidence interval measurement values for the lower body dimensions

Descriptive statistics (n=123)					
Lower body dimensions (cm)	**Minimum**	**Maximum**	**Mean**	**Std. deviation**	**95% confidence interval**
Waist girth	65	133	82.84	12.16	81.39 to 84.29
Hip girth	85	142	99.46	9.37	98.34 to 100.58
Left in-seam	62	94	75.95	5.07	75.34 to 76.55
Left out-seam	88	117	103.39	6.03	102 to 104.11
Left thigh girth	44	81	54.15	6.00	53.44 to 54.87
Left calf girth	31	46	35.77	2.98	35.42 to 36.13
Hip height	64	109	83.27	6.86	82.46 to 84.09
Left knee girth	31	47	37.76	2.69	37.44 to 38.08
Left ankle girth	15	49	27.48	4.76	27.31 to 27.64
Front crotch length	17	60	33.72	5.93	33.02 to 34.43

Table 4.8 presents the descriptive statistic values of the three primary (independent key) control body dimensions and seven dependent body dimensions that were predicted to determine secondary dimensions for the lower anthropometric size charts. The mean values of the primary (independent key) control body dimensions highlighted in Table 4.8 were rounded up or down to the whole number. These values of the primary (lower independent key) control body dimensions were established by the waist girth 83 cm, hip girth 99 cm and left in-seam 76 cm.

The original mean values of the left out-seam, left thigh girth, left calf girth, hip height, left knee girth, left ankle girth and front crotch length in Table 4.8 were not applied as the average values of lower body anthropometric size charts, however, the new mean values were predicted later in step 2 of this chapter. After the descriptive statistic values of the independent and dependent body dimensions were identified, three steps described below were performed to develop the anthropometric size charts of an upper and lower body of men.

Step 1: Determining the size intervals and ranges of the primary key body dimensions.

The first step in developing the upper and lower body anthropometric size charts was to calculate the size intervals and size ranges to produce evenly distributed sizes of each primary (independent key) body dimension. The size intervals for each primary (independent key) body dimension were calculated by initially subtracting the lower bound value from the upper bound value of the 95 % confidence interval (Gupta & Zakaria, 2014:55). The acceptable accommodation rate guideline between 65 % and 85 % by Xia and Istook (2017:237) was used to allocate the size ranges of upper and lower body anthropometric size charts. The guidelines also suggested that size ranges should be allocated in such a way that few sizes cover most of the population that a size chart is intended to fit. The advantage of allocating few sizes also assists the consumers to easily recognise the size which they estimate to fit their bodies. (Xia & Istook (2017:237). Therefore, after testing the size ranges using different values, six size ranges were considered appropriate for the maximum coverage for the 123 men of a Rectangle_morphotype in this study. The calculations of the differences between the lower bound and upper bound values of 95 % confidence interval for primary (upper and lower independent key) body dimensions are presented in Table 4.9 and Table 4.10.

Table 4.9: Calculations for predicting the size intervals for the primary (upper independent key) body dimensions

Key body dimension	Calculation (in cm) (95% confidence interval upper bound - lower bound)	Result (rounded up/down to the whole number)
Upper body girth		
Chest girth	100.28 (upper bound) - 97.97 (lower bound) = 2.31	Rounded down to 2
Neck girth	40.92 (upper bound) - 40.09 (lower bound) = 0.83	Rounded up to 1
Upper body length		
Left shirt sleeve	88.16 (upper bound - 86.61 (lower bound) = 1.55	Rounded up to 2

Table 4.9 shows that the primary (upper independent key) body dimensions were established by the chest girth 2 cm, neck girth 1 cm and left shirt sleeve 2 cm.

Table 4.10: Calculations for predicting the size intervals for the primary (lower independent key) body dimensions

Key body dimension	Calculation (in cm) (95% confidence interval upper bound-lower bound)	Result (rounded to the whole number)
Lower body girth		
Waist girth	84.29 (upper bound) - 81.39 (lower bound) = 2.9	Rounded up to 3
Hip girth	100.58 (upper bound) - 98.34 (lower bound) = 2.24	Rounded down to 2
Lower body length		
Left in-seam	76.55 (upper bound) - 75.34 (lower bound) = 1.21	Rounded down to 1

Table 4.10 shows that the primary (lower independent key) body dimensions were established by the waist girth 3 cm, hip girth 2 cm and left in-seam 1 cm. After the primary (upper and lower independent key) body dimensions were established, a regression statistical analysis method was performed to predict the mean (average) of each secondary (dependent key) body dimension.

Step 2: Regression analysis for determining the mean (average) of the secondary (dependent key) body dimensions.

The mean (average) was identified by the regression equations on key body dimensions. The fitted regression model is:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \epsilon$$

Equation 1: The fitted regression model adapted from Ali and Younas (2021)

Where β_0 denotes the intercept, β_1 denotes the slope corresponding to independent variable X_1; β_2 denotes the slope corresponding to independent variable X_2 and ϵ is the random error.

Table 4.11, 4.12. 4.13 and 4.14 identified each secondary (dependent key) body dimension in one or more than two primary (independent key body) dimensions. In these tables the regression coefficients of the intercept (β_0), the slope (β_1) corresponding to the independent variable X_1 and the slope (β_2) corresponding to the independent variable X_2 were also established to predict the mean values of each secondary (dependent key) body dimension.

Table 4.11: The calculations to determine the regression coefficients for the upper body girth related dimensions

Regression coefficient calculations for the upper body girth related measurements (n=123)			
Secondary body dimension	**Unstandardised coefficients**	**R square**	**P-value**
Left bicep girth	26.052	0.701	0.000
Chest girth	-0.008		0.000
Neck girth	0.051		0.001
Right wrist	14.092	0.629	0.000
Chest girth	-0.001		0.001
Neck girth	0.017		0.012

Secondary body dimension	Unstandardised coefficients	R square	P-value
Left forearm girth	25.793	0.665	0.000
Chest girth	-0.020		0.013
Neck girth	0.006		0.001
Left elbow girth	22.495	0.544	0.000
Chest girth	0.005		0.002
Neck girth	-0.004		0.000

Table 4.11, shows the multivariate linear regression significant relationships between the four dependent body dimensions of right wrist girth, left bicep girth, left forearm girth, left elbow girth and the independent body dimension of the chest girth, neck girth (p-value<0.05).The 'R square' value showed a coefficient of 0.701, 0.629, 0.665,0.544 suggesting that 70 %, 63 %, 67 %, 54 % of the variation in the right wrist girth, left bicep girth, left forearm girth, left elbow girth respectively, can be explained by the chest girth and neck girth body dimension. The percentage of variation indicated a strong positive relationship between the analysed body dimensions.

Table 4.12: The calculations to determine the regression coefficient constants for the upper body length related dimensions

Regression coefficient calculations for the upper body length related measurements (n=123)			
Secondary body dimension	**Unstandardised coefficients**	**R square**	**P-value**
Shoulder to shoulder width	32.328	0.720	0.000
Left shirt sleeve	0.067		0.002

As shown in Table 4.12, bivariate linear regression showed significant relationship between the shoulder- to- shoulder width body dimension and the independent body dimension of the left shirt sleeve (p-value<0.05). The 'R square' value showed a coefficient of 0.720, suggesting that 72 % of the variation in the shoulder- to- shoulder width, can be explained by the left shirt sleeve body dimension. The percentage of variation indicated strong positive relationship between the analysed body dimensions.

Table 4.13: The calculations to determine the regression coefficient constants for the lower body girth related dimensions

Regression coefficient calculations for the lower body girth related measurements (n=123)			
Secondary body dimension	**Unstandardised coefficients**	**R square**	**P-value**
Left thigh girth	47.267	0.715	0.000
Waist girth	0.047		0.000
Hip girth	-0.017		0.000
Left calf girth	29.981	0.621	0.000
Waist girth	0.029		0.001
Hip girth	0.001		0.000
Left knee girth	35.515	0.610	0.000
Waist girth	0.004		0.002
Hip girth	-0.017		0.000
Left ankle girth	27.144	0.602	0.000
Waist girth	0.012		0.000
Hip girth	-0.019		0.001

As seen in Table 4.13, multivariate linear regression showed significant relationship between the four dependent body dimensions of left thigh girth, left calf girth, left knee girth, left ankle girth and the independent body dimension of the waist girth, hip girth (p-value<0.05).The 'R square' value showed a coefficient of 0.715, 0.621, 0.610,0.602 suggesting that 72 %, 62 %, 61 %, 60 % of the variation in the left thigh girth, left calf girth, left knee girth, left ankle girth respectively, can be explained by the waist girth and hip girth body dimension. The percentage of variation indicated strong positive relationship between the analysed body dimensions.

Table 4.14: The calculations to determine the regression coefficient constants for the lower body length dimensions

Regression coefficient calculations for the lower body length related measurements (n=123)			
Secondary body dimension	**Unstandardised coefficients**	**R square**	**P-value**
Left out-seam	91.727	0.620	0.000
Left in-seam	0.062		0.000
Front crotch length	30.540	0.577	0.000
Left in-seam	-0.009		0.001
Hip height	68.129	0.704	0.000
Left in-seam	0.18		0.003

As noted in Table 4.14, bivariate linear regression showed significant relationship between the three dependent body dimensions of left out-seam, front crotch length, hip height and the independent body dimension of the left in-seam (p-value<0.05).The ‘R square’ value showed a coefficient of 0.620, 0.577, 0.704 suggesting that 62 %, 58 %, 70 % of the variation in the left out-seam, front crotch length and hip height body dimensions respectively, can be explained by the left in-seam body dimension. The percentage of variation indicated strong positive relationship between the analysed body dimensions.

To obtain the mean (average) size for the right wrist using Equation 1 $y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \epsilon,$ was calculated as follows:

Right wrist girth (y) = 14.092 (β_0) + [-.001 (β_1) *99 independent variable X_1 (chest girth) + 0.017 (β_2) *41 independent variable X_2 (neck girth)] = 14.69, which was rounded up to 15. Therefore, as a result, the mean (average) size of the right wrist girth was 15 cm. The remaining calculations of the mean (average) size that were established for the secondary (upper and lower dependent key) body dimensions for the current size charts were performed using the same guidelines. Therefore, the secondary (upper dependent key) body dimensions were established by the left bicep girth 27 cm, left elbow girth 23 cm, left forearm girth 24 cm, right wrist girth 15 cm and shoulder to shoulder width 35 cm.

The secondary (lower dependent key) body dimensions were identified by the left thigh girth 49 cm, left calf girth 32 cm, left knee girth 34 cm, left ankle girth 26 cm, left out-seam 96 cm, front crotch length 30 cm and hip height 69 cm. After the means (averages) of these secondary (upper and lower dependent key) body dimensions were established, the next step was to determine their size intervals and ranges for the current size charts of the study.

Step 3: Determining the size intervals and ranges of the secondary (dependent key) body dimensions for the size charts

The size intervals for the secondary (dependent key) body dimensions were calculated using the same guidelines of initially subtracting the lower bound value from the upper bound of 95 % confidence interval for each specified dimension as in step 1. The calculations of the differences between the lower bound and upper bound values of 95 % confidence interval for the upper and lower body dimensions are presented in Table 4.15 and Table 4.16.

