One Size Fits All? An Exploratory Study of the Body-Garment Relationship for a Sheath Dress

A Thesis
SUBMITTED TO THE FACULTY OF THE
UNIVERSITY OF MINNESOTA
BY

Robin Lee Carufel

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

Elizabeth Bye, Ph.D.

April 2017

I would like to acknowledge my advisor, Dr. Elizabeth Bye, for without her this thesis would have never started or finished.

I would also like to acknowledge the contributions of Dr. Marylin DeLong, who steered me towards excellent references.

Finally, I would like to acknowledge Dr. Linsey Griffin, who graciously stepped into my committee at the last minute and provided excellent feedback.

This thesis is dedicated to my amazing husband, Aaron Carufel. Thank you for your enduring patience for all the time I had to spend writing instead of with you, for freely sharing your expertise with Excel, and your steadfast support as I chase my dream.

Abstract

Body-form variations and corresponding pattern dimensions were analyzed for 39 subjects with the aim of informing the development of a body-form based block system. Results indicated that similar body measurements did not produce similar body forms, and that findings from comparing body-form variations to pattern dimensions can provide important suggestions for the creation of a body-form based block system. However, whole block shapes could not be categorized based on the body-form variations analyzed here. Recommendations for specific pattern components, such as front neck drop and shoulder slope are presented.

Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

This case study explores the relationship between the human body and the clothing that covers it. This relationship covers objective and subjective measures of fit as well as the design features of a garment. These three areas interact in multiple ways, most of which are still unknown. These areas require separate research before tackling the associations between them. This study focused on objective measures of fit for American women between the ages of 18 and 54.

Assumptions about the body-garment relationship abound in the apparel industry but have no scientific backing. Stemming from the switch from made-to-measure to ready-made clothing, manufacturers have been trying to figure out ways to cater to the variety of body-forms inherent to the American population without resorting to customized manufacturing practices. Unfortunately, with the loss of traditional customization practices, the knowledge of how to pattern for various body-forms has been mostly lost to history. Currently apparel manufacturers consolidate sizing and design to fit many body-types in one garment; leading to the current trend of shapeless, oversized garments, that fit few women.

While we know how to measure the human body thanks to traditional anthropometry, we have yet to classify body-forms that are of practical use to the apparel industry. Linear body measurements do not accurately describe a body's form in a way that is useful for pattern-drafting. Adjustments are an accepted part of the development process, but slow down production. Research using objective measures of fit to evaluate the body-garment relationship is vital to support current and future apparel manufacturing practice.

The purpose of this case study was to determine if apparel block shapes could be categorized based on distinct body-form variations. The goal of this thesis was to empirically establish that similar body measurements do not produce similar body forms.

The remainder of this chapter will explain the problem, the rationale and significance of this research, and end with a list of key terms. Chapter two critiques the relevant literature pertaining to body-form and pattern-shape. Chapter three shares the process of choosing a sample set, and describes the basic statistical make-up of the final sample set.

Chapter four applies a modified version of Gazzuolo's (1985) body-garment relationship framework to this study. Chapter five presents the results from the dimensional, visual, and physiological components, and chapter six concludes with a discussion of the results as well as future research recommendations.

The Problem

The problem facing the apparel industry is that the clothing it makes does not fit its intended population. One contributing factor of poor fit stems from not understanding the physical forms of the American female populace. This paper asks the questions: What do American women's bodies actually look like? And how do these variations relate to garment patterns?

Other researchers have posed similar questions, but their solutions have been based on assumptions about the human body rather than anchored in a content analysis. This may be due to a lack of formal theories present in the apparel design discipline focused on pattern-drafting and fit.

We can start by parsing out what we know from what we think we know. Apparel has been a trial-and-error industry since the first person chose to cover themselves in leaves and animal skins. This has led to differing ways to create patterns (drafting vs. draping via Joseph-Armstrong, 2006; Bergh, 2006; Jaffe & Relis, 2005), as well as different ways to grade patterns (direct vs. proportional via Aldrich, 2007), and different ways to fit and alter patterns (Minott, 1978; Palmer & Alto, 2005; Rasband & Liechty, 2006). This smorgasbord of options provides us with numerous techniques for varying situations.

Unfortunately, most of these options have not been tested empirically, and some of those tested were shown to be less than accurate. For instance, Bye, LaBat, McKinney, and Kim (2008) tested the fit of customized versus traditionally graded garments to conclude that traditionally graded patterns did not provide a good fit across a range of seven sizes. Schofield and LaBat (2005b) compared two bodice patterns, one with grade rules from traditional grading practices and one with grade rules developed from regression analysis of the 1988 ANSUR survey, based on seven assumptions found during their earlier research (Schofield & LaBat, 2005a) to find that none of the traditional grading assumptions were supported.

One example of theory created by and for the apparel community is the FEA Consumer Needs Model by Lamb and Kallal (1992) (Figure 1). The FEA, or Functional-Expressive-Aesthetic, model aims to help an apparel designer develop design criteria based on the needs of their specific target population.

Figure 1: FEA Consumer Needs Model from Lamb & Kallal (1992), Fig. 1, p. 42

The functional segment includes the elements of fit, mobility, comfort, protection and donning/doffing. Much of the work done in this segment leads to a physical product, like the project by LaBat and Sokolowski (1999) which redesigned an athletic ankle brace for a sports medicine soft goods company. In this project, the researchers drafted a design process and tested it. Other research in this area has led to understanding that an entire segment of the population (women aged 55 and older) did not fit the voluntary sizing system then in place, and triggered the creation of a new one (Patterson & Warden, 1983; Goldsberry, Shim & Reich, 1996a; Salusso, Borkowski, Reich & Goldsberry, 2006).

While this is a helpful general model, it leaves out how to conduct each aspect of each component. To make this an easier model to use, each sub-component (i.e. Fit, Art Elements, Status) needs theories and methodologies of their own. This project focused on empirically identifying factors related to the fit sub-component. By comparing analyses of the female body with their corresponding custom-fit pattern blocks, the researcher questioned how the body-form affected the pattern-shape.

The first research question deals with description, while the second is theoretical:

1. What are the body-form variations across a single size?
2. What do these findings suggest for the development of a body-form based block system?

Significance & Rationale

There are over 78 million women between the ages of 18 and 54 in the US as of the most recent census (US Census Bureau, 2015) and they all need clothing that fits. As sizing standards are considered trade secrets and a competitive advantage in the apparel industry, it is unknown how many companies draft their own standards and how many use the ASTM voluntary standards provided by the US government.

ASTM standards do not fit the US female population well, as shown by the results from research conducted by Patterson & Warden (1983), Salusso-Deonier, DeLong, Martin, and Krohn (1985), Goldsberry et al. (1996a), Salusso et al. (2006), Ashdown (1998), Simmons, Istook, and Devarajan (2004), Alexander, Connell, and Presley (2005), Pisut and Connell (2007), and Alexander, Pisut, and Ivanescu (2012).

Research into body-form variations and how they affect pattern blocks can improve sizing standards by making them more realistic. In addition, the use of Gazzuolo's (1985) body-garment relationship framework tests a model that has the potential to advance fit theory. By testing specific relationships between body-form variations and pattern block components (for example, bust prominence vs. bust dart depth), this research provides a starting point for examining which factors influence apparel pattern shapes. Understanding which relationships affect the final apparel pattern shape allows pattern-drafters to more accurately represent different body-types in clothing. This will provide apparel manufacturers with the means to tailor their products more specifically to their target customers, improving their competitive advantage and increasing brand loyalty.

Definition of Terms

Assumption: An educated guess about the relationship between a body-form variation and a dimension.

Basic Block: A two-dimensional foundational garment pattern with no style lines, style ease, seam allowances, hems, dart interiors or markings; also called a sloper or master.

Body-form: The female human body; a three-dimensional biomorphic form.

Body-form variation: A specific physical aspect of the human body-form, such as neck thickness or shoulder length.

Circumference: The full, circular distance around the body.

Depth: A straight line spanning the distance from dart point to the midpoint of the dart opening.

Dimension: A measurement taken from the basic block.

Ease: The space between the garment and the body.

Fit: The relationship of the garment to the body; impacted by ease.

Fit Criteria: Rules based on how the garment should interact with the body.

Length: The distance between two points, generally vertical.

Size: Denotes a group of women similar in height, bust, waist, and hip girth measurements.

Width: The distance between two points, not necessarily straight, and generally horizontal.

Chapter 2 Literature Review

This chapter discusses the primary factors that informed this project, defines important terminology and explains the assumptions underlying the project. The first half focuses on body form, and the second half focuses pattern shape.

Body Form

This section outlines and critiques research concerning body-form variation. Of specific interest are systems for classifying subjects, such as sizing standards and form assessment.

Sizing

Sizing systems divide a given population into groups based on body measurements so that the majority of the population is represented in the system using the least number of sizes possible (Petrova, 2007). Such systems are relatively new – up until the early 1900s custom-fit apparel still dominated the market (Aldrich, 2007). Additionally, sizing surveys, the act of measuring the populace, are time consuming and expensive (LaBat. 2007). Table 1 lists historical surveys and standards pertaining to adult females starting from the O'Brien and Shelton survey of 1941 until 2013.

Only six anthropometric sizing surveys have been conducted in the US in the last 75 years: The O'Brien and Shelton survey in 1941, ANSUR in 1988, NCTRF in 1990, the Reich and Goldsberry survey in 1993, CAESAR in 1998, and SizeUSA in 2002. These surveys influenced the government's published standards for women's apparel: CS215-58, PS 42-70, ASTM D5585, D5586, D6829, D6960, D7197 and D7878. Sizing standards are documents developed through stakeholder consensus that represent the total range of sizes for ready-made garments (LaBat, 2007; Petrova, 2007). These standards are voluntary and the extent of their use is unknown as sizing is considered a competitive advantage by the industry.

Year	Name	Description
1941	USDA Misc. Pub. 454: Women's measurements for garment and pattern construction	150,000 women; published by the US Department of Agriculture; part of the O'Brien and Shelton study
1945	CS151	Commercial standard, recommended by The Mail Order Association of America
1958	CS215-58; Body Measurements for the Sizing of Women's Patterns and Apparel	Voluntary standard; published by the National Bureau of Standards; based on analysis of 1939-1940 study; 9 sizes, bust ranges from 30.5" to 43"
1970	PS 42-70	Voluntary product sizing standard; set grades at 1" for girth and 1.5" for height; published by the U.S. Dept. of Commerce; 9 sizes, bust ranges from 31.5" to 44"
1988	ANSUR	Measured 1,774 men and 2,208 women; US Army Natick
1990	NCTRF	National survey of U.S. Navy personnel
1991	NAHM Standard for the Size of Pantyhose and Women's Tights	Pantyhose specification recommended by the National Association of Hosiery Manufacturers (NAHM); originally developed around 1970 using information taken from consumer feedback on the NAHM website; based on 1941 U.S. Dept. of Agriculture data and 1968 E. I. DuPont de Nemours & Co. via the Home Testing Institute data.
1993	ASTM Survey of Women 55+	Reich & Goldsberry surveyed 6,786 women aged 55+ from 38 states; measured at 58 body locations
1994	ASTM D5586	Standard tables of body measurements for Women aged 55+ (All Figure Types); based on Reich & Goldsberry (1993) survey; reapproved 1995, 2001, 2010
1994	ASTM D5585	Standard table of body measurements for adult female Misses figure type; sizes 2-20, bust range 32"-44.5"; reapproved 1995, 2001
1998-2002	CAESAR (Civilian American and European Surface Anthropometry Resource)	10,000 people in North America, Italy & the Netherlands; Cyberware body scanner for some measurements + 40 measurements were taken via tape measure and caliper.

2002	ASTM D6829	Standard table of body measurements for Juniors; sizes 0-19; bust range 30.5”- 43”; reapproved 2015
2002-03	SizeUSA	10,800 people, 13 cities; $[TC]^2$ body scanner
2004	ASTM D6960	Standard table of body measurements for Women’s Plus-size figure type; sizes 14W-32W; bust range 39.5”- 57.5”; withdrawn 2013, no replacement
2006	ASTM D7197	Standard table of body measurements for adult Misses Maternity sizes 2-22; bust range 35”- 49.5”; reapproved 2013
2011	D5585-11[e1]	New standard table for adult female Misses figure type, sizes 00-20; bust range 31.125”- 46”
2013	D7878-13[e1]	Standard table for body measurements for adult female Misses Petite figure type, sizes 00P-20P; bust range 31.125”- 46”

Table 1: Sizing Surveys & Standards related to adult women, 1901-present (US only)

Most research on sizing standards focuses on proving how poorly they fit their intended population. Patterson and Warden (1983) tested the similarity of measurements from 205 women aged 65 to 96 against the O’Brien and Shelton (1941) database. They found 25 of the 33 measurements were statistically significantly different, meaning that the O’Brien and Shelton database poorly accommodated these subjects. They found that the largest girths in their population were at the waist, hip, and abdominal extension.

Simmons, et al. (2004) ran 21 measurements from 254 female subjects through ASTM D5585-95, ASTM D5586-95 55+, PS 42-70 and CS215-58 for all height categories (Juniors, Juniors Petite, Misses Petite, Missy, Misses Tall, Half Sizes and Women’s). Best fit was calculated using percentage difference, tolerance difference and weighted tolerance difference. Percentage difference was calculated in increments of 5% and indicated that the majority of subjects (44%) fit the CS215-58 standard best, though 93% of subjects had measurements greater than 5% of the standard. Tolerance difference suggested that ASTM D5586-95 55+ provided the best fit for 35% of subjects, though on average 10 of the 21 measurements were out of tolerance, 100 subjects were completely out of tolerance for all 21 measurements, and 253 subjects were out of tolerance for the bust measurement. Weighted tolerance showed only 23% of measurements were within tolerance, 57% were within two times the tolerance, 5% were within three times the tolerance and 15% were more than three times the tolerance. Regardless of the evaluation method, at least 50% of subject's measurements were inconsistent with the standards.

To test the accuracy of ASTM D6960-04: *Standard Table of Body Measurements for Women's Plus-size Figure Type; sizes 14W-32W* Alexander et al. (2012) compared the bust, waist, and hip circumferences of the standard with women from the SizeUSA database. The tolerance for each size was -1" to +.9999". Figure 2 provides the bust, waist and hip measurements for all ten sizes as well as how many women fit each single measurement, how many fit two measurements, and how many fit all three measurements. In total 4,105 women fit the sizes based on bust girth, 4,855 women fit the sizes based on waist girth, and 3,968 women fit the sizes based on hip girth. For the combinations of two measurements 1,228 subjects matched both bust and waist, and 874 matched waist and hip. Combining all three measurements resulted in 261 matches, though none of them fit sizes 30W or 32W (Figure 2). T-tests revealed that a) SizeUSA subjects were approximately 2" larger than the ASTM standard at the waist, and b) hip girths were generally smaller than the ASTM standard. This analysis showed that as sizes increase fewer women satisfy all three measurements and that hip measurements may be smaller than assumed.

One critique of the study is that the total number of subjects is not listed, thus it is impossible to know what percentage fit the standard.

Table 2. Number of women in the SizeUSA sample who satisfied bust, waist, and hip measurements according to ASTM standards (ASTM D-6960-04).

	ASTM bust	SizeUSA women who satisfy the bust measurements	ASTM waist	SizeUSA women who satisfy the waist measurements	SizeUSA women who satisfy the bust & waist measurements	ASTM hips	SizeUSA women who satisfy the hip measurements	SizeUSA women who satisfy the waist and hip measurements	SizeUSA women who satisfy the bust, waist and hip measurements
14W	39.5	1080	31.5	1135	385	41.5	1321	336	120
16W	41.5	878	33.5	926	261	43.5	992	206	58
18W	43.5	712	35.5	805	204	45.5	625	134	33
20W	45.5	503	37.5	641	150	47.5	407	88	24
22W	47.5	339	39.5	447	86	49.5	231	36	9
24W	49.5	255	41.5	326	70	51.5	179	30	11
26W	51.5	164	43.5	242	37	53.5	112	20	4
28W	53.5	102	45.5	165	23	55.5	45	11	2
30W	55.5	53	47.5	111	6	57.5	32	10	0
32W	57.5	19	49.5	57	6	59.5	24	3	0

Figure 2: Table 2 from Alexander et al. (2012), p. 8

In addition to proving the sizing systems fit an intended population poorly, some research also proposed alternative sizing systems. Salusso-Deonier et al. (1985) developed a multivariate method for structuring a sizing system around body-form variation using principle component analysis. Principle component analysis groups multiple measurements into principle components (PC) for classification. Fifteen principle components were extracted from the 54 measurements taken from 1,217 Army women, aged 17 to 35 of either White or African American descent. PC1 (overall body thickness, 38 measurements) and PC2 (body length, 23 measurements) explained 60% of the variation among subjects' proportions and so were selected as the variables for the Principle Component Sizing System (PCSS). All subject's PC1 and PC2 scores were plotted and the graph sectioned into size ranges defined by height and weight.

The PCSS system was compared to PS 42-70. Salusso-Deonier et al. (1985) classified subjects into PS 42-70 sizes using height and bust girth. PS 42-70 covered 95% of the sample. Differences between similar sizes of PS 42-70 and the PCSS were computed. Thicknesses were similar, but lengths were not, especially for shoulder length, cross-front and cross-back width, crotch height, and sleeve inseam length. Notably these differences coincided with the areas of greatest misfit found during classification.

To quantitatively test the two systems, 200 subjects were randomly selected and sorted via computer algorithm into the best fitting size for both systems. Goodness of fit was calculated by comparing the difference between the subject's measurements with their size's measurements. Results indicated that the PCSS system was better 95% of the time for the whole body and upper body and 67% of the time for the lower body. These results may indicate that population lengths and widths, though not necessarily circumferences, vary more widely than assumed in government sizing standards. It also suggests that the lower body may vary more widely than the upper body.

Goldsberry et al. (1996a) compared the measurements from 6,652 women aged 55 and older to PS 42-70. Subjects were sorted into PS 42-70's sizes and the mean differences between the subject's measurements and PS 42-70's measurements were calculated. The results showed that 80% of the sample had statistically significant differences from PS 42-70, manifested in wider central and lower torsos, flatter buttocks, lower bust-lines, broader shoulders and enlarged armscyes. PS 42-70 was concluded inadequate for the needs of women 55 and older. ASTM D5586-94: *Standard Tables of Body Measurements for Women Aged 55+ (All Figure Types)* was developed based partly on this study's results.

Ten years after the development of ASTM D5586-94 Salusso et al. (2006) tested it against a new sizing system generated using principle component analysis. The Principle Component Sizing System 55+ (PCSS 55+) used 6,657 subjects from the original 1993 ASTM-funded Goldsberry and Reich survey used to generate ASTM D5586-94. PCSS 55+ had 25 sizes (30 less than ASTM D5586-94) and fit 95% of subjects. Comparisons of PCSS 55+ to PS 42-70 and ASTM D5586-94 indicated that PCSS 55+ was a more efficient and effective sizing system.

Ashdown (1998) built three optimized lower-body specific sizing systems (Linear, Two-Tiered and Unconstrained) and tested them against ASTM D5585-94. The linear system had proportionally consistent increments between all ten sizes. The two-tiered system had two tiers with five sizes each, and used proportionally consistent increments between sizes within each tier. The unconstrained system searched for ten optimized sizes so grades between sizes differed. 752 women were chosen from the 1988 ANSUR database based on stature and a waist-to-hip difference of 10.5". Half the sample was used to build the three optimized systems while the other half was used to test them and ASTM D5585-94. Figure 3 presents three-dimensional plots of each sizing system plus the data cloud of the 376 subjects. Aggregate loss (the difference between the body measurement of a subject and the measurement of their closest size) was calculated for all four systems as a ranking mechanism. All three optimized systems performed better than ASTM D5585-94 (Table 2).

Sizing System	Aggregate Loss %
ASTM D5585-94	4.8%
Linear	2.9%
Two-Tiered	2.7%
Unconstrained	2.7%

Table 2: Aggregate Loss Percent, data from Ashdown (1998), p. 335

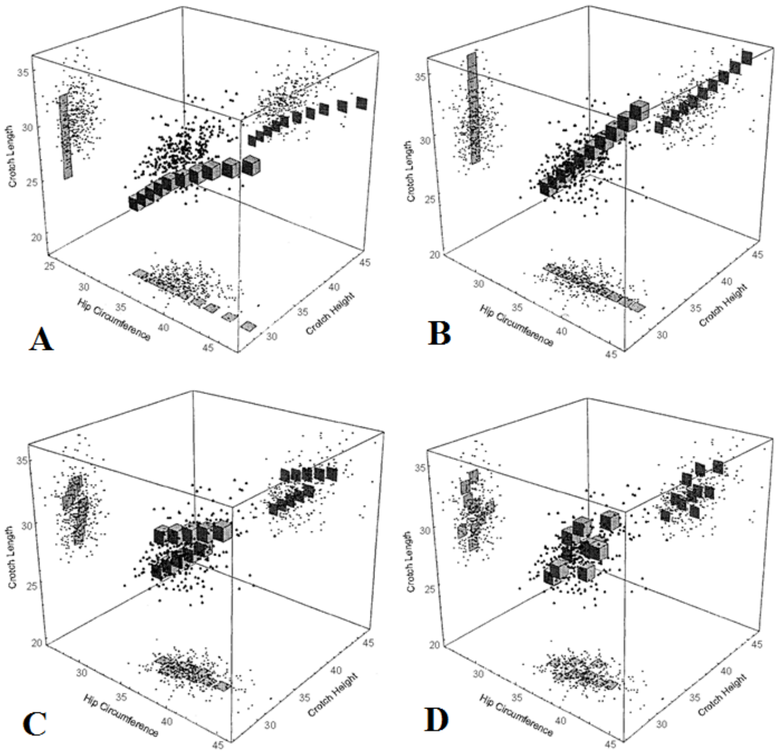


Figure 3: Graphical representations of goodness of fit of subjects with each sizing system; A. ASTM D5585-94, B. Linear, C. Two-Tiered, D. Unconstrained (Ashdown, 1998, pp. 333-4)

Form Assessment

Body-form assessment is an under-studied area in academia, but the topic appears in all basic sewing books. Body form assessment scales classify human bodies into specific categories. Categories may take the form of sizes, numbers, heights, volumes, letters, or shapes. This section highlights studies concerned with classifying human body form, beginning with the difference between a shape and a form.

<u>Shape vs. Form</u>

The design field has defined the terms ‘shape’ and ‘form’ thusly:

1. ‘Shape’ is a two-dimensional enclosed space, distinctly separated in some way (ex. an outline) from the background and other shapes (Hemmis, 2016).
2. ‘Form’ is a three-dimensional shape, where the third dimension is added by depth or volume (Hemmis, 2016).

There are three types of shapes: geometric, curvilinear and biomorphic. Geometric shapes are defined by mathematical formulas, for instance, length times height always describes a rectangle. Curvilinear shapes are those curved shapes found in nature that are not biological, for example, the outline of a lake. Biomorphic shapes are those ambiguous shapes from biological organisms, such as an amoeba. (Hemmis, 2016) The human body, in all its varied heights, weights, volumes, angles, and arcs, is a biomorphic form.

Due to the difficulty of describing biomorphic forms like the human body, forms are often flattened to allow for shape identification. More research into form identification of the human body is essential to fully understand body-form variation.

Figure Evaluation – Observed vs. Standard

Pattern drafting and fitting texts are where most designers and pattern makers learn about human body classification, or as it is colloquially known, 'figure evaluation'. Figure evaluation relies on comparisons between an observed form and a standard one. As such, patterning and alteration texts focus on defining the standard form as well as common "deviations".

Figure evaluations can be broken into four categories: Proportions, Posture, Whole Body and Body Components. In the following sections both the standard and deviations will be discussed.

Proportions

Proportions are the relationships between different body component lengths (Palmer & Alto, 2005). These relationships are the fundamental building blocks of any garment patterning system. Clear understanding of the locations of major body sites assists in the determination of pattern features, such as seamlines and darts; and determines grading rules.

Patterning texts agree that the standard figure is evenly divided lengthwise at the hips, and that the knees are halfway between hipline and floor (Latzke & Quinlan, 1940; Liechty, Pottberg, & Rasband, 1986; Maehren & Meyers, 2005; Rasband & Liechty, 2006), but from there, texts differ. Latzke and Quinlan (1940) set the standard figure at seven heads tall; Liechty et al. (1986) set the standard figure at seven and a half heads tall; and Palmer and Alto (2005) set the standard figure at 8 heads tall. Maehren and Meyers (2005), and Rasband and Liechty (2006) set the underarm as halfway between the top of the head and hipline, while Latzke and Quinlan set the halfway point at the nipples (Figure 4).

Maehren and Meyers (2005) put the waistline halfway between underarm and hipline. Rasband and Liechty (2006) set the elbows at waist level, equally dividing the arm in half, with the wrist bone level with the crotch and fingertips with the mid-thigh. Latzke and Quinlan (1940) are the only text to define the relationships for widths, setting the shoulders and hips at one and a half heads each, the bust at one and a quarter heads, the waist at one head, the knees and calves at three-quarter heads each, the ankles at a half head, the upper arm at one third of a head, the elbow at one quarter of a head, and the wrist at three-sixteenths of a head; with the length for the foot at one head.

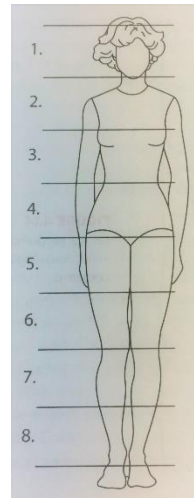


Figure 4: Proportions (from Liechty et al., 2010, Fig. 4.15, p. 74)

There are three deviations from the standard figure for proportions: short-waisted, long-waisted and asymmetrical. Short- and long-waisted proportions refer to ratios of length measurements between the underarm and hips. Short-waisted figures have waists closer to the underarm than the hips, resulting in a waist higher than that found in the standard figure (Maehren & Meyers, 2005). Long-waisted figures are the opposite; waists are closer to the hips than the underarm, resulting in a waist lower than that found in the standard figure (Maehren & Meyers, 2005). Asymmetrical proportions refer to either a difference between the right and left sides of the body (Minott, 1974, 1978) or between the front and back fullness at specific body sites (Liechty et al., 1986).

Posture

Correct (or average or standard) posture is typified by an upright stance, with head and neck centered over the shoulders, hips and ankles; a slightly lifted chest; shoulders pulled back and slightly down; abdomen contracted and flat, buttocks contracted and pulled slightly under; arms hanging relaxed at sides with elbows bent slightly forward; knees straight but relaxed and feet pointing straight ahead with ankles at right angles to feet (Latzke & Quinlan, 1940; Minott, 1974; Liechty et al., 1986). An example of excellent posture is shown on the left-hand side of Figure 5.

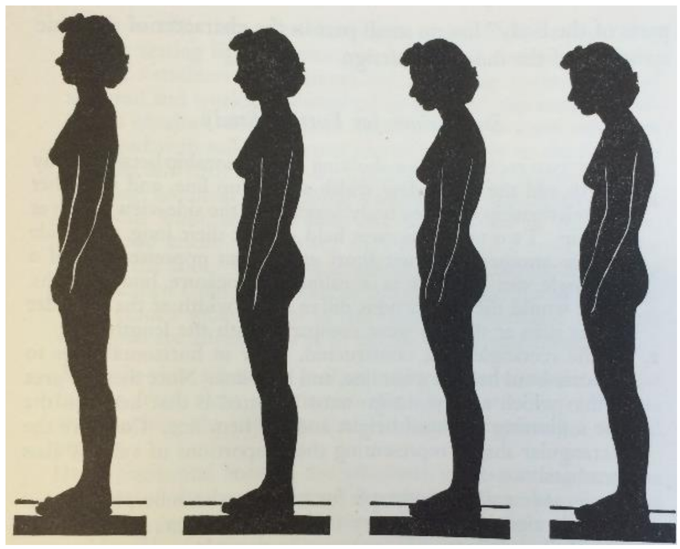


Figure 5: Examples of Posture, from left: Excellent, Good, Poor, Bad. (from Latzke & Quinlan (1940), Fig. 42, p. 73)

Rasband and Liechty (2006) state that "poor posture is the most common figure variation" (p. 29). Poor posture alters the body configuration, causing key areas, such as shoulders, breasts, buttocks, etc. to move out of alignment. There are five common incorrect posture variations cited in the literature: Overly Erect Posture, Slumped Posture, Swayed Back, Tilted Hip-Forward Posture and Tilted Hip-Backward Posture.

Overly erect posture results in a prominently lifted bust and lengthened chest measurement, an arched back and shortened upper back measurement, a pulled back head and hyperextended knees. Slumped posture (aka Rounded back posture) results in the opposite: a concave chest and shortened chest measurement, rounded upper back and shoulders, increased upper back width and length measurements, and a forward tilting head. Swayed back posture is typified by a forward tilting pelvis, prominent abdomen and protruding buttocks. (Liechty et al., 1986)

Those with tilted hip-forward posture have slightly slouched backs, with either prominent hip bones or a roll in the front waist, and flat, low buttocks. The front floor-to-waist measurement is typically longer than the back floor-to-waist measurement. Those with the tilted hip-backward posture are the opposite: the stomach appears lower, the buttocks are high and prominent, and the person appears to be leaning forward. The front floor-to-waist measurement is typically shorter than the back floor-to-waist measurement. (Minott, 1974).

Whole Body

Eight whole body figure shapes were identified from the reviewed pop-culture patterning texts: Average/Hourglass, Triangle, Inverted Triangle, Rectangle, Tubular, Oval/Rounded, Elliptical and Diamond (Figure 6). The goal of classifying women by overall figure shape is to teach them where they deviate from the average figure shape.

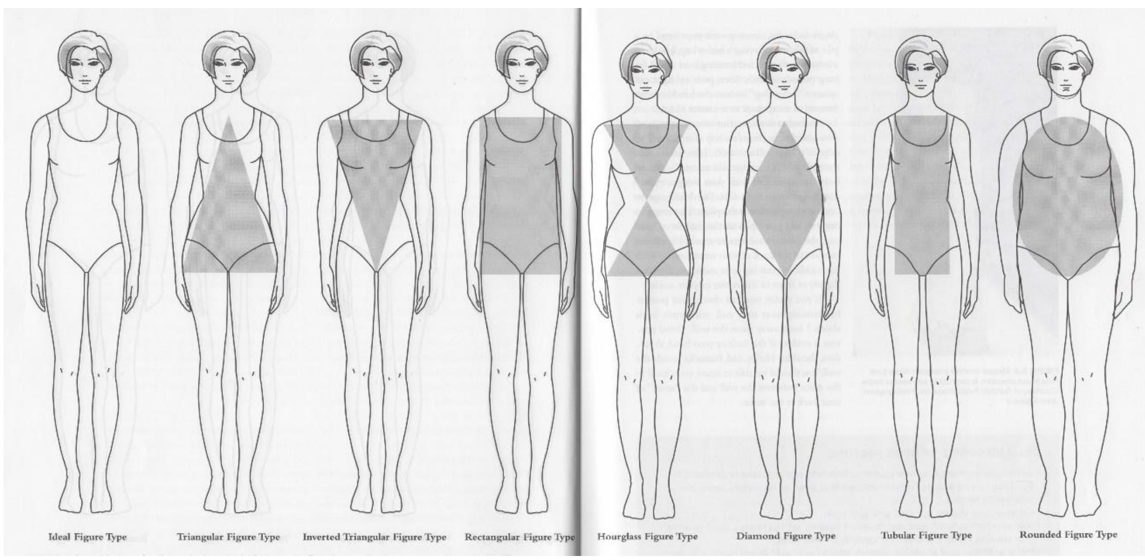


Figure 6: Examples of average and alterative whole body shapes (from Rasband & Liechty, 2006, Fig. 2.2, pp. 25-6)

The average figure shape is generally considered to be an hourglass. For the average/hourglass figure shape, the shoulders and hips are equally wide and the waist is 10-11" smaller than the bust and hip circumference measurements. In general, this shape is considered well balanced, with no area more or less prominent than any other. (Maehren & Meyers, 2005; Rasband & Liechty, 2006)

The triangle figure shape is typified by hips that are wider than their shoulders, with a two inch or larger difference between the hip and bust circumference measurements. This difference causes the body to appear bottom-heavy. The inverted triangle figure is the opposite of the triangle figure. The shoulders are wider than the hips, with a one inch or larger difference between the bust and hips. This difference causes the body to appear top-heavy. (Maehren & Meyers, 2005; Rasband & Liechty, 2006)

The rectangular figure has equally wide shoulders, waist, and hips, with the waist circumference measuring seven inches or less in difference from the bust or hips. The tubular figure is a variation of the rectangluar figure – they are narrower through the shoulders and hips and thinner overall. Both the retanglar and tubular figures appear straight up and down. (Maehren & Meyers, 2005; Rasband & Liechty, 2006)

The oval/rounded figure has fullly-rounded body areas and is generally considered short of stature. The elliptical shape is relatively narrow, yet still rounded. The diamond figure is represented by a wider midriff (or waist) than their shoulders or hips. (Latzke & Quinlan, 1940; Rasband & Liechty, 2006)

Research into whole-body forms for is scarce. One study on somatotypes by Olds, Daniell, Petkov, and Stewart (2013) used K-means cluster analysis to find the naturally occurring body forms for a purposive sample 301 Austrialian adults (148 males, 153 females) aged 17 to 65. Olds et al. defined somatotyping as "the quantification of human body shape, independent of body size" (p. 936). Below are the measurements extracted from the scans:

- "eight segmental volumes (head + neck + thorax, abdomen, pelvis, upper arms, lower arms + hands, buttocks, thighs, lower legs + feet);
- nine breadths: head width, bigonial, biacromial, nipple spacing, biiliocristal, bitrochanteric, biepicondylar femur, bimalleolar, biepicondyler humerus;
- six girths: arm, forearm, waist, hip, calf, ankle; and
- six lengths: head, acromiale-radiale, radiale-stylion, upper leg, lower leg, foot length." (p. 937)

K-means cluster analysis requires the researcher to input the number of clusters prior to analysis. In order to determine the number of clusters Olds et al. (2013) separated scans by gender, then applied a v-fold cross-validation to the scans, yielding 3 clusters per gender. Mean values for the 29 dimensions were calculated across each cluster and were termed "cluster centroids", representing the most 'typical' shape per cluster. Z-scores were used to quantify the differences between centroids and subjects. Caricatures, or an “anthropometric profile that exaggerates the differences between the cluster centroid and the overall average for the sample” (p. 938) were also developed. Every subject in a cluster was compared with both centroid and caricature figures to find the scan most similar to each.

For the males, cluster one comprised 22% of the sample, and was categorized as endomorphic; cluster two comprised 31% of the sample and was categorized as endo-mesomorphic; and cluster three compromised 47% of the sample and was categorized as ectomorphic. For the females, cluster one comprised 41% of the sample and was described as substantially adipose; cluster two comprised 34% of the sample and was described as “relatively slim, narrow, and muscular” (p. 941); and cluster three comprised 25% of the sample and was described as ectomorphic. Olds et al. (2013) concluded that this study provided support for the tripartite classification system and found that cluster analysis was an objective way to group profiles. They admit that the outputs are fully dependent on the inputs and that with different inputs their study could have found different clusters.

The centroid and caricature figures visually indicate differences between the average subject and the most extreme subject for each cluster. The problem with this approach is that shape is viewed only through the tripartite ecto-, endo- and mesomorph system, which ignores shape and focuses on volume. For example, the female centroid of cluster one could be described as an “oval” form, whereas the caricature for cluster one could be described as a “top hourglass” form. It is entirely possible for these two women to have the same volume, but they cannot be classified as the same form. Moreover, the measurements utilized for this analysis are surprising; chest girth is missing, yet foot length and nipple space are included. Overall, this study shows that shape can vary across similar volumes, indicating that it may also vary within a single size.

The most extensive research into whole-body form generated by apparel academics is in the Istook, Simmons, and Devarajan (2004) Female Figure Identification Technique (FFIT) for Apparel system. The FFIT for apparel project aimed to mathematically analyze and sort body shapes using scans taken from the Textile/Clothing Technology

Corporation ([TC]^2)'s database. The purpose of the research was to "develop preliminary subgroups for the female population that will aid in the better fit of clothing" (p. 2) through the use of measurements, proportions, and shapes derived from the 3D data.

The original plan sorted the sample using cluster analysis, but this method grouped subjects of disparate shapes into the same categories. The researchers returned to the literature to determine any descriptors to help with the sorting process. They identified five shapes: hourglass, oval, triangle, inverted triangle, and rectangle. The numerical values of the bust, waist, high hip, hip, stomach, and abdominal girths were entered into a software program in ranges that corresponded to each shape.

A pilot study was conducted using 31 scans from [TC]^2 and all 31 scans landed in one of the five categories. When the researchers ran the full experiment of 222 scans, a few subjects failed to fall into any of the five categories, thus four new categories were added: spoon, diamond, bottom hourglass, and top hourglass; totaling nine categories. The 31 control scans were run through the nine categories and all but the triangle and top hourglass categories were filled. The 222 scans were run through the nine categories and all but the inverted triangle, diamond and top hourglass categories were filled.

The largest category at 40% (89/222) was the bottom hourglass category; the second largest was the hourglass at 21.6% (48/222); third largest at 17.1% (38/222) was the spoon category; followed by rectangle (15.8%), oval (3.6%), and triangle (1.8%). Current and previous sizing systems were assessed for body shape type via the FFIT for apparel software. Results indicated that ASTM D5585-95 fits the Spoon category only, meaning ASTM D5585-95 did not meet the needs of the majority of American consumers with regards to body form variation.

This study purposely kept to the most elemental aspects of body shape analysis in order to provide a solid base for additional studies to build upon. Some critiques of the study are the choice of measurements, the order in which scans were sorted into shape categories and the discrepancy between the first control test and the second control test with regards to the triangle category.

It is unclear why the bust, waist, high hip, hip, stomach and abdominal circumferences were chosen as the measurements for this study. Salusso-Deonier et al.

(1985) found that body thickness and length were crucial components for creating a sizing system and paved the way for future empirical assessment of the most important measurements needed in assessing the human body for sizing purposes. While categorizing a body for whole-body form requires a different mindset than classifying a body for size, the idea that there are certain measurements that are more predictive of size should indicate there are certain measurements more predictive of form. Running a principle component analysis on the body measurements would have provided the FFIT for apparel study with an empirical set of basic measurements to derive ratios from.

The order in which scans are sorted is well thought out in this study, but a program that could analyze the ratios and sort into shape categories without the need to place one category before another would be more valuable. This issue directly leads into the final issue with the FFIT study. The triangle category was filled during the first control trial with five shapes, but not during the second trial with nine shapes, even though the subjects' data did not change between trials. This discrepancy calls into question some of the basic ratios used by the software, as well as the process of body-form classification.

To validate the FFIT for apparel software Devarajan (2003) chose to test three objectives:

1. Try FFIT on a larger population;
2. Test the software's accuracy and verify the five ratios are better predictors of body shape than random chance alone; and
3. Analyze if the nine shape are statistically different from each other.

The validation tested 887 body scans – 222 from the North Carolina State University (NCSU) body scan database and 665 from $[TC]^2$'s database. The 887 scans were split into two groups: training data (356 scans comprised of 222 scans from NCSU and 134 scans from $[TC]^2$) and test data (531 scans from $[TC]^2$).

The first objective was tested by comparing the results from cluster analysis with those from the FFIT for apparel software. Devarajan (2003) aimed to see if the number of clusters obtained using the five body measurement ratios equaled the number of shape categories used in the FFIT for apparel software. All 531 scans were sorted into a shape category and all nine categories were filled, with the rectangle shape having the greatest number of scans and the diamond and inverted triangle categories tying for the least number of scans. Because all of the scans were classified into categories Devarajan (2003) concluded that the FFIT for apparel software works for larger populations.

For the second objective, a discriminant function was developed from the training data and validated using the test data. All of the data was visually analyzed by experts as part of creating the discriminant function. Data from frequency tables were used to compare the accuracy of sorting with the discriminant function against sorting with the FFIT for apparel software. The FFIT software was more accurate for all but the diamond and inverted triangle shapes and was more accurate when all the percentages were averaged into a Hit ratio (66.10 for the discriminant function versus 89.27 for the FFIT software). Since the Hit ratio of the FFIT for apparel software was higher than the Hit ratio for the discriminant function Devarajan (2003) determined that the five ratios used to classify body shapes are more accurate than random chance alone.

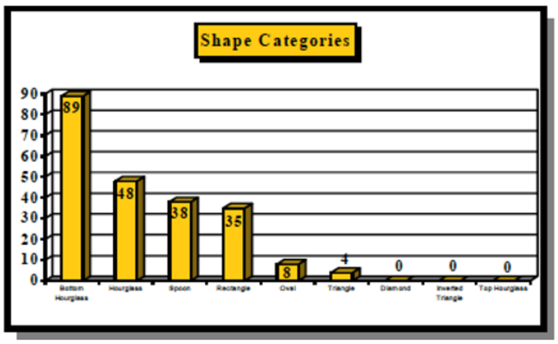
To test the final objective, multivariate analysis of variance (MANOVA) was used on all 887 scans. MANOVA determined if all nine body shapes were significantly different based on the five body ratios utilized as category determinants. The shapes are: hourglass, bottom hourglass, top hourglass, triangle, inverted triangle, oval, spoon, rectangle, and diamond. The six measurements are the bust, waist, hips, high hip, stomach, and abdomen circumferences. The five ratios are:

1. Absolute difference between the bust and hip measurement.
2. Difference between bust and waist measurement.
3. Difference between hip and waist measurement.
4. Ratio of high hip to waist.
5. Difference between the bust and the average of waist, stomach and abdomen measurements (Devarajan, 2003, Table 6, p. 47).

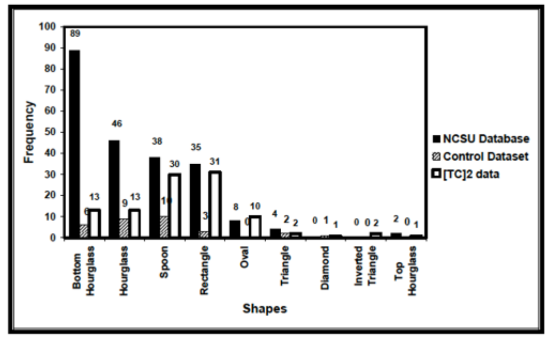
Devarajan (2003) used Wilk’s Lambda as the statistical criteria for assessing the final objective and found it was very small for each of the five ratios. This revealed a significant difference between the nine shape groups based upon the five body measurement ratios used in the FFIT for apparel software.

There are two important points that must be addressed. The same data used to create the software was used (in part) to validate it. Of the 887 scans used, 253 were the same scans used to create the software (222 from the NCSU database and 31 from [TC]^2's database). While redundancy is necessary in validation, the data were used as a convenient sample rather than as validation.

The second issue appears when you look carefully at the data in Figure 7.



Istook et al. (2004), Figure 3: Sample distribution by shape, p. 9



Devarajan (2003), Figure 9: Distribution of shapes - Training data, p. 55

Figure 7: Istook et al. (2004) versus Devarajan (2003)

A discrepancy occurs in the hourglass data. Devarajan (2003) has 46 scans in the hourglass category while Istook et al. (2004) has 48 scans. After the visual analysis of the training data two scans were found to be incorrectly categorized. These two scans were re-categorized as top hourglass and the software code was rewritten. It can only be assumed that the Devarajan (2003) thesis uses the updated software.

One study that branched off from the original FFIT for apparel study compared body shapes between Korean and American women and looked into the proportions of shapes according to age (Lee et al., 2007). Using [TC]^2's Body Measurement Software (BMS), measurements were extracted from the 3D avatars of 6,310 American women and 1,799 Korean women. The bust, waist, high hip, hip, stomach and abdominal circumferences were used to sort shapes. While there are nine shapes identified in the FFIT for apparel study, this study only used seven shapes: hourglass, bottom hourglass, top hourglass, spoon, triangle, inverted triangle, and rectangle. The researchers argued that the oval and diamond shapes were left out due to a lack of data which would not allow them to process the ratios for these shapes.

Results from the comparison showed distinct differences between proportions of shape between American and Korean women. A breakdown of the categories is summarized in Table 3.

Categories	American Women	Korean Women
Hourglass	3rd	5th
Bottom Hourglass	4th	4th
Top Hourglass	6th	N/A
Spoon	2nd	3rd
Triangle	5th	2nd
Inverted Triangle	7th	6th
Rectangle	1st	1st

Table 3: American vs. Korean Body Shapes

When comparing the proportions between American and Korean women it was found that American women have greater proportions for bust, waist, high hip, and hip circumferences as well as higher proportions in the waist, high hip and hip heights. Korean women have higher proportions for bust height.

The most important finding of this study was that most American women fall under the rectangle category, and not the bottom hourglass category as previously seen in the original FFIT for apparel study. This suggests a major difference in how apparel should be patterned because proportions for a rectangular body will be different from proportions for a bottom hourglass body. This also shows how important it is to do shape-analysis studies on larger populations.

The major difference between this study and the original FFIT for apparel study was the use of only seven of the nine shapes. It was not only the choice to use seven shapes, but the choice to use these particular seven shapes that is surprising. The top hourglass shape was not found in either of tests run by Istook et al. (2004), yet was chosen for inclusion in this study. The oval and diamond shapes, while rarely found in the original study, were present, thus it would make sense to use them for this study. The claim that the oval and diamond shapes were not used due to error on the part of the SizeUSA database is strange, since both the original FFIT for apparel study (Istook et al., 2004) and the validation of the FFIT for apparel software (Devarajan, 2003) used data from the SizeUSA database without issue.

Body Components

Another way of thinking about figure classification is to break the body down into its component parts and evaluate each part separately from the others. In some instances, the same component is evaluated by multiple measures. For example, shoulders are evaluated both by slope and by width. Evaluation of body components is conducted both visually, usually with images to use as references, and by measurements. Analysis by body component is useful when more detail is needed than that provided by whole body evaluation.

The neck can be classified as average, wide, or narrow in width, or average, short, or long in length (Figure 8). No measurements accompany these images. (Minott, 1978)

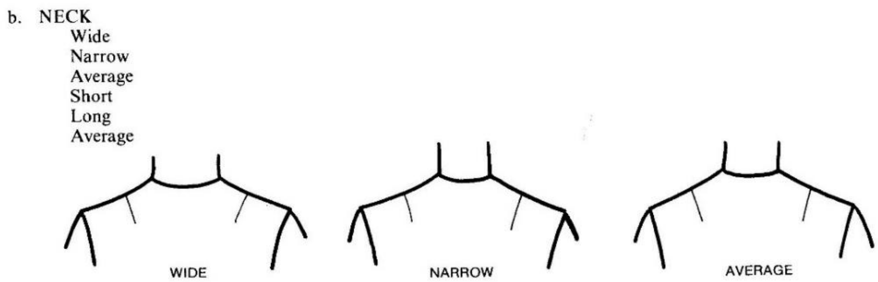


Figure 8: Neck Width and Length (from Minott, 1978, Fig. 7.1b, p. 52)

Shoulder slope is measured by extending a vertical line from the shoulder point to the level of the base of the neck. An average shoulder slope measures 2”, sloping shoulders measure more than 2”, and square shoulders measure less than 2”. (Maehren & Meyers, 2005).

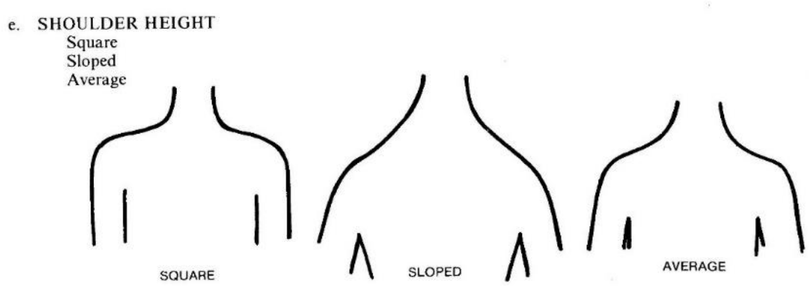


Figure 9: Shoulder Slope (from Minott, 1978, Fig. 7.1e, p. 53)

Shoulder width is determined by the difference between the shoulder blade measurement and the cross-back shoulder width measurement. Average figures have the same or up to a half inch difference, wide figures have back shoulder widths 5/8” or larger than their shoulder blade measurements, and narrow figures have shoulder blade measurements 5/8" or larger than their cross-back shoulder width measurement. (Minott, 1978). Figure 9 shows Minott's (1978) illustrations of shoulder slope, and Figure 10 shows her illustrations of shoulder width.

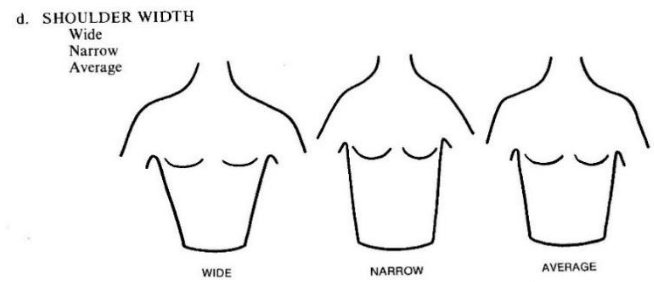


Figure 10: Shoulder Width (from Minott, 1978, Fig. 7.1d, p. 53)

Back width can be classified as average, broad or narrow in width (Figure 11). No measurements accompany these images. (Minott, 1978)

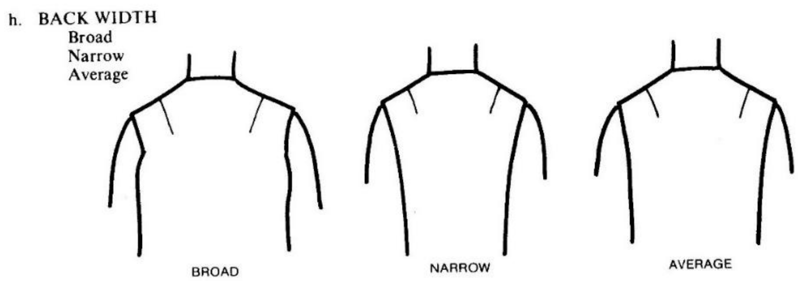


Figure 11: Back Width (from Minott, 1978, Fig. 7.1h, p.54)

The chest is the area above the bust and can be classified as hollow, prominent or average (Minott, 1978) (Figure 12).

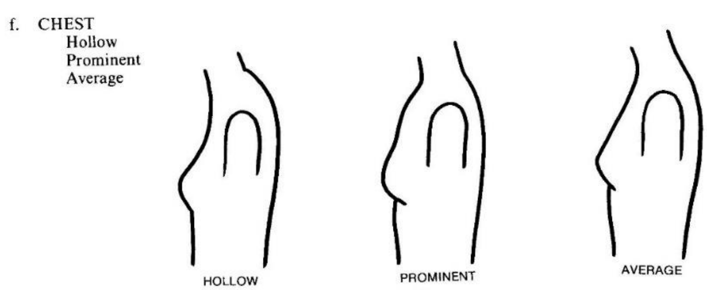


Figure 12: Chest (from Minott, 1978, Fig. 7.1f, p. 53)

The bust can be classified by fullness and by height of the bust point (Minott, 1978; Maehren & Meyers, 2005). Average fullness is considered a B cup, and the bust circumference measures 10” larger than the waist (Liechty et al., 1986; Maehren & Meyers, 2005). A full bust is considered a C cup or larger; and a small bust is an A cup, with little or no curve (Maehren & Meyers, 2005). There are no written explanations for bust point height, only the images provided by Minott (1978). Bust fullness and bust point height are illustrated in Figure 13.

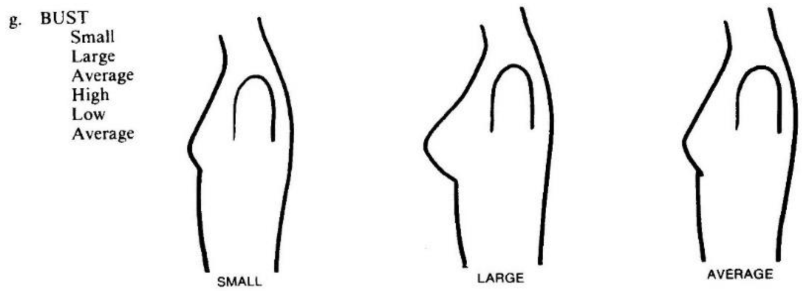


Figure 13: Bust (from Minott, 1978, Fig. 7.1g, p. 54)

The arms are primarily evaluated by upper arm fullness (Figure 14). Maehren and Meyers (2005) describe the average arm as softly curved without excessive flesh or muscle, and Minott (1978) quantifies the average arm as a 1.5” to 2.25” difference between the upper arm circumference and the elbow circumference. Full arms appear “heavy”, with more flesh and muscle (Maehren & Meyers, 2005). They are quantified by a 2.25” or greater difference between the upper arm circumference and elbow circumference (Minott, 1978). Thin arms appear bony, with little flesh or muscle mass (Maehren & Meyers, 2005), they are quantified by a 1/4” to 1 3/8” difference between the upper arm circumference and the elbow circumference (Minott, 1978).

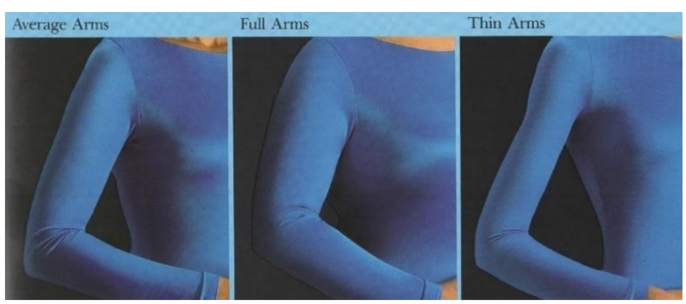


Figure 14: Arm Fullness (from Maehren & Meyers, 2005, p.29)

Maehren and Meyers (2005) classify the waist as either average, thick or small (Figure 15). An average waist has a 9.5” to 10” difference from the hip circumference. A thick waist has a less than 9.5” difference from the hip circumference and little to no waist indentation. A small waist has a greater than 10" difference from the hip circumference and a pronounced waist indentation.

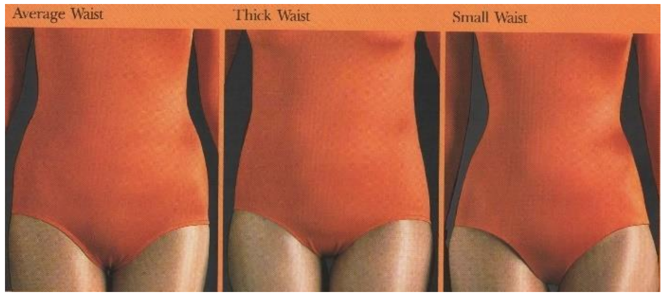


Figure 15: Waist (from Maehren & Meyers, 2005, p. 30)

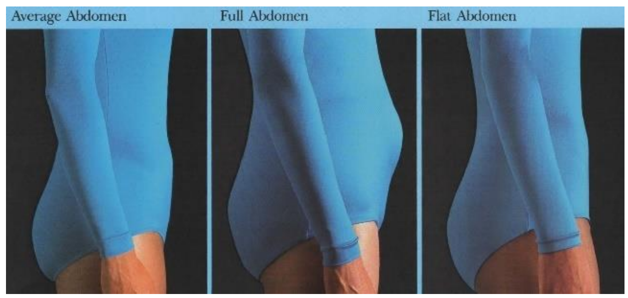


Figure 16: Abdomen (from Maehren & Meyers, 2005, p. 34)

The abdomen is below the waist and can be either average, full or flat (Figure 16). An average abdomen is slightly rounded, while a full abdomen is prominently rounded. A flat abdomen appears either straight or hollow. (Maehren & Meyers, 2005)

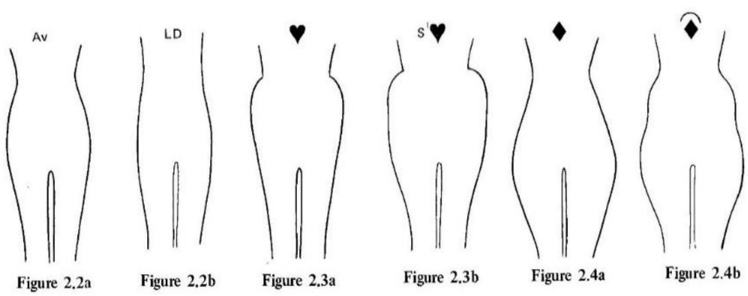


Figure 17: Hip shapes, from left: Average, Little Difference, Heart, Semi-Heart, Diamond and Rounded Diamond (from Minott, 1974, Fig. 2.2a & 2.2b, p. 11)

There are five options for the hips: Average, Small, Full, Heart and Diamond (Figure 17). There is disagreement on what an average waist-to-hip difference is. Liechty et al. (1986) quantify average hips at 10" larger than the waist; Maehren and Meyers (2005) argue they are 9.5" to 10" larger than the waist, a .5" range; and Minott (1978) argues they are 8" to 11.5" larger than the waist, a 3.5" range.

A disagreement also exists for the small hip shape (i.e. Minott's Little Difference hip shape). Maehren and Meyers (2005) quantify small hips as less than 9.5" larger than the waist, while Minott (1978) quantifies them at less than 8" larger than the waist; a 1.5" difference. Only Maehren and Meyers acknowledge the full hip shape, which is quantified as at least 10" larger than the waist.

Minott (1978) distinguishes between the upper and lower hip circumferences. The upper hip circumference is measured 3" to 4.5" below the waist. While not specified, the lower hip circumference may be considered the same as the true hip circumference, 7" to 9" below the waist.

Minott (1974, 1978) breaks the heart shape into two categories: Heart and Semi-heart. Heart has a greater upper hip circumference than lower hip or seat-level circumferences. The heart-shape is also prominently rounded below the waist. Semi-heart has similar upper and lower hip circumferences, with the lower hip circumference possibly up to 1.5" larger than the upper hip circumference. The curve below the waist is not as extreme as the heart shape.

Minott (1974, 1978) breaks the diamond shape into two categories: Diamond and Rounded Diamond. Diamond is distinguished by prominent thighs and a lower hip 11.5" or larger than the waist. The rounded diamond is distinguished by both prominent thighs and curves below the waist. There is a 2" or more difference between the upper and lower hip circumferences, and there may be less than an 11.5" difference between lower hip and waist.

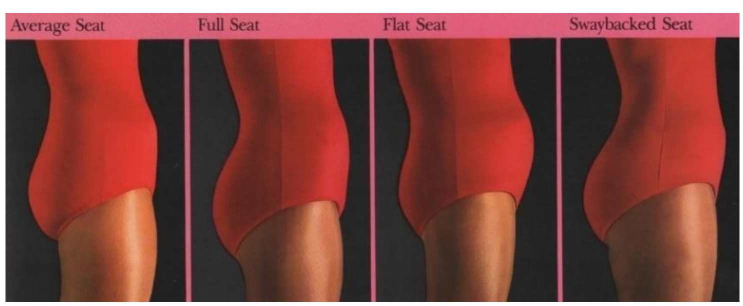


Figure 18: Seat (from Maehren & Meyers, 2005, p. 35)

Maehren & Meyers (2005) outline four options for seat shape: Average, Full, Flat and Swaybacked (Figure 18). Average seats have a small, high curve. Full seats have larger, rounded curves. Flat seats have little to no curve. Swaybacked seats jut prominently from the hollow just below the waist.

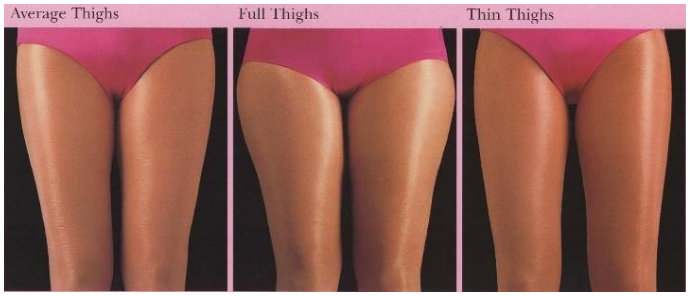


Figure 19: Thighs (from Maehren & Meyers, 2005, p. 32)

Maehren and Meyers (2005) classify three thigh fullness's: Average, Full and Thin (Figure 19). An average thigh is softly rounded, with a small gap between the inner thighs. Full thighs bulge out and have no gap between the thighs. Thin thighs appear straight along the inner thigh and have a large gap.

Body Shape Assessment Scale

The Body Shape Assessment Scale (BSAS)© was created by Connell, Ulrich, Brannon, Alexander and Presley (2006) to address the issue of body shape classification. It is the only academic research that combines posture, whole-body form, and component body form classification. This study identified existing body shape scales, tested them using 42 body scans of women aged 20-55, and developed the following nine BSAS© subscales from the results:

1. Body Build: Slender, Average, Full and Heavy
2. Body Shape: Hourglass, Pear, Rectangle, and Inverted Triangle
3. Hip Shape: Straight, High, Mid, and Low
4. Shoulder Slope: Square, Average, and Sloped
5. Front Torso Shape: b, B, & D
6. Bust Shape: Flat, Average, and Prominent
7. Buttocks Shape: Flat, Average, and Prominent
8. Back Shape: Flat, High, Middle, and Low
9. Posture: Aligned, Forward Alignment, and Compensating Alignment

Body Build, Body Shape and Posture are for the whole body, while the remaining six are for body components. An additional 100 scans were classified by five experts using the BSAS© and the results were utilized to create a software program for assessing large populations quickly and efficiently.

The Body Shape subscale was adapted from August (1981), which used six body shapes: circle, pear, rectangle, inverted triangle and hourglass. Connell et al. (2006) observed no circle or inverted triangle shapes in their sample of 42 women, thus those were eliminated from the scale. The Female Figure Identification Technique (FFIT) for apparel study (Istook et al., 2004) has nine statistically validated shapes (Devarajan, 2003), which include an inverted triangle and an oval shape. Why the FFIT for apparel shapes were not included is unclear, as they are covered in the literature review. At the very least the nine FFIT shapes should have suggested to the BSAS© researchers that four shapes are too few to cover the entire population adequately.