Table 4.15: Calculations for predicting the size intervals for the secondary (upper dependent key) body dimensions

Key body dimension	Calculation (in cm) (95% confidence interval upper bound - lower bound)	Result (rounded up/down to the whole number)
Upper body girth		
Left bicep girth	30.55 (upper bound) - 29.63 (lower bound) = 0.92	Rounded up to 1
Left elbow girth	25.57 (upper bound) - 25.05 (lower bound) = 0.52	Rounded up to 1
Left forearm girth	26.36 (upper bound) - 25.83 (lower bound) = 0.53	Rounded up to 1
Right wrist girth	16.43 (upper bound) - 16.08 (lower bound) = 0.35	Rounded down to 0
Upper body length		
Shoulder to shoulder width	41.68 (upper bound) - 40.54 (lower bound) = 1.14	Rounded down to 1

Table 4.15 shows that the size intervals of the secondary (upper dependent key) body dimension girth were established by the left bicep girth 1 cm, left elbow girth 1 cm, left forearm girth 1 cm and right wrist girth 0 cm. The length was identified by the shoulder-to- shoulder width 1 cm.

Table 4.16: Calculations for predicting the size intervals for the secondary (lower dependent key) body dimensions

Key body dimension	Calculation (in cm) (95% confidence interval upper bound - lower bound)	Result (rounded up/down to the whole number)
Lower body girth		
Left thigh girth	54.87 (upper bound) - 53.44 (lower bound) = 1.43	Rounded down to 1
Left calf girth	36.13 (upper bound) - 35.42 (lower bound) = 0.71	Rounded up to 1
Left knee girth	38.08 (upper bound) - 36.44 (lower bound) = 1.64	Rounded up to 2
Left ankle girth	27.64 (upper bound) - 27.31 (lower bound) = 0.33	Round down to 0
Lower body length		
Left out-seam	104.1111 (upper bound) - 102.67 (lower bound) = 1.44	Rounded down to 1
Front crotch length	34.43 (upper bound) - 33.02 (lower bound) = 1.41	Rounded down to 1
Hip height	84.09 (upper bound) - 82.46 (lower bound) = 1.63	Rounded up to 2

Table 4.16 shows that the size intervals of the secondary (lower dependent key) body dimensions size intervals were identified by the girth of the left thigh girth 1 cm, left calf girth 1 cm, left knee girth 2 cm and left ankle girth 0 cm. The lengths were established by the left out-seam 1 cm, front crotch length 1 cm and hip height 2 cm.

To develop upper and lower body anthropometric size charts, the mean (average) values of each independent and dependent body dimension were tabulated. The mean (average) values for the primary (upper independent key) body dimensions were the chest girth 99 cm, left shirt sleeve 87 cm and neck girth 41 cm. For the primary (lower independent key) body dimensions were the waist girth 83 cm, hip girth 99 cm and left in-seam 76 cm.

Size intervals of 2 cm, 2 cm and 1 cm were either added or subtracted from the mean (average) of the chest girth, left shirt sleeve and neck girth respectively to establish six sizes of independent primary (upper independent key) body dimensions. Size intervals of 3 cm, 2 cm and 1 cm were either added or subtracted from the mean (average) of the waist girth, hip girth and left in-seam respectively to establish six sizes of each primary (lower independent key) body dimensions.

The mean (average) values for the secondary (upper dependent key) body dimensions were the left bicep girth 27 cm, left elbow girth 23 cm, left forearm girth 24 cm, right wrist girth 15 cm and shoulder to shoulder width 35 cm. For the secondary (lower dependent key), body dimensions were the left thigh girth 49 cm, left calf girth 32 cm, left knee girth 34 cm, left ankle girth 26 cm, left out-seam 96 cm, front crotch length 30 cm and hip height 69 cm.

Size intervals were allocated in each secondary (upper dependent key) body dimension by either adding to the mean (average) to establish larger size value or subtracting from the mean to establish smaller size value. Size interval of 1 cm, 1 cm, 1 cm, 0 cm, and 1 cm were either added or subtracted from the mean (average) of the left bicep girth, left elbow girth, left forearm girth, right wrist girth and shoulder to shoulder width respectively to establish six sizes of each secondary (upper dependent key) body dimensions. Size interval of 1 cm, 1 cm, 2 cm, 0 cm, 1 cm, 1 cm, and 2 cm were either added or subtracted from the mean (average) of the left thigh girth, left calf girth, left knee girth, left ankle girth, left out-seam, front crotch length and hip height respectively to establish six sizes of each secondary (lower dependent key) body dimensions.

Therefore, Table 4.17 below present the anthropometric size charts for the upper body, and Table 4.18 present the anthropometric size charts for the lower body for the 123 men of a Rectangle morphotype arranged from the smallest to the largest size.

Table 4.17: Anthropometric size charts for size ranges for the upper body for the 123 men of a Rectangle morphotype in this study

Upper body	Size ranges (inch)	37	38	39	40	41	41
Upper body girths (cm)	Chest girth	95	97	99	101	103	105
	Neck girth	38	40	41	42	43	44
	Left bicep girth	25	26	27	28	29	30
	Left elbow girth	21	22	23	24	25	26
	Left forearm girth	22	23	24	25	26	27
	Right wrist girth	15	15	15	15	15	15
Upper body lengths	Left shirt sleeve	83	85	87	89	91	93
	Shoulder to shoulder width	33	34	35	36	37	38

Table 4.18: Anthropometric size charts for size ranges for the lower body for the 123 men of a Rectangle morphotype in this study

Lower Body	Size ranges (cm)	30	31	33	34	35	36
Lower body girths	Waist girth	77	80	83	86	89	92
	Hip girth	95	97	99	101	103	105
	Left thigh girth	47	48	49	50	51	52
	Left knee girth	34	35	34	35	36	37
	Left calf girth	28	30	32	34	36	38
	Left ankle girth	26	26	26	26	26	26
Lower body lengths	Left in-seam	74	75	76	77	78	79
	Left out-seam	94	95	96	97	98	99
	Left crotch length	28	29	30	31	32	33
	Hip height	65	67	69	71	73	75

Table 4.17 shows that the size ranges for the e-tape anthropometric measurements of the upper body for the 123 men of a Rectangle morphotype with their uniform/constant of 2 cm size intervals, ranged from the smallest size of 37 inch (chest girth) to the largest size of 41 inch with corresponding (cm) based sizes ranging from 95 cm to 105 cm. For the lower body for the 123 men of a Rectangle morphotype in Table 4.18, the sizes ranged from the smallest size of 30 inch (waist girth) to the largest size of 41 inch with corresponding (cm) based sizes ranging from 77 cm to 92 cm. In contrast, the men's tailoring mannequin manufacturers traditional size chart (Appendix J) for the upper body garment, such as a basic shirt for men's tailoring mannequin (Figure-Forms) was developed for sizes in the ranges of inch based (chest girth) size codes starting from 38 inch to 42 inch with corresponding (cm) based sizes ranging from 95 cm to 108 cm. The size intervals varied from 1 cm, 2 cm, 3 cm to 6 cm. The anthropometric size chart for the lower body garment, such as the trouser, was developed for three size ranges of inch based (waist girth) size codes starting from 32 inch to 36 inch, with corresponding (cm) based sizes ranging from 81 cm to 93 cm. The size intervals varied from 1 cm, 2 to 3 cm. Therefore, this indicates that although the men's tailoring mannequin uses the same method of determining the size charts as the one that was adopted for men of a rectangle in this study, their size intervals are not consistent. This agrees with the literature where it was mentioned that dominant factors that contribute to the fit and sizing issues experienced by men in South Africa include the lack of consistency in sizing across RTW garments (Jadezweni (2020:1; Wasserman 2020:1).

Thereafter, in the next section, the anthropometric measurements of the upper and lower body for men of a Rectangle morphotype were compared to those of the men's tailoring mannequin of the Figure-Forms mannequin manufacturing company of a similar body size.

4.6 COMPARING THE ANTHROPOMETRIC MEASUREMENTS FOR THE SIZE 40 INCH (CHEST GIRTH) AND SIZE 34 INCH (WAIST GIRTH) FOR THE MEN OF A RECTANGLE BODY MORPHOTYPE TO THOSE OF THE MEN'S TAILORING MANNEQUIN OF A SIMILAR BODY SIZE

The third objective of the study was to compare the anthropometric measurements for the men of a Rectangle morphotype established in this study for the upper and lower body to those of the men's tailoring mannequin of the similar body size. The anthropometric measurements for the men of a Rectangle morphotype in this study were referred to as the e-tape, because they were extracted using a 3-D full-body scanner, whereas those of the men's tailoring mannequin used in the comparison was traditionally extracted and not scanned, as the researcher was not able to access the 3-D full-body scanner due to COVID-19 regulations.

The 40- inch chest girth- based size for an upper body and 34- inch waist girth- based size for the lower body was chosen for the comparison, because most of the men's tailoring mannequins are made of this body size. Therefore, it was deemed to be suitable for comparison to the men of a Rectangle morphotype of a similar body size.

The body morphotype of the men's tailoring mannequin was established to be a Trapezoid based on the chest girth (102 cm and hip girth (92 cm) measurements (Millam, 2021), whereas in this study, the Rectangle morphotype was the chest girth (101 cm) and hip girth (101 cm). In total, 13, e-tape anthropometric measurements, such as chest girth with corresponding secondary anthropometric dimensions of the neck girth, right wrist girth, left elbow girth, shoulder to shoulder width, were compared for an upper body in Table 4.19. The waist girth with corresponding secondary dimensions of the hip girth, left thigh girth, left knee girth, left calf girth, left ankle girth, left in-seam, and left out-seam were compared for a lower body in Table 4.1.9.

Table 4.19: Comparison of the upper and lower body anthropometric measurements for the men of a Rectangle morphotype developed in this study to those of the men's tailoring mannequin of the similar body size.

Body dimension	**The anthropometric measurements proposed for the new men's tailoring mannequin of a rectangle body morphotype**	**Differences between the traditional and e-tape anthropometric measurements**	**The anthropometric measurements for the men's tailoring mannequin**
Upper body girths		**Key differences**	
Neck girth	42 cm	**+ 2 cm**	44.0 cm
Chest girth	101 cm	**+1 cm**	102.0 cm
Right wrist girth	15 cm	**+ 3.5 cm**	18.5 cm.
Left elbow girth	24 cm	**+ 4.5 cm**	28.5 cm

Upper body length		Key differences	
Shoulder to shoulder width	36 cm	**+ 11 cm**	47.0 cm
Lower body girths		**Key differences**	
Waist girth	86 cm	**0 cm**	86 cm
Hip girth	101 cm	**-9 cm**	92 cm
Left thigh girth	50 cm	**+ 10 cm**	60 cm
Left knee girth	35 cm	**+ 3 cm**	38 cm
Left calf girth	34 cm	**+ 4.5 cm**	38.5 cm
Left ankle girth	26 cm	**- 3 cm**	23 cm
Lower body lengths		**Key differences**	
Left in-seam	77 cm	**+ 3 cm**	80 cm
Left out-seam	97 cm	**+ 13 cm**	110 cm

Denomination: (+) denotes the increase in the differences between the anthropometric measurements of the 40 -inch chest girth- based size for an upper body and 34- inch waist girth- based size for the lower body

Denomination: (-) denotes the decrease in the differences between the anthropometric measurements of the 40- inch chest girth- based size for an upper body and 34- inch waist girth- based size for the lower body

Table 4.19 shows that the size 40- inch chest girth- based men's tailoring mannequin anthropometric measurement of (102 cm) was 1 cm larger than the chest girth (101 cm) of the upper body e-tape anthropometric measurement for men of a Rectangle in this study. The neck girth (44 cm) was 2 cm larger than the neck girth (42 cm) of the upper body anthropometric measurement for the men in this study. The right wrist girth (18.5 cm) of the men's tailoring mannequin was 3.5 cm larger than the right wrist (15 cm) of the upper body anthropometric measurement for men in this study. The left elbow girth (28.5 cm) and shoulder to shoulder width (47 cm) were observed to be 4.5 cm and 11 cm larger than those of the anthropometric measurements of the upper body for men in this study, respectively.