The terminology used in the BSAS© is subjective. For example, one person's "flat" could be another person's "average". Additional queries include how body build is determined and if there is a mathematical formula to distinguish between "full" and "heavy". One interesting observation by the authors was that subjects who barely belong to one category are close to belonging to adjacent categories. This points to the fluidity of body shape and marks one of the major difficulties involved in classification of biomorphic forms.

Section Summary

Based on the above review of sizing systems and shape assessment scales and incorporating the theoretical understanding that the human body is a biomorphic form, the first assumption of this study is: People have unique and distinctive body forms.

In apparel, form categorization is a means to an end. Knowing the form provides useful information for designing, patterning, fitting, and aesthetics.

Pattern

This section outlines and critiques research concerning patternmaking and grading practice. Of specific interest are the underlying assumptions of patternmaking and grading. This section ends with the second underlying assumption of this research study, and the research questions.

What is a pattern?

There are three ways to create garment patterns in the garment industry. The first is draping, where a designer manipulates fabric directly on a body-form. The second is drafting, where a designer uses measurements to draft a two-dimensional garment pattern, either on paper or a computer. The third method is flat patterning, which manipulates basic drafted patterns to create stylized patterns for grading and production.

There are three types of garment patterns in the garment industry. A foundational pattern is called a basic block, a sloper, or a master. They have no style lines, style ease, seam allowances, hems, dart interiors, or markings. A style block is a variation of the basic block that represents a manufacturer's preferred starting style or silhouette. Style blocks include style lines and ease, but not seam allowances, hems, dart interiors, or markings. The style block is graded up and down to provide a manufacturer with a range of sizes for production. Production patterns are the final type of garment pattern. They are used to make markers for cutting materials, and include style lines, style ease, seam allowances, hems, dart interiors, and all pattern markings needed to ensure correct production of the final garment. (Joseph-Armstrong, 2006).

Ease is the space between the garment and the body. There are two types of ease: basic and style. Basic, comfort, or movement ease allows for necessary body movements, such as breathing and walking. In general, the industry uses two inches of basic ease at the bust and hips and one inch of basic ease at the waist. Style ease is any additional space added after the addition of basic ease. The amount of style ease added depends on the designer's intentions for garment aesthetics.

As discussed in the body-form section, a shape is a two-dimensional enclosed space, distinctly separated from its surroundings in some way (Hemmis, 2016). Remember also that the human body is a biomorphic form, thus it is a three-dimensional ambiguous shape. In this study, a garment pattern is a two-dimensional abstraction of a body's form; in other words, a garment pattern is the shape that represents a given body-form.

History

Before the industrial revolution made ready-made apparel available cheaply, all clothing was custom-made. Dressmakers and tailors analyzed the body-form and movements of their clients, to produce garments that fit perfectly (Kidwell & Christman, 1974). A brief history of garment manufacture provides understanding of how the garment industry ended up with the patterning, grading, and sizing system that it has now.

The original unit of measure for tailors was a strip of parchment paper, notched at important body locations for each client. These notched strips were eventually replaced with tape measures, which included units of measurement instead of notches. Measurements from the tapes became the basis for drafting patterns and cutting material in the eighteenth and nineteenth centuries. (Kidwell & Christman, 1974; Aldrich, 2007)

Originally, new clothing was created from measurements taken from the client's garments, not their bodies. In the mid-1800s tailors started measuring the bust and waist under a client's attire, though remaining measurements were still taken over the garment. It wasn't until the beginning of the 1900's that taking measurements near the body became the standard. (Aldrich, 2007)

Dressmakers relied on the creation of a 'body' (i.e. the pattern shape that fit an individual's body) to make women's apparel. Aldrich (2007) argues that as literacy rates increased amongst women, dressmakers started publishing pattern-drafting books to show their process and provide peers with templates and measurement tools. The method of drafting a 'body' was simple, and various styles of garment could be created from this base pattern. The 'body' is the origin of the current basic blocks used by the garment industry. (Aldrich, 2007)

Ready-made apparel began due to America's rising class demanding clothing as aesthetically pleasing as those worn by America's upper class, though without the price attached to 'customers work'. Tailors responded by modifying their manufacturing process to provide respectable, reasonably priced clothing for purchase directly off the shelf. (Kidwell & Christman, 1974)

The shift from 'customers work' to ready-made required a reimagining of the pattern-drafting process. Tailors invented two drafting systems during the first half of the nineteenth century: Direct, and Proportional. Direct systems used a variety of measurements taken from a body or garment to calculate pattern points and draft a new pattern. Proportional, or divisional, systems were based on the principle that the human body is proportional and that a single measurement, for example the bust, could predict the rest. The proportional system led to the idea of proportional sizing, which is the foundation of current ready-made sizing and grading. (Kidwell & Christman, 1974; Heisey, Brown & Johnson, 1988; Aldrich, 2007).

The mid-1800s brought about the American Civil War, with thousands of soldiers in need of uniforms, as well as a newfound interest in human anatomy, specifically the study of body proportions. Soldiers were measured and their data analyzed. Guillame Compaing and Henry Wampen used their knowledge of human anatomy to create the earliest grading systems. In 1881, Charles Hecklinger, an American tailor, combined the idea of the 'body' with proportional drafting to develop the first systematic adaptation methods for block patterns, which became the basis for applying size charts to patterns (Kidwell & Christman, 1974; Aldrich, 2007).

Improvements in textile technology, manufacturing equipment and systems, transportation, the development of an American wool industry, and an influx of semi-skilled immigrants allowed the American garment industry to flourish (Kidwell & Christman, 1974; Aldrich, 2007). The creation of the 'progressive bundle system', where similar pieces of individual garments were cut and bundled together for easier transportation around the factory, improved factory efficiency (Aldrich, 2007).

With the increase in manufacturing, grading methodology changed. The three most popular grading methods were: Vincent's 1908 nesting system, Scheifer's 1908 shift system, and the radial system. Vincent's nesting system had a pattern-maker draft the smallest, middle, largest sizes, which were nested; diagonal lines were drawn through the main points of these three patterns and the remaining sizes were marked along these lines. Scheifer's shift method began with a base pattern and, by following a set of instructions, a semi-skilled worker could grade any pattern. The radial method was a combination of the previous two methods whereby radial lines extend from specific points of a base pattern and alternate sizes were marked along the radial lines. (Aldrich, 2007).

Men's ready-made apparel was easily attainable and of good quality. Women's lagged behind. Aldrich (2007) attributed this lag to the complexity of women's garments in the late nineteenth century: the corset, the tailored bodice, and the tailored jacket. The years 1908 to 1913 saw a drastic change in women's styles. The corset was abandoned in favor of a more relaxed, 'soft cylinder' look, which could easily be drafted with a rectangular block pattern. Along with the change in style came a change in attitude: women began believing that ready-made was superior to home-made. (Aldrich, 2007).

All of the changes the American apparel industry went through during the two hundred years of the industrial revolution improved the financial security of the country, eliminated class-distinctions in dress and made American citizens the richest average citizens in the world. And, while manufacture of ready-made became more consistent than home-made, the loss of skill in fitting garments has set the current apparel industry a new round of problems.

Research

Research into pattern shape focuses either on grading or on pattern shape change driven by the body. Schofield and LaBat (2005a) analyzed 40 US sizing charts from 1873 to 2000, finding that a) all charts had constant intervals between sizes for all measurements, b) as size increased so did all vertical measurements, c) there were constant differences between the principle girths, and d) grades were used. It was concluded that grading predates sizing systems, sizing is partially based on accepted practice, and that very few grade rules are based on body measurements. Schofield and LaBat (2005b) built upon their previous research by testing the grading assumptions they discovered. Two bodice patterns, one with grade rules from traditional grading practices, and one with grade rules developed from regression analysis of the 1988 ANSUR survey, were compared. They concluded that none of the grading assumptions of traditional grading were supported.

Bye, LaBat, McKinney, and Kim (2008) compared traditional grading practices to optimum ones through the evaluation of the fit of sheath dresses drafted using traditional grading rules, and sheath dresses custom-fit to subjects. Eight women, ranging in age from 19 to 36 years, were found that matched the bust, waist, hop, and height measurements for ASTM D5585-95 sizes 6-20. The size 8 was used as the fit model. A basic sheath dress (side seam front bust darts, two front and two back waist darts, back shoulder darts, opening at center back and no waistline seam) was graded using traditional grading methods, with grade intervals of 1" for sizes 6-10, 1.5" for sizes 10-18, and 2" for sizes 18-20. Ease amounts were kept consistent throughout the range at 2" at the bust and hip, and 1" at the waist. Participants were scanned in the traditionally graded dresses to provide a permanent record.

The fit-to-shape patterns were made by adjusting the sheath dresses until they visually met all eight of Armstrong's (2000a, b) fit criteria:

1. "center front and center back aligns with the body center;
2. armscye fits smoothly;
3. the waist level aligns with body waist;
4. no stress or gapping at neckline;
5. side seam hangs vertically;
6. shoulder seam centered on the shoulder;
7. skirt hangs straight from the hip to the hem and cross grain parallel to the floor; and
8. no strain at bust, waist or hip." (Bye et al., 2008, p. 82-3).

After adjusting the dresses on the subjects, the patterns were adjusted to reflect these changes.

The final dresses and corresponding patterns were analyzed both quantitatively and qualitatively. Quantitative analysis included counting the number of adjustments, organizing the adjustments by body measurement and grade location for each size, averaging the adjustments for each size; nesting the patterns and analyzing for differences between sizes, comparing the sizes between the two nests; and measuring and comparing key pattern segments. Qualitative analysis included visually assessing the difference between the traditionally graded pattern and the fit-to-shape pattern for each size, as well as comparing the silhouettes of each subject to every other subject.

The average number of alterations was 3.4 per size, and more than half of the total alterations occurred in the neck and shoulder areas. Due to the number of alterations and the placement of the alterations, the authors concluded that traditional grading does not provide good fit across a size range. Based on its exploratory nature, the results of this study cannot be generalized, but when combined with the results of Schofield and LaBat (2005a, b), indicate that traditional manufacturing cannot provide well-fitting apparel for a population.

A few studies compare patterns from different body forms, though they do not compare the pattern to the body. Schofield, Ashdown, Hethorn, LaBat, and Salusso (2006) explored satisfaction with pant shape for women 55 and older. One hundred and seventy-six women, aged 55 to 80, tried on pants with either a full- or flat-seat, performed simple movements in the pants, and rated their satisfaction with the pants. In addition, experts analyzed the fit of the pants. The majority of subjects preferred the flat-seat pants, and expert analysis determined that the flat-seat pants fit subjects best.

The largest issue with this study was that while the researchers used hip circumference as the primary control dimension when sizing the pant patterns, the participants were allowed to choose any size their preferred for the fit evaluations. This changed the study from observing "objective good fit" to observing "subjective good fit", which was not the stated aim of the study. This could have skewed the results of the expert evaluators, as they were not looking at pants that were supposed to fit correctly. To see how well the pants fit based on linear measurements, the researchers needed to assign sizes based on participants' linear measurements.

Sohn and Bye (2012) investigated changes in sheath dress patterns throughout the three pregnancies of two women; finding that each woman's body changed differently, resulting in two very different patterns. This study provided evidence that a) grading should not be proportional because humans do not grow proportionally, and b) different bodies change differently and that these differences affect the patterns.

Song and Ashdown (2012) built upon their 2011 study, which found three lower-body forms (curvy, hip tilt, and straight) from an analysis of 2,981 18-to-35-year-old SizeUSA subjects. In the 2012 study, they tested if basic blocks created for these three lower-body forms were a better starting point in the customization of pants than a standard basic block.

Out of the 83 female participants (aged 18 to 35), nine participants were used as fit models for each of the three groups and nine participants were used as fit testers for each of the three groups. Each of the fit models had two pairs of pants created for them – one pant was customized using the body-form block pattern as the base (Type A), and one pant was customized using the industry pattern as the base (Type B). The 27 participants tried on both pairs of pants, filled out a questionnaire assessing twelve body locations, and at the end of the fit session were asked to choose the pair that fit best. Three fit experts were asked to judge the fit using photographs taken of the participants and were asked to choose the best fitting pair of pants for each participant.

For the fit experts, out of 81 of the total comparisons, 70.4% were in favor of the shape-driven customized pants, and 24.7% were in favor of the standard-driven customized pants. The Type A pant was scored significantly higher than the Type B pant. For the fit models, 59.3% selected the Type A pant, and 40.7% selected the Type B pant as the best fitting pant. The researchers concluded that basic blocks made using body form information generates better fitting customized patterns.

Section Summary

Based on the above analysis of history and patterning practice, it becomes clear that body-form variation does affect apparel block shapes. Additionally, the way we have traditionally graded and sized patterns is not sufficient to provide the current population with well-fitting clothing.

Chapter 3 Sample Selection

This chapter presents the sample selection process. To facilitate understanding of body form variations, female subjects who share a single size were selected. Body scans of female subjects from both the University of Minnesota's Human Dimensioning Laboratory© scan database and the CAESAR database were analyzed and selected for inclusion based on four factors: gender, age, height, and circumference measurements for the bust, waist, and hips.

HDL Master Database

The University of Minnesota's College of Design houses the Human Dimensioning Laboratory© (HDL) which maintains a database of scanned subjects for use in research. This Master Database (MDB) consists of 365 scans from 305 subjects. Both genders are included and range in age from 18 to 78 with an average age of 26. Three subjects are pregnant, and over half the subjects are Caucasian, with 35.6% electing not to include their race. The majority of female subjects wear bras and panties while the male subjects wear either boxers or briefs. Descriptive statistics for the database are summarized in Table 4 and Table 5.

Summary				
Race	**# Females**	**# Males**	**# Total**	**% Total**
White	176	23	199	54.5%
No Response	130	0	130	35.6%
Asian	24	3	27	7.4%
Other	3	0	3	0.8%
African American	2	0	2	0.5%
Mixed White/African American	2	0	2	0.5%
Native American/Alaskan	1	0	1	0.3%
Mixed White/Asian	1	0	1	0.3%
Total	339	26	365	100.0%

Table 4: MDB Racial Diversity - entire population

Summary					
# Subjects	365				
Age		**Height**		**Weight**	
Mean	26	Mean	66.35"	Mean	146.2 lbs
Median	21	Median	66.18"	Median	140.0 lbs
Mode	20	Mode	65.89"	Mode	130.0 lbs
Minimum	18	Minimum	58.91"	Minimum	97.4 lbs
Maximum	78	Maximum	77.55"	Maximum	295.6 lbs
Bust		**Waist**		**Hips**	
Mean	37.27"	Mean	32.88"	Mean	40.70"
Median	36.54"	Median	32.06"	Median	40.18"
Mode	35.51"	Mode	33.97"	Mode	40.18"
Minimum	25.70"	Minimum	23.97"	Minimum	32.30"
Maximum	55.13"	Maximum	59.91"	Maximum	59.63"

Table 5: MDB Description - entire population

To narrow the subject pool four criteria were applied to the MDB:

1. Subjects must be female.
2. Subjects may not be pregnant.
3. Only one scan per subject, and subject must have all data readily available.
4. Subjects must be between 18 and 54 years of age.

Only one scan per subject was used, so for subjects with multiple sets of data the researcher chose the scan that a) assumed the proper scanning posture, and b) wore underwear. The scansuits used by subjects in the MDB are illustrated in Figure 20. In a comparison of fourteen torso measurements from thirty-two subjects wearing only bras and underpants, to the same subjects wearing scansuits, Kim, LaBat, Bye, Sohn, & Ryan (2014) found that scansuits compress the body, resulting in smaller measurements. Underwear scans were preferable to scansuit ones, though both were included.

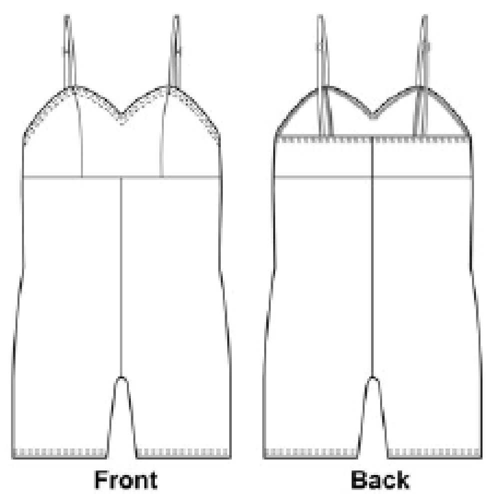


Figure 20: Technical sketch of HDL scansuit from Kim et al. (2014), Fig. 2, p. 5

The 18-54 age range was chosen to follow the ASTM age groupings, which splits adult women into two groups, 18-54 and 55+.

Application of these four criteria resulted in 256 female subjects with an average age of 23 and similar diversity profile to the broader database.

CAESAR Database

The Human Dimensioning Laboratory© owns a copy of the CAESAR database, which includes scans, measurements, and demographic information for each subject. CAESAR North America includes 2391 subjects, of which over 75% are Caucasian. Age ranges from 18 to 79, with an average age of 40. Female subjects wear a sports bra and short bicycle shorts. Male subjects wear bicycle shorts. Descriptive statistics for this database are summarized in Table 6 and Table 7.

The CAESAR North America database was screened using the same criteria as the MDB database. Application of the criteria resulted in 1109 female subjects with an average age of 37 and similar diversity profile to the broader database.

Summary					
# Subjects	2391				
Age		**Height**		**Weight**	
Mean	40	Mean	67.11”	Mean	169.8 lbs
Median	39	Median	66.93”	Median	162.5 lbs
Mode	39	Mode	66.73”	Mode	151.0 lbs
Minimum	18	Minimum	49.13”	Minimum	86.5 lbs
Maximum	79	Maximum	82.05”	Maximum	399.9 lbs
Bust		**Waist**		**Hips**	
Mean	39.24”	Mean	33.39”	Mean	41.35”
Median	38.50”	Median	32.76”	Median	40.59”
Mode	36.22”	Mode	28.35”	Mode	41.42”
Minimum	29.09”	Minimum	21.93”	Minimum	31.50”
Maximum	61.97”	Maximum	67.01”	Maximum	72.20”

Table 6: CAESAR Description - entire population

Summary				
Race	**# Females**	**# Males**	**# Total**	**%**
White	964	872	1836	76.8%
African American	148	116	264	11.0%
Asian/Pacific Islander	93	83	176	7.4%
Asian/Pacific Islander Chinese	45	38	83	3.5%
Asian/Pacific Islander Filipano	16	13	29	1.2%
Asian/Pacific Islander Asian Indian	4	13	17	0.7%
Asian/Pacific Islander Japanese	7	9	16	0.7%
Asian/Pacific Islander Vietnamese	11	4	15	0.6%
Asian/Pacific Islander Korean	7	4	11	0.5%
Asian/Pacific Islander Other	3	2	5	0.2%
Spanish/Hispanic	18	33	51	2.1%
Spanish/Hispanic Mexican American	8	16	24	1.0%
Spanish/Hispanic Other	8	11	19	0.8%
Spanish/Hispanic Puerto Rican	2	3	5	0.2%
Spanish/Hispanic Cuban	0	3	3	0.1%
Other Mixed Race	25	12	37	1.5%
Other Not Listed Above	7	4	11	0.5%
No Response	5	4	9	0.4%
Native American/Alaskan	4	3	7	0.3%
Total	1264	1127	2391	100.0%

Table 7: CAESAR Racial Diversity - entire population

Height

This study focused on understanding body form variations within a single size, so it was necessary to limit the height range so that extreme variations did not skew results.

The American Society for Testing and Materials' (ASTM) sizing standards were reviewed for height ranges for the Misses category. The most current standard, ASTM D5585-11^{e1}, sets the height for all sizes at 65". Alternative ASTM standards were reviewed and are summarized in Table 8.

Standards	Minimum	Maximum
ASTM D5585-11^{e1}, Misses 00-20	65"	65"
ASTM D5585-95 (2001), Misses 2-20	63.5"	68"
ASTM D7878-13^{e1}, Misses Petite 00P-20P	62.5"	62.5"
ASTM D5586-10, Misses 55+	62.7"	67.08"
ASTM D5586-10, Misses Tall 55+	66.66"	69.81"
ASTM D5586-10, Misses Petite 55+	59.63"	62.57"

Table 8: Height ranges in ASTM size standards

ASTM D5585-95 (2001), an older version of the Misses standard, spans a range of 4.5", which might not show variations in body form due to height. ASTM D7878-13^{e1}, the current standard for Misses Petite, sets the height for all sizes at 62.5". This was the shortest height found, so it was set as the lower limit for this study's height range.

ASTM D5586-10, the current standard for Misses 55+ gives ranges for all subsets of the 55+ standard (Misses, Tall, Petite, Women's, Half-sizes), but they overlap. Additionally, the ASTM D5586-10 set includes a comparison of heights for D5586 to D5585, indicating that the sizes from the different standards do not correspond to each other, rendering D5586 inappropriate for evaluating women under 55 years of age.

With no acceptable upper limit provided by ASTM, the researcher consulted with two experts who suggested setting the upper limit at 70". The full range then became 62.5" to 70", which spanned 7.5".

Application of this height criterion to both the MDB and CAESAR databases resulted in 215 and 821 female subjects, respectively. The average ages and diversity profiles of the datasets remained the same as the screened ages and diversity profiles for the databases.

Method

Two methods were tested to establish a sample set for this research. The first method sorted subjects into ASTM sizes, but failed to produce a large enough sample size. The second was a self-sorting method which produced nineteen sample sets with 40+ subjects per group. One sample set was selected for this study.

Both methods used the bust, waist and hip girth measurements of the subjects, as they are important for both body form and garment fit. Istook et al. (2004) used these measurements when developing the Female Figure Identification Technique (FFIT) for apparel software. In their study of fit preferences of young adult women Alexander, Connell, and Presley (2005) found that a majority of their sample had fit problems at the bust, waist and hips of their clothing. Additionally, in a test of how accurate ASTM D6960-04 was Alexander et al. (2012) used bust, waist, and hip girth measurements to sort subjects from the Size USA database into standard sizes.

ASTM D5585-11^{e1}

The American Society for Testing and Materials (ASTM) provides the apparel industry with voluntary product standards for use in sizing clothing. The current Misses standard, D5585-11^{e1} *Standard Tables of Body Measurements for Adult Female Misses Figure Type, Size Range 00-20,* was used in this study (Figure 21). Using data from the U.S. Department of Commerce, CAESAR, Size USA, Alvanon Inc. and various industry sources, D5585-11^{e1} is the most up to date sizing standard available (ASTM International, 2011).

This standard introduced two body types: Curvy and Straight. These two shapes are defined by different values for the waist, high hip, hip seat, thigh and mid-thigh girth measurements (ASTM International, 2011). This study evaluated subjects based on the values for the Straight body type due to findings in Lee et al. (2007) that indicated American women are predominantly rectangular in shape.

TABLE 1 Body Measurements, Inch-Pound Units

Size	00	0	2	4	6	8	10	12	14	16	18	20
Body Weight (Mean), lb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Body Weight (Range), lb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Girth Measurements, in.	00	0	2	4	6	8	10	12	14	16	18	20
Head Girth	21¼	21¼	21½	21½	21¾	21¾	22	22	22¼	22¼	22½	22½
Neck Base Girth	13¼	13½	13¾	14	14¼	14⅝	14⅞	15⅛	15½	15¾	16	16⅜
Mid-Neck Girth	12⅜	12⅝	12⅞	13⅛	13⅜	13⅝	13⅞	14¼	14⅝	15	15½	16
Shoulder Girth	37⅛	37¾	38⅜	39	39¾	40½	41¼	42	43	44¼	45½	46⅞
Chest/Bust Girth	31⅛	31¾	33	34⅛	35¼	36¼	37¼	38¾	40⅜	42⅛	44	46
Under-Bust Girth	25¾	26½	27¼	28	29	30	31	32½	34	35¾	37⅝	39⅝
Upper-Chest Girth	31¾	32¼	33¼	34⅛	35	35⅞	36¾	38	39¼	40⅝	42¼	43⅞
Waist Girth – Curvy	23⅞	24⅝	25⅜	26⅛	27	28	29	30¾	32½	34½	36¾	39
Waist Girth – Straight	25⅜	26⅛	26⅞	27⅝	28½	29½	30½	32¼	34	36	38¼	40½
High-Hip Girth – Curvy	29½	30¼	31⅛	32⅝	33¾	34¾	35¾	37¼	38⅞	40½	42¼	44⅜
High-Hip Girth – Straight	29¾	30½	31⅜	32⅞	34	35	36	37½	39⅛	40¾	42½	44⅝
Hip/Seat Girth – Curvy	34	34⅝	35⅞	37⅛	38¼	39¼	40¼	41¾	43¼	45	46¾	48¾
Hip/Seat Girth – Straight	33¼	33⅞	35⅛	36⅜	37½	38½	39½	41	42½	44¼	46	48
Thigh Girth – Curvy	20½	20⅞	21¼	21⅝	22⅛	22⅝	23⅛	24	24⅞	26¼	27½	28¾
Thigh Girth – Straight	20⅛	20½	20⅞	21¼	21¾	22¼	22¾	23⅝	24½	25¾	27	28¼
Mid-Thigh Girth – Curvy	18⅜	18¾	19⅛	19½	20	20½	21	21⅞	22¾	23¾	24⅞	26
Mid-Thigh Girth – Straight	18⅛	18½	18⅞	19¼	19¾	20¼	20¾	21⅝	22½	23½	24⅝	25¾
Knee Girth	12⅝	12¾	13	13⅜	13¾	14⅛	14½	15	15½	16	16½	17
Calf Girth	12⅛	12¼	12½	12⅞	13¼	13⅝	14	14½	15	15½	16	16½
Ankle Girth	8⅛	8¼	8⅜	8⅝	8⅞	9⅛	9⅜	9⅝	9⅞	10⅛	10⅜	10⅝
Armscye Girth	14½	14¾	15⅛	15½	15¾	16	16¼	16⅞	17½	18⅛	18⅞	19⅝
Upper-Arm Girth	9¾	10	10¼	10½	10¾	11⅛	11½	11¾	12⅛	12½	13	13⅝
Elbow Girth	9⅛	9¼	9⅜	9½	9⅝	9¾	9⅞	10⅛	10⅜	10⅝	11	11⅞
Wrist Girth	5⅛	5¼	5⅜	5¾	5⅞	6	6⅛	6¼	6⅜	6½	6⅝	6¾
Hand Girth	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trunk Length (total vertical girth) – Curvy	57⅛	57½	58	58½	59	59½	60	60⅞	61¾	62⅞	64	65⅛
Trunk Length (total vertical girth) – Straight	57	57⅜	57⅞	58⅜	58⅞	59⅜	59⅞	60¾	61⅝	62¾	63⅞	65
Vertical Measurements, in.	00	0	2	4	6	8	10	12	14	16	18	20
Height, in.	65½	65½	65½	65½	65½	65½	65½	65½	65½	65½	65½	65½
Head and Neck Length	9¼	9¼	9¼	9¼	9¼	9¼	9¼	9¼	9¼	9¼	9¼	9¼
Cervicale Height	56¼	56¼	56¼	56¼	56¼	56¼	56¼	56¼	56¼	56¼	56¼	56¼
Cervicale to Crotch – Curvy	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾
Cervicale to Crotch – Straight	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾	25¾
Center Back Waist Length	16⅛	16⅛	16⅛	16⅛	16⅛	16⅛	16⅛	16¼	16⅜	16½	16⅝	16¾
Center Front Waist Length	13⅞	14	14⅛	14¼	14⅜	14½	14½	14⅝	14¾	14⅞	15	15⅛
Scye Depth	5¾	5¾	5⅞	6	6⅛	6⅛	6¼	6⅜	6½	6¾	6⅞	7
Side Waist Length	8½	8½	8⅜	8¼	8⅛	8⅛	8	7⅞	7⅞	7¾	7⅝	7⅝
Waist to Hip/Seat Height – Curvy	8⅛	8⅛	8¼	8¼	8¼	8¼	8¼	8¼	8¼	8¼	8¼	8¼
Waist to Hip/Seat Height – Straight	8⅛	8⅛	8⅛	8⅛	8⅛	8⅛	8⅛	8⅛	8⅛	8⅛	8⅛	8⅛
Waist to Knee Height – Curvy	22⅞	22⅞	23	23	23	23	23	23	23	23	23	23
Waist to Knee Height – Straight	22⅞	22⅞	22⅞	22⅞	22⅞	22⅞	22⅞	22⅞	22⅞	22⅞	22⅞	23
Waist Height	40½	40½	40½	40½	40½	40½	40½	40½	40½	40½	40½	40½
High-Hip Height	37	37	37	37	37	37	37	37	37	37	37	37
Hip/Seat Height	32½	32½	32½	32½	32½	32½	32½	32½	32½	32½	32½	32½
Crotch Height	30½	30½	30½	30½	30½	30½	30½	30½	30½	30½	30½	30½
Rise Height	10	10	10	10	10	10	10	10	10	10	10	10
Knee Height	17⅞	17⅞	17⅞	17⅞	17⅞	17⅞	17⅞	17⅞	17⅞	17⅞	17⅞	17⅞
Ankle Height	2¾	2¾	2¾	2¾	2¾	2¾	2¾	2¾	2¾	2¾	2¾	2¾
Width and Length Measurements, in.	00	0	2	4	6	8	10	12	14	16	18	20
Crotch Length (total)	24¼	24½	24¾	25	25¼	25½	25⅞	26¼	26¾	27¼	27¾	28¼
Shoulder Length	4¾	4⅞	4⅞	5	5	5⅛	5⅛	5⅛	5¼	5¼	5⅜	5½
Shoulder Slope	20⅜ °	20¼ °	20⅛ °	20°	19⅞ °	19⅝ °	19½ °	19¼ °	19°	18¾ °	18⅜ °	18⅛ °
Shoulder Drop	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝
Across Back Shoulder Width	14½	14⅝	14⅞	15⅛	15¼	15½	15⅝	15¾	16	16⅜	16¾	17⅛
Across Front Shoulder Width	14½	14⅝	14⅞	15⅛	15⅜	15¾	15⅞	16	16¼	16¾	17	17⅜
Upper Back Width	13¼	13½	13¾	14	14¼	14½	14⅝	14¾	15	15⅜	15¾	16⅛
Upper Front Chest Width	12⅜	12⅝	12⅞	13⅛	13⅜	13⅝	13⅞	14	14¼	14⅝	15	15⅜
Back Width	12⅞	13	13¼	13½	13⅞	14⅛	14⅜	14⅝	14⅞	15¼	15⅝	16⅛
Front Chest Width	12⅝	12¾	13⅛	13½	13⅞	14¼	14⅝	15	15½	15⅞	16½	17⅛
Bust Point to Bust Point	6⅝	6¾	7	7¼	7½	7¾	8	8¼	8½	8¾	9	9¼
Neck to Bust Point	9¾	9⅞	10	10⅛	10¼	10⅜	10½	10¾	11	11¼	11½	11¾
Bust Point to Bust Point (Halter)	25⅝	26	26⅜	26¾	27⅛	27½	27⅞	28½	29⅛	29¾	30⅜	31
Cervicale to Wrist Length	30⅛	30¼	30⅜	30½	30⅝	30¾	30¾	30¾	30⅞	31⅛	31¼	31½
Shoulder and Arm Length	27⅝	27¾	27¾	27⅞	27⅞	28	28	28	28⅛	28¼	28⅜	28½
Arm Length	22¾	22⅞	22⅞	22⅞	23	23	23	23	23	23	23	23
Hand Length	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hand Width	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Foot Length	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Foot Width	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Figure 21: ASTM D5585-11^{e1} Standard table of body measurements for adult female Misses figure type, size range 00-20 (ASTM International, 2011, p. 3)

ASTM Size 12 Filter

The MDB subset was filtered to find subjects within +/-1" of the ASTM D5585-11^{e1} bust, waist and hip girth measurements for the straight size 12. ASTM D5585-11^{e1} uses variable grading, though the differences are all in increments of one-eighth inches. Size 12 was chosen because analysis of the ASTM standard showed it to have a minimum 1.5" grade between adjacent sizes.