Therefore, it can be concluded that the girth measurements for an upper body of the size 40- inch chest girth based anthropometric measurements for men's tailoring mannequin were larger than those of the men of a Rectangle in this study.

The size 34- inch waist girth- based men's tailoring mannequin anthropometric measurement of (86 cm) was similar to the waist girth (86 cm) of the lower body e-tape anthropometric measurement for men of a rectangle morphotype in this study. The left thigh girth (60 cm), left knee (38 cm), left calf girth (38.5 cm), were 2 cm, 10 cm, 3 cm, and 4.5 cm respectively larger than the hip girth (101 cm), left thigh girth (50 cm), left knee girth (35 cm) and left calf girth (34 cm) of size 34 inch (waist girth) anthropometric measurements for men in this study. The hip girth (92 cm) and left ankle girth (23 cm) of the men's tailoring mannequin were 9 cm, 3 cm respectively smaller than the hip girth (101 cm), left ankle girth (26 cm) of the lower body anthropometric measurements for men in this study.

The left in-seam (80 cm) of the men's tailoring mannequin was 3 cm longer than the in-seam (77 cm) of the lower body e-tape anthropometric measurement of men in this study, and the out-seam (110 cm) was 13 cm longer than the out-seam (97 cm) of the lower body anthropometric measurement of men in this study.

Therefore, from the findings of the upper body anthropometric measurements, the most notable differences were observed between the shoulder- to- shoulder width of men's tailoring mannequin, which was 11 cm larger than the shoulder- to- shoulder width of e-tape anthropometric measurement of men in this study. From the findings of the lower body anthropometric measurements, the most notable differences were observed on the left thigh girth and left out-seam. The left thigh girth for the men's tailoring mannequin was 10 cm larger than anthropometric measurement of men in this study. The left out-seam was 13 cm longer than the left out-seam of the anthropometric measurement of men in this study.

Therefore, discrepancies were mostly observed in the shoulder- to- shoulder width for a size 40 (chest) inch upper body, and thigh girth and out-seam for a size 34 (waist) inch lower body for the men's commercially available tailoring mannequin when compared to those of men of a Rectangle morphotype established in this study.

Furthermore, the men’s mannequin manufacturer size chart (see Appendix K) that was used in the comparison was traditionally extracted and not scanned, as the researcher was not able to access the 3-D full-body scanner due to COVID-19 regulations.

CHAPTER FIVE

CONCLUSION

5.1

The conclusions and implications of the study are presented in accordance with the research objectives 1 to 3 outlined in Chapter 1, section 1.3 of this dissertation. The chapter discusses the contributions of the study to the field of garment sizing and fit for men, and reflected critically on the sizing limitations and makes recommendations for future research.

The demographic findings of this study were from a convenience and purposeful sample of 270 men aged between 18 to 56 years that fell into the body weight between 45 kg to 133 kgs. Most of these men within the body height category of 172 cm were single (70%), and mostly African (74%) residing in Gauteng.

The dominant body morphotype for men (123; 45.5%) in this study was classified as a Rectangle. These men exhibited similar chest girth (101 cm) and hip girth (101 cm) measurements. This finding concurs with Shin *et al*. (2011) and Wilson (2016), American studies, which also found that the chest and hip girth measurements of men were similar. In contrast, the men's tailoring mannequin of a Trapezoid 'ideal' body morphotype (Figure-Forms) that is currently used to manufacture RTW clothes, exhibits a larger chest girth (102 cm) and smaller hip girth (92 cm) measurements. This clearly shows that the RTW garment, such as a basic shirt, that is manufactured and size based on the larger chest girth measurement of the Trapezoid 'ideal' body morphotype is likely to fit loosely across the chest in men of a Rectangle morphotype. This implies, therefore, that the men of a Rectangle morphotype would have to spend more money visiting a tailor for altering the excess fabric that bunches up around the back of the basic shirt when it is tucked in to their basic trouser. Furthermore, the excess of the fabric from the basic shirt, based on the chest girth of the men's tailoring mannequin, means that the manufacturers are using more fabric than they should.

Furthermore, the RTW garment, such as a basic trouser is likely to fit tight around the hip in men of a Rectangle morphotype due to having the larger hip girth than that of the Trapezoid 'ideal' morphotype. This implies therefore that the men of a Rectangle morphotype would have to spend more money visiting a tailor for altering the side seams because of unflattering wrinkles that frame the crotch body part, and the waist band that is not closing in their basic trouser to fit.

Although the subjective responses for the demographic questionnaire (Figure 4.3) indicated that most men (87%) and (89%) respectively reported no experience of fit problems across chest on the basic shirt and around the hip on the basic trouser, discrepancies were found, however, from the chest girth and hip girth of men's tailoring mannequin when compared to those of the men of a Rectangle morphotype in this study. Therefore, this suggests that clothing manufacturers and the designers of the menswear tailoring for manufacturing RTW clothes in South Africa should also consider the Rectangle morphotype with chest girth and hip girth anthropometric dimensions established in this study, rather than those currently in use in the Trapezoid body morphotype to provide RTW clothing that fits men in South Africa.

The anthropometric size chart developed for the upper body for men of a Rectangle morphotype ranged from inch based (chest girth) size code of 37 inch (95 cm) to 41 inch (105 cm) The size interval for an anthropometric size chart developed for the upper body for men of a Rectangle morphotype was found to be consistently increasing or decreasing by 2 cm.

The anthropometric size chart developed for the lower body ranged from inch based (waist girth) size code of 30 inch (77 cm) to 36 inch (92 cm). The size interval for an anthropometric size chart developed for the lower body for men of a Rectangle morphotype was found to be consistent, as it was either increasing or decreasing by 3 cm around the average size.

In contrast, the anthropometric size chart for the upper body for men's tailoring mannequin ranged from inch based (chest girth) size codes of 38 inch (95 cm) to 42 inch (108 cm). In contrast the size interval for an anthropometric size chart developed for the upper body for men's tailoring mannequin was found to be inconsistent as it was either increasing or decreasing by 1 cm to 6 cm around the average size.

The anthropometric size chart for the lower body garment ranged from inch based (waist girth) size codes of 32 inch (81 cm) to 36 inch (93 cm). The size interval for an anthropometric size chart developed for the lower body for men's tailoring mannequin was found to be inconsistent as it was either increasing or decreasing by 1 cm to 3 cm around the average size.

This indicates that the size ranges of men of a Rectangle was spread uniformly in proportions, and that of the men's tailoring mannequin was spread in varied proportions. Therefore, due to the inconsistency in grading size of the RTW clothes that are manufactured using a men's tailoring mannequin as a reference, men of a rectangle morphotype would experience fit problems because their clothing size grading shows consistency.

The shoulder- to- shoulder width for the size 40 inch (chest girth) based upper body for the men's tailoring was found to be 47 cm, which is 11 cm larger compared to 36 cm for that of the men of a Rectangle body morphotype. This indicates that the basic shirt garment would fit loose across the shoulders of the men of a Rectangle morphotype if it is designed based on the men's tailoring mannequin due to the wider shoulder to shoulder width measurement. The implication of making the basic shirt this wider means that the men of a Rectangle morphotype would have to waste more time and money to visit tailors for alterations. Therefore, the manufacturers and retailers should also adopt the shoulder- to- shoulder width of the men of a rectangle morphotype identified as the dominant body morphotype in this study to prevent the altering of the shoulder- to- shoulder width of the basic shirt.

The left thigh girth for the size 34 inch (waist girth) based lower body for the men's tailoring was found to be 60 cm, which is 10 cm larger than 50 cm for that of the men of a Rectangle body morphotype. This indicates that the basic trouser garment would fit loose around the thigh of the men of a Rectangle morphotype if it is designed based on the men's tailoring mannequin due to larger left thigh girth measurement. The implication of making the basic trouser this large means that the men of a Rectangle morphotype would have to pay extra money for the services that offer alterations to adjust the larger thigh girth for the basic trouser to fit. Therefore, the manufacturers and retailers should also adopt the left thigh girth measurement of the men of a Rectangle morphotype identified as the dominant body morphotype to prevent the altering of the thigh girth for the basic trouser.

The left out-seam for the size 34 inch (waist girth) based lower body for the men's tailoring was found to be 110 cm, which is 13 cm longer than 97 cm for that of the men of a Rectangle body morphotype. This indicates that the basic trouser garment would fit longer in length on the men of a Rectangle morphotype if it is designed based on the men's tailoring mannequin due to the longer left out-seam measurement. The implication of making the basic trouser this long in length means that the men of a Rectangle morphotype would have to pay extra money for the services that offer alterations to shorten the longer basic trouser to fit. Therefore, the manufacturers and retailers should also adopt the left out-seam measurement of the men of a Rectangle morphotype identified as the dominant body morphotype to prevent the altering of the length of the basic trouser.

5.2 CONTRIBUTIONS OF THE STUDY TO GARMENT SIZING AND FIT RESEARCH

The findings of this study are anticipated to contribute to the existing theory and practice of menswear apparel sizing and fit research. In South Africa, this is the only known study that collected data using a 3-D full-body scanner to classify the men's body morphotypes from anthropometric e-tape measurements.

The menswear market is currently manufacturing RTW garments for a Trapezoid 'ideal' men's body morphotype. Hence the researcher is suggesting that the Rectangle morphotype is considered as the 'ideal' morphotype as determined in this study to expand fit for dominant men in their target markets.

5.3 LIMITATIONS OF THE STUDY

This study was conducted subject to the limitations of the sampling strategy. The study used secondary anthropometric data based on non-probability convenience and purposive sampling methods for a sample of 270 men residing in Gauteng, South Africa, aged between 18 to 56 years. The findings cannot to generalised to all men residing in South Africa. However, the purpose of this study was to use e-tape anthropometric dataset of men from 'all walks of life' and was not based on ethnicity of the male population in the country. Therefore, further studies might focus on a larger random sample size, representative of the different population groupings in the country, to establish similarities and difference within and between ethnic groupings.

5.4 RECOMMENDATIONS FOR FURTHER STUDIES

The researcher is suggesting that the measurements be initially used to create patterns for constructing a basic shirt and trouser garments from the measurements established in this study, and that they are tested for the fit on a sample of men with a rectangular morphotype and body size such as those of this study. In this study, discrepancies were found in the chest girth and the hip girth of the men's tailoring mannequin (trapezoid body morphotype) when compared to a Rectangle morphotype. Therefore, the researcher suggests that the factors such as body volume index (BVI) and body mass index (BMI) of men with a Rectangle body morphotype should be determined to test if there is a correlation with the discrepancies that were identified in the anthropometric measurements, namely the chest and the hip girth for the men's tailoring mannequin. It was also clear from the findings that the subjective self-reported perceived fit problems of the men in this study are incongruent with the fit problems suggested by the anthropometric measurements of the actual Rectangle body morphotype in this study. Therefore, this suggests that further studies should further explore 3-D scanned anthropometric measurements, and the body parts, where most self-perceived fit problems are being reported by men of a Rectangle morphotype.

REFERENCES

Abdullah, F.S., Manan, N.S.A., Ahmad, A., Wafa, S.W., Shahril, M.R., Zulaily, N., Amin, R.M., & Ahmed, A. (2017). Data mining techniques for classification of childhood obesity among year 6 school children. *International conference on soft computing and data mining*, pp.465-474.

Adu-Boakye, S., Power, J., Wallace, T., & Chen, Z. (2014). Development of a sizing system for Ghanaian women for the production of ready-to-wear clothing. *The 88th textile institute world conference, Selangor, Malaysia,* pp.1-15.

Ahmed, A.A. (2014). A study of correlations within the dimensions of lower limb parts for personal identification in a Sudanese population. *The Scientific World Journal*, 14, 1-6.

Akaranga, S.I., & Makau, B.K. (2016). Ethical considerations and their applications to research: A case of the University of Nairobi. *Journal of Educational Policy and Entrepreneurial Research*, 3(12), 1-9.

Ali, P., & Younas, A. (2021). Understanding and interpreting regression analysis. *Evidence Based Nursing*, 24(4), 116.118.

Alubel, M., Yada, M., & Singh, N. (2017). Anthropometric size chart for Ethiopian girls for better garment design. *Journal of Fashion Technology and Textile Engineering*, 5(2), 1-11.

Amao, S.R. (2018). Application of principal component analysis on the body morphometric of Nigerian indigenous chickens reared intensively under southern Guinea savanna condition of Nigeria*. Journal of Environmental and Agriculture in Developing Countries*, 10(1), 1-12.

Apeagyei, P.R. (2010). Application of 3-D body scanning technology to human measurement for clothing fit. *International Journal of Digital Content Technology and its Applications*, 4(4), 58-68.

Armstrong, L. (2013). *What's your body type? Part2*. Available at: https://weightwise.com/blog/whats-your-body-shape-part-2/ [Accessed 31 March 2020].

Balach, M., Lesiakowska-Jablonska, M., & Frydrych, I. (2020). Anthropometry and size groups in the clothing industry. *Autex Research Journal*, 20(1), 56-62.

Beshah, B., Berhane, B., Shimelis, T., Betsha, T., & Amare, M. (2014). Anthropometric data of Bahirdar city's adult men for clothing design. *International Journal of Vocational and Technical Education*, 6(5), 51-57.

Bizcommunity. (2014). *Woolworths' find your perfect fit survey results in*. Available at: https://m.168/115882.html [Accessed 25 February 2021].

Body-dynamics. (2016). *The biggest body issues of men and how you can overcome them*. Available at: http://www.body-dynamics.co.za/ the-biggest-body-issues-of-men-and-how-you-can-overcome-them/ [Accessed 18 August 2020].

Bougourd, J., & Treleaven, P. (2010). UK national sizing survey – SizeUK. *International conference on 3D body scanning technologies, Lugano, Switzerland,* pp.327-337.

Brooksworth, F., Mogaji, E., & Bosah, G. (2022). *Fashion marketing in emerging economies volume ii*. UK: Palgrave Macmillan.

Brolin, E. (2016). *Anthropometric diversity and consideration of human capabilities*. PhD Dissertation. Sweden: Chalmers University of Technology.

Buelens, B., Burger, J., & Van De Brakel, J.A. (2018). Comparing inference methods for non-probability samples. *International Statistical Review*, 86(2), 169-377.

Capelassi, C.H., Carvalho, M.A., Kattel, C.E.I., & Xu, B. (2017). Sizing for the apparel industry using statistical analysis: A Brazilian case study. *17th world textile conference AUTEX 2017- textiles - shaping the future,* pp.1-5.

Capthatt. (2020). *Male body types-discover your body type, looks & style tips*. Available at: https://capthatt.com/male-body-types-discover-your-body-shape-looks-style-tips/ [Accessed 10 December 2020].

Carufel, R., & Bye, E. (2020). Exploration of the body-garment relationship theory through the analysis of a sheath dress. *Fashion and Textiles*, 7(22), 1-28.

Centeno, C. (2020). *How to dress your body type (muscular, skinny, fat)-fashion tips for men's body types*. Available at: https://www.realmenrealstyle.com/dress-body-shape-guide [Accessed 12 December 2020].

Chang, A., & Schulz, P.J. (2018). The measurements and an elaborated understanding of Chinese e-health (C-e-HEALS) in chronic patients in China. *International Journal of Environmental Research and Public Health*, 15(1553), 1-12.

Chattaraman, V., Simmons, K.P., & Ulrich, P.V. (2013). Age, body size, body image, and fit preferences of male consumers. *Clothing and Textiles Research Journal*, 31(4), 291-305.

Chisosa, D.F., & Muzenda, V. (2020). Designing for the plus-size men: Towards a better fitting: A case of Harare, Zimbabwe. *Journal Textile Engineering Fashion Technology*, 6(3), 95-100.

Chuerubim, M.L., & Da Silva, I. (2018). Analysis of the variability of applying the principal components technique in multivariate data from traffic accidents. *Sigma Journal of Engineering and Natural Sciences*, 36(4), 1023-1032.

Connell, L.J., Ulrich, P.V., Brannon, E.L., Alexander, M., & Presley, A.B. (2006). Body shape assessment scale: Instrument development for analysing female figures. *Clothing and Textile Research Journal*, 24, 80-95.

Cottle, F.S. (2012). S*tatistical human body form classification: Methodology development and application*. PhD dissertation. Alabama: Auburn University.

De Franzo, S.E. (2011). *What's the difference between qualitative and quantitative research?* Available at: https://www.snapsurveys.com/blog/qualitative-vs-quantitative-research [Accessed 13 July 2020].

De Klerk, H.M., Mabuza, L.I., & Adamski, K. (2014). Body shape versus body form: A comparison of the body shapes of female Swazi consumers with those of body forms used in apparel manufacturing. *Journal of Family Ecology and Consumer Sciences*, 42, 85-101.

Devi, V.V., & Prasad, K. (2011). Impact of retail services on retail sales. *Journal of Business and Retail Management Research,* 6(1), 73-81.

Dianat, I., Molenbroek, J., & Castellucci, H. I. (2018). A review of the methodology and applications of anthropometry in ergonomics and product design ergonomics. *An International Journal of Research and Practice in Human Factors and Ergonomics*, 61(12), 1696-1720.

Diprose, G., Ba, B., Montazerian, M., Leymarie, F.F., Sycheva, A., & Hoadley, R. (2020). How to measure human body when wearing clothes by using camera systems. *Proceedings of EVA London 2020*, pp.369-378.

Do, W., & Choi, E. (2016). A product and sizing system investigation of domestic and foreign dress form for the development of senior men's dress form. *Fashion and Textiles*, 18(5), 708-715.

Elnour, E.F.E. (2015). *Application of data mining techniques for establishing standard sizing system for Sudanese army officers garments*. PhD dissertation. New Delhi: Sudan University of Science and Technology.

Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K., & Kyngäs, H. (2014). Qualitative content analysis: A focus on trustworthiness. *Sage Open*, 4(1), 1-10.

Faber, M.E. (2013). *Men's body area shape analysis and outdoor performance clothing fit preferences and issues*. Masters dissertation. Alabama: Auburn University.

Faust, M.E. & Carrier, S. (Eds). (2014). *Designing apparel for consumers: The impact of body type and size*. Manchester: Woodhead Publishing Series in Textiles.

Gill, S. (2015). A review of research and innovation in garment sizing, prototyping and fitting. *Textile Progress*, 47(1), 1-85.

Gleadall-Siddal, D.M., Turpin, R.L., Douglas, C.C., Ingle, L., & Garrett, A.T. (2020). Test–retest repeatability of the NX-16: A three-dimensional (3D) body scanner in a male cohort. *Sport Sciences for Health*, 16, 337-346.

Gravelle, J., & Rogers, C. (Eds). (2014). *Researching the police in the 21st century: International lessons from the field*. London United Kingdom: Palgrave Macmillan.

Gupta, D., & Zakaria, N. (Eds). (2014). *Anthropometry, apparel sizing and design*. England: Woodhead Publishing.

Hancock, E. (2017). *There are only five male body types, according to health experts*. Available at: http://metro.co.uk/2017/05/21/there-are-only-five-male-body-shapes-according-to-health-experts-6650097 [Accessed 02 March 2020].

Haradhan, M. (2017). Two criteria for good measurements in research: Validity and reliability. *Annals of Spiru Haret University*, 17(3), 58-82.

Heymsfield, S.B., Bourgeois, B., Ng, B.K., Sommer, M.J., Li, X., John, A., & Shepherd, J.A. (2018). Digital anthropometry: A critical review. *European Journal of Clinical Nutrition*, 7(5), 680-687.

Hoegg, J., Scott, M.L., Morales, A.C., & Dahl, D.W. (2014). The flip side of vanity sizing: How consumers respond to and compensate for larger than expected clothing sizes. *Journal of Consumer Psychology*, 24(1), 70-78.

Hsu, C., & Ying-Zhou, L. (2013). Using multivariate statistics to analyse body characteristics index for garment supply chain and industrial application. *Proceedings of 2013 IEEE international conference on service operations and logistics and informatics, SOLI*, pp.211-214.

Hu, P., Li, D., Wu, G., Komura, T., Zhang, D., & Zhong, Y. (2018). Personalised 3D mannequin reconstruction based on 3D scanning. *International Journal of Clothing Science and Technology*, 30(2), 159-174.

Human solutions. (2015). *The Precise for fit perfectionist from scan directly to production*. Available at: http://www.human-solutions.com/fashion/front_content.php?idcat=139&lang=7 [Accessed 25 September 2020].

Jadezweni, A. (2020). *Vanity sizing unmasked: Why clothing sizes from different retailers are so inconsistent*. Available at: https://www.w24.co.za/Style/Fashion/Trends/vanity-sizing-unmasked-why-clothing-sizes [Accessed 29 August 2020].

John-Anthony, O., & Demirkiran, I. (2014). Principal component analysis: Data reduction and simplification. *McNair Scholars Research Journal*, 1, 1-15.

Joseph-Armstrong, H. (2014). *Pattern making for fashion for fashion design*. (5Th ed.). England: Pearson Education Limited.

Kaliyadan, F. & Kulkarni, V. (2019). Types of variables, descriptive statistics and sample size. *Indian Dermatology Online Journal*, 10(1), 82-86.

Kausher, H., & Srivastava, S. (2016). A review on sizing systems for readymade garments in India and different types of body shapes of females. *International Journal of Home Science*, 2(3), 136-138.