An excel spreadsheet was created with the 215 eligible subjects' database number, bust, waist, and hip girth measurements. The following formula was used:

=IF(AND(SGIRTH<=AGIRTH+1,SGIRTH>=AGIRTH-1)=TRUE,1,0)

Where 'SGIRTH' corresponds to the girth measurement for each subject, and 'AGIRTH' corresponds to the ASTM girth measurement for size 12. For size 12 the bust girth is 38.75", the waist girth is 32.25", and the hip girth is 41". The formula finds if a subject's girth measurement is between -1" and +1" of the ASTM size 12 measurement for each individual circumference. The same formula was applied to the CAESAR North American dataset. Results are summarized in Table 9.

	Bust	Waist	Hips	Total	Bust + Waist	Bust + Hips	Waist + Hips	All Three
MDB	16	23	32	71	5	11	4	1
CAESAR	46	47	119	212	26	28	18	7
Total	62	70	151	331	31	39	22	8

Table 9: Results from ASTM Size 12 Filter for MDB and CAESAR

Combining the seven subjects from the CAESAR database with the one subject from the MDB resulted in a total of eight subjects. Eight subjects are not an adequate sample size, so both CAESAR and the MDB were reviewed to see if any of the ASTM D5585-11^{e1} sizes (00-20) produced an acceptable sample size for this study.

Final Subset: MDB + CAESAR

Combining the eligible candidates from the MDB and CAESAR databases resulted in 1036 subjects. The age range of this subset is 18 to 54, with an average age of 34. Descriptive statistics for the final subset are summarized in Table 10 and Table 11.

Summary					
# Subjects	1036				
Age		**Stature**		**Weight**	
Mean	34	Mean	65.56”	Mean	152.6 lbs
Median	34	Median	65.31”	Median	143.5 lbs
Mode	20	Mode	63.78”	Mode	135.0 lbs
Minimum	18	Minimum	62.50”	Minimum	86.5 lbs
Maximum	54	Maximum	69.92”	Maximum	344.9 lbs
Bust		**Waist**		**Hips**	
Mean	37.50”	Mean	31.33”	Mean	41.45”
Median	36.47”	Median	30.04”	Median	40.42”
Mode	33.86”	Mode	28.35”	Mode	41.42”
Minimum	30.20”	Minimum	22.17”	Minimum	31.50”
Maximum	61.22”	Maximum	58.98”	Maximum	68.43”

Table 10: MDB + CAESAR data – female, age 18-54, height 62.5”-70”

Summary		
Race	**#**	**%**
White	774	74.7%
African American	102	9.8%
No Response	75	7.2%
Asian/Pacific Islander	50	4.8%
Asian/Pacific Islander Other	19	1.8%
Asian/Pacific Islander Chinese	18	1.7%
Asian/Pacific Islander Vietnamese	4	0.4%
Asian/Pacific Islander Filipano	3	0.3%
Asian/Pacific Islander Korean	3	0.3%
Asian/Pacific Islander Japanese	2	0.2%
Asian/Pacific Islander Asian Indian	1	0.1%
Other Mixed Race	15	1.4%
Other Not Listed Above	8	0.8%
Spanish/Hispanic	7	0.7%
Spanish/Hispanic Mexican American	3	0.3%
Spanish/Hispanic Other	3	0.3%
Spanish/Hispanic Puerto Rican	1	0.1%
Native American/Alaskan	5	0.5%
Total	1036	100%

Table 11: MDB + CAESAR races - female, age 18-54, height 62.5"-70"

ASTM All Size Filter

Bust, waist, and hip girth measurements were used to sort the 1036 subjects. Each measurement was sorted independently of the other two, thus many subjects ended up with measurements sorted into different sizes. For example, subject DB0008-3's bust and hip measurements were classified as size 16, but her waist was classified as size 18. The process was formatted so that no single measurement could be sorted into more than one size. Thus, there was a possibility for 3108 matches (1036 subjects x 3 independent measurements) between the subject measurements and the twelve ASTM sizes.

The same formula used to filter the size 12 subjects was modified to find all twelve sizes:

=IF(AND(SGIRTH<SIZE+TOLERANCE,SGIRTH>=SIZE-TOLERANCE)=TRUE,1,0)

SGIRTH corresponds to a subject's girth measurement, and SIZE corresponds to the ASTM D5585-11^{e1} girth measurement for each size, 00-20. Instead of using a tolerance of +/- 1" for all sizes, the difference between each adjacent size was found, then halved. This distance then became the lower and upper tolerance limits for each size. The upper limit is represented by 'SGIRTH<SIZE+TOLERANCE' and the lower limit is represented by 'SGIRTH>=SIZE-TOLERANCE'.

For example, to find the range for the ASTM size 8 bust girth, both the lower and upper limits were calculated. To find the lower limit, the difference between size 6 (35.25") and size 8 (36.25") was found (1"). One inch divided in two is one half inch, so the lower limit for size 8 is 36.25" - .5" = 35.75". To find the upper limit, the difference between size 8 (36.25") and size 10 (37.25") was found (1"). One inch divided in two is one half inch, so the upper limit for size 8 is 36.25" + .5" = 36.75". The range for size 8 is then 35.75" to 36.75". To avoid overlapping any sizes the formula allowed all measurements up to but not including the lower limit for the next size up. The formula for size 8 bust girth looks like this:

=IF(AND(SGIRTH<36.25+.5,SGIRTH>=36.25-.5)=TRUE,1,0)

A 'Sum Criteria' column was placed after the bust, waist and hip columns for each size and was used to see how many of the three girth measurements each subject fit for that size: '0', '1', '2', or '3".

Results

After sorting 3108 measurements from the 1036 subjects into the twelve ASTM D5585-11[e1] sizes, the data was summarized into Table 12 and Table 13 for analysis.

Size	1 Match	2 Matches	3 Matches	Total
00	70	0	0	70
0	77	8	0	85
2	136	29	0	165
4	199	40	2	241
6	256	53	2	311
8	251	52	6	309
10	271	85	4	360
12	254	57	2	313
14	192	44	4	240
16	120	27	7	154
18	77	20	3	100
20	50	16	4	70
Total	1953	431	34	2418

Table 12: Total number of girth matches organized by size

	1 Match			2 Matches			3 Matches	
Size	**Bust**	**Waist**	**Hips**	**B&W**	**B&H**	**W&H**	**B&W&H**	**Total**
00	14	54	2	0	0	0	0	70
0	30	46	1	7	0	1	0	85
2	80	44	12	20	7	2	0	165
4	86	56	57	19	17	4	2	241
6	98	76	82	29	11	13	2	311
8	87	71	93	25	12	15	6	309
10	78	71	122	36	27	22	4	360
12	53	78	123	23	18	16	2	313
14	44	46	102	15	12	17	4	240
16	19	38	63	12	5	10	7	154
18	21	22	34	10	5	5	3	100
20	13	10	27	8	4	4	4	70
Total	623	612	718	204	118	109	34	2418

Table 13: Subject's matches by specific girth combinations, organized by size

Of the 3108 possible matches, there were 2481 hits. This indicates that ASTM D5585-11[e1] was able to accommodate 77.8% of the 3108 measurements for this group of

1036 female subjects. As seen in Table 12 the ‘1 Match’ column has 1953 hits; the ‘2 Matches’ column has 431 hits, and the ‘3 Matches’ column has 34 hits. This means that of the 1036 subjects, only 34 (3.3%) had all three girths sorted into the same size. Table 13 was created to better understand which girths matched each size.

Sizes 00, 0, and 2 all had subjects within the accepted range for the bust, waist, hips, or some combination thereof, but no size had subjects matching all three measurements. Sizes 4, 6, and 12 all had two subjects matching all three measurements; size 18 had three subjects; sizes 10, 14, and 20 each had four subjects; and size 8 had six subjects. Size 16 had the greatest number of subjects matching all three measurements: seven.

Based on these results, ASTM D5585-11^{e1} did not provide a compatible point of reference for either the Master Database or the CAESAR North America database. Searching all the ASTM sizes produced a smaller sample set than when looking only at +/-1” of size 12. A self-sorting method was chosen as an alternate approach to sample selection.

Self-Sort Method

The self-sorting method used the data from the final subset of 1036 subjects to determine subjects who were similar to each other for each of the three key girth measurements (bust, waist, hip).

Unlike ASTM’s sizing standards or Simmons et al.’s (2004) FFIT for apparel, which use preconceived definitions of body forms to create their systems, this self-sorting method allowed the deferment of body form classification. Delaying body form classification was crucial for this study to retain its validity, as body-form variations were classified after the garment was fit to the body and the pattern dimensions were collected. By sorting the sample set into size groups using bust, waist, and hip girths, body-form variations were revealed after the patterning process was finished.

There was no precedent for this sorting method found in the literature, thus a data analysis expert was consulted. The goal was to find a set of women who were similar enough that they could be considered the same size. Subjects within +/-1” of each other’s girth measurements were considered similar in size. Alexander et al. (2012) used this range to test the measurements of SizeUSA subjects against ASTM sizes. Additionally, a +/-1" tolerance was reasonable, given a one inch grade is accepted as an industry standard. Only subjects who matched all three girths and formed a large enough sample group were considered for inclusion in this study.

Four matrices were created: one for bust girth, one for waist girth, one for hip girth, and one for the sum of the prior three. To create bust, waist and hip girth matrices, the database number and girth measurement for all 1036 eligible subjects were arrayed both vertically and horizontally (Figure 22) such that every subject was tested against every other subject. Matches were represented by the number '1' and were color coded for ease of visual confirmation while searching the matrix. Figures 22 and 23 are modified examples of the real matrices. In these examples subjects DB0003-DB0008 were eliminated from the 'Subject #' row because subjects DB0009-DB0012 were more illustrative of the matching process.

	Subject #	DB0002-2	DB0009	DB0010	DB0011	DB0012
Subject #	**Bust**	32.6	33.15	32.46	33.26	36.31
DB0002-2	32.6	0	1	1	1	0
DB0003	39.81	0	0	0	0	0
DB0004-3	36.91	0	0	0	0	1
DB0005	32.77	1	1	1	1	0
DB0006	34.83	0	0	0	0	0

Figure 22: Sample of bust matrix showing layout and color coding

The equation used to determine if subjects were within +/-1" of each other is:

=IF(SUBR=SUBC,0,IF(AND(SRGIR<=SCGIR+1,SRGIR>=SCGIR-1)=TRUE,1,0))

Where 'SUBR' corresponds to the subject number in the subject row and 'SUBC' corresponds to the subject number in the subject column. If these two match, then the equation requires a response of '0'; otherwise the results would show that every person matches themselves. For example, the cell shared by DB0002-2 (column) and DB0002-2 (row) has a '0' in it, which means that the equation recognizes that this is the same person and so must not compare their girths (Figure 22).

When 'SUBR' does not match 'SUBC', then the equation continues onto the next part of the process, determining if the girth of the subject in the row (SRGIR) is within

+/-1” of the girth of the subject in the column (SCGIR). The upper limit is represented by ‘SRGIR<=SCGIR+1’, and the lower limit is represented by ‘SRGIR>=SCGIR-1’. If the subjects’ girth is within +/-1” of each other, then the equation produces a response of ‘1’. For example, the cell shared by DB0005 and DB0010 has a ‘1’ in it, which means that they are within +/-1” of each other for the bust girth measurement (Figure 22). If the subjects’ girth is not within +/-1” of each other, then the equation produces a response of ‘0’. For example, the cell shared by DB0003 and DB0009 has a ‘0’ in it, which means that they are not within +/-1” of each other for the bust girth measurement (Figure 22).

The final matrix amalgamated the results from the bust, waist and hip girth matrices to determine the final number of matches between subjects. To create the final matrix, the database number for all 1036 eligible subjects was arrayed both vertically and horizontally (Figure 23), maintaining the order from the bust, waist, and hip matrices.

Matches	**Subject #**	DB0002-2	DB0009	DB0010	DB0011	DB0012
2	DB0002-2	0	1	3	2	0
1	DB0003	0	0	0	0	0
7	DB0004-3	0	1	0	1	2
4	DB0005	3	1	3	2	0
4	DB0006	0	1	0	1	1

Figure 23: Sample of final matrix showing layout and color coding

The equation for this matrix is:

='Bust Matrix'!C#+'Waist Matrix'!C#+'Hip Matrix'!C#

Where ‘C#’ refers to the specific cell within a matrix shared by two subjects. The cells could either have a ‘0’, ‘1’, ‘2’, or ‘3’ in them. The cells containing the numbers 1, 2, and 3 were color coded in various shades of green for ease of visual confirmation when searching the matrix. A ‘1’ meant that subject pair had only one girth measurement within the specified +/-1” tolerance. A ‘2’ meant that subject pair had two girth measurements within the specified +/-1” tolerance. A ‘3’ meant that subject pair had all three girths within the specified +/-1” tolerance, and were considered “a match”.

The ‘Matches’ column, on the left-most side of Figure 23, was created to count how many times subjects in the ‘Subject #’ column matched all three girths with subjects in the ‘Subject #’ row. Groups were formed based on how many matches a subject in the ‘Subject #’ column had with subjects in the ‘Subject #’ row.

Results

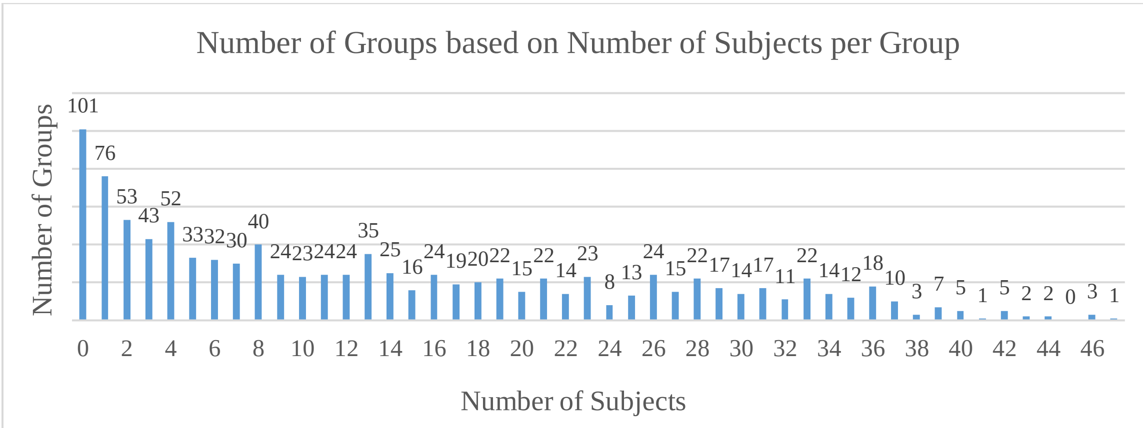


Figure 24: Bar chart showing number of groups based on number of subjects per group

Figure 24 charts the number of groups (y-axis) based on the number of subjects in each grouping (x-axis). The higher the number of subjects in a group the lower the number of groups there are, illustrating how difficult it is to create sizes that fit a majority of the population. One hundred and one subjects did not match any other subject, leaving 935 subjects matched with at least one other subject. An average group consisted of 13.8 members. There were nineteen groups with 40+ matches, and the largest group consisted of 47 members.

These nineteen groups were chosen for further analysis, as 40 subjects was an adequate number to see body form variation across a size. The nineteen groups each had one subject who matched to everyone else. This subject was marked as the ‘fit model’ for their group. Each fit model’s age, bust girth, waist girth, hip girth, height, weight, and number of matches are presented in Table 14.

As this was an exploratory study, only one group was desired for analysis. To insure a diverse sample set, each fit model’s age, bust girth, waist girth, hip girth, height, and weight were compared to their match group’s averages (Figure 25).

Subject #DB0046-3		Group	Subj - Grp.
Age	21	35	-14
Bust	36.60	36.55	0.05
Waist	29.08	29.18	-0.10
Hip	40.21	40.01	0.20
Height	63.46	65.97	-2.51
Weight	0.0	153.5	-153.5
Matches	42		

Figure 25: Example of the layout and color coding used to assess the fit models

The difference between the fit model and the group average is seen in the 'Subj – Grp.' column of Figure 25. Negative differences (when the group average was higher than the subject's data) were color coded for easy viewing.

Four rounds of review occurred to determine the best set of subjects. The first point of review determined if any crucial measurements were missing. Subjects DB0046-3 and DB0152 were removed as their weight measurements were missing. The average, minimum, and maximum of the differences was calculated for the remaining seventeen fit models.

The second point of review required the value of the differences between the fit model and group average for bust, waist, and hip girths be within or equal to half the minimum or maximum value from the average of the Round 1 passes. The bust range was -.11 to .09. The waist range was -.06 to .07. The hip range was -.11 to .08. Seven fit models passed the second round.

The third point of review required observation of the body scans. Fit models were eliminated if their scan exhibited unusual variations (i.e. asymmetry, disproportionate, poor posture, etc.). Six fit models passed the third round.

For the final point of review, a fit expert was asked to review the final six candidates. The fit model needed to closely represent the average of their sample set. #1751 and #2461 were 14 and 12 years younger than their sample set respectively. #1994 and #2486 were 4.09” and 3.20” taller than the average of their sample set respectively. This left #104 and #2062. Fit model #2062 was chosen because she had a greater number of matches than fit model #104.

	#104	#1140	#1222	#1801	#1939	#2011	DB0046-3	#1460	#2461
Age	32	48	39	46	29	29	21	23	23
Bust	35.12	35.94	35.00	33.23	36.65	34.84	36.60	35.94	35.79
Waist	28.31	28.43	28.35	26.42	29.53	27.64	29.08	29.69	28.39
Hip	39.49	39.92	39.57	38.27	39.45	39.76	40.21	39.96	40.39
Height	64.37	65.63	65.16	69.02	69.09	66.18	63.46	64.29	63.46
Weight	128.5	137.5	144.0	136.0	142.0	127.0	0.0	145.5	133.5
Matches	40	40	40	40	40	41	42	42	42

	#2486	#2598	#2062	#2389	#1751	#1994	DB0139	DB0152	#121	#2681
Age	37	39	33	40	19	37	20	28	49	40
Bust	36.34	36.22	35.83	36.69	35.75	35.75	36.51	36.23	36.30	36.22
Waist	29.80	29.53	28.82	29.17	28.78	28.82	29.60	29.79	29.25	29.13
Hip	40.59	39.13	39.61	39.53	39.33	39.29	39.64	39.86	39.25	39.96
Height	69.02	63.31	66.81	67.52	63.94	69.76	68.72	62.80	64.76	64.17
Weight	145.5	131.5	142.0	138.5	135.0	140.0	130.0	0.0	140.0	144.0
Matches	42	42	43	43	44	44	46	46	46	47

Table 14: Data of the 19 fit models, arranged from least number of matches to most

Fit model #2062 is 33 years old, the same average age as her sample set. She weighs 142.0 pounds, which is 4.8 pounds more than her group's average. She is 66.81" tall, which is 1.22" taller than her group's average. She has a bust girth of 35.83" (.05" smaller than the group's average), a waist girth of 28.82" (the same as the group's average), and a hip girth of 39.61" (.02" smaller than the group's average). Figure 26 shows the front, right side, back, and left side views of #2062's scan. While her alignment is slightly skewed, it was determined that it would not have enough of an effect on the pattern block to require choosing another candidate.

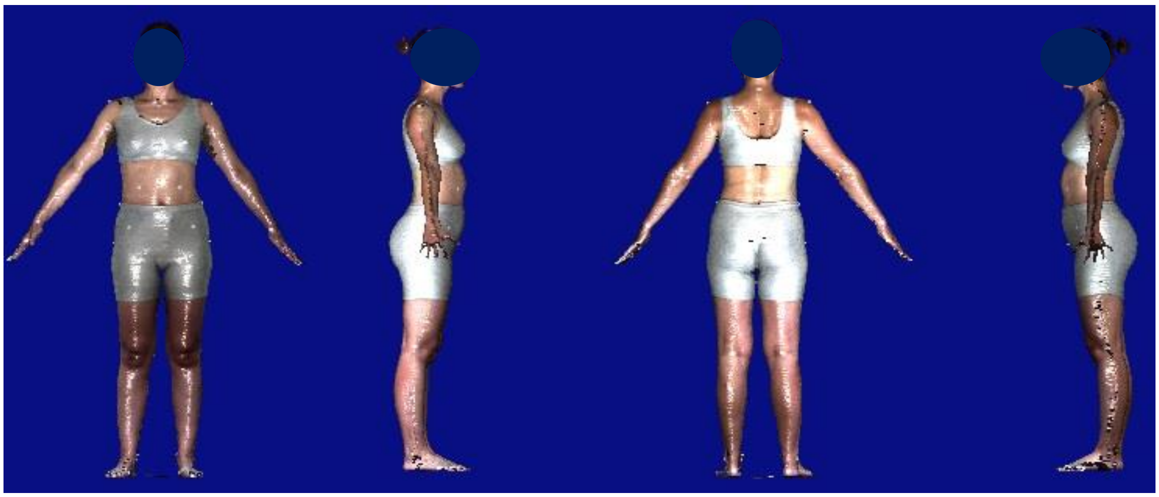


Figure 26: Front, right side, back, and left side images for the fit model

Fit model #2062's sample set consists of 43 subjects: nine from the MDB and 34 from CAESAR. The age range spans 31 years with an average age of 33. Figure 27 illustrates the age distribution of the sample set: 18-19 has three subjects (7%); 20-29 has sixteen subjects (37%); 30-39 has ten subjects (23%); 40-49 has thirteen subjects (30%); and 50-54 has one subject (2%).

Height spans 7.26" with a group average of 65.59". Weight spans 21 pounds with a group average of 137.2 pounds. Both the bust girth and waist girth span 1.93" with group averages of 35.88" and 28.82" respectively. Hip girth spans 1.82" with a group average of 39.63". Descriptive statistics are summarized in Table 15.

The different races present in this subset are: White (N = 36, 84%), African American (N = 2, 5%), and Asian (N = 1, 2%). Four subjects (9%) elected not to include their race in the databases. Often a sample heavily skewed towards one race is considered a limitation. This research sorted by primary measurements only. Race may be a factor in body-form variation, but further analysis of other sample sets is necessary to provide a thorough understanding.

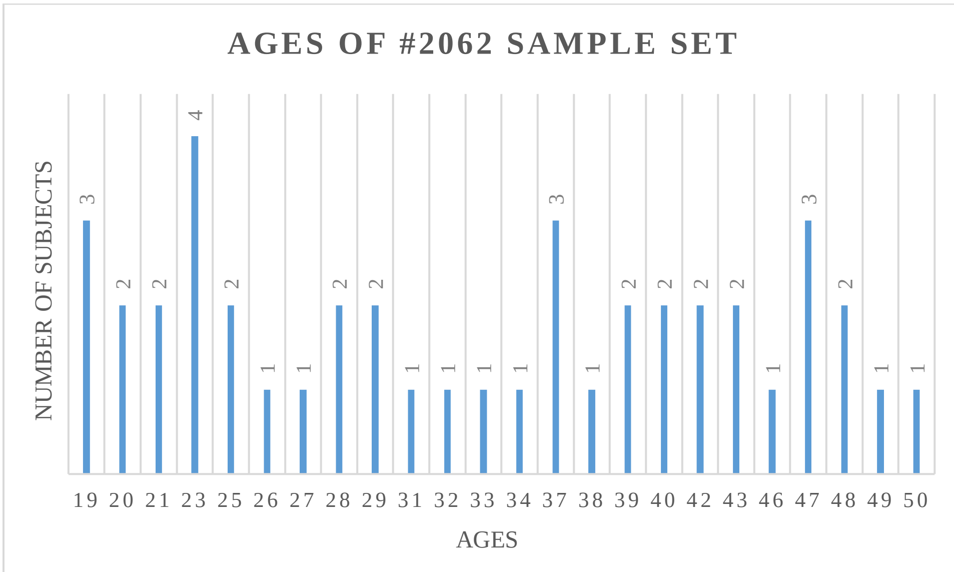


Figure 27: Ages of #2062 Sample Set

Summary					
Age		**Height**		**Weight**	
Mean	33	Mean	65.59”	Mean	137.2 lbs
Median	33	Median	64.89”	Median	137.0 lbs
Mode	23	Mode	64.72”	Mode	144.0 lbs
Minimum	19	Minimum	62.50”	Minimum	128.5 lbs
Maximum	50	Maximum	69.76”	Maximum	149.5 lbs
Bust		**Waist**		**Hips**	
Mean	35.88”	Mean	28.82”	Mean	39.63”
Median	35.86”	Median	28.78”	Median	39.57”
Mode	35.39”	Mode	28.35”	Mode	39.96”
Minimum	34.88”	Minimum	27.87”	Minimum	38.77”
Maximum	36.81”	Maximum	29.80”	Maximum	40.59”

Table 15: Descriptive Statistics for Final Sample Set

Chapter 4 Methods

This research aims to explore the proposition 1) that similar body measurements do not produce similar body forms, and 2) that apparel block shapes can be categorized based on distinct body form variations. The research questions are:

1. What are the body form variations across a single size?
2. What do these findings suggest for the development of a body-form based block system?

This chapter presents the theoretical framework, the procedure to generate, collect and analyze data, and the twenty-seven assumptions used to test question two.

A modified version of Gazzuolo's (1985) Body-Garment Relationship (BGR) framework provides the theoretical framework to guide this research (Figure 28). The BGR is composed of four major components: the analytical component, the dimensional component, the visual component and the physiological component. The analytical component guided the process of abstracting the garment, determining the operational definitions for orienting the garment to the body and identifying essential dimensions. The dimensional component focused on the pattern; the collection of measurements identified during the analytical phase allowed for pattern block comparison among the sample set. The visual component focused on analysis of the body form; allowing for comparisons among the sample set. The physiological component compared the pattern-shape variances identified during the dimensional phase, against the body-form variances identified during the visual phase to clarify how the body affected block formation.

This framework combines qualitative and quantitative research into one mixed methods approach. The analytical and visual components focused on in-depth understanding via description, a key tenant of qualitative research. The dimensional and physiological components focused on comparisons between quantitative and categorical data. A mixed methods approach provides the researcher with a more comprehensive understanding of the body-garment relationship. As this project was exploratory in nature, statistical analyses, such as principle component analysis and analysis of variance were not conducted. The scope of this project became too large to conduct such tests, though the researcher suggests such tests be conducted to more fully understand the correlations between the body and garment.

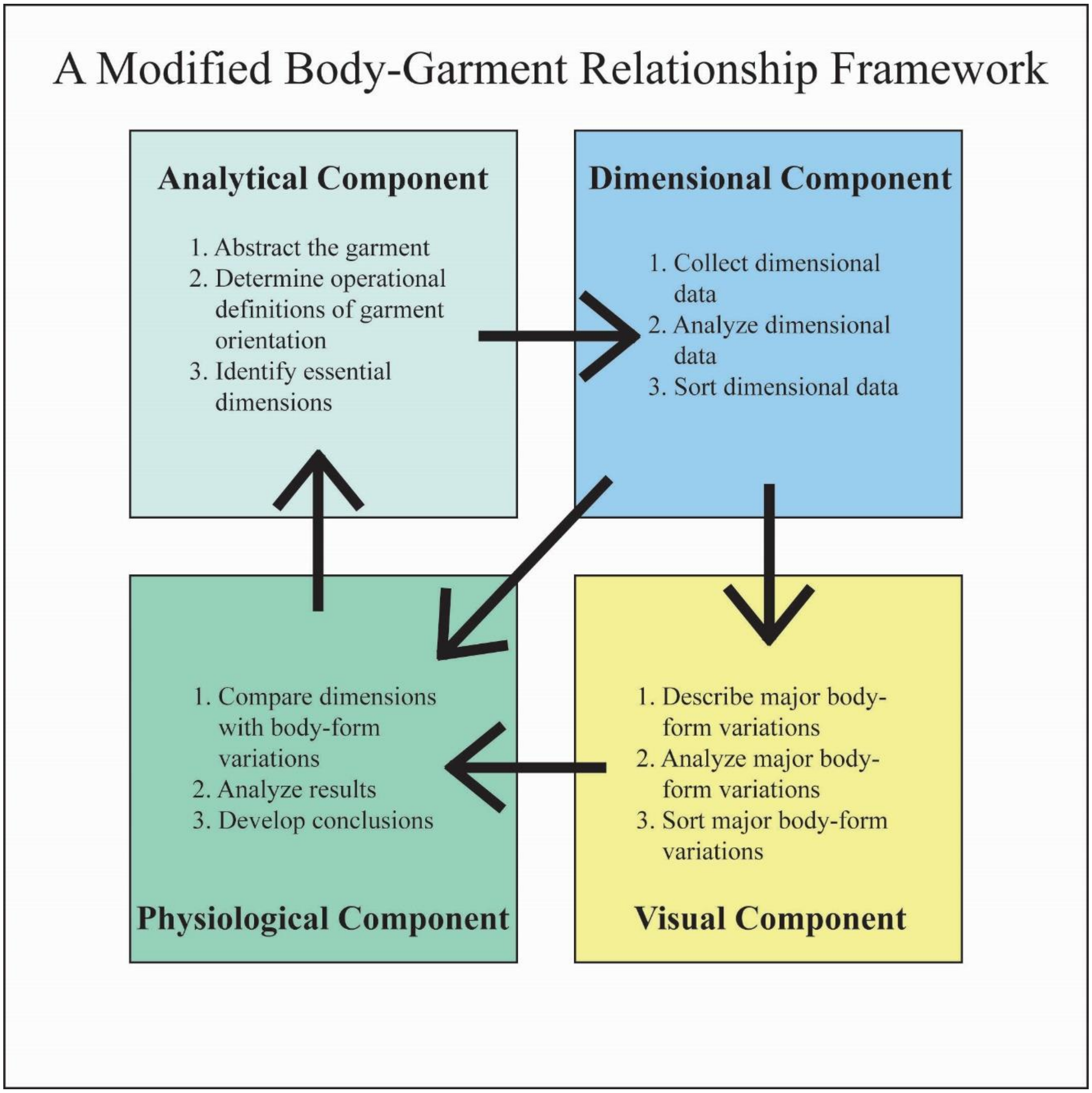


Figure 28: The modified version of Gazzuolo's (1985) Body-Garment Relationship Framework used in this study

Differences from Gazzuolo's BGR

While Gazzuolo's (1985) Body-Garment Relationship framework is an ideal guide for this research, there are two crucial differences between the research method suggested by Gazzuolo and that used in this study:

1. Use of virtual fitting.
2. Visual analysis of fit.

Due to technological advances since Gazzuolo proposed her framework, the data available for this study is digital. This means that instead of fitting real fabric to live models, the researcher fit virtual fabric to virtual models (aka 'avatars'). These avatars are scans of real women, gathered at an earlier time using a body scanner. Body scanners are ideal form capturing devices because they are a fast, non-contact, accurate method of body measurement that provides a permanent record in the form of an avatar that can be saved and used by any researcher with access to the scanner's database (Bye, LaBat & DeLong, 2006; Nayak, Padhye, Wang, Chatterjee, & Gupta, 2015). Benefits of the avatars include the ability to rotate the scan so that any angle of the body-form can be easily viewed, the ability to extract data in the form of points, lengths, surfaces, shapes and volume (Bye et al, 2006), and the ability to export the scan to computer-aided design (CAD) systems.