Kim, H.S., Choi, H.E., Park, C.K., & Nam, Y.J. (2019). Standardization of the size and shape of virtual human body for apparel products. *Fashion and Textiles*, 6(33), 1-20.

Kleinlugtenbelt, Y.V., Krol, R.G., Bhandari, M., Goslings, J.C., Poolman, R.W., & Scholtes, V.A.B. (2018). Are the patient-rated wrist evaluation (PRWE) and the disabilities of the arm, shoulder and hand (DASH) questionnaire used in distal radial fractures truly valid and reliable. *Bone & Joint Research*, 7, 36-45.

Koepke, N., Zwahlen, M., Wells, J.C., Bender, N., Hennerberg, M., Rühli, F.J., & Stahub, K. (2017). Comparison of 3-D laser-based photonic scans and manual anthropometric measurements of body size and shape in a validation study of 123 young Swiss men. *Peer Journal*, 5, 1-22.

Kumar, R. (2011). *Research methodology: A step-by-step guide for beginners*. New Delhi: Sage Publishers.

Labat, K.L., & Ryan, K.S. (2019). Human body: A wearable product designer's guide. *Ergonomics*, 63(4), 522-523.

Lau, D.L., Zhang, Y., & Liu, K. (2017). *Structured light phase measuring profilometry pattern design for binary spatial light modulators*. Available at: https://researchgatete.net/publication/317425638_Structured_Light_Phase_Measuring [Accessed 29 May 2020].

Lee, K.S., Song, H.K., & Kim, S. (2020). Categorization of lower body types of abdominal obese men using a script-based 3D body measurement software. *Fashion and Textiles*, 7(3), 1-16.

Lescay, R.N., Becerra, A.A., & González, A.H. (2016). Anthropometry: Comparative analysis of technologies for the capture of anthropometric dimensions. *Revista*, 13(26), 47-59.

Leung, L. (2015). Validity, reliability and generalizability in qualitative research*. Journal of Medical Primary Care*, 4(3), 324-327.

Li, P., Corner, B., Carson, J., & Paquette, S. (2015). A three-dimensional shape database from a large-scale anthropometric survey. *Proceedings 19th Triennial Congress of the IEA, Melbourne*, pp.1-7.

Löffler-Wirth, H., Willscher, E., Ahnert, P., Wirkner, K., Engel, C., Loeffler, M., & Binder, H. (2016). Novel anthropometry based on 3D body scans applied to a large population based cohort. *Plos One*, 11(7), 1-20.

Makgopa, S.S. (2018).The importance of store attributes on university students' clothing store selection. *Journal of Business and Retail Management Research*, 12(4), 134-142.

Makhanya, B.P., De Klerk, H.M., Adamski, K., & Mastamet-Mason, A. (2014). Ethnicity body type differences and female consumers' apparel fit problems. *International Journal of Consumer Studies*, 38, 1-9.

Manish, M., & Sima, K. (2012). Determinants of retail customer satisfaction: A study of organised retail outlets in Delhi. *Delhi Business Review*, 13(1), 117-126.

Martin, J., & Govender, K. (2013). Indenturing the body: Traditional masculine role norms, body image discrepancy and muscularity in a sample of South African Indian boys. *Culture, Society and Masculinities*, 5(1), 21-45.

Martinez, M. (2019). *How to dress for your body type for men: Man of many*. Available at: https://manofmany.com/fashion/mens-fashion-advice/how-to-dress-for-your-body-shape-for-men [Accessed 27 March 2020].

Mchiza, Z.J., Parker, W., Makoae, M., Sewpaul, R., Kupamupindi, T., & Labadarios, D. (2015). Body image and weight control in South Africans 15 years or older: SANHANES-1. *BMC Public Health*, 15(9992), 1-11.

Medrano, N., Olarte-Pascual, C., Pelegrín-Borondo J., & Sierra-Murillo Y. (2016). Consumer behavior in shopping streets: The importance of the salesperson's professional personal attention. *Frontiers in Psychology*, 7(125), 1-14.

Mengual-Macenlle, N., Marcos, P.J., Golpe, R., & González-Rivas, D. (2015). Multivariate analysis in thoracic research. *Journal of Thoracic Disease*, 7(3), 1-5.

Millam, R. (2021). *The anthropometric measurements of a men's tailoring mannequin of Figure-Forms South African mannequin manufacturer*. Personal Conversation.

Moss, C., Kuche, D., Bekele, T.H., Salasibewu, M., Ayana, G., Abera, A., Eshetu, S., Dangour, A.D., & Allen, E. (2021). Precision of measurements performed by a cadre of anthropometrists trained for a large household nutrition survey in Ethiopia. *Current Developments in Nutrition* 4(9), 1-8.

Mountain khakis. (2020). *Men's body types for different fit*. Available at: https://www.mountain khakis.com/blogs/news/men-s-body-types-for-different-fit [Accessed 10 December 2020].

Mpampa, L.M., Azariadis, P.N., & Sapidis, N.S. (2010). A new methodology for the development of sizing systems for the mass customization of garments. *International Journal of Clothing Science and Technology*, 22(11), 49-68.

Muthambi, A., De Klerk, H.M., & Mastamet-Mason, A. (2016). Sizing for ethnicity in multi-cultural societies: Validation of the size specifications for young South African women of African descent. *Journal of Family Ecology and Consumer Sciences*, 44, 1-10.

Narang, V. (2014). *Pattern development for menswear using block method: A fresh approach*. PhD dissertation. New Delhi: National Institute of Fashion Technology.

Nkambule, M.T. (2010). *Apparel sizing and fit preferences and problems of plus-size Swazi working women*. Masters dissertation. Pretoria: University of Pretoria.

Ola-Afolayan, O., & Mastamet-Mason, A. (2013). A customised size chart for the African pear-shaped plus-size South African women. 2013 *DEFSA Conference Proceedings,* pp.202-210.

Ola-Afolayan, O., Zwane, P.E., & Mastamet-Mason, A. (2021). Statistical modelling of key body dimensions in developing the size chart for the south African pear-shaped women. *Journal of Consumer Sciences*, 49, 52-63.

Opaleye, A.A., Kolawale, A., & Charles-Owaba, O.E. (2019). Application of fuzzy clustering methodology for garment sizing. *American Journal of Data Mining and Knowledge Discovery*, 4(1), 24-31.

Otieno, R.B. (2013). Body measurement technology and utilisation: Implications for Africa. *African Journal of Education, Science and Technology*, 1(1), 51-64.

Pandarum, R., & Yu, W. (2015). *Apparel sizing and fit*. In R. Nayak and R. Padhye (Eds). *Apparel manufacturing technology,* chap. 7. United Kingdom: Woodhead Publishing.

Pandarum, R., Harlock, S.C., & Hunter, L. (2017). An empirical study exploring body perception and apparel fit preferences for South African women. *Journal of Consumer Sciences*, 2, 40-54.

Pandarum, R., Harlock, S.C., Hunter, L., & Leaf, G.A.V. (2020). A normative method for the classification and assessment of women's 3-D scanned morphotypes. *International Journal of Clothing Science and Technology*, 33(3), 421-433.

Pandarum, R., Yu, W., & Hunter, L. (2011). 3-D breast anthropometry of plus-sized women in South Africa. *Ergonomics*, 54(9), 866-875.

Pandey, P., & Pandey, M. (2015). *Research methodology: Tools and techniques*. Romania: Bridge Centre.

Petrak, S., Mahnic, M., & Rogale, D. (2015). Impact of male body posture and shape on design and garment fit. *Fibres & Textiles in Eastern Europe*, 23(6), 150-158.

Petrova, A., & Ashdown, S.P. (2012). Comparison of garment sizing systems. *Clothing and Textiles Research*, *Journal*, 30(4), 267-284.

Phasha, M.M., Harlock, S., & Pandarum, R. (2020). Developing size charts for petite South African women from 3-D body scanned e-tape measurements. *Journal of Consumer Sciences*, 48, 98-111.

Reardon, C.A., & Govender, K. (2011). Shaping up: The relationship between traditional masculinity, conflict resolution and body image among adolescent boys in South Africa. *Vulnerable Children and Youth Studies*, 6(1), 78-87.

Rudansky-Kloppers, S. (2017). Key factors influencing the online buying decision when purchasing products in specific product categories. *African Journal of Science, Technology, Innovation and Development*, 9(1), 43-54.

Saeidi, E. (2018). *Men's jeans fit based on body type categorization*. PhD dissertation. United States of America: Louisiana State University and Agricultural and Mechanical College.

Scataglini, S., & Gunther, P. (Eds). (2019). *DHM and posturography*.1st ed. United States: Academic Press.

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anaesthesia and Analgesia*, 126(5), 1763-1768.

Schulze, R., & Boscardini, M.L. (2018). Leadership perceptions of principals with and without special education backgrounds. *Journal of School Leadership*, 28, 1-27.

Sheldon, W.H.(1940). *Atlas of men: Somatotyping the adult male at all ages*. Bexley Ohio: Gramercy Publishing.

Sheperis, D.S., Korani, K., Milan, N.M., & Sheperis, C.J. (2019). Marketing of professional counselors: A q-sort study of best practices. *Journal of Counseling and Development*, 97, 25-32.

Shin, S.J.H., Istook, C.L., & Lee, J.H. (2011). Various men's body types and drops for developing menswear sizing systems in the United States. *Journal of the Korean Society of Clothing and Textiles*, 35(12), 1454-1465.

Simmons, K., Istook, C.L., & Devarajan, P. (2004a). Female figure identification technique (FFIT) for apparel: Part 1 describing female shapes. *Journal of Textiles and Apparel, Technology Management*, 4(1), 1-5.

Simmons, K., Istook, C.L., & Devarajan, P. (2004b). Female figure identification technique (FFIT) for apparel: Part 2 developing of shape sorting software. *Journal of Textiles and Apparel, Technology Management*, 4(1), 1-15.

Sindicich, D.K., & Black, C. (2011). An assessment of fit and sizing of men's business clothing. *Journal of Fashion Marketing and Management*, 15(4), 446-463.

Song, H.K., & Ashdown, S.P. (2010). An exploratory study of the validity of visual fit assessment from three-dimensional scans. *Clothing and Textiles Research Journal*, 28(4), 263-278.

Styku. (2020). *Does the clothing I wear affect how Styku takes measurements?* Available at: https://www.styku.com/help/search/does-the-clothing-i-wear-matter [Accessed 18 September 2020].

Sullivan, G.M. (2011). A primer of assessment instruments. *Journal of Graduate Medical Education*, 3(3), 119-120.

Tabo, B. (2020). 3-D Anthropometric dataset, University of South Africa. Personal Conversation.

Tiwari, A.M., & Anand, B.N. (2016). Anthropometry of Indian youth for apparel sizing. *14th International Conference on Humanizing Work and Work Environment*, pp.1-5.

Van Rensburg, L.J., Jacobs, B., & Graham, M. (2023). Male fashion leadership: Hedonic and utilitarian clothing shopping motivations within the South African context. *International Journal of Fashion Design, technology and Education*, 16 (1), 88-99.

Varte, L.R., Rawat, S., Singh, I., Choudhary, S., Singh, S., & Panjwani, U. (2017). Lower and upper clothing ensemble sizing using a 3-D whole body scanner in Indian adult males. *Journal of Human Ergology*, 46, 29-38.

Vithanage, C.P., Jayawardana, T.S.S., & Niles, S.N. (2013). The development of pant sizing system for Sri Lankan females. *International Journal of Research in Social Sciences*, 1(1), 30-38.

Vithanage, C.P., Jayawardana, T.S.S., Thilakaratne, C.D., & Niles, S.N. (2015). Kernel-based clustering approach in developing apparel size charts.

International Journal of Engineering Sciences and Research Technology, 4(1), 482-488.

Vitronic. (2020). *Human body measurement*. Available at: https://www.vitronic.com/en-us/3d-bodyscan/human-body-measurement [Accessed 27 September 2020].

Walliman, N. (2011). *Research methods: The basics*. London and New York: Routledge Taylor and Francis Book.

Wang, Z., Wang, J., Xing, Y., Yang, Y., & Liu, K. (2019). Estimating human body dimensions using rbf artificial neural networks technology and its application in activewear pattern making. *Applied Sciences*, 9(1140), 1-14.

Wasserman, H. (2020). *A medium at Woolworths? You're actually a XXL at Mr Price: Why SA's clothing size are crazy*. Available at: https://www.businessinsider.co.za/medium-at-woolworths-makes-you-an-xxl-at-mr-price-2018-3 [Accessed 18 September 2020].

Wilson, A.F. (2016). *Body type classifications of males 26 to 35 using size USA three-dimensional scan data*. PhD dissertation. North Carolina: North Carolina State University.

Xia, S., & Istook, C. (2017). A method to create body sizing systems. *Clothing and Textiles Research Journal*, 35(4), 235-248.

Xie, H., & Zhong, Y. (2020). Structure-consistent customized virtual mannequin reconstruction from 3-D scans based on optimization. *Textile Research Journal*, *90*(7-8), 937-950.

Yadav, S. & Chanana, B. (2020). Developing standard size chart for teenage girls of 17-19 years using anthropometry. *International Research Journal on Advanced Science Hub*, 2(12), 15-20.

Yan, S., Wirta, J., & Kämäräinen, J.K. (2020). Anthropometric clothing measurements from 3-D body scans. *Machine Vision and Applications*, 31(7), 1-11.

Yumpu. (2020). *Whole body color 3D scanner*. Available at: https://www.yumpu.com/en/document/read/37026434/whole-body-color-3d [Accessed 27 September 2020].

Zakaria, N., & Gupta, D. (Eds). (2020). *Anthropometry, apparel sizing and design*. 2nd ed. England: Woodhead Publishing.

Zeraatkar, M., & Khalili, K. (2020). A fast and low-cost human body 3D scanner using 100 cameras. *Journal of Imaging*, 6(21), 1-15.

Zhang, S. (2020). Research on young females' body classification based on SVM. *International Journal of Science*, 7(6), 269-274.

Žuraj, M., Šparl, P., & Žnidaršič, A. (2017). Analysis of individual aspects influencing non-purchasing in an online environment and consumer willingness to purchase custom-made apparel. *Organizacija*, 50(4), 352-363.

Appendix A: Questionnaire (Tabo, 2020) secondary dataset

(Please complete pages section A and B only)

Generic 3-D Data Collection Form

Apparel, Health and Consumer research for Men

For office use only	
Date:	
Reference number:	

A. Demographic information

Please complete Section A and B of this form (PRINT IN BLOCK LETTERS / CROSS THE RELEVANT BOX WITH A 'X' / CIRCLE YOUR CHOICE where applicable). Note that the information provided herein will be treated as strictly confidential.

1. Age					
2. Marital status	Single	Married	Divorced	Separated	Widowed
	1	2	3	4	5
3. Population group	African	Coloured	Indian	White	Other
	1	2	3	4	5
4. Place of residence	Johannesburg		Pretoria		
	1		2		

Manual anthropometric measurements

6. Body weight							**, kg**	**14. Body height**					**, cm**

B. Psychographic (market) information

The following questions are related to the way you choose the clothes you buy. Please answer all the questions which suites your behaviour best.

7. What is your preferred way of purchasing your clothes? Please circle the number.

1) Physically going to the shops
2) Through catalogues
3) Through internet/online shopping
4) Other (s) specify ……………………………

8. Please indicate from which retail outlet(s) you purchase the following garments:

Ready-to-wear items	**Retail outlet (s)**
1) Shirts long sleeve	
2) Shirts short sleeve	
3) T-shirts	
4) Jackets	
5) Trousers	
6) Short trousers	
7) Pull-overs	
8) Jerseys	

9. Indicate your fit preferences by marking with an 'X' your suitable choice for each garment type.

	Figure hugging		Slim-fitting		Semi-fitted		Loose-fitting		Very loose-fitting	
1) Shirts long sleeve		1		2		3		4		5
2) Shirts short sleeve		1		2		3		4		5
3) T-shirts		1		2		3		4		5
4) Jackets		1		2		3		4		5
5) Trousers		1		2		3		4		5
6) Pull-Overs		1		2		3		4		5
7) Jerseys		1		2		3		4		5

10. Do you have problems with ready-to-wear clothing that is currently being sold at retail outlets in South Africa? Please tick the relevant number.

Yes	No
1	2

11. Please choose the specific problems you have with ready-to-wear clothing by circling the relevant box:

	1	2	3
a) Neckline	Too High	Too low	No problem
b) T-shirt collar	Too tight	Too loose	No problem
c) Shirt collar	Too tight	Too loose	No problem
d) Across shoulders	Too tight	Too loose	No problem

e) Across back	**Too tight**	**Too loose**	**No problem**
f) Across chest	**Too tight**	**Too loose**	**No problem**
g) Around waist	**Too tight**	**Too loose**	**No problem**
h) Around hip	**Too tight**	**Too loose**	**No problem**
i) Sleeve-around upper arm	**Too tight**	**Too loose**	**No problem**
j) Sleeve length	**Too short**	**Too long**	**No problem**
k) Shirt length	**Too short**	**Too long**	**No problem**
l) Trouser-around waist	**Too tight**	**Too loose**	**No problem**
m) Trouser-around hip	**Too tight**	**Too loose**	**No problem**
n) Trouser-around thighs	**Too tight**	**Too loose**	**No problem**
o) Trouser-crotch length	**Too short**	**Too long**	**No problem**
p) Trouser length	**Too short**	**Too long**	**No problem**

12. Choose from tables below the current retail garment size/s you purchase per garment as indicated:

Men's shirt chest size

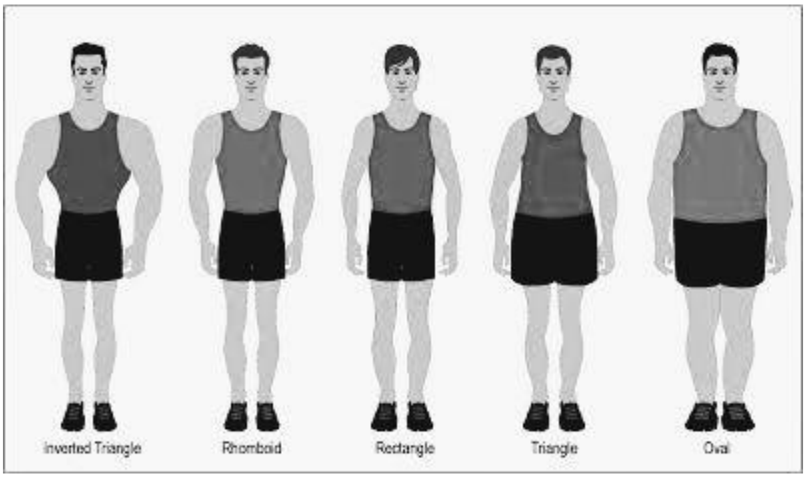
Men's chest sizes	
(Inch/cm)	
32/81	1
34/86	2
36/91	3
38/97	4
40/102	5
42/107	6

44/112	7
46/117	8
48/122	9
50/127	10
52/132	11
54/137	12
56/142	13

13. Trouser (waist size)

Men's waist sizes	
(Inch/cm)	
29/74	1
30/76	2
31/79	3
32/81	4
33/84	5
34/86	6
36/91	7
38/97	8
40/102	9
42/107	10
44/112	11

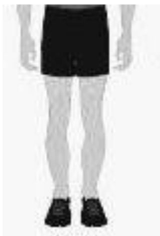
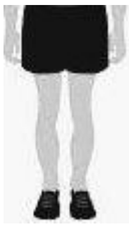
14. Please look at the body morphotypes below and choose on that best represents your body's silhouette. Tick the most relevant option.



1	**2**	**3**	**4**	**5**

https://metro.co.uk/2017/05/21/there-are-only-five-male-body-shapes-according-to-health-experts-6650097/

15. Which of the body parts below best describes your morphotype?

1. Waist	 1.1	 1.2	 1.3	 1.4
2. Legs	 2.1	 2.2	 2.3	 2.4

3. Body posture	 3.1	 3.2	 3.3	 3.4
4. Hip	 4.1	 4.2	 4.3	 4.4
5. Arms	 5.1	 5.2	 5.3	 5.4
6. Abdomen	 6.1	 6.2	 6.3	 6.4

7. Seat	 7.1	 7.2	 7.3	 7.4
8. Chest	 8.1	 8.2	 8.3	 8.4

https://www.google.com/search?q=http%3A%2F%2Fwww.ennis+physioclinic.i.. https://blogmindvalley.com/male-body-types/amp/

Thank you for taking part in the study

Appendix B: Ethics certificate

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 23/03/2021

NHREC Registration # : REC-170616-051
REC Reference # : 2021/CAES_HREC/058
Name : Mr MC Mnyaiza
Student #: 46486860

Dear Mr Mnyaiza

Decision: Ethics Approval from 23/03/2021 to 31/03/2024

Researcher(s): Mr MC Mnyaiza
46486860@mylife.unisa.ac.za

Supervisor (s): Ms K Pandarum
pandak@unisa.ac.za; 011-471-2550

Working title of research:

Evaluating body morphotype and size charts for men residing in Gauteng from 3-D scan e-tape anthropometric measurements

Qualification: M Consumer Science

Thank you for the application for research ethics clearance by the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted for three years, **subject to submission of yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

The researcher is cautioned to adhere to the Unisa protocols for research during Covid-19.

Due date for progress report: 31 March 2022

*The **negligible risk application** was **reviewed** by the UNISA-CAES Health Research Ethics Committee on 23 March 2021 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

University of South Africa
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www.unisa.ac.za

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
8. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

*The reference number **2021/CAES_HREC/058** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

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Appendix C: Consent form

TITLE OF RESEARCH PROJECT

MODELLING BODY WEIGHT INDICATORS IN PROVIDING BODY TYPE AND SIZE CLASSIFICATION USING MULTIVARIATE TECHNIQUES FOR MEN IN SOUTH AFRICA

Dear Mr/Mrs/Miss/Ms ______________________________ Date..…/..…/2020/21

NATURE AND PURPOSE OF THE STUDY

Clothing researchers state that the body measurements used to manufacture ready-to-wear clothes in the apparel industry do not cater for the majority of the male consumers, this also applies to men in south Africa. The aforementioned lack of relevant information for men's body size and the confusion that currently exists in the fashion industry as result of inconsistencies in sizing system can be seen as contributing factors to their clothing sizing and fit dissatisfactions. Given that ready-to-wear clothes are manufactured from body measurements using foreign size charts that do not reflect the varying men's body dimensions, the purpose of this study is to investigate the sizing and fit of clothing offered for men and to collect 3D full body scan data of men, as there is no known data published for use by retailers in South African that use 3D body scan data to date.