The virtual-fitting process for this research used Optitex's pattern-making CAD program. This CAD program follows the traditional pattern making and fitting process; patterns are created two-dimensionally and then sewn to create a three-dimensional garment. The difference from traditional, manual pattern-making and fitting lies in the streamlining of the process. Because the sewing is done virtually it takes seconds to "sew" the pattern together. This allows pattern makers to see a sample of their work immediately, so they can correct fit and style errors in mere minutes, instead of the time it takes to pattern, cut and sew an actual garment. This speeds up the traditional flat-pattern-to-3D-garment process, and replaces the need to draft a new pattern from scratch.

As it currently exists, virtual measurement and virtual garment design software do not allow for pattern makers to use Gazzuolo's (1985) planar method (the methodology she proposes for use with the BGR framework). While body scanners can take any measurement, and find the x/y/z coordinates of specific body locations, they cannot mark those locations for export into a CAD program. Additionally, the ability to decide where pattern pieces are placed on the body in a virtual environment only allows for a crude approximation of placement on a large body segment, such as ‘the left arm’. Though the degree of precision necessary for the planar methodology is not yet fully realized in virtual environments, the technology provides new information previously unavailable, such as tension maps and model invisibility.

Visual analysis of fit has a long history that validates its accuracy. A well-trained fitter understands how the garment should look on the body when it fits correctly and has the knowledge of how to alter a pattern to arrive at this result. There is a wide spectrum of interpretation of the term ‘good fit’, thus to allay the issue of using a personal interpretation of ‘good fit’, precise garment abstraction and clear definitions of the fit rules have been established. Garment abstraction and fit rules are discussed in-depth during the analytical phase of this chapter.

Analytical Component

The analytical component abstracts the garment, determines the operational definitions of garment orientation and identifies essential dimensions. This sets the foundation and bounds the research; which requires a thorough discussion of the sheath dress and the fit rules to be used.

A basic, sleeveless sheath dress was selected for this experiment because it covers the locations most often associated with body form: the shoulders, bust, waist, stomach, abdomen, high hip, hips, and thighs (Simmons et al., 2004; Lamport, 2008, 2010). Sleeves add an extra layer of complexity to garment fit, but are not critical to reviewing body-form variation, thus they were not included. Basic blocks, with their minimal ease amounts, are the closest approximation of the body that is possible for a garment. As this study focused on understanding body form through the analysis of a garment's shape, the basic block was the ideal tool. An image of the sheath dress is presented in Figure 29.

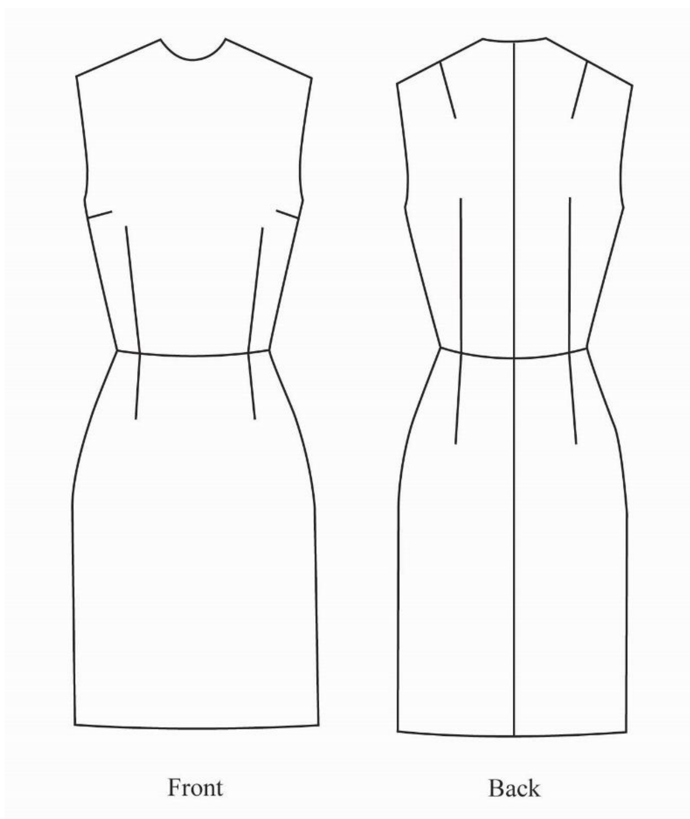


Figure 29: Sheath Dress

Sheath Dress Abstraction

Gazzuolo (1985) states that garment abstraction can be thought of as the specification of all the components of pattern-shape variance, such that all the elements of the body-form are considered and applied to the garment (pp. 58-63). The sheath dress is not an exact replica of the body-form for two reasons:

1. The garment and the body may not share the same space at the same time.
2. The sheath dress does not always lie along the body surface.

It is physically impossible for two objects to inhabit the same space at the same time. The body is moldable to a certain extent, thus, when a too-tight garment is worn it may 1) be displaced, 2) stretch to cover the area, or 3) displace the body, forcing the skin, fat and muscle mass to temporarily relocate until the garment is removed. In a virtual environment, the avatars are not moldable meaning the garment cannot displace the body. Displacement of the garment and the garment stretching to cover an area are possible in the virtual environment. In some instances, the garment may be so tight that the seams of the virtual garment rip.

While it is possible for garments to be patterned to lie along every body-surface, including body hollows, such as the area between the breasts, those patterns are stylized versions of the basic blocks. The sheath dress used in this experiment spans the hollows and lays along the prominences. This creates space between the garment and the body, which is what makes this basic block an abstraction rather than an exact replica (see Figure 30 for an example of the hollows present in a sheath dress).

Instead of describing the garment in the way found in most patterning texts, which tend to focus on how flattering the garment looks on the body,

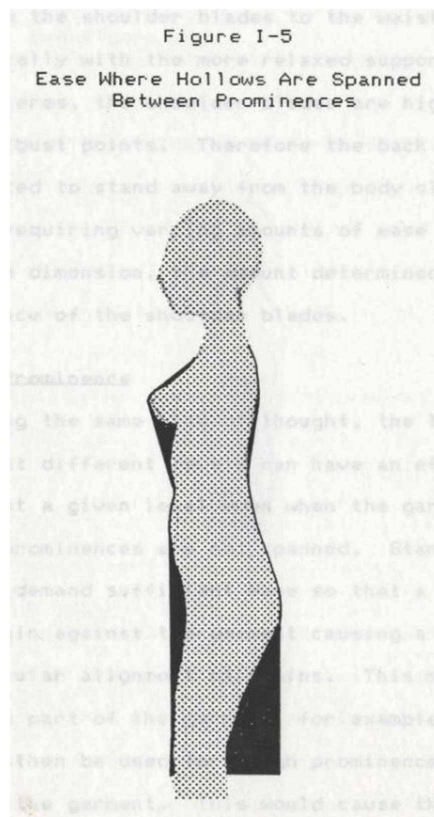


Figure 30: Gazzuolo (1985) "Figure I-5: Ease Where Hollows Are Spanned Between Prominences", p. 79

Gazzuolo (1985) outlines six discussion elements necessary for abstracting the garment:

a. "Level of abstraction (complexity)
b. Grain orientation
c. Means of suspension
d. Reduction
e. Division
f. Correspondence" (p. 506)

Each element is discussed in turn.

Level of Abstraction

This is a correspondence-level garment, meaning it is the highest level of complexity for garment abstraction. The front and back of the dress are differentiated and the seamlines and darts of this sheath dress are located relative to the body-form. Figure 31 shows the six block pieces that make up the sheath dress.

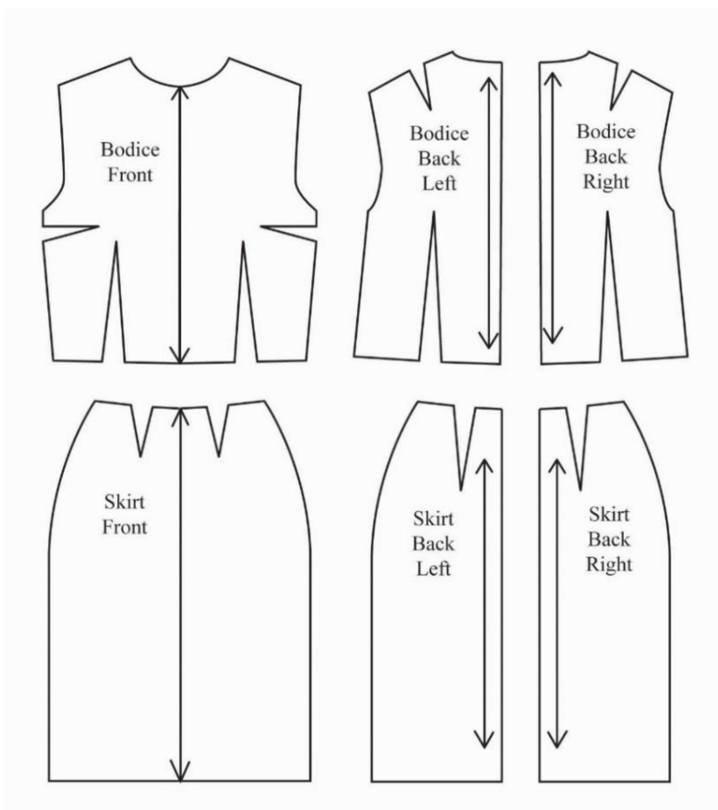


Figure 31: Sheath Dress Block Pieces

The Bodice

The bodice's longest length (both front and back) extends vertically from the high point shoulder to the waistline seam. The greatest width for the bodice front extends from the right-hand corner of the bottom of the armscye and the right side-seam (aka the underarm point), to the left-hand underarm point. The greatest width for the bodice back extends horizontally from the underarm point to the center back seam. The bodice center front line extends vertically from the center of the hollow between the clavicles at the base of the neck to the waistline. The bodice center back seam extends vertically from the top of the spinous process of the seventh cervical vertebrae to the waistline. The waistline for the bodice lies in the center of each subject's natural waist, defined as where the body visually indents on the sides.

The bodice front has four darts: one each on either side of the center front line in the waist seam and one each on either side of the center front in the side seam. None of the bodice front darts reach all the way to the bust apex, they measure a shorter length so that the fullness they create at their points covers the bust apex.

The bodice back left has two darts: one at the mid-point of the shoulder seam and one in the waist seam. Like the front darts, the bodice back left darts measure short of the shoulder blade apex so that their fullness, created at their points, covers it. The bodice back right is the mirror image of the bodice back left. In addition to having different dart locations for the bodice front and the bodice back, the dart lengths and widths vary in their dimensional reduction from front to back.

There are four major prominences for the bodice: the shoulder blades, the shoulder point, the bust, and the rib cage. Gazzuolo (1985) only focuses on the prominences affecting the front and back of the garment, but as technology allows spherical rotation of the avatar, we can now include side prominences. The prominences affecting the front of the bodice are the bust and shoulder point. The prominences affecting the back of the bodice are the shoulder blades and the shoulder point. The prominences affecting the sides of the bodice are the bust and rib cage. The bust may be wide enough to extends beyond the width of the chest and create hollows along the side seam. Likewise, the rib cage may also be wide enough to form a hollow between it and the waist seam.

The Skirt

The skirt's longest length begins at the center waistline and extends vertically to the bottom edge of the block (aka the hem). The waistline for the skirt lies in the center of each subject's natural waist, defined as where the body visually indents on the sides. The greatest width for the skirt front extends horizontally across the level of greatest lower-body side prominence. The greatest width for the skirt back left extends horizontally from the side seam at the level of greatest lower-body side prominence to the center back seam. The skirt back right is a mirror image of the skirt back left. The skirt hem ends at the suprapatella.

The skirt front has two darts: one on either side of the center front line at the waist seam, extending towards the greatest lower-body front prominence. These darts align with the bodice front waist darts. Unlike the bodice, which is drafted of straight lines, the skirt side seams curve from the level of the greatest lower-body side prominence to the waist seam. The length and degree of curve depends upon the subject.

The skirt back left has one dart which extends towards the buttocks. This dart aligns with the bodice back waist dart. Like the skirt front, the side seams of the skirt back left curve from the level of the greatest lower-body side prominence to the waist seam. The length and degree of curve depends upon the subject. The skirt back right is the mirror image of the skirt back left. In addition to having different dart locations for the skirt front and the skirt back, the dart lengths and widths will also vary in their dimensional reduction from front to back.

There are six possible major prominences for the skirt: the stomach, the abdomen, the high hip, the hip, the buttocks, and the thighs. The prominences affecting the front of the skirt are the stomach and abdomen. It is likely that one of the two will be the major prominence, rather than both being major prominences. The prominence affecting the back of the skirt is the buttocks. The prominences affecting the sides of the skirt are the high hip, hip and thighs. Again, it is likely that one of the three will be the major prominence, rather than all three being major prominences.

Grain Orientation

Grain is the direction of yarns in a fabric. A woven fabric has two grains, a lengthwise grain (identified by the warp yarns) and a crosswise grain (identified by the weft yarns). Lengthwise grain is less elastic than crosswise grain, which is good for maintaining vertical stability while also allowing the material to stretch slightly as it rounds the body's curves. It is standard practice to orient the lengthwise direction of blocks along the lengthwise grain of a piece of fabric.

For this research, the blocks were oriented so that the lengthwise grain fell vertically along the center front and center back of each block piece, but was on the bias at the bodice side seams and the curved sides of the skirt. Bias is not a grain, instead it is all other directions besides the lengthwise or crosswise grains (Gazzuolo, 1985, p. 65). It is also much more elastic than either the lengthwise or crosswise grains, as there is nothing preventing it from stretching in whichever direction it chooses. As such, having certain areas of the blocks fall on the bias, while unavoidable, made it necessary to pay close attention to the balance of the garment.

Balance is essentially the way a garment hangs on the body (Gazzuolo, 1985). Both vertical and lateral balance must be addressed if the garment is to maintain its intended suspension on the body (Wilson, 1950 via Gazzuolo, 1985). Balance points for this sheath dress included the center front and center back neck points, the high-point shoulder points, the shoulder points, the center front and center back waist points, and the side waist points. Balance lines for the sheath dress included the bust-line and the line of greatest lower body prominence. Adjusting the lengths and widths attached to the balance points maintain correct grain orientation for the basic blocks.

Means of Suspension

According to Gazzuolo (1985), suspension is the act of a garment hanging from the body, which is achieved by making the garment opening smaller than the body below it, so that the garment stays on the body. This sheath dress is suspended from the body at two locations: 1) the shoulders, and 2) the location of greatest lower-body prominence.

The suspension at these two locations is determined by the total neckline circumference and the waistline circumference.

The neck has the smallest circumference of the upper body. The total circumference of the neckline is what determines the widthwise position of the shoulder seams. A larger-than-necessary neckline will push the shoulder seams towards the edge of the shoulders, potentially causing the garment to slide off the body at the shoulders. Careful determination of the total neckline circumference will help maintain the proper position of the bodice and help properly position the entire garment.

The upper body suspension site ends at the waistline, which is a secondary suspension location for this sheath dress. The waist is the smallest circumference of the lower body, and the second smallest of the upper body. With improper placement of the shoulder seams a larger-than-necessary waist circumference can potentially cause the skirt to slide off the body at the location of greatest lower-body prominence. Careful determination of the waistline circumference will help maintain the proper position of the skirt.

As the garment is an abstraction of the body-form, spaces appear under the greatest prominences. The area that includes all of these spaces is called a 'suspension site'. For the bodice, the suspension site spans from the shoulder to the waistline and includes spaces from the shoulder to the bust prominence, the shoulder blade prominence to the waist, the bust prominence to the waist, and the rib cage to the waist. For the skirt, the suspension site spans from the abdomen/stomach to the hem, and includes spaces from the abdomen/stomach to the thighs or hem, the high-hip/hip/thigh to the hem, and the buttocks to the hem.

Reduction/Enlargement

In order to achieve suspension and shape the garment to the body, either reduction or enlargement must occur. Reduction, is the act of making garment lengths and widths smaller. Enlargement is the opposite of reduction, or, the act of making garment lengths and widths larger. Both are necessary as the basic blocks are altered to fit each subject rather than made anew each time.

According to Gazzuolo (1985) there are two types of reduction: 1) Dimensional reduction, used for altering a larger amount to a smaller one; and 2) Contour reduction, used to shape the garment to align with the body's natural contours. This follows that there are two types of enlargement: dimensional and contour. Reduction and enlargement can occur simultaneously in the same garment. For example, the bust circumference may need to be reduced while the hip circumference may need to be enlarged in order to fit the subject's body correctly.

Methods to reduce and enlarge the blocks include: darts, tucks, pleats, gathers, shaped seams, smocking, easing, flare or a combination of these (Gazzuolo, 1985, p. 89). For these basic blocks, the only reduction/enlargement features necessary are darts and shaped seams.

Dimensional reduction/enlargement occurs at any location necessitating a change in length or width measurements. For example, changing the bodice front shoulder seam so that it matches the length of the bodice back shoulder seam. Another example would be changing the dart intake at the waistline to align the waistline circumference more closely to the body's waist circumference. For this sheath dress, dimensional reduction/enlargement can occur at any seamline, the hem, and at all of the darts.

Contour reduction/enlargement occurs at locations necessitating shaping so that the garment aligns with the body's natural curves. Contour shaping may occur in this sheath dress are at the neckline, armhole, and skirt side seams.

<u>Division</u>

Division is essentially how the garment is broken down into separate pieces. Division is responsible for determining the seam locations for each block piece. For this sheath dress, there two main units: the bodice and the skirt. These are further divided into six block pieces: the bodice front, the bodice back left, the bodice back right, the skirt front, the skirt back left, and the skirt back right (Figure 31).

The bodice front and the skirt front divide at the waistline creating two front pieces. The bodice back divides from the skirt back at the waistline and is again divided down the center back so that there are four back pieces. The bodice front attaches to the bodice back at the shoulder seams and the side seams. The skirt front attaches to the skirt back at the side seams.

The side seam for the skirt is perpendicular to the floor and splits the body in half (Gazzuolo, 1985). There is no consensus on where the bodice side seams should be placed (Gazzuolo, 1985). Thus, for this research, the bodice side seam will extend from one inch below the subject's armpit (at the mid-point of front and back) to the mid-point of the subject's side waist.

The division of the shoulder seams front and back determine their forward or backward position on the body as well as how the neckline circumference is divided. Careful attention to forward/backward position of the shoulder seams will help maintain proper bodice positioning on the upper body.

Correspondence

Correspondence specifies the anatomical locations of the major pattern points. For this garment, correspondence occurs at all block borders as well as the points of greatest prominence. The correspondence points and seams are ordered from the top of the body down:

High-Point-Shoulder. The high-point-shoulder falls at the base of the neck, along the middle of the top of the shoulder for both the front and back block pieces.

Shoulder Point. The shoulder point falls at the outermost edge of the acromion for both front and back block pieces.

Shoulder Seam. The shoulder seam extends from the high-point-shoulder in a straight line ending at the shoulder point. The shoulder darts are embedded in the shoulder seam and must be sewn before the front and back shoulder seams are sewn together.

Center Back Neck Point. The center back of the bodice block falls at the top of the spinous process of the seventh cervical vertebra.

Center Front Neck Point. The center front of the bodice block falls at the center of the hollow between the clavicles at the base of the neck.

Neckline. The neckline is created when the shoulder seams are sewn together and curves around the base of the neck, starting at the center back neck point, passing through the right high-point-shoulder, the center front neck point, the left high-point shoulder, and ending again at the center back neck point. The curve of the back neckline will be shallower than the curve of the front neckline.

Shoulder Blade Apex. The shoulder blade apex is the most protruded point of the greatest shoulder blade prominence. The shoulder darts are located at the mid-point of the shoulder seam, and are oriented diagonally towards the shoulder blade apex. The back waist darts are centered under the shoulder blade apex in the waist seam, extend vertically, and vary in width and length depending upon the subject. Freedom of movement is provided by the fullness at the bodice back waist dart points.

Underarm Point. The underarm point falls 1” below the axilla, midway between the subject’s front and back, for both front and back blocks. The underarm point is the uppermost side seam point and the bottommost armscye point.

Armhole. The armhole is created when the shoulder seams and side seams of the bodice are sewn together, and curves around the arm socket, from the underarm point, up the chest, through the shoulder point, and down the back to end at the underarm point. The curve under the arm is greater than the curve over the shoulder point.

Bust Apex. The bust apex is the point of greatest bust prominence, usually at the nipple. The bust darts are located in the bodice side seams, pointing towards the bust apex. The waist darts are in the bodice waist seam, are centered under the bust apex, and extend vertically. The width and length of the bodice darts depends on the subject. The fullness at their points provides the necessary room for breathing.

Center Front Waist Point. The center front waist point is vertically centered under the center front neck point, in the middle of the subject’s waist.

Center Back Waist Point. The center back waist point is vertically centered under the center back neck point, along the spine, in the middle of the subject’s waist.

Side Waist Points. The side waist points fall at the mid-point between the subject’s front and back, in the middle of the subject’s waist, and are the same for the bodice and skirt on both the right and left sides of the body.

Waist Seam. The waist seam extends around the body horizontally, making a full circle from the center back waist point, the side right waist point, the center front waist point, the side left waist point, and back to the center back waist point. The waist seam connects the bodice to the skirt. The bodice and skirt darts are embedded in the waist seams and must be sewn before the waist seams are sewn together.

Greatest Lower-Body Front Prominence. This point varies depending upon the subject and may correspond to either the stomach or abdomen. The skirt front waist darts will vary in width and length depending on the subject.

Buttocks Prominence. The skirt back waist darts point towards the buttocks prominence, but do not reach all the way to it.

Greatest Lower-Body Side Prominence. This point may correspond to either the high-hip, hip, or thighs and varies by subject. This is where the side seam starts curving up to the side waist point.

Knees. The garment will hang straight down from the point of greatest lower-body prominence to end the hem directly at the suprapatella.

Side Seam. The side seam starts at the underarm point, extending in a straight line to the side waist point, where it curves to the point of greatest lower body prominence, and then extends straight down to end at the hem. The bust dart is embedded in the bodice side seam and must be sewn before the side seam.

Center Front Line. The center front line starts at the center front neck point, passes through the mid-point of the left and right bust apexes, goes through the center front waist point, passes over the bellybutton, and extends in a vertical line to the hem. The center front line is imaginary in this dress, but important, as it helps orient the lengthwise grain.

Center Back Seam. The center back seam starts at the center back neck point, travels along the middle of the spine, passes through the center back waist point and extends in a vertical line to the hem. The center back seam is created when the back left and back right halves of the dress are sewn together. Lengthwise grain is aligned with the center back seam.

Explanation of Fit Rules

The fitting rules were developed from the description of the sheath dress in the correspondence section. Fitting rules are not suggested in Gazzuolo's (1985) BGR framework, but an addition based on the needs of this study. Gazzuolo did not need fit rules because her use of the planar methodology fit the blocks to her subjects using x/y/z coordinates. Visual analysis of fit was employed as the methodology for fit evaluation and the principles of reduction and enlargement were used to achieve it. This section explains each rule, ending with a list in Table 16.

This specific garment abstraction provided a consistent 2D block for comparison across the sample set. Thus, changing the abstraction by splitting blocks into more pieces, combining blocks into fewer pieces, or altering the locations of correspondence points, darts, and seams would have made comparison between blocks impossible. Blocks needed to be similar in their major elements for comparison:

1. Dress cannot change substantially in configuration from the one described during garment abstraction – maintains number of block pieces, correspondence points, and seams.

Ease is the amount of space added to the pattern for the comfort of the subject. Patterning texts differ as to how much ease is necessary, though they all agree that some is needed. The subjects in this study were virtual and could not specify ease preference. The elimination of ease preference was beneficial, as the closer the garment conformed to the body, the more accurately body-form variations were represented in the block shapes. As long as the dress fit the subject well, the amount of space between the subject and the block was viewed as the correct ease. This led to the second rule:

2. Blocks conform as close to body as possible without displacing or stretching the garment at any location.

Adjustments at balance points (center front and center back neck points, high-point shoulder, shoulder points, center front and center back waist points, side waist points, and points of greatest lower-body side prominence) affect the grain orientation of each block. The side seam usually does not follow the lengthwise grain, though this may vary by subject. The shoulder seams, while straight, are usually sloped at some angle, causing the grain to be on the bias at the shoulders. The center front and center back are always on the lengthwise grain. If these two locations were oriented correctly, then the entire garment was considered balanced. The following rules supported this:

3. Center front and center back lengthwise grain are perpendicular to floor.
4. Hem is parallel to the floor at center front and center back.

Darts are reduction/enlargement elements that help the garment abstraction conform to the body. Their lengths and widths varied depending on the subject. Darts needed to point towards the major prominence in their area:

5. Dart tips point towards the major prominence in their area.

The reason for abstracting the correspondence points, seams, and major prominences was to help determine where the pattern and the body aligned so that blocks could be compared during the dimensional phase. This rule oriented the block-shape to the space inhabited by the body-form:

6. Correspondence points of blocks match correspondence locations on body:

- High point shoulder matches mid-point of shoulder at base of neck.
- Shoulder point matches outermost edge of the acromion.
- CB neck point matches top of spinous process of the seventh cervical vertebra at base of neck.
- CF neck point matches center of hollow between clavicles at base of neck.
- Underarm point matches midway between subject’s front and back, 1” below axilla.
- CF waist point matches middle of subject’s waist, centered under CF neck point.
- CB waist point matches middle of subject’s waist, centered under CB neck point on spine.
- Side waist point matches midway between subject’s front and back, in middle of subject’s waist.
- Point of greatest lower-body side prominence matches the subject’s side at the high-hip, hip or thigh level.
- Hem matches the height of the suprapatellas.

If the correspondence points met there was no need to specify fitting rules for the correspondence of major prominences or seams. Major prominences will change depending on the subject. Seams are the connections between correspondence points. Technically, the neckline is not a seam, but it is an important location, as the suspension of the garment depends on the width of the neckline. The same holds true for the waist seam. These two seams must follow the contour of the body quite closely, thus the following rules:

7. Neckline curves through all correspondence points at base of neck.
8. Waist seam curves through all correspondence points at waist.

Block Creation

Basic blocks created by the University of Minnesota were the basis for this pattern. The fit model's bust girth, waist girth and hip girth measurements were compared to the bust girth, waist girth and hip girth measurements of the basic blocks and the most representative size was selected. The front shoulder dart was moved into the side seam, at bust level.

Moving the bust dart into the side seam allowed accurate triangulation of the bust prominence on the bodice block. Reducing the number of waist darts in the skirt from two per side to one per side made it easier to track changes in the skirt darts. Changes in position, length, and width of darts provided useful dimensional data.

The fit rules were applied to the blocks, resulting in a custom set of blocks for the fit model. Song and Ashdown (2012) showed how starting with a pattern customized to your population provided a better fitting final garment after customizing the pattern further for each individual in their study. Customized starting blocks were used in this research to reduce the amount of alterations necessary and to end with better fitting final garments.

Only the right side of the garment was adjusted. Optitex's CAD system automatically mirrors changes made on the "working half" of the garment to the "mirrored half" of the garment so that changes are identical.

1. Dress cannot change substantially in configuration from the one described during garment abstraction – maintains number of block pieces, correspondence points and seams.
2. Blocks conform as close to body as possible without displacing or stretching the garment at any location.
3. Center front and center back lengthwise grain are perpendicular to floor.
4. Hem is parallel to the floor at center front and center back.
5. Dart tips point towards the major prominence in their area.
6. Correspondence points of blocks match correspondence locations on body:
• High point shoulder matches mid-point of shoulder at base of neck.
• Shoulder point matches outermost edge of the acromion.
• CB neck point matches top of spinous process of the seventh cervical vertebra at base of neck.
• CF neck point matches center of hollow between clavicles at base of neck.
• Underarm point matches midway between subject's front and back, 1" below axilla.
• CF waist point matches middle of subject's waist, centered under CF neck point.
• CB waist point matches middle of subject's waist, centered under CB neck point on spine.
• Side waist point matches midway between subject's front and back, in middle of subject's waist.
• Point of greatest lower-body side prominence matches the subject's side at either the high-hip, hip or thigh level.
• Hem matches the height of the suprapatellas.
7. Neckline curves through all correspondence points at base of neck.
8. Waist seam curves through all correspondence points at waist.

Table 16: Fitting Rules for Basic Sheath Dress

Dimensional Component

The dimensional component used the operational definitions from the analytical phase to generate, collect, and analyze data from the pattern blocks. The goal of the dimensional component was to describe the major block-shape variations in this sample. Lengths and widths were collected from the blocks at specific locations correspondent to critical body-form sites. Sorting the blocks into groups based on the dimensional data effectively sorted the body-forms into groups as well. Analysis of the quantitative data allowed for comparison between the blocks and block-groups in the sample set.

Generation

To generate data, the pattern blocks were fit to each individual within the sample. There is no specific method to follow for fitting garments to individuals. Thus, the researcher chose to fit each individual based on the individual needs of each subject.

In general, width was addressed first. The appropriate darts, seams, or circumferences were enlarged or reduced. Once the garment was large enough to skim the body, length was adjusted. This often led to a re-adjustment in the width of the garment. Only one adjustment was made at any given time so that the effect of the change could be viewed by the researcher. The process continued until the garment met the fitting rules outlined during the analytical phase (Table 16).

Collection

Data collection consisted of choosing dimensions that corresponded to specific body-form variations. It was necessary that dimensions directly compared to the body-form, so that the physiological phase could be carried out smoothly. All dimensions were collected from the right-hand side of the garments, to correspond with the side of the garments that were altered. The collected dimensions are highlighted in Figure 32.

The two neck dimensions are highlighted in dark blue on the bodice blocks. The first neck dimension is the neck circumference, composed of the measurements from the center front neck point to the high-point shoulder and the high-point shoulder to the center back neck point, doubled. The second neck dimension is the front neck drop, the vertical distance between the center front neck point and the height of the high-point shoulder, represented by the vertical teal line in Figure 32.