RESEARCH PROCESS

1. The data collection process will use 3D scanning technology to collect body dimensions of men.
2. This research uses a NX16-3D body Scanner to capture the body landmark measurement points of the whole body in 6 seconds. The method is quick, non-intrusive and uses white light (like those found in your offices and homes) to capture the 3D scan data and is therefore safe to your health.
3. Scanning will be conducted in your undergarments that may not be black or navy blue in colour.
4. The data is collected anonymously and no personal details are attached to your 3D scan nor your demographic form. The demographic form and the consent forms will be filed separately in a locked cupboard and will be accessible only to the researcher.

CONFIDENTIALITY

The information you will provide us with will be strictly confidential and collected anonymously, to be used for research purposes only for sizing and fit clothing applications.

WITHDRAWAL CLAUSE

My participation is voluntary. I have the right to be a part of the study, choose not to participate or to stop participating at any time without penalty.

35

Appendix D: Preferred way of purchasing, preferred retail outlets and garment fit preferences of male subjects (N=270)

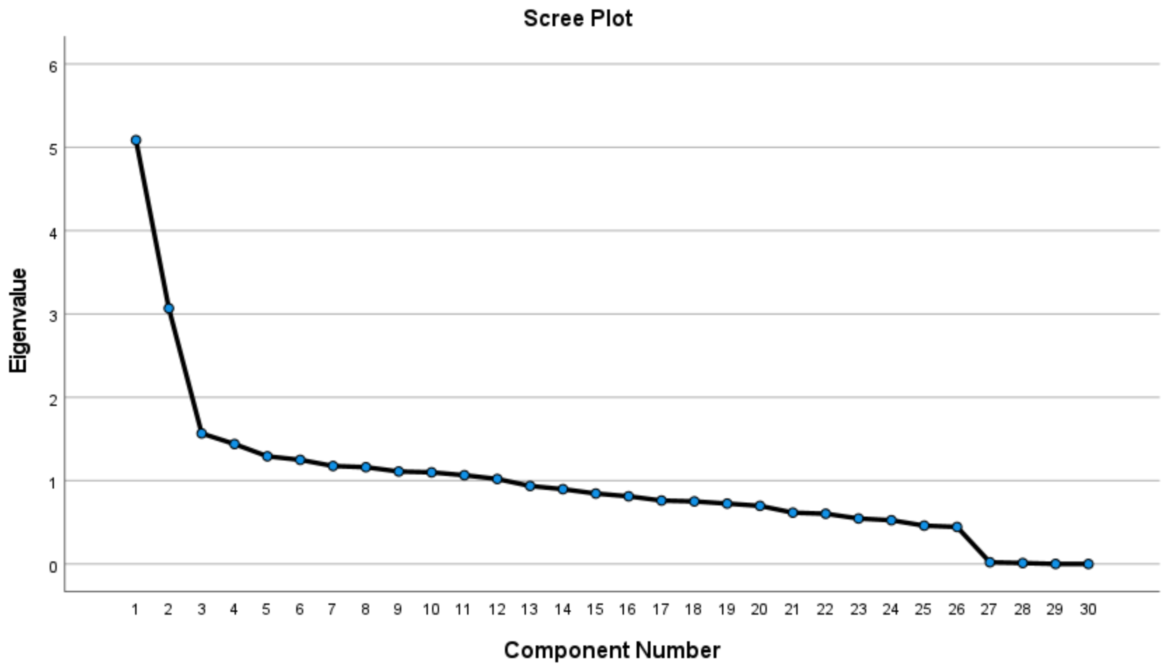
Variable	RTW garment category	Number of subjects	Percentage (%)
Preferred way of purchasing	Physical store	200	74
	Catalogue	11	4
	Internet	32	12
	Other	27	10
Preferred retail outlets			
Shirts long sleeve	Exact	118	44
	Markham	84	31
	Truworths	49	18
	Woolworths	19	7
Shirts short sleeve	Exact	95	35
	Markham	81	30
	Truworths	62	23
	Woolworths	32	12
T-shirts	Exact	97	36
	Markham	78	29
	Truworths	65	24
	Woolworths	30	11
Jackets	Exact	84	31
	Markham	84	31
	Truworths	70	26
	Woolworths	32	12

Trousers	Exact	86	32
	Markham	92	34
	Truworths	62	23
	Woolworths	30	11
Short trousers	Exact	105	39
	Markham	81	30
	Truworths	54	20
	Woolworths	30	11
Pull-overs	Exact	59	22
	Markham	100	37
	Truworths	68	25
	Woolworths	43	16
Jerseys	Exact	86	32
	Markham	89	33
	Truworths	65	24
	Woolworths	30	11
Garment fit preferences			
Shirts long sleeve	Figure hugging	73	27
	Slim-fitting	97	36
	Semi-fitted	65	24
	Loose-fitting	19	7
	Very loose-fitting	16	6

Shirts short sleeve	Figure hugging	59	22
	Slim-fitting	100	37
	Semi-fitted	70	26
	Loose-fitting	30	11
	Very loose-fitting	11	4
T-shirts	Figure hugging	57	21
	Slim-fitting	84	31
	Semi-fitted	92	34
	Loose-fitting	32	12
	Very loose-fitting	5	2
Jackets	Figure hugging	38	14
	Slim-fitting	78	29
	Semi-fitted	111	41
	Loose-fitting	41	15
	Very loose-fitting	3	1
Trousers	Figure hugging	57	21
	Slim-fitting	89	33
	Semi-fitted	92	34
	Loose-fitting	30	11
	Very loose-fitting	3	1
Short trousers	Figure hugging	46	17
	Slim-fitting	89	33
	Semi-fitted	84	31
	Loose-fitting	41	15
	Very loose-fitting	11	4

Pull-overs	Figure hugging	57	21
	Slim-fitting	95	35
	Semi-fitted	65	24
	Loose-fitting	38	14
	Very loose-fitting	16	6
Jerseys	Figure hugging	49	18
	Slim-fitting	86	32
	Semi-fitted	81	30
	Loose-fitting	43	16
	Vey loose-fitting	11	4

Appendix E: A scree plot of PCA for the e-tape body dimensions required for classification of male body morphotypes



Appendix F: A rotated component matrix showing factor loadings for the prediction of the key body dimensions required for classifying body morphotypes.

BODY DIMENSIONS	PC1	PC2	PC3	PC4	PC5
Neck height (front)	**0.982**	-0.127	-0.061	0.028	-0.025
Neck height (back)	**0.982**	-0.125	-0.062	0.027	-0.026
Chest height	**0.980**	-0.145	-0.065	0.027	-0.020
Stomach height	**0.973**	-0.152	-0.044	0.023	-0.028
Thigh height	**0.960**	-0.043	-0.069	0.110	-0.031
Left in-seam	**0.959**	-0.046	-0.071	0.108	-0.032
Right calf height	**0.950**	-0.104	-0.076	0.102	-0.058
Left calf height	**0.942**	-0.086	-0.075	0.097	-0.059
Left knee height	**0.733**	-0.033	0.103	-0.244	0.195
Left waist to hip	**0.596**	-0.315	0.031	0.054	0.122
Left forearm	**0.547**	0.112	-0.134	-0.036	0.139
Left bicep	**0.523**	-0.054	-0.314	0.100	-0.051
Right back waist to crotch level	**0.469**	0.295	0.005	0.209	-0.024
Waist front	-0.238	**0.546**	0.094	-0.196	0.176
Left leg surface	0.157	**0.507**	0.170	-0.137	0.135
Left thigh	0.119	**0.497**	-0.178	0.078	-0.246
Left shoulder to elbow	-0.015	**0.483**	0.037	-0.119	0.118
Waist girth	-0.175	**0.469**	0.045	-0.291	0.112
Overarm height	0.092	**0.465**	-0.180	-0.268	0.215
Left front side neck to armscye level	0.160	**0.451**	-0.060	-0.150	-0.012
Hip girth	0.012	**0.444**	-0.017	-0.139	0.098
Right coat insleeve	-0.157	**0.434**	0.074	**0.491**	-0.060

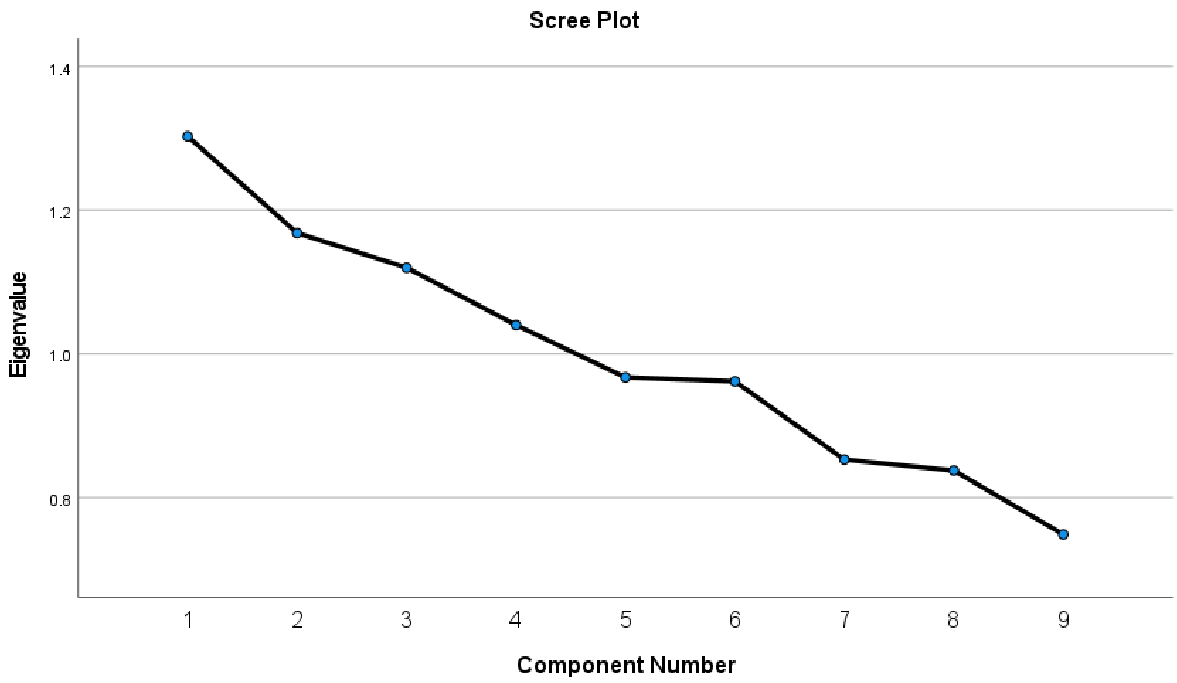
Left calf	0.059	**0.428**	-0.070	-0.076	0.035
Chest front	0.064	**0.427**	0.009	0.289	-0.148
Chest girth	0.029	**0.414**	-0.039	0.080	-0.092
Hip height	0.063	0.099	**0.934**	0.121	0.138
Left knee	0.094	-0.038	**0.624**	-0.223	-0.026
Right shoulder length	0.019	-0.109	**0.510**	**0.534**	-0.113
Shoulder to shoulder width	0.112	0.075	**0.485**	**0.438**	0.075
Right thigh length	0.055	-0.050	**0.425**	0.018	0.378
Right ankle height outside	-0.024	0.100	0.038	**0.503**	0.099
Left out-seam	0.061	0.165	0.324	**0.498**	-0.208
Buttocks angle	-0.061	0.076	-0.261	**0.423**	0.314
Left coat out-sleeve	0.226	-0.003	-0.083	**0.439**	0.333
Left shirt sleeve	0.285	0.240	0.312	**0.471**	-0.208
Left ankle girth	0.053	0.097	0.377	**0.482**	-0.357
Left shoulder to waist back	0.031	0.137	-0.045	0.211	**0.453**
Right shoulder to waist back	-0.079	0.065	0.222	0.069	**0.450**
Right knee	0.112	0.251	-0.051	-0.146	**0.420**
Across chest horizontal	-0.069	0.349	0.090	0.160	**0.434**
Abdomen front	-0.188	0.190	0.018	0.129	**0.458**
Abdomen girth	-0.112	0.132	-0.004	-0.034	**0.496**