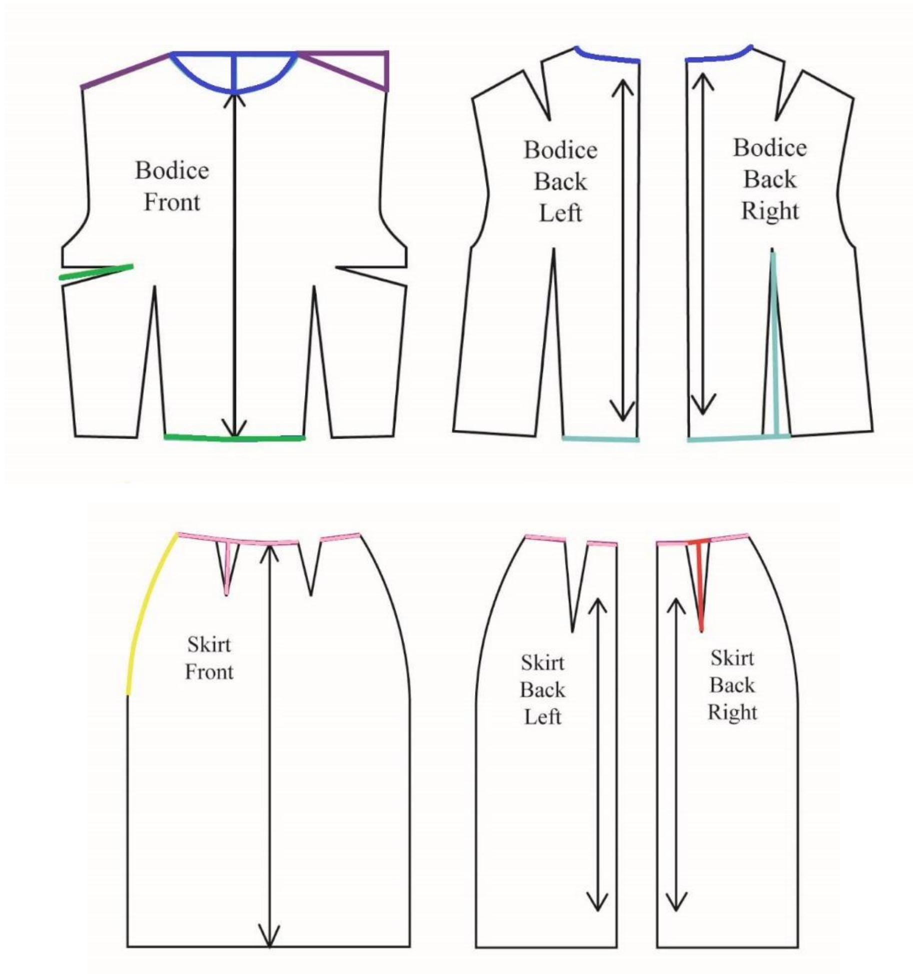


Figure 32: Dimensions

The two shoulder dimensions are highlighted in purple on the bodice front block. The first shoulder dimension is the shoulder seam length; a straight line from the high-point shoulder to the shoulder point. Due to the use of the shoulder dart on the bodice back block, the front and back shoulder seams measured the same length, so only the front shoulder seam was measured.

The second shoulder dimension is the averaged shoulder slope. Shoulder slope was taken using the method suggested for determining body shoulder slope in Maehren and Meyers' (2005) book, *The Perfect Fit*. A horizontal line was extended from the high-point shoulder, while a vertical line was extended from the shoulder point. The distance from the shoulder point to the level of the horizontal line represented the shoulder slope. This may be referred to as shoulder drop in other texts. Both the front and back shoulder slopes were taken. To take the back shoulder slope the dart was first closed, then the measurement was taken. The dart was re-opened afterwards. The two slopes were averaged to create a composite measurement.

The three dimensions that correspond to the shoulder blade are highlighted in light blue on the bodice back pieces. The first shoulder blade dimension is the bodice back waist dart depth: the vertical distance between the dart point and the midpoint of the dart opening. The second shoulder blade dimension is the bodice back waist dart width, which is the measurement of the dart opening. The third shoulder blade dimension is the distance between the back waist darts: a straight line from the center back waist point to the first dart leg, doubled.

The two bust dimensions are highlighted in green on the bodice front block. The first bust dimension is the bust dart depth: the distance between the dart point and the midpoint of the dart opening. The second bust dimension is the distance between the front waist darts: a straight line from the first dart leg to the center front waist point, doubled.

The four dimensions that correspond to the greatest lower-body front prominence are highlighted in pink on the skirt front block. The first greatest lower-body front prominence is the waist circumference. This was calculated by adding the distance from the waist of the bodice front block to the distance from the waist of the bodice back blocks. Both of these distances were calculated the same way: the distance from the right side waist point to the outside dart leg added to the inside dart leg to the center waist point, doubled. The second greatest lower-body front prominence is the front waist width, which equates to the front half of the waist circumference dimension.

The third greatest lower-body front prominence is the skirt front waist dart depth: the distance from the dart point to the midpoint of the dart opening. The fourth greatest lower-body front prominence is the skirt front waist dart width: the measurement of the dart opening.

The two buttocks dimensions are highlighted in red on the skirt back right piece. The first buttocks dimension is the skirt back waist dart depth: the distance from the dart point to the midpoint of the dart opening. The second buttock dimension is the skirt back waist dart width: the measurement of the dart opening.

The final dimension corresponds to the greatest lower-body side prominence and is highlighted in yellow on the skirt front block. The skirt curve length curves from the right side waist point to the point of greatest lower-body side prominence.

Analysis

A spreadsheet of dimensions was organized by subject. Each subject received an identifier (a1-a44) to protect their identity. Each dimension was sorted from smallest to largest and graphed. Descriptive frequencies (mean, minimum, maximum, range and standard deviation) were calculated for each dimension in addition to each subject's standard deviation from the mean within each dimension.

Graphs were set up with subjects on the x-axis and measurements on the y-axis. Each visible value on the y-axis equates to one standard deviation. The minimum and maximum y-axis values equate to the smallest and largest standard deviation necessary to show all data points for each dimension. The graphs visually represented the range of the measurements within a single dimension and allowed for group identification.

Visual Component

Gazzuolo's (1985) intent with the visual component was to quantitatively compare the critical values of one subject's body with another's. Gazzuolo's visual component focuses on analysis of the major lengths, widths, angles, and radii of the body to understand the proportionate and spatial relationships among critical body sites and to uncover the extent of physical prominences. Gazzuolo's visual component focuses on analysis of the body form; allowing for comparisons among the sample set. Upon consideration of the technological advances beyond those available in 1985, and the blocks being empirical abstractions of each subject's body, this section was updated.

Gazzuolo (1985) used photographs to take measurements of the body. This research used body scans, which are virtual three-dimensional representations of the body taken via a body scanner. Scanning technology has the ability to extract any number of measurements in a matter of seconds, thus providing detailed measurements of each subject. But, since the blocks are empirical abstractions of the body, the dimensions collected from the blocks were used in lieu of the dimensions taken from the body.

The goal for the visual component was to describe the major body-form variations of this sample set to answer the first research question: What are the body-form variations across a single size? Qualitative visual analysis and rich descriptions of the subjects were used to understand the variability of the sample.

Body-form variations were identified by close inspection of each subject's body scan using ScanWorX, software developed for analysis of body scan data. Figure 33 shows the regions analyzed for each subject. Purple equates to the neck and shoulders; green to the bust; blue to the shoulder blades; pink to the greatest lower-body front prominence; orange to the buttocks; and yellow to the greatest lower-body side prominence. Based on the analytical component, these six regions each held the potential to affect the outcome of the dress-blocks, altered during the dimensional phase.

To organize the results from the visual analysis phase, an Excel spreadsheet was created to record each individual's body-form variations. Variations were labeled by specific body-part (i.e. shoulder or bust) and measurement entity (i.e. length or fullness). Each variation had at least two categories with labels such as 'long', 'small' or 'at high-hip'. Tallies of how many subjects fell into each category within each body-form variation allowed for comparisons within individual body-form variations.

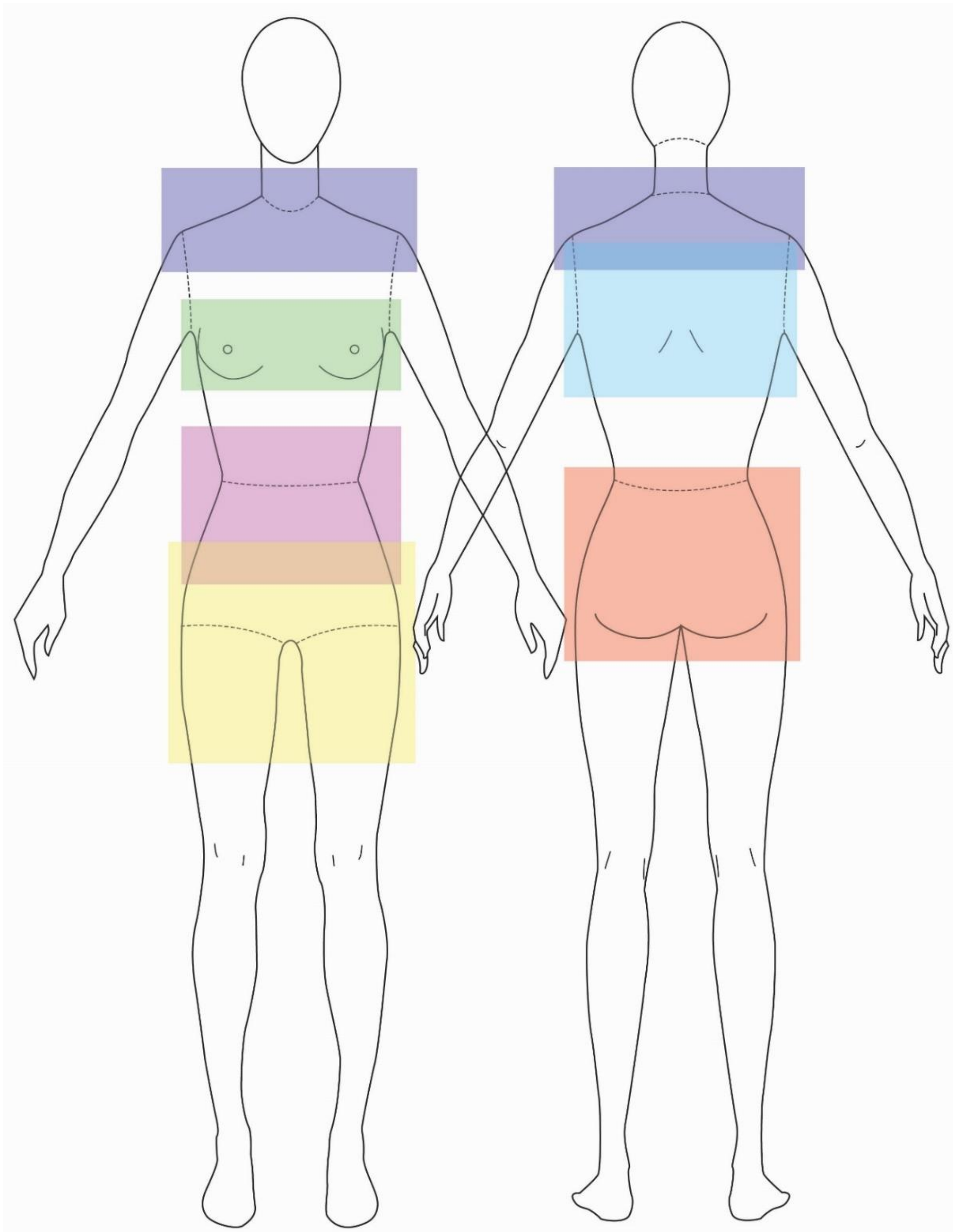


Figure 33: Regions analyzed during visual analysis

Physiological Component

The physiological component explains the block-shape variances using the body-form variances. Gazzuolo (1985) recommends digging deep into all the possible reasons a subject's body may present a variation. Reasons may include heredity, nutrition, and the environment. Understanding what causes body-form variations could allow designers to create better fitting garments for targeted populations. While this information would be invaluable to the apparel market, this level of detail is outside the scope of this study.

Body-form variables were compared to pattern dimensions utilizing the groupings identified during the dimensional component. Descriptions of the body-form variables identified during the visual component gave meaning to the measurements collected during the dimensional component. Table 17 lists the body component, pattern dimension, and assumption for each of the body-form variables associated with the body component.

Assumptions were based upon consideration of how the body could affect the pattern blocks at specific locations. A strict one-to-one comparison was used to bound the research. Garment abstraction aided in this endeavor, as it caused the researcher to consider both the way the sheath dress was constructed and how it interacted with the body. Explanations for each assumption are as follows.

The pattern blocks are made up of points connected by lines. The lines alter based on the change in point locations. Points can move horizontally and vertically. Diagonal movement is a combination of horizontal and vertical movements and thus will not be discussed in the following analysis.

The neck circumference and front neck drop are affected by changes in the neck points. The side neck points can either move horizontally (inwards towards the neck, or outwards, towards the shoulder point) or vertically (towards the torso or away from it). The center front and center back neck points can only move vertically. When all neck points shift towards the neck the result should be a smaller neck circumference, and when they all shift away from the neck the result should be a larger neck circumference.

Three body-form variations have an opportunity to affect the neck circumference: neck thickness, the neck-to-shoulder transition, and collarbone prominence. How thick the neck is may cause the some or all of the neck points to shift position. The type of neck-to-shoulder transition may cause the side neck points to shift horizontally. A more prominent collarbone may be due to a subject having a less fat and muscle mass, making their bones easier to see. If this is the case, then it can be extrapolated that this subject may have a thinner neck. Thus, the more prominent the collarbone, the smaller the neck circumference should be, and vice versa.

The front neck drop may be affected by one body-form variation: neck tilt. How tilted the neck is may cause the center front neck point to move vertically. A greater tilt should shift the center front neck point more towards the torso. It is also possible that the side neck points may shift vertically, and if they move in concert with the center front neck point, then they would negate the effect of neck tilt on the pattern, at least as measured by front neck drop. It is expected that even if the side neck points do move, the change in center front neck point will be large enough to show the effect of neck tilt as measured by front neck drop.

The shoulder seam and averaged shoulder slope are affected primarily by changes in the shoulder point, and secondly by changes in the side neck points. The shoulder point can move horizontally and vertically: towards the torso or away from it. The side neck points can move horizontally or vertically, as described above. Both horizontal and vertical changes in either the shoulder point or the side neck points should shorten or lengthen the shoulder seam. If both the shoulder point and side neck point move in concert with each other this would most likely equate to a change in the neck, rather than a change in the shoulder. Only vertical changes at the shoulder point or side neck points affect the shoulder slope.

Three body-form variations have the opportunity to affect the shoulder seam: shoulder length, shoulder point softness, and shoulder point alignment. Shoulder length may cause the shoulder point to shift horizontally, either shortening or elongating the shoulder seam. The shoulder point on the body was identified as being either sharp or soft during the visual analysis phase of the research. A sharper shoulder point was easier to perceive than a soft one, making the placement of the pattern shoulder point easier on the sharp shoulders than the soft ones, which may result in longer shoulder seam measurements for subjects with soft shoulders. Shoulder point alignment compares the alignment of the shoulder point with the bust, high-hip, and thigh of the subject. The type of alignment with each body component should indicate the shoulder seam length.

Four body-form variations have the opportunity to affect the averaged shoulder slope dimension: shoulder slope, shoulder point sharpness, shoulder length, and the neck-to-shoulder transition. Vertical changes in the shoulder point or the side neck point reflect the slope of the shoulder on the body. If the body's shoulder slope is steeper, then the shoulder seam should mimic that, resulting in a greater slope measurement. Shoulder point softness may affect the slope, as the longer the shoulder seam becomes the greater the slope measurement should also be. As stated previously, neck-to-shoulder transition type may shift the side neck points horizontally, which should affect the length of the shoulder seam, and by extension the amount of shoulder slope.

The bodice back waist dart depth and width are affected by the back waist dart tip point and the back waist dart leg points. All of these points can move horizontally and vertically. The dart tip point only moves horizontally when the dart leg points move right or left in tandem. As the dart tip point moves vertically upward, towards the neck, the back waist dart lengthens; as the dart point moves vertically downwards, towards the waist, the back waist dart shortens. As the dart leg points move horizontally apart they widen the dart; as they move horizontally towards each other they narrow the dart. The dart legs were always moved the same distance so that the dart tip point stayed in the center of the dart. As the dart leg points move vertically upwards, towards the neck, they decrease the bodice back waist dart depth, and as it moves vertically downwards, towards the waist, they increase the bodice back waist dart depth.

The between back waist darts distance is affected by the back waist dart leg points. When the dart leg points move in the same direction they alter the distance between the center back and the dart. Movement towards the center back narrows the between back waist darts distance, while movement towards the side seam widens the between back waist darts distance.

One body-form variation has the opportunity to affect the bodice back waist dart depth: prominence point alignment. The shoulder blade prominence point equated to three locations on the arm and may pull the dart tip point towards the neck, resulting in a longer dart depth for the higher locations.

Two body-form variations have the opportunity to affect the bodice back waist dart width: blade prominence and blade description. A larger shoulder blade prominence may push the dart leg points outwards, increasing the width of the back waist dart. Five types of shoulder blade descriptions were found during the visual analysis of the sample. The flatter or softer types may pull the dart leg points inwards, narrowing the bodice back waist dart.

One body-form variation has the opportunity to affect the between back waist darts distance: shoulder blade width. Shoulder blades farther apart in width should result in increased distance between the inner dart legs of the back bodice blocks. A wider shoulder blade width could result from a narrower back waist dart or from the back waist dart moving further from the center back seam.

The bust dart depth is affected by the horizontal movements of the three dart points. When the dart tip point moves towards the bust it lengthens the bust dart; when it moves towards the side seam it shortens the bust dart. When the dart leg points move towards the side seam they lengthen the bust dart; when they move towards the bust they shorten the bust dart. When the dart points move in tandem the dart depth does not change.

Two body-form variation have the opportunity to affect the bust dart depth: bust fullness and ribcage containment. General sewing knowledge assumes that the larger the prominence, the deeper and wider the corresponding dart. Given this assumption, it follows that the fuller the bust, the deeper the dart. Ribcage containment may be the result of smaller busts, which should lead to shorter bust dart depths.

The between front waist dart distance is affected by the horizontal movement of the bodice front waist dart. Movement towards the center front narrows the distance between the front waist darts distance, while movement towards the side seam widens the between back waist darts distance. One body-form variation has the opportunity to affect the between back waist darts distance: bust point width. Bust points further apart in width should result in increased distance between the inner dart legs of the front bodice block.

The waist circumference is affected by the horizontal movements of the side waist points, the center back waist points, and the waist dart leg points. Care was taken to keep the waist of the bodice and skirt the same during the patterning phase. Inward movement of the of the side and center back waist points, as well as outward movement of the waist dart leg points should result in a narrower waist circumference. Outward movement of the side and center back waist points, as well as inward movement of the waist dart leg points should result in a wider waist circumference.

One body-form variation has the opportunity to affect the waist circumference: waist indentation. Waist indentation varies among the sample, from non-existent to indented. The degree of indentation may result in waist circumference variation, with the more indented waists smaller in circumference.

The front waist width equates to half of the full waist circumference, and is affected by the horizontal movements of the side waist points and the bodice front waist dart leg points. As the side waist points move outwards, away from the torso, and the waist dart leg points move inwards, narrowing the dart, the front waist width should increase. As the side waist points move inwards, towards the torso, and the waist dart leg points move outwards, widening the dart, the front waist width should decrease.

Three body-form variations have the opportunity to affect the front waist width: greatest lower-body front prominence identifier, description, and past bust extension. The type of GLBFP varies among the sample and may change the width measurement by moving the front waist dart legs inward or outward. Past bust extension may be affected by the type of GLBFP. This assumption does not strictly match with the front waist width, but if the type of GLBFP does extend past the bust, it is more likely the front waist width is larger.

The skirt front waist dart depth and width are affected by the horizontal and vertical movements of the front waist dart tip point and the front waist dart leg points. All dart points can move horizontally and vertically, though the dart tip point only moves horizontally when the dart leg points move horizontally in the same direction. As the dart tip point moves downwards, towards the hem, the dart deepens; and as it moves upwards, towards the waist, the dart shortens. As the dart leg points move horizontally outwards they widen the dart; and as they move horizontally inwards they narrow the dart. The dart legs can also move vertically; as they move upwards, towards the neck, they deepen the dart and as they move downwards, towards the hem, they shorten the dart.

One body-form variation has the opportunity to affect the skirt front waist dart depth: greatest lower-body front prominence alignment. One body-form variation has the opportunity to affect the skirt front waist dart width. These assumptions are based on the premise that the larger the prominence, the deeper and wider the corresponding dart. Visual analysis revealed that the GLBFP aligned at various points along the lower torso, indicating that the dart depth may vary based on these points. Visual analysis also revealed that the GLBFP could be described a few different ways. Flatter and softer GLBFPs may pull the dart legs closer together, narrowing the dart.

The skirt back waist dart depth and width are affected the same way that the skirt front waist dart depth and width are. Three body-form variations have the opportunity to affect the skirt back waist dart depth: buttocks length, the fullest part of the buttocks and buttocks alignment. One body-form variation has the opportunity to affect he skirt back waist dart width: buttocks prominence. All assumptions are based on the premise that the larger the prominence, the deeper and wider the corresponding dart. A longer buttock can pull the skirt back waist dart tip point towards the hem, thereby lengthening the dart. If the fullest part of the buttocks is lower, then the skirt back waist dart tip point should be pulled towards the hem, lengthening the dart. Alignment of the buttocks was shown to vary during visual analysis, indicating that the dart depth may vary based on these points. Buttocks prominence was composed of two categories: flat and prominent. A prominent buttock may push the dart legs further apart, widening the dart.

The skirt side seam curve length is affected by the side waist point and the greatest lower-body side prominence point. Care was taken to insure the front and back curves were the same. The points can all move horizontally and vertically. Horizontal changes affect the curvature, which affect the length, as a rounder curve is longer than a flatter one. Moving the side waist point horizontally inwards, towards the center of the body, should result in a longer curve length; while moving it outwards, away from the center of the body, should result in a shorter curve length. Moving the side waist point vertically downwards, towards the hem, should result in a shorter curve length, while moving it upwards, towards the neck, should result in a longer curve length. Moving the GLBSP point horizontally inwards, towards the center of the body, should result in a shorter curve length; while moving it outwards, away from the center of the body, should result in a longer curve length. Moving the GLBSP point vertically downwards, towards the hem, should result in a longer curve length; while moving it upwards, towards the waist, should result in a shorter curve length. Combinations of movement between the side waist point and the GLBSP point can result in any number of shorter or longer curve lengths.

Three body-form variables have the opportunity to affect the skirt side seam curve length: the greatest lower-body side prominence location, alignment and description. Visual analysis revealed two locations for the GLBSP: high-hip and thigh. The location on the body affected where the GLBSP point was placed, so the curve length should be partly dependent upon the location of the GLBSP. Visual analysis revealed that the GLBSP could be described a few different ways. Flatter and softer GLBSPs may make the curve flatter, shortening the curve length.

Body Component	Pattern Dimension	Assumptions
Neck	Neck circumference	The thicker the neck, the larger the neck circumference. A smooth neck-to-shoulder transition will produce a larger neck circumference, while a sharp neck-to-shoulder transition will produce a smaller neck circumference. The more prominent the collarbone, the smaller the neck circumference will be.
Neck	Front neck drop	The more forward tilted the neck is in relation to the torso, the longer the front neck drop measurement will be.
Shoulder	Shoulder seam	The longer the shoulder, the larger the shoulder seam measurement will be. The softer the shoulder point, the longer the shoulder seam measurement will be. The farther the shoulder point is outside the bust, high-hip and thigh widths, the longer the shoulder seam measurement will be.
Shoulder	Averaged shoulder slope	The more sloped the shoulder, the larger the shoulder slope measurement will be. The softer the shoulder point, the larger the shoulder slope measurement will be. The longer the shoulder, the larger the shoulder slope measurement will be. A smooth neck-to-shoulder transition will produce a larger shoulder slope measurement, while a sharp neck-to-shoulder transition will produce a smaller shoulder slope measurement.
Shoulder Blade	Bodice back waist dart depth	The further the shoulder blade prominence point is from the waist, the larger the bodice back waist dart depth measurement will be.
Shoulder Blade	Bodice back waist dart width	The more prominent the shoulder blade, the larger the bodice back waist dart width measurement will be. The type of shoulder blade prominence will affect the measurement of the bodice back waist dart width.
Shoulder Blade	Between back waist darts distance	The wider apart the shoulder blade prominence points are, the larger the between back waist darts distance measurement will be.

Bust	Bust dart depth	The fuller the bust, the larger the bust dart depth measurement will be. Busts contained within the ribcage will have smaller bust dart depth measurements than busts not contained within the ribcage.
Bust	Between front waist darts distance	The wider apart the bust points are, the larger the between front waist darts distance measurement will be.
GLBFP	Waist circumference	The more indented the waist, the smaller the waist circumference measurement will be.
GLBFP	Front waist	The type of GLBFP will affect the measurement of the front waist. Certain types of GLBFP's will extend past the bust, while others will not.
GLBFP	Skirt front waist dart depth	The lower the GLBFP is aligned, the larger the skirt front waist dart depth measurement will be.
GLBFP	Skirt front waist dart width	The type of GLBFP will affect the measurement of the skirt front waist dart width.
Buttocks	Skirt back waist dart depth	The longer and lower the buttocks prominence, the larger the skirt back waist dart depth measurement will be.
Buttocks	Skirt back waist dart width	The more prominent the buttocks, the larger the skirt back waist dart width measurement will be.
GLBSP	Skirt Side Seam Curve Length	The lower the location of the GLBSP on the body, the longer the curved portion of the skirt side seam will be on the pattern. The type of prominence will affect the skirt side seam curve measurement.

Table 17: Assumptions

Chapter 5 Results

This chapter presents the results from the dimensional, visual, and physiological components of data analysis. Though the majority of people have some level of body asymmetry, only the right side of the dress blocks were altered, assuming a symmetrical body. Four of the 43 subjects were removed from the sample set due to extreme asymmetry which compromised the fit of the garment on the avatars.

The fit model is the standard for this sample, and thus was not included in analysis of the sample. Information about the fit model is presented during the dimensional and visual components to show how the sample differs from the standard.

Dimensional

Nineteen measurements were extracted from the blocks. Some of the measurements were manipulated to determine measurements meaningful to body-form variation. As only the right side of the patterns was altered, the width measurements equal one quarter of the full body circumference. To calculate a circumference, the front and back measurements were doubled and added together. The front and back shoulder slopes were averaged to simplify analysis. This resulted in sixteen dimensions for analysis.

Each dimension was sorted from smallest to largest and graphed using a dot plot. Dot plots were chosen to allow the researcher to see how the sample measurements ranged naturally. A histogram was considered; however, this method requires pre-selection of groups. There is no data to suggest preset ranges for individual dimensions. Additionally, histograms require equidistant ranges for each bar on the graph, which did not support the formation of unique groups.

The graphs present the range of measurements for each dimension, and illustrate groupings among subjects. Groupings were color coded, with a red dot denoting the fit model. Descriptive frequencies (mean, minimum, maximum, range, and standard deviation) were calculated for each dimension. The fit model was excluded from the data used to calculate the descriptive frequencies, but included in the graphs. The number of standard deviations each subject was from the mean was calculated and the minimum and maximum standard deviations were set as the minimum and maximum limits on the y-axis of each graph.

Neck Dimensions

Two dimensions corresponded to the neck: neck circumference and front neck drop. The front neck drop was measured by placing a horizontal line at both the high-point shoulder and the center front neck points and measuring the vertical distance between the lines.

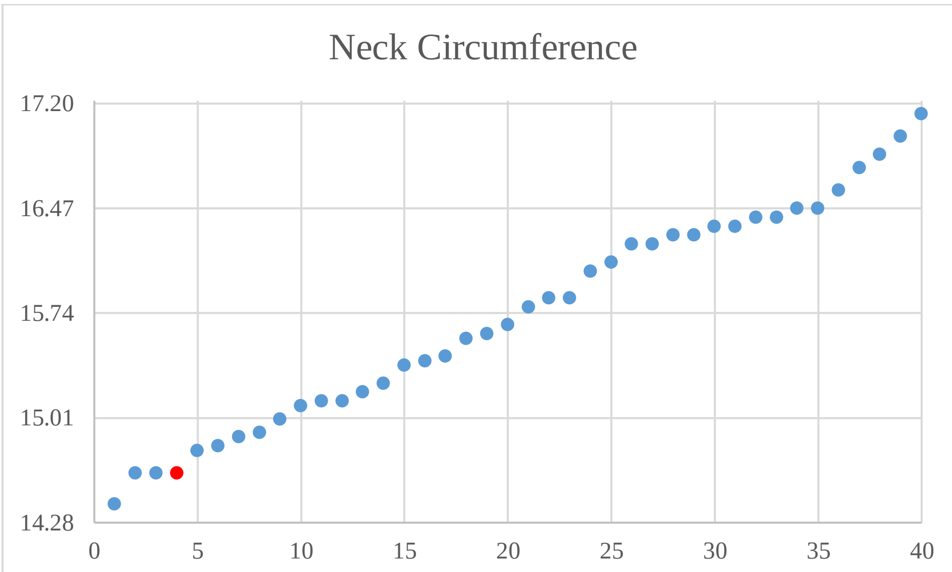


Figure 34: Neck Circumference

The mean for the neck circumference was 15.75"; 1.125" larger than the fit model. The range was 2.72", with the minimum at 14.41" and the maximum at 17.13". The standard deviation was 0.725". The fit model equaled the second smallest neck circumference measurement in the sample: 14.625". No distinct group were identified from this graph, though the diagonal line indicates variation in fit (Figure 34).

The mean for the front neck drop was 3.58"; 0.53" larger than the fit model. The range for this dimension was 1.16", with the minimum at 2.86" and the maximum at 4.05". The standard deviation was 0.35". The fit model equaled the sixth smallest front neck drop measurement in the sample: 3.05”. Five groups were identified from this graph (Figure 35).

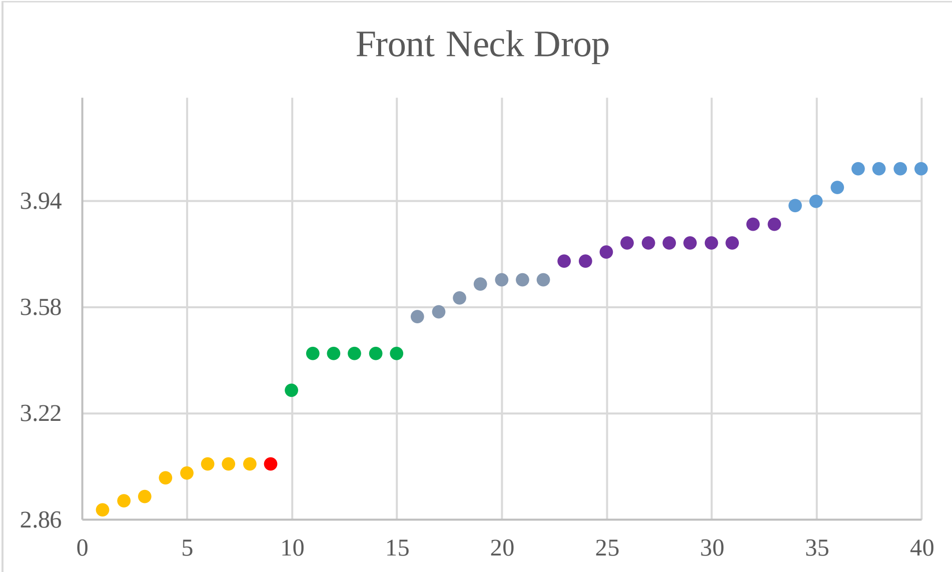


Figure 35: Front Neck Drop

Shoulder Dimensions

Two dimensions corresponded to the shoulder: shoulder seam and averaged shoulder slope. Shoulder seam is the distance from the high-point shoulder to the shoulder point. Averaged shoulder slope is composed of the front and back shoulder slope measurements. Shoulder slope was measured by placing horizontal lines through the high-point shoulder and shoulder point, and then measuring the vertical distance between the lines.

The mean for shoulder seam was 3.95”; 0.05” smaller than the fit model. The range for this dimension was 0.97”, with the minimum at 3.5” and the maximum at 4.47”. The standard deviation was 0.22”. The fit model equaled the sixth largest shoulder seam measurement in the sample: 4”. Five groups were identified from this graph (Figure 36).

The mean for averaged shoulder slope was 1.24”; .01” smaller than the fit model. The range for this dimension was 0.70”, with the minimum at 0.875” and the maximum at 1.57”. The standard deviation was 0.14”. The fit model equaled the tenth smallest averaged shoulder slope measurement in the sample: 1.25”. Five groups were identified from this graph (Figure 37).

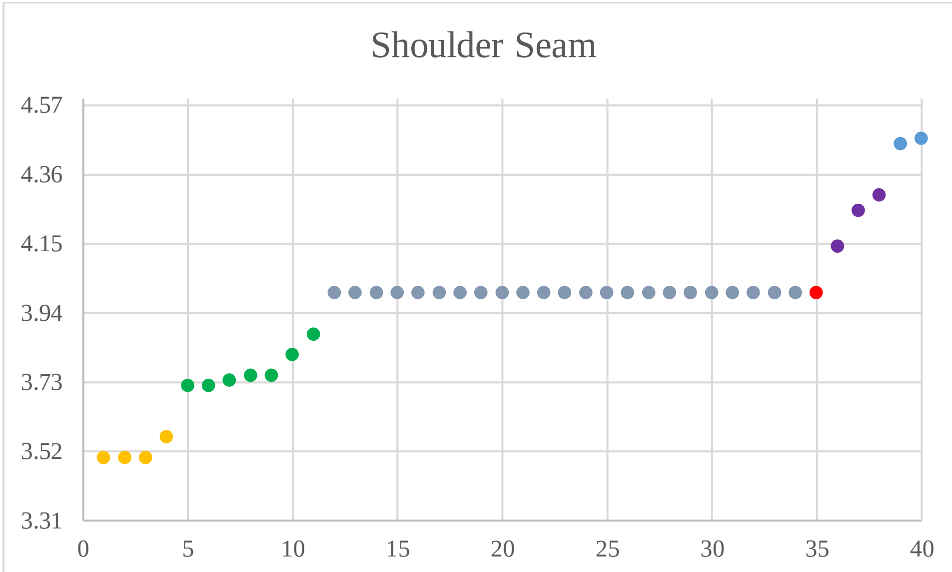


Figure 36: Shoulder Seam

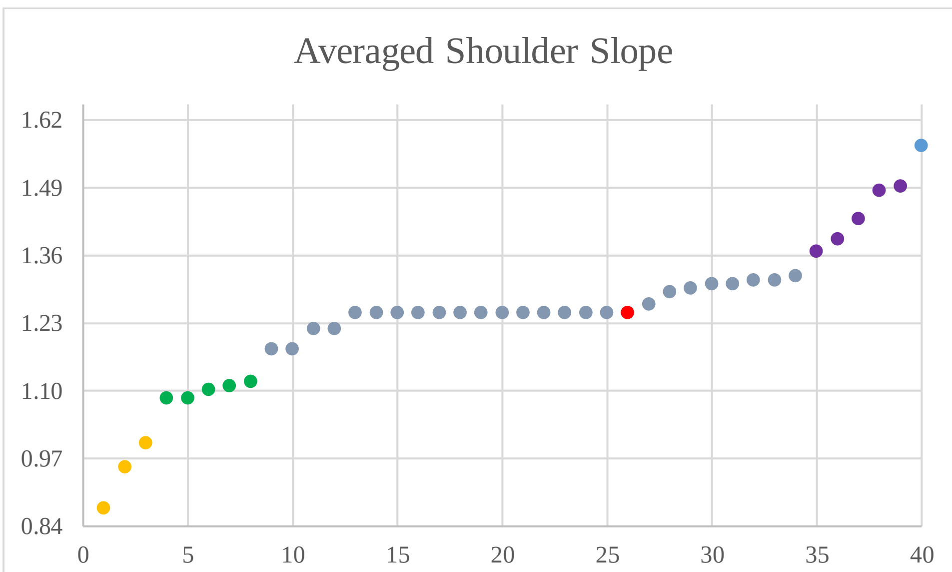


Figure 37: Averaged Shoulder Slope

Shoulder Blade Dimensions

Three dimensions corresponded to the shoulder blades: bodice back waist dart depth, bodice back waist dart width, and the between back waist darts distance. The between back waist darts distance equals the center back waist point to the first bodice back waist dart leg measurement, doubled.

The mean for the bodice back waist dart depth was 7.36”; 1.39” smaller than the fit model. The range for this dimension was 3.25”, with the minimum at 5.5” and the maximum at 8.75”. The standard deviation was 0.68”. The fit model equaled the largest bodice back waist dart depth measurement in the sample: 8.75”. Five groups were identified from this graph (Figure 38).

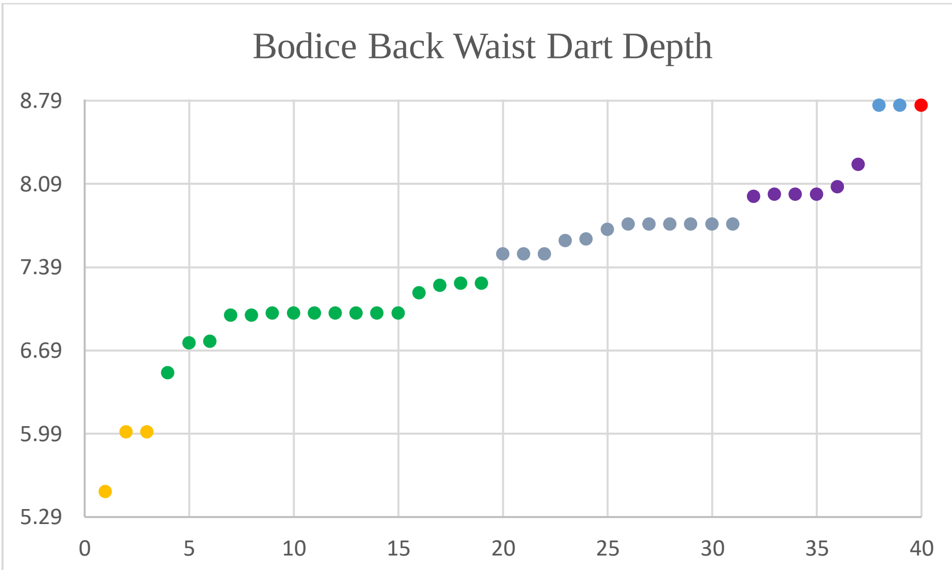


Figure 38: Bodice Back Waist Dart Depth

The mean for the bodice back waist dart width was 1.53”; 0.22” smaller than the fit model. The range for this dimension was 0.89”, with the minimum at 0.875” and the maximum at 1.77”. The standard deviation was 0.25”. The fit model equaled the second largest bodice back waist dart width measurement in the sample: 1.75”. Four groups were identified from this graph (Figure 39).

The mean for the between back waist darts distance was 5.68”; 0.75” larger than the fit model. The range for this dimension was 3.53”, with the minimum at 4.94” and the maximum at 8.47”. The standard deviation was 0.8”. The fit model equaled the smallest between back waist darts distance measurement in the sample: 4.94”. Three groups were identified from this graph (Figure 40).

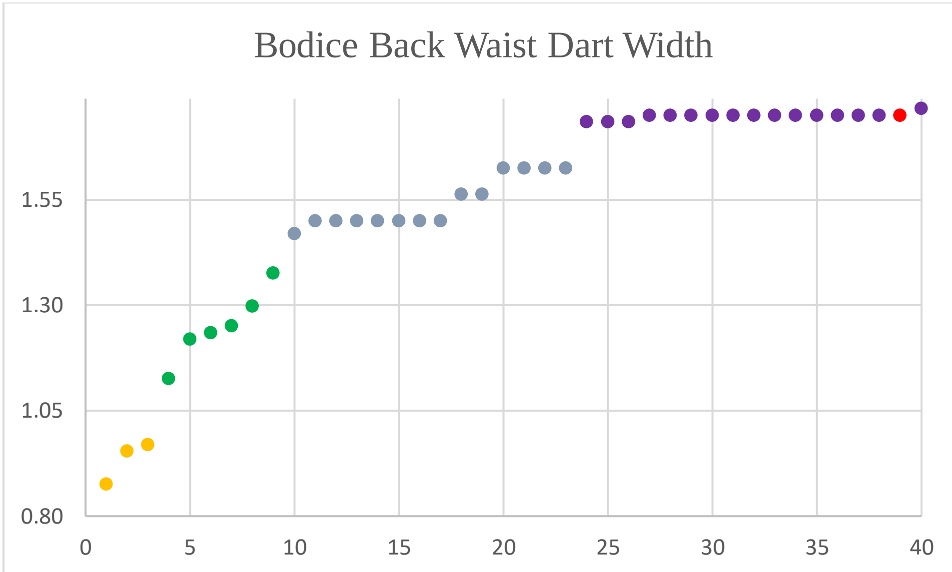


Figure 39: Bodice Back Waist Dart Width

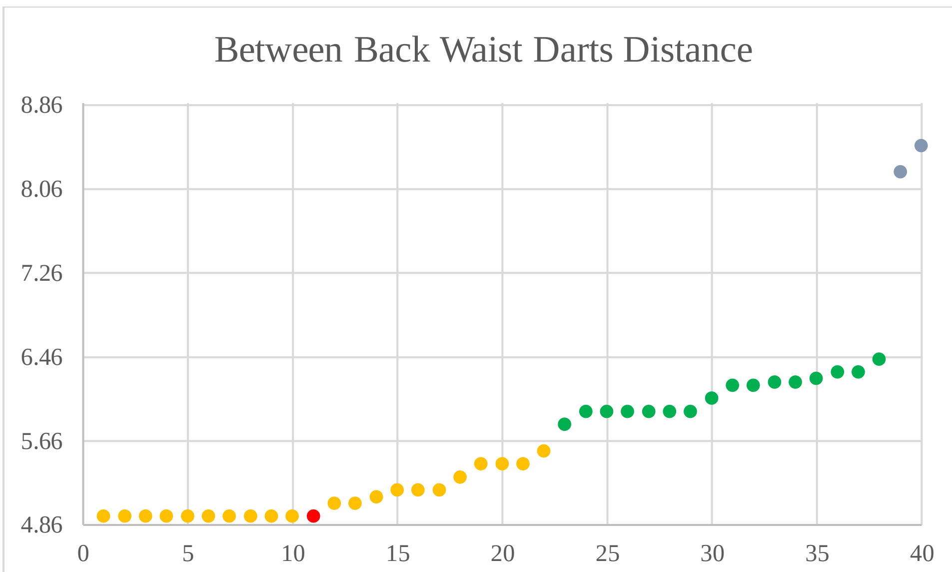


Figure 40: Between Back Waist Darts Distance

Bust Dimensions

Two dimensions corresponded to the bust: bust dart depth and between front waist darts distance. The between front waist darts distance equals the center front waist point to the first bodice waist dart leg measurement, doubled.

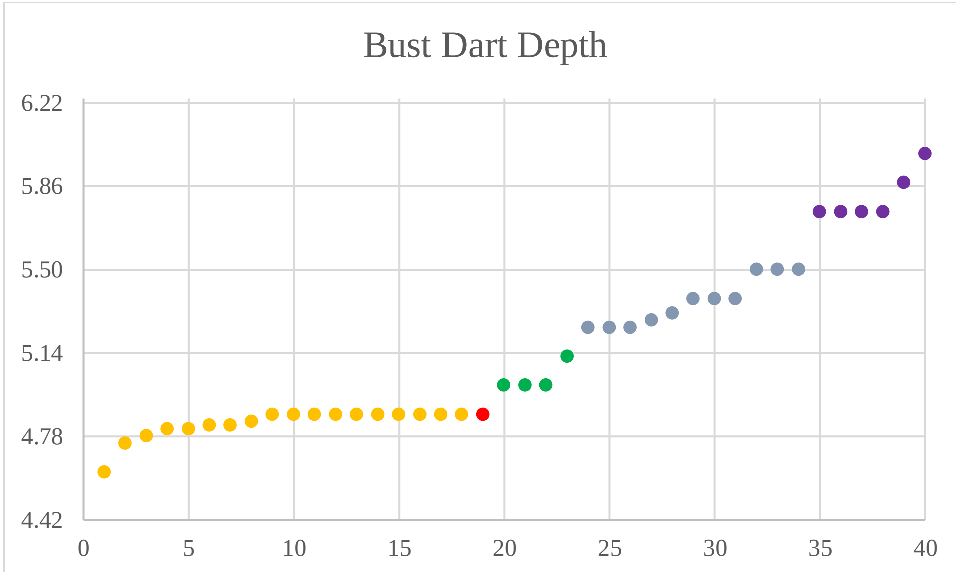


Figure 41: Bust Dart Depth

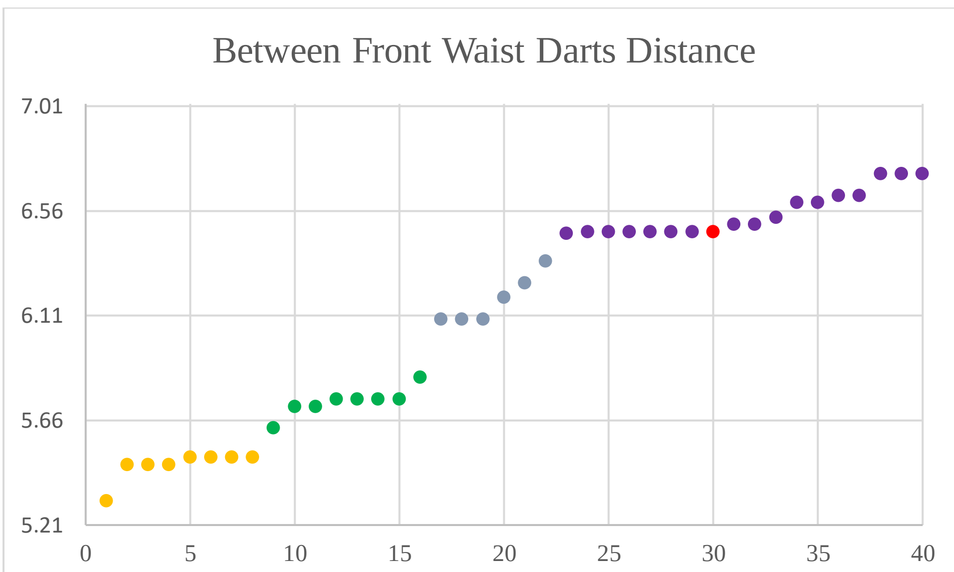


Figure 42: Between Front Waist Darts Distance

The mean for the bust dart depth was 5.15"; 0.28" larger than the fit model. The range for this dimension was 1.38", with the minimum at 4.63" and the maximum at 6". The standard deviation was 0.37". The fit model equaled the seventh smallest bust dart depth measurement in the sample: 4.875". Four groups were identified from this graph (Figure 41).

The mean for the between front waist darts distance was 6.1"; 0.36" smaller than the fit model. The range for this dimension was 1.41", with the minimum at 5.31" and the maximum at 6.72". The standard deviation was 0.45". The fit model equaled the sixth largest between front waist darts distance measurement in the sample: 6.47". Four groups were identified from this graph (Figure 42).

GLBFP Dimensions

Four dimensions corresponded to the greatest lower-body front prominence: waist circumference, front waist width, skirt front waist dart depth, and skirt front waist dart width.

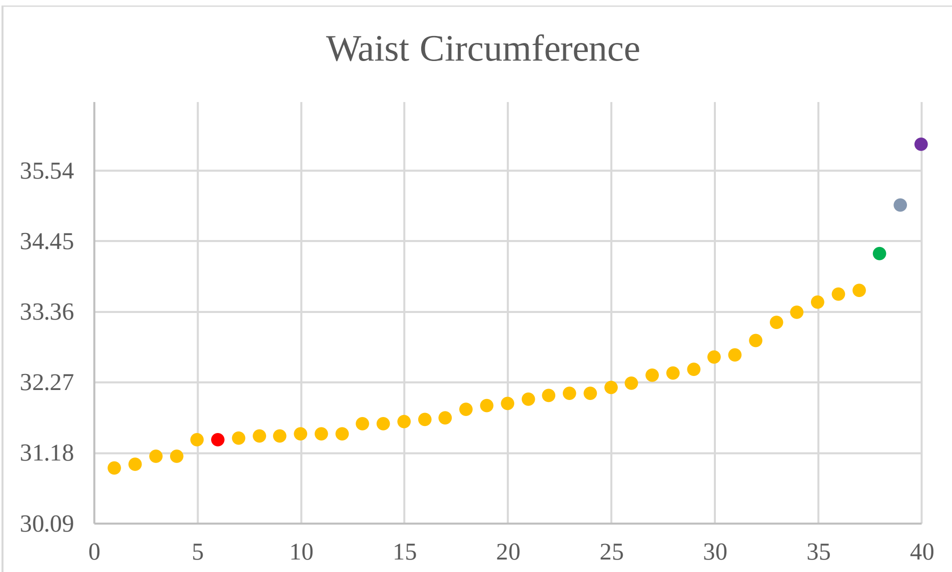


Figure 43: Waist Circumference

The mean for waist circumference was 32.28", 0.91" larger than the fit model. The range for this dimension was 5", with the minimum at 30.94" and the maximum at 35.94". The standard deviation was 1.09". The fit model equaled the third smallest waist circumference measurement in the sample: 31.125". Four groups were identified from this graph (Figure 43).

The mean for the front waist width was 17.41", 0.44" larger than the fit model. The range for this dimension was 4.13", with the minimum at 15.66" and the maximum at

19.78”. The standard deviation was 0.82”. The fit model equaled the sixth smallest front waist width measurement in the sample: 16.97”. Six groups were identified from this graph (Figure 44).

Figure 44: Front Waist Width

The mean for the skirt front waist dart depth was 4.17”; 1.83” smaller than the fit model. The range for this dimension was 3”, with the minimum at 3” and the maximum at 6”. The standard deviation was 0.68”. The fit model equaled the ninth largest skirt front waist dart depth measurement in the sample: 4.23”. Five groups were identified from this graph (Figure 45).

The mean for the skirt front waist dart width was 0.69”, 0.05” smaller than the fit model. The range for this dimension was 0.41”, with the minimum at 0.48” and the maximum at 0.89”. The standard deviation was 0.08”. The fit model equaled the sixth largest skirt front waist dart width measurement in the sample: 0.73”. Three groups were identified from the graph (Figure 46).

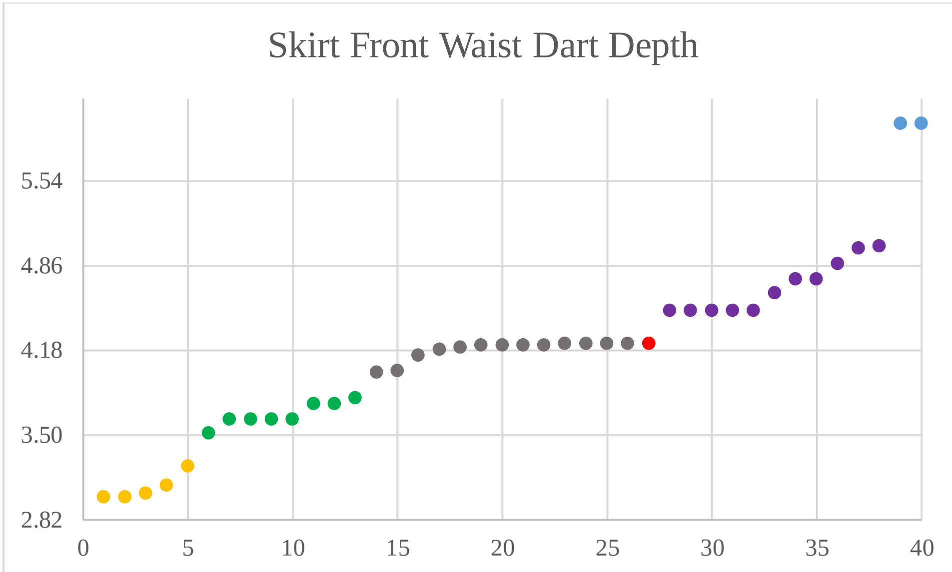


Figure 45: Skirt Front Waist Dart Depth

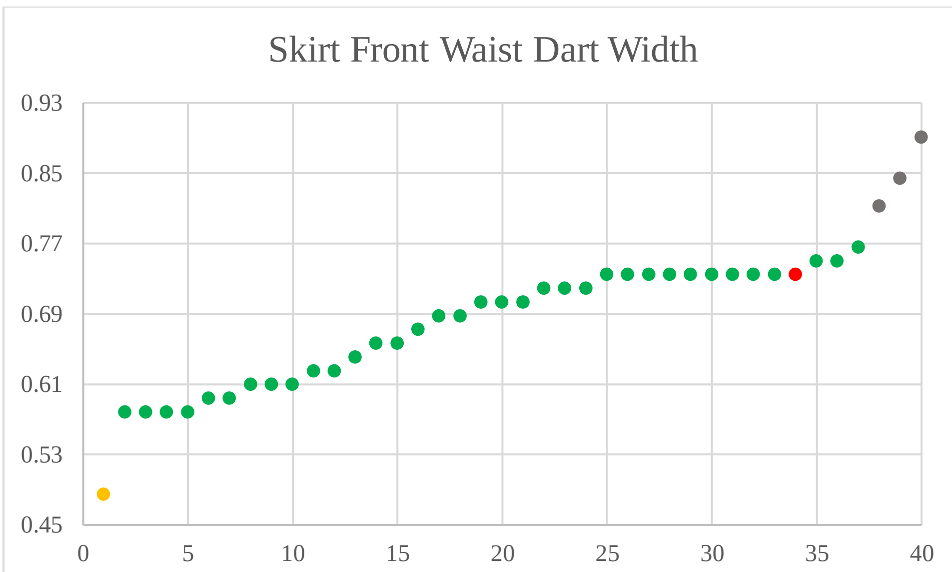


Figure 46: Skirt Front Waist Dart Width

Buttocks Dimensions

Two dimensions corresponded to the buttocks: skirt back waist dart depth and skirt back waist dart width.

The mean for the skirt back waist dart depth was 7.39”; 0.52” larger than the fit model. The range for this dimension was 3.63”, with the minimum at 5” and the maximum at 8.63”. The standard deviation is 0.75”. The fit model equaled the sixth smallest skirt back waist dart depth measurement in the sample: 6.875”. Three groups were identified from this graph (Figure 47).

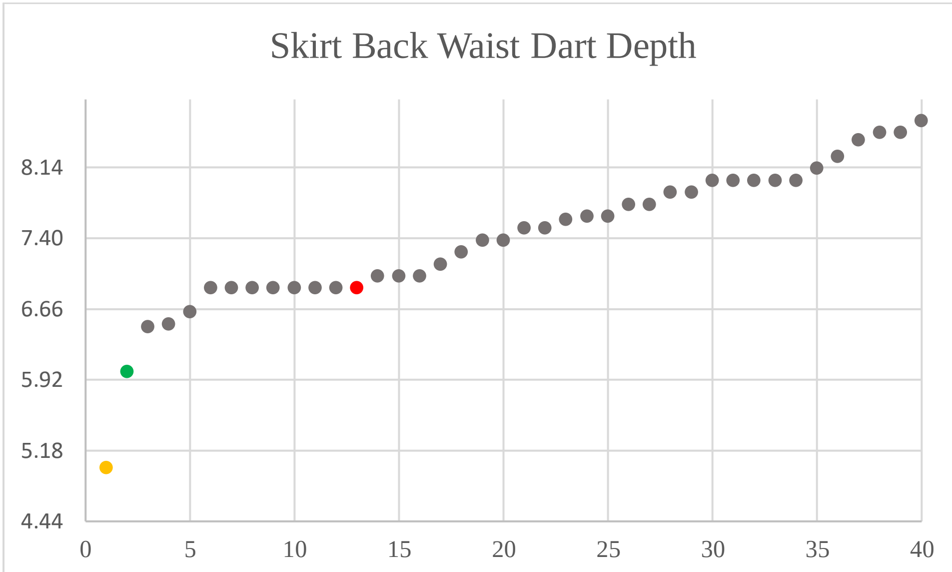


Figure 47: Skirt Back Waist Dart Depth

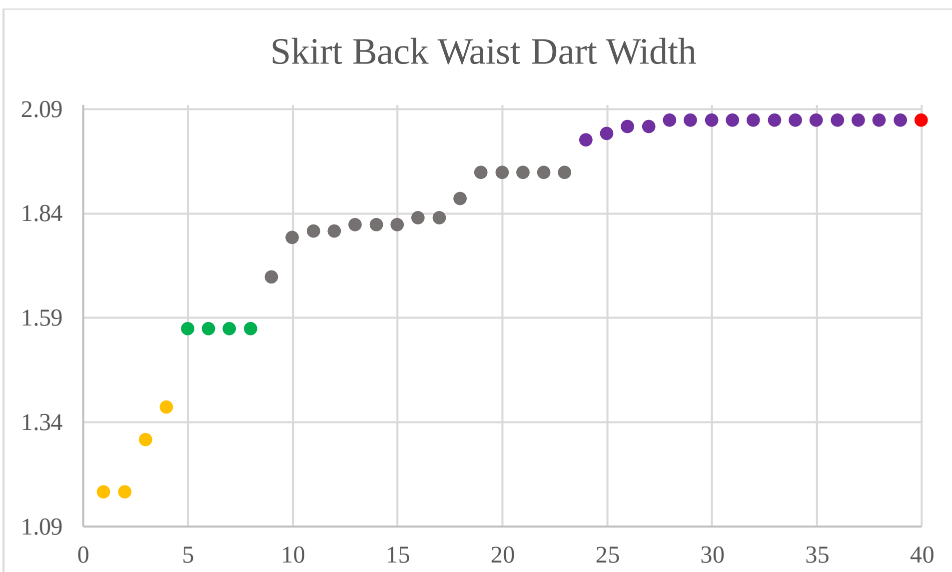


Figure 48: Skirt Back Waist Dart Width

The mean for the skirt back waist dart width was 1.84”; 0.22” smaller than the fit model. The range for this dimension was 0.89”, with the minimum at 1.17” and the maximum at 2.06”. The standard deviation was 0.26”. The fit model equaled the largest skit back waist dart width measurement in the sample: 2.06”. Four groups were identified from this graph (Figure 48).

GLBSP

One dimension corresponded to the greatest lower-body side prominence: skirt curve length. The skirt curve length extends from the waist to the point of greatest lower-body side-prominence.

The ratio of the skirt curve to the skirt side seam mean was 10.78”; 0.34” smaller than the fit model. The range for this dimension was 8.28”, with the minimum at 4.83” and the maximum at 13.11”. The standard deviation was 1.92”. The fit model had the fifteenth smallest skirt curve length measurement in the sample. Two groups were identified from this graph (Figure 49).

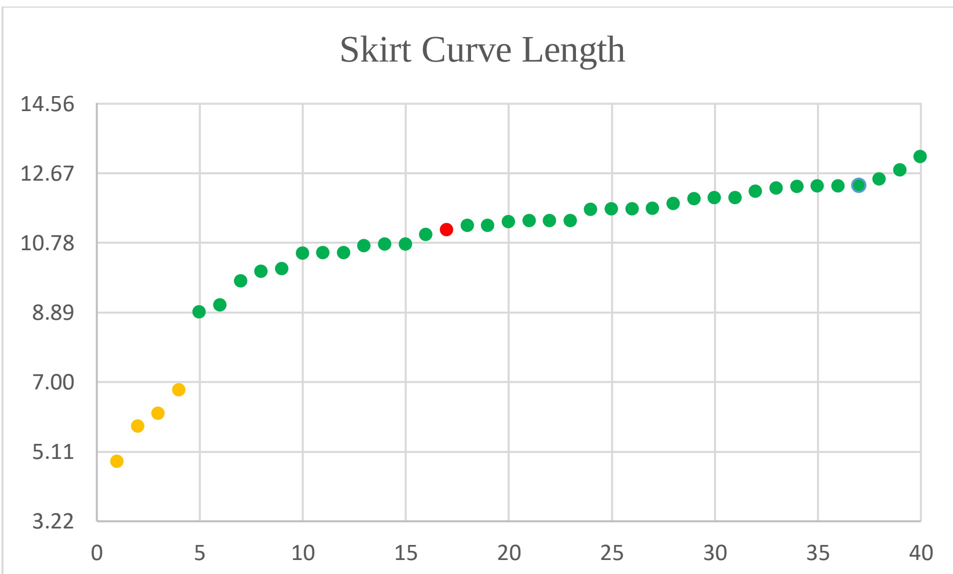


Figure 49: Skirt Curve Length

Visual

Each dimension corresponded to at least one body-form variable. Scans were visually analyzed in ScanWorX, measurement software by Human Solutions of North America, Inc. Descriptions were generated from the scans. Data and graphs for the twenty-seven body-form variables are presented in this section. Each graph includes the descriptors and count for each variable.

Neck

Analysis of the neck included neck thickness, the neck-to-shoulder transition, collarbone visibility, and neck tilt. The fit model had an average neck thickness, a smooth neck-to-shoulder transition, a visible collarbone, and a slightly forward neck tilt.

Neck thickness produced three groups: thin, average, and thick (Figure 50). Thirteen subjects had thin necks, twelve subjects had average necks, and fourteen subjects had thick necks. Neck-to-shoulder transition produced two groups: sharp and smooth (Figure 51). There were twenty-eight subjects in the sharp group, and eleven subjects in the smooth group. Collarbone visibility ranged from flat, nearly flat, visible, and prominent (Figure 52 & Figure 53). Neck tilt ranged from straight, slightly forward, forward, and far forward (Figure 54 & Figure 55).