Appendix G: Final cluster scores of the key body dimensions using the K-means method

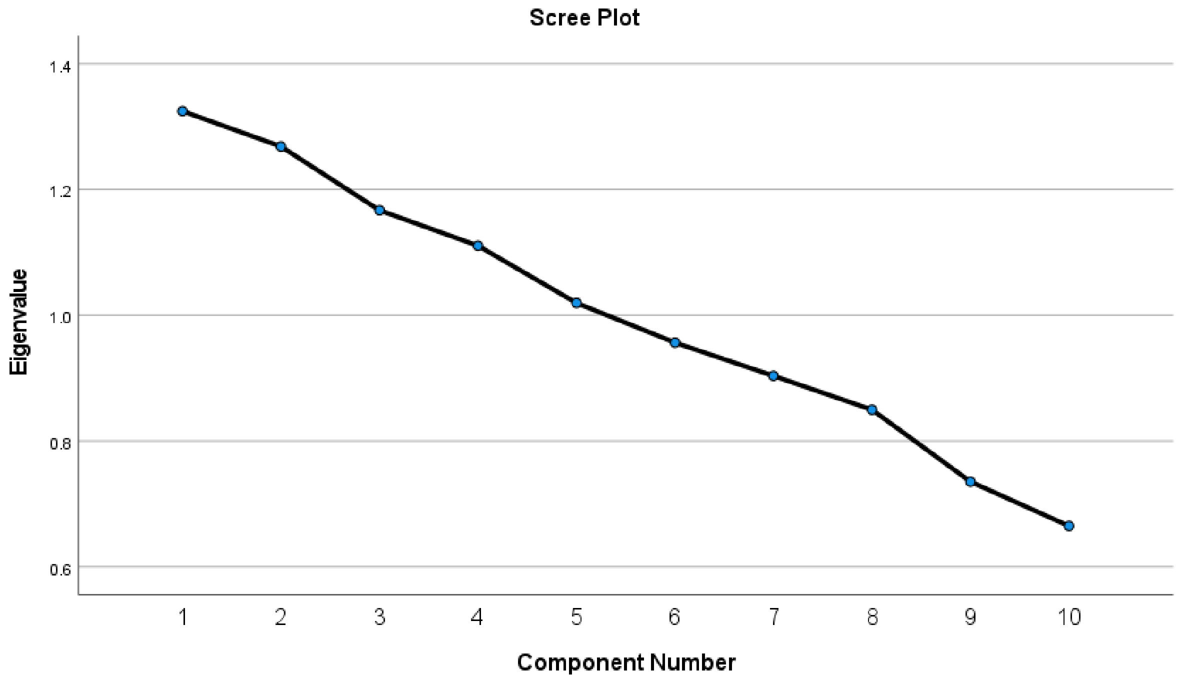
Final cluster scores (n=270)				
Body dimensions	**Cluster**			
	1	**2**	**3**	**4**
Neck height (front)	0.176	0.491	-2.114	0.467
Neck height (back)	0.178	0.492	-2.116	0.466
Chest height	0.176	0.475	-2.112	0.473
Stomach height	0.134	0.489	-2.079	0.467
Left front side neck to armscye level	-0.139	0.408	-0.174	-0.088
Left shoulder to waist back	0.029	-0.042	0.069	-0.046
Right shoulder to waist back	0.023	0.202	0.241	-0.179
Left waist to hip	-0.121	-0.777	0.019	0.285
Right back waist to crotch level	-0.032	0.219	-0.236	-0.082
Hip height	0.066	-0.000	-0.400	0.114
Thigh height	-1.973	0.404	0.139	0.492
Right thigh length	-0.073	0.207	0.101	-0.069
Left knee height	-1.329	0.206	0.296	0.300
Right calf height	-1.906	0.399	0.168	0.460
Left calf height	-1.861	0.437	0.106	0.448
Left in-seam	-1.976	0.404	0.140	0.492
Left out-seam	-0.051	-0.002	0.091	-0.032
Right ankle height outside	0.032	0.087	0.034	-0.098
Shoulder to shoulder width	-0.103	0.308	-0.169	-0.060
Chest front	-0.215	0.272	-0.097	-0.013
Across chest horizontal	-0.013	0.093	0.123	-0.069

Waist front	0.127	0.809	-0.141	-0.329
Abdomen front	-0.261	0.467	-0.137	-0.000
Buttocks angle	0.164	-0.077	0.256	-0.102
Right coat insleeve	0.101	0.149	0.075	-0.094
Left shoulder to elbow	0.203	0.136	-0.170	-0.100
Overarm height	0.027	0.066	-0.236	0.015
Right shoulder length	0.030	0.051	-0.067	-0.026
Left shirt sleeve	-0.215	0.186	0.088	-0.053
Left coat out-sleeve	-0.047	-0.067	0.076	-0.005
Chest girth	0.105	0.208	-0.033	-0.272
Waist girth	-0.109	0.748	0.063	-0.259
Hip girth	0.013	0.467	0.084	-0.272
Abdomen girth	0.037	0.341	-0.233	-0.069
Left thigh	-0.293	0.208	0.122	-0.037
Right knee	-0.145	0.143	-0.139	0.096
Left knee	-0.122	0.147	-0.074	-0.010
Left calf	-0.012	0.038	0.072	-0.058
Left leg surface	-0.138	0.195	0.079	-0.084
Left ankle girth left	-0.152	0.165	0.007	-0.007
Left forearm	0.029	0.189	-0.272	0.019
Left bicep	0.058	-0.108	0.008	0.035

Appendix H: Scree plot for the upper body dimensions



Appendix I: Scree plot for the lower body dimensions



Appendix J: Figure-Forms size chart

Figure-Forms size chart

Upper body chest (size ranges-inch)	**38**	**40**	**42**
Upper body chest girths (cm)	95 to 99	102	108
Lower body waist (size ranges-inch)	**32**	**34**	**36**
Lower body waist girths (cm)	81 to 84	85 to 91	93

Appendix K: Figure-Forms size 40 inch and size 34 inch size chart

Body dimensions	**Anthropometric measurements**
Neck girth	44.0 cm
Chest girth	102.0 cm
Right wrist girth	18.5 cm.
Left elbow girth	28.5 cm
Shoulder to shoulder width	47.0 cm
Waist girth	86 cm
Hip girth	92 cm
Left thigh girth	60 cm
Left knee girth	38 cm
Left calf girth	38.5 cm
Left ankle girth	23 cm
Left in-seam	80 cm
Left out-seam	110 cm

Appendix L: Proofreading certificate

ONE STOP SOLUTION
Professional Editing Services

Proofreading Certificate

It is hereby certified that this dissertation has been proofread and edited for spelling, grammar and punctuation by a professional English language editor from www.OneStopSolution.co.za

Client

Mthokozisi Carolus Mnyaiza

Body morphotype and 3-D scanned e-tape anthropometric measures for men in Gauteng

Editor

Bruce Wesson
Name

Signature

Date

I cannot guarantee that the changes that I have suggested have been implemented nor do I take responsibility for any other changes or additions that may have been made subsequently. The track changes of the language editing will be available for inspection upon enquiry, for a period of one year.

Contact

One Stop Solution
18 Woltemade str
Kabega Park
Port Elizabeth
6045

Redène Steenberg
076 481 8341
www.OneStopSolution.co.za

Appendix M: Turnitin report

M C Mnyaiza Final Dissertation

ORIGINALITY REPORT

17%	15%	6%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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Appendix N: Questionnaire for visual analysis of the rectangle body morphotype

Dear Subject,

Mthokozisi Mnyaiza is a post-graduate student at the University of South Africa (UNISA: 2021/CAES_HREC/058) and would really appreciate your thought on the visual analysis of body forms for men.

This questionnaire will take around 5 to 10 minutes of your time to complete.

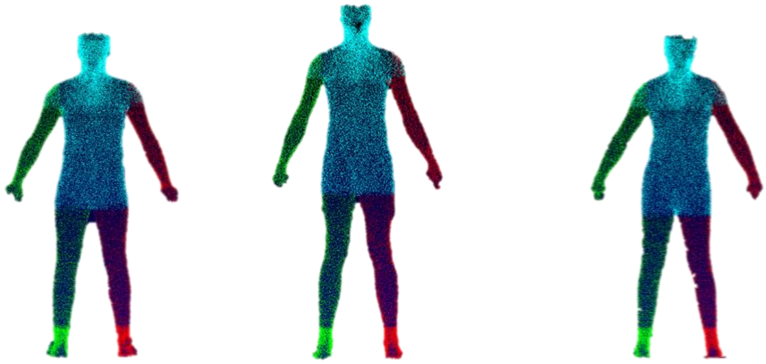
All your answers will be anonymous and remain confidential. Please look carefully at the image of the rectangle body form for men in Section A on page 2 below and answer the question that follows honestly.

If you have any further questions, please contact me at 46486860@mylife.unisa.ac.za or 0727427759

Section A: Visual analysis of body forms for men

The image of the rectangle body form for men

1. Please look at the 3-D body scan silhouettes below and mark with an X next to the number (s) that you think best represent the rectangle body form in each row. Mark the most relevant option (s).

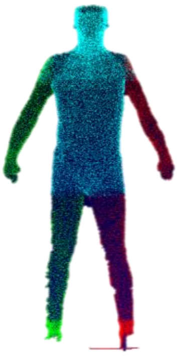


1.1 1.2 1.3

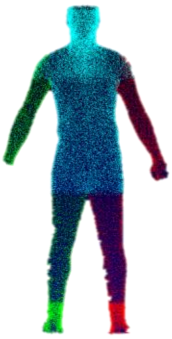
1.4

1.5

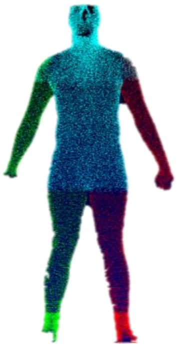
1.6



1.7



1.8



1.9

Thank you so much for taking the time to complete this questionnaire.