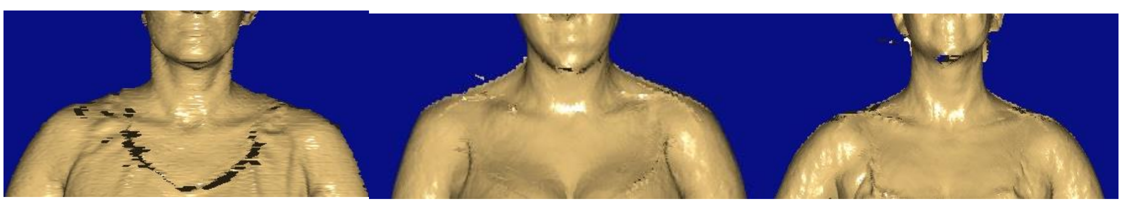


Figure 50: Examples of Neck Thickness from left: Thin, Average, Thick

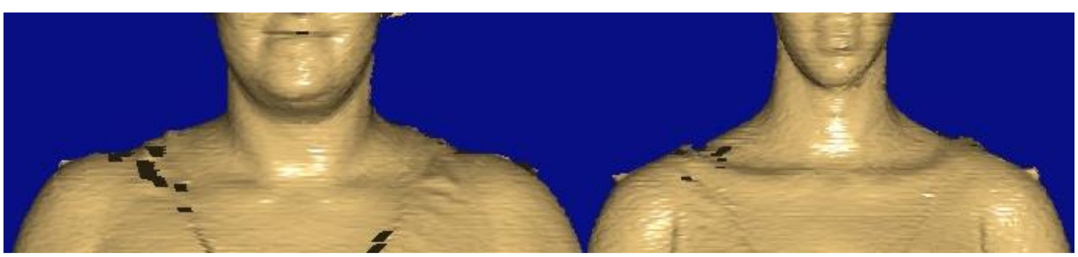


Figure 51: Examples of Neck-to-Shoulder Transition, from left: Sharp, Smooth

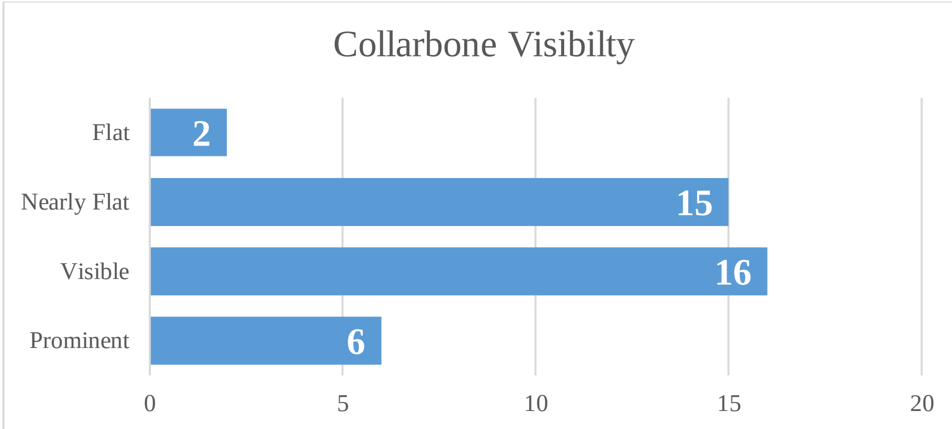


Figure 52: Collarbone Visibility

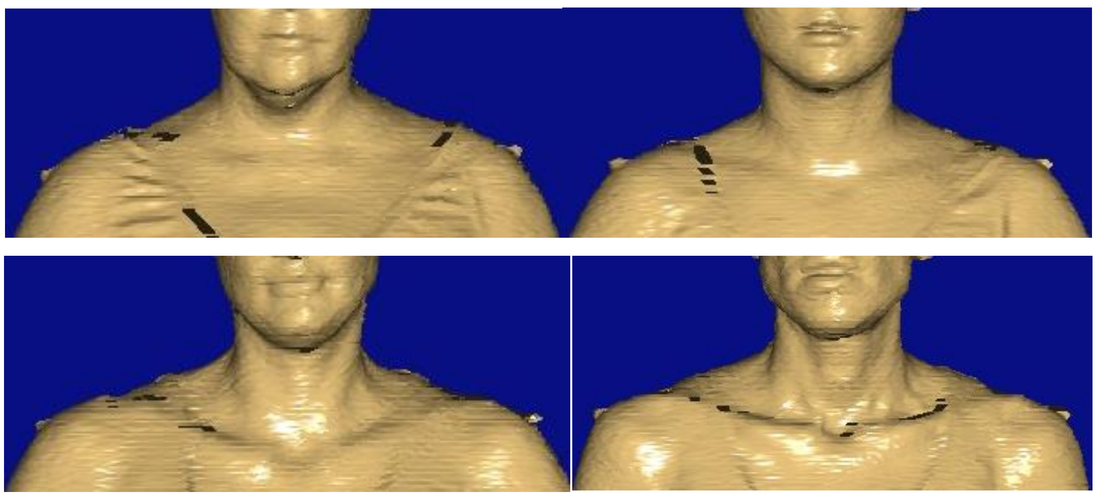


Figure 53: Examples of Collarbone Visibility, from top left: Flat, Nearly Flat, Visible, Prominent

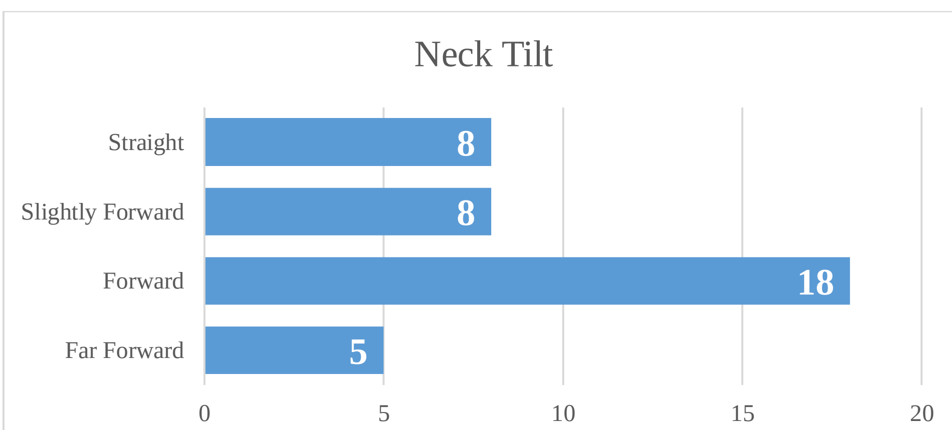


Figure 54: Neck Tilt

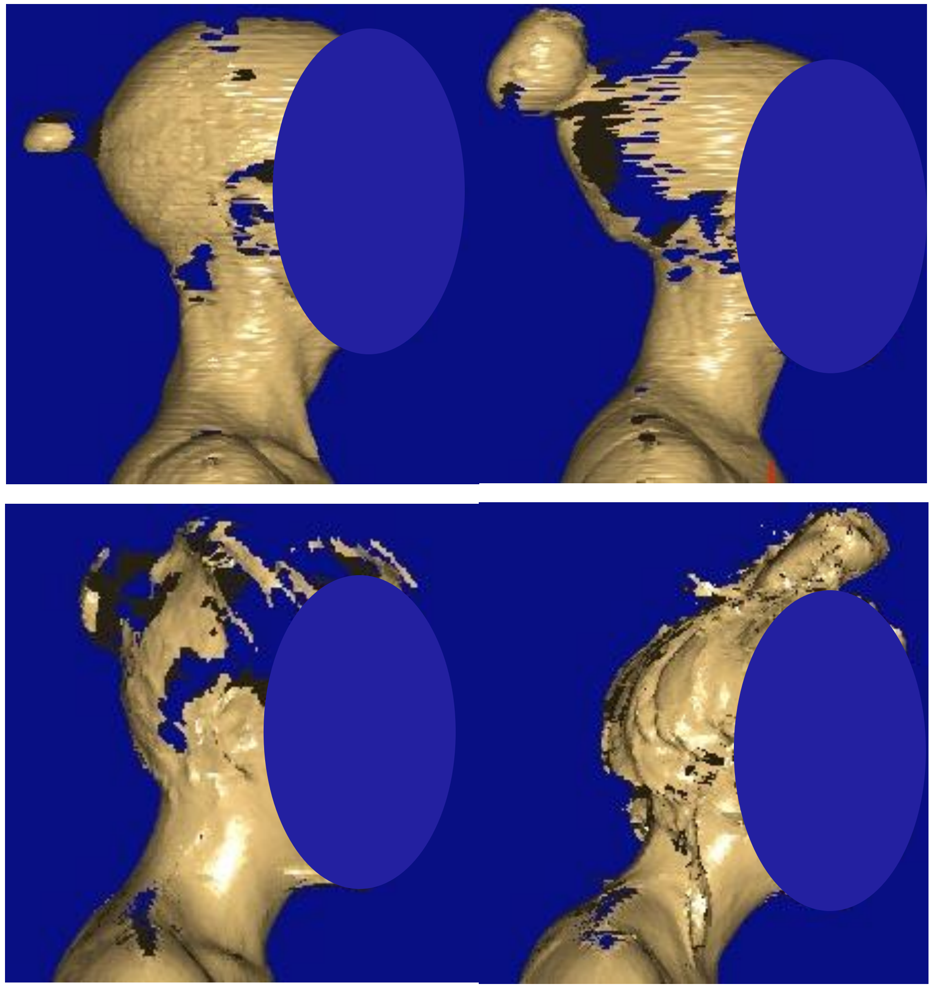


Figure 55: Examples of Neck Tilt, from top left: Straight, Slightly Forward, Forward, Far Forward

Shoulder

Analysis of the shoulder included shoulder length description, shoulder point sharpness, shoulder point alignment, and shoulder slope description. The fit model had an average shoulder length, soft shoulder points that aligned with the bust, but were inside the high-hip and thigh, and slightly sloped shoulders.

Shoulder length description produced three groups: short, average, and long (Figure 56). Eleven subjects were in the short group, ten subjects were in the average group, and eighteen subjects were in the long group. Shoulder point sharpness was either sharp or soft (Figure 57). The sharp group included sixteen subjects, and the soft group included twenty-three subjects.

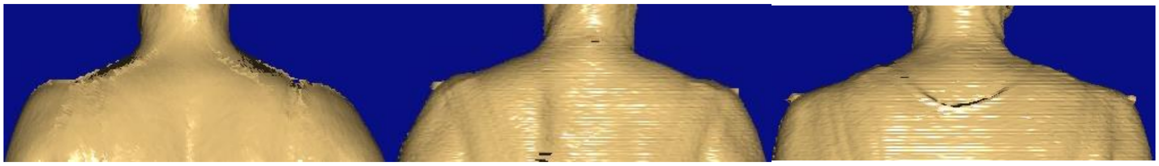


Figure 56: Examples of Shoulder Length, from left: Short, Average, Long

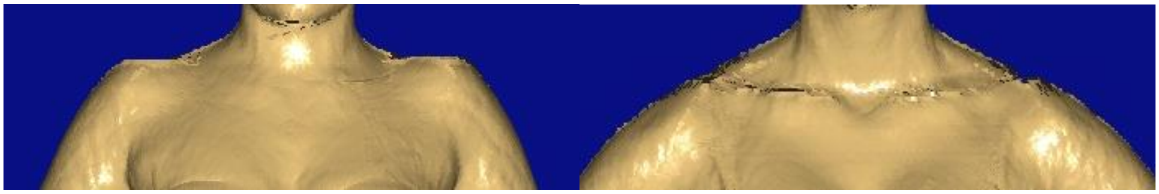


Figure 57: Examples of Shoulder Point Sharpness, from left: Sharp, Smooth

Shoulder point alignment was assessed by the placement of sagittal planes at both shoulder points and analysis of the relation of the planes to the bust, high-hip, and thigh. Alignment was inside, aligned, or outside of each body component (Figure 58 & Figure 59). Shoulder slope description ranged from flat, slightly sloped, sloped, more sloped, and steep (Figure 60 & Figure 61).

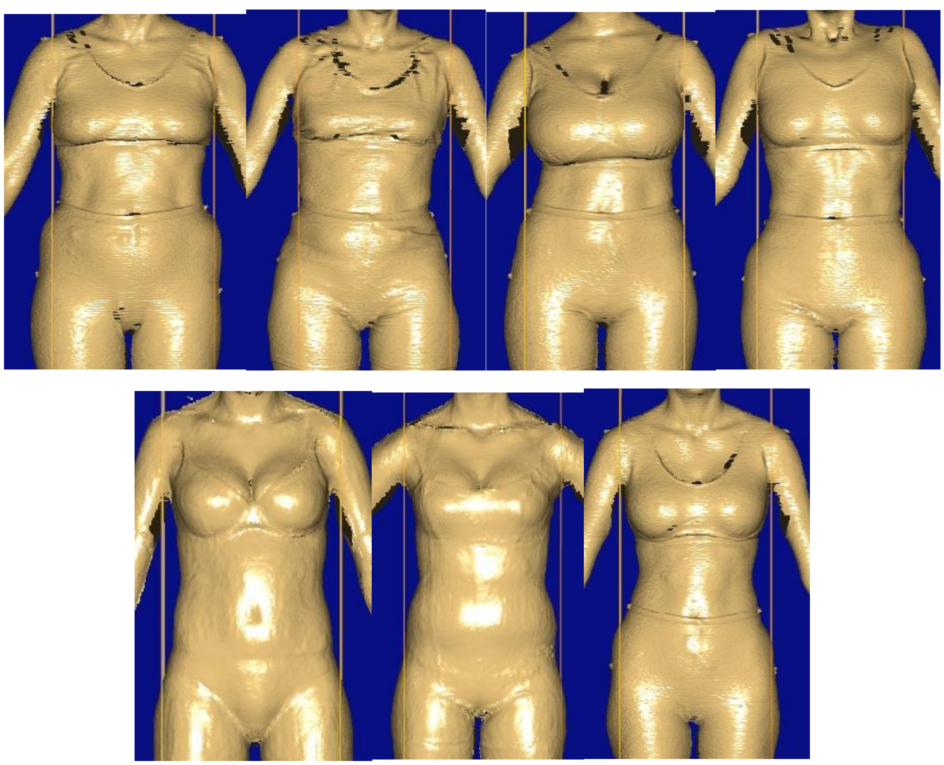


Figure 58: Examples of Shoulder Point Alignment, from left: Inside b, hh & t; Aligned w/b, outside hh, inside t; Aligned w/b & hh, inside t; Aligned w/b, inside hh & t; Outside b & hh, inside t; Outside b, aligned w/hh, inside t; Outside b, inside hh & t

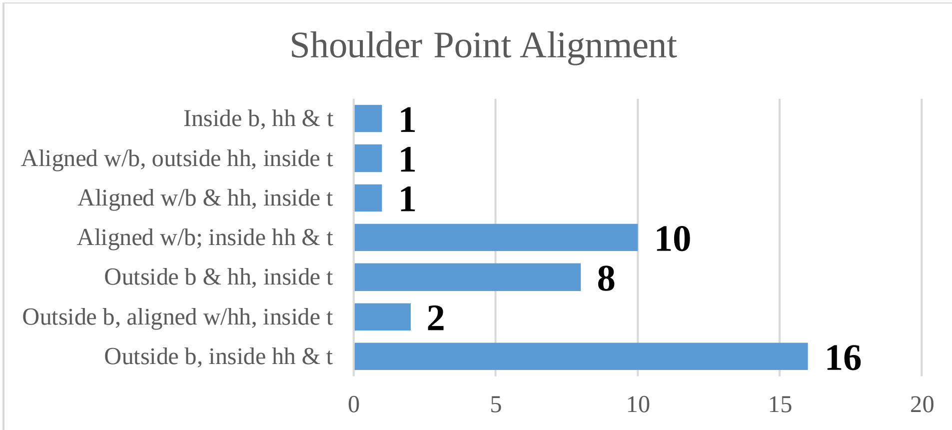


Figure 59: Shoulder Point Alignment

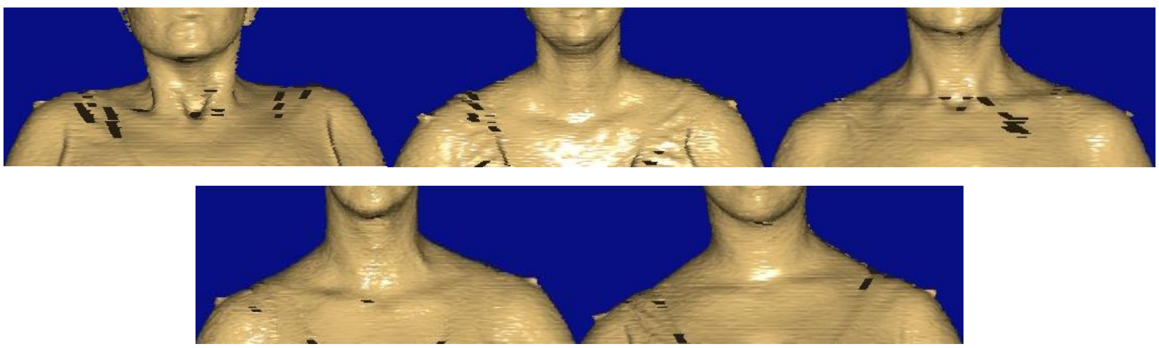


Figure 60: Examples of Shoulder Slope, from left: Flat, Slightly Sloped, Sloped, More Sloped, Steep

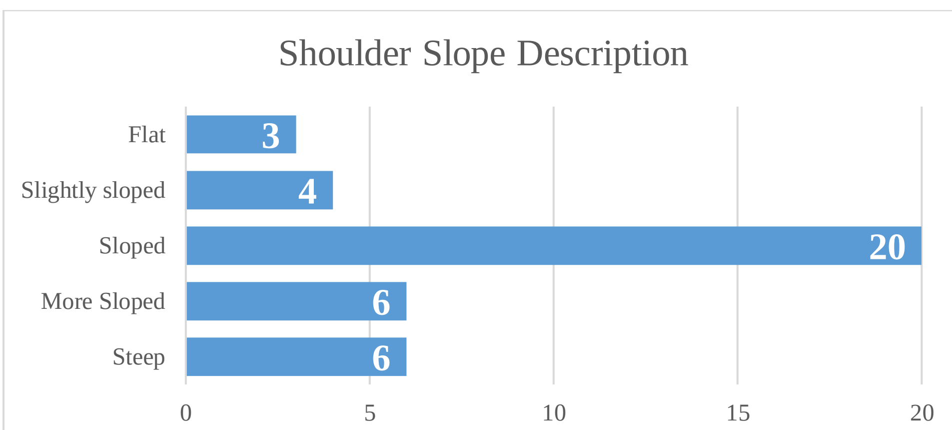


Figure 61: Shoulder Slope Description

Shoulder Blades

Analysis of the shoulder blades included prominence point alignment, blade prominence, blade description, and blade width. The fit model's shoulder blade prominence was aligned at the arm join, her blade prominence was visible and rounded in appearance, and average in width.

Prominence point alignment was assessed by marking the prominence points with a transverse plane and seeing where on the body it matched. Prominence point alignment occurred at the armpit, arm join, or above the arm join. Seven subjects' shoulder blades aligned with their armpits, thirty subjects' shoulder blades aligned with their arm join, which is above the armpit, and one subject's shoulder blades aligned above the arm join. One subject's alignment was obscured due to the sports bra covering her back.

Blade prominence was flat, almost flat, visible, or prominent (Figure 62 & Figure 63). Blade points were flat, softly pointed, pointed, softly rounded, or rounded (Figure 64 & Figure 65).

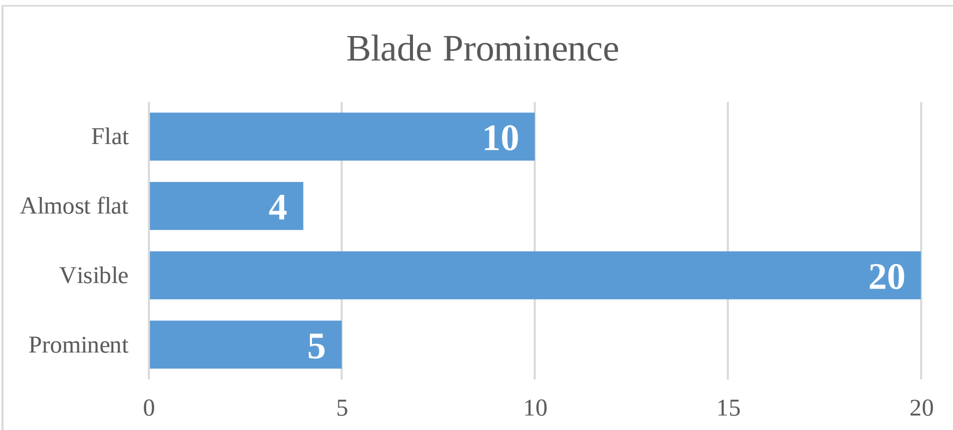


Figure 62:Blade Prominence

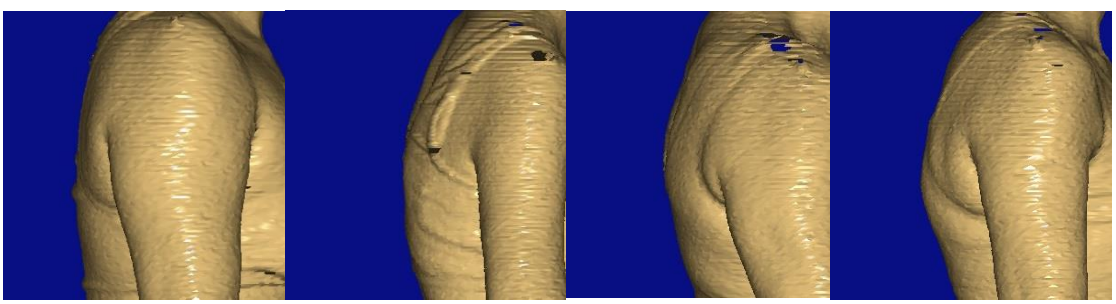


Figure 63: Examples of Shoulder Blade Prominence, from left: Flat, Almost Flat, Visible, Prominent

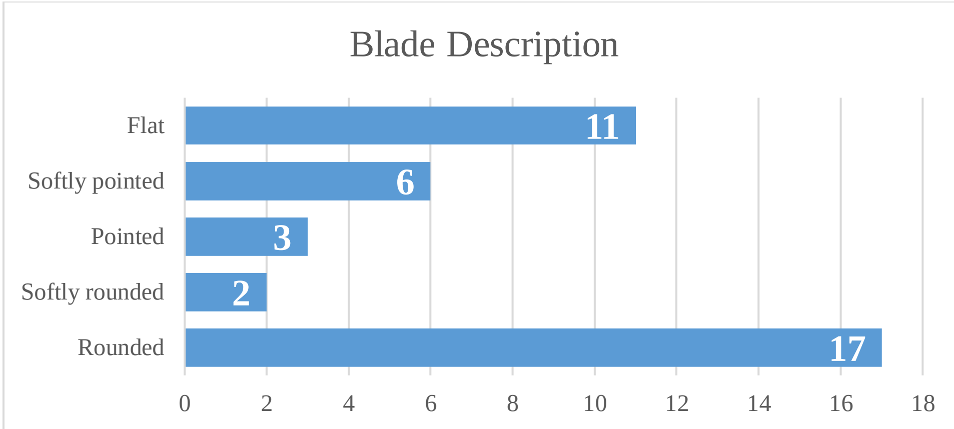


Figure 64: Blade Description

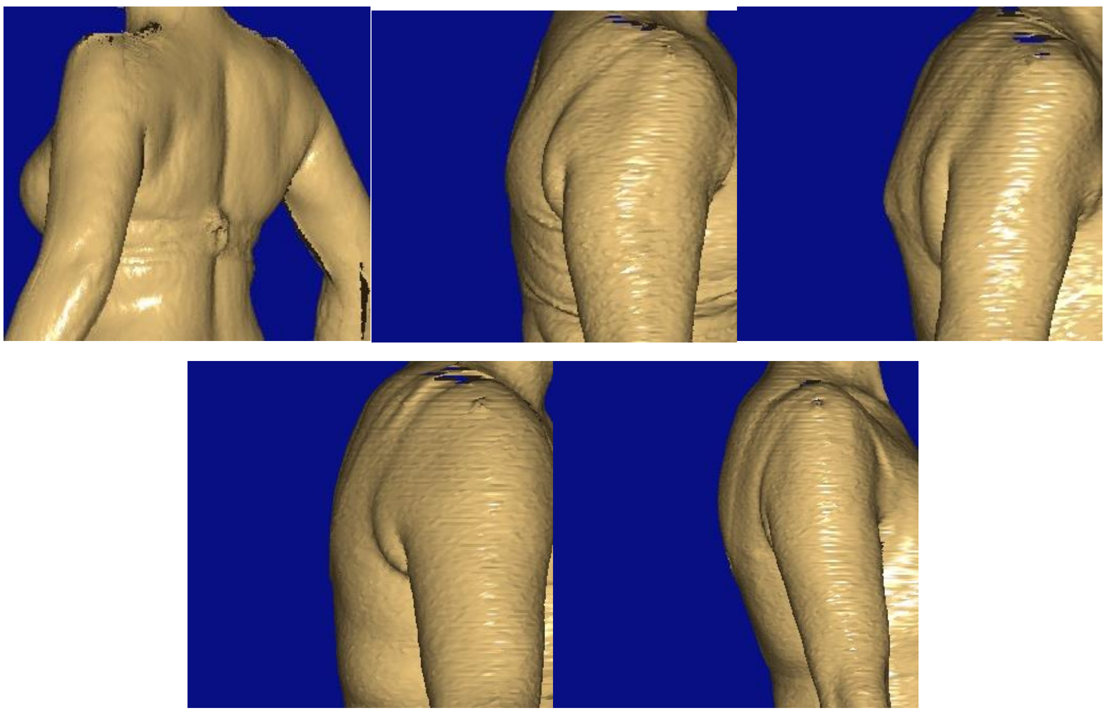


Figure 65: Examples of Shoulder Blade Description, from left: Flat, Softly Pointed, Pointed, Softly Rounded, Rounded

Width between the blades was assessed by marking the blade prominence points with sagittal planes and determining the distance between them in relation to the entire back. Blade width produced three categories: narrow, average, and wide (Figure 66). Fifteen subjects had narrow widths, seven subjects had average widths, and fourteen subjects had wide widths. Three subjects' widths were obscured due to the sports bras covering their backs.

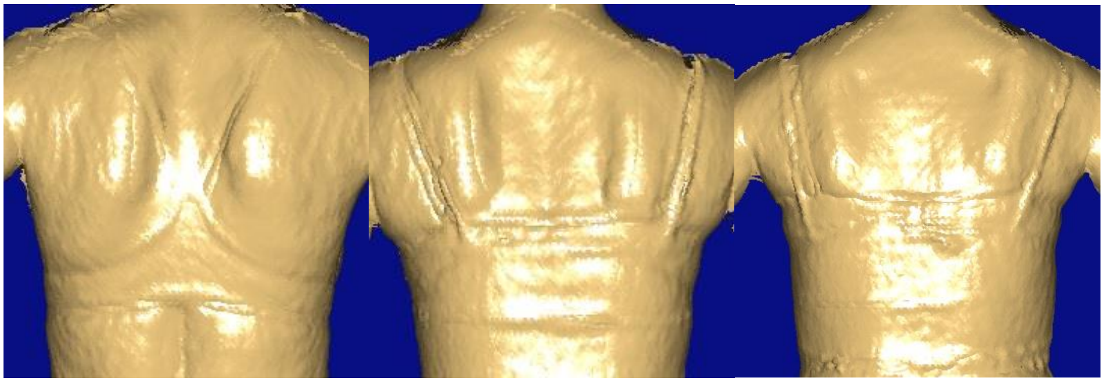


Figure 66: Examples of Blade Width, from left: Narrow, Average, Wide

Bust

Analysis of the bust included descriptions of bust fullness and bust point width, as well as determination of ribcage containment. The fit model had an average bust fullness, her breasts were contained within her ribcage, and the distance between the bust points was wide.

Bust fullness produced descriptors: very small, small, average, full, and very full (Figure 67 & Figure 68). Ribcage containment was determined by assessing if the breasts were wider than the torso at the bustline (Figure 69). Twenty-six subjects had their busts contained within their ribcage, while thirteen did not.

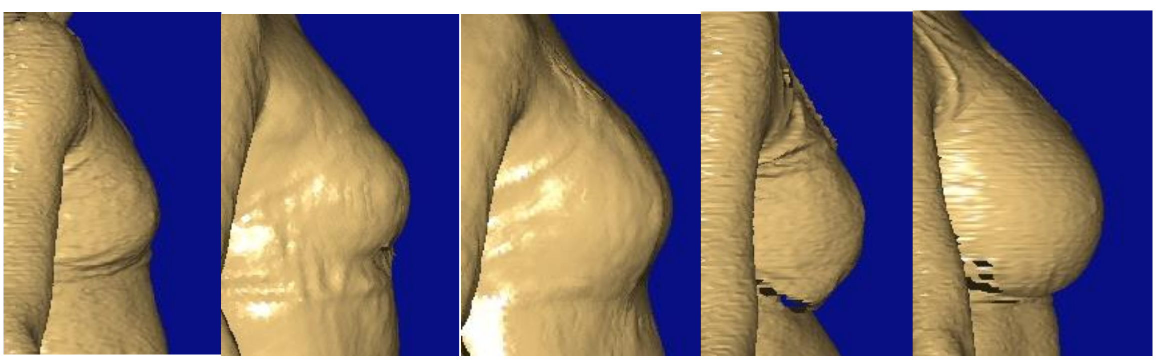


Figure 67: Examples of Bust Fullness, from left: Very Small, Small, Average, Full, Very Full

Bust point width was assessed by marking the bust points with sagittal planes and determining the distance between them in relation to the entire front. Bust point widths produced descriptors: narrow, average, and wide (Figure 70). Nine subjects had narrow bust point widths, thirteen subjects had average bust point widths and seventeen subjects had wide bust point widths.

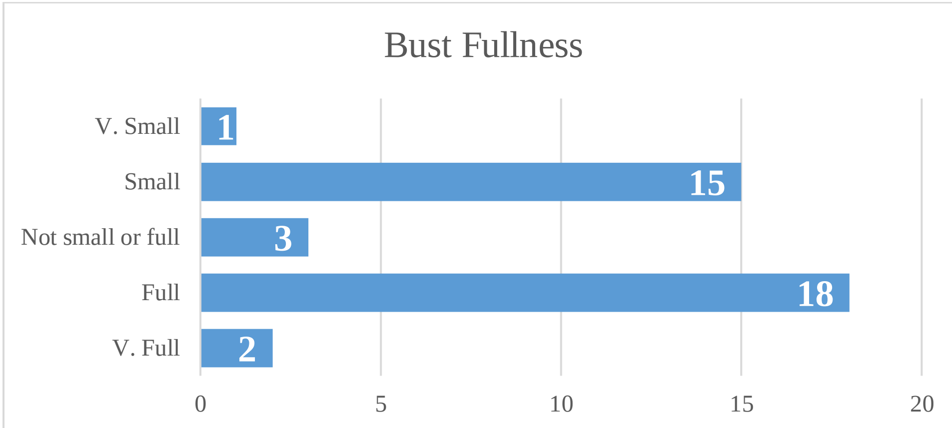


Figure 68: Bust Fullness

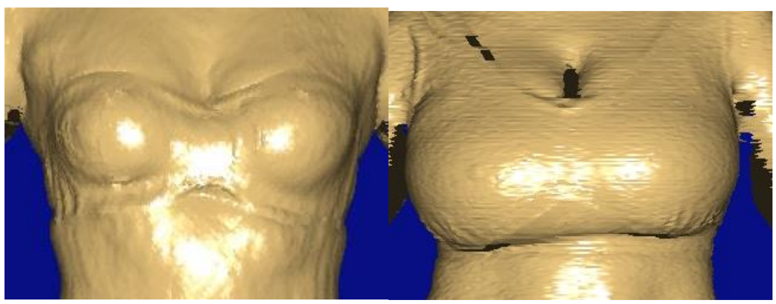


Figure 69: Examples of Ribcage Containment, from left: Contained, Not Contained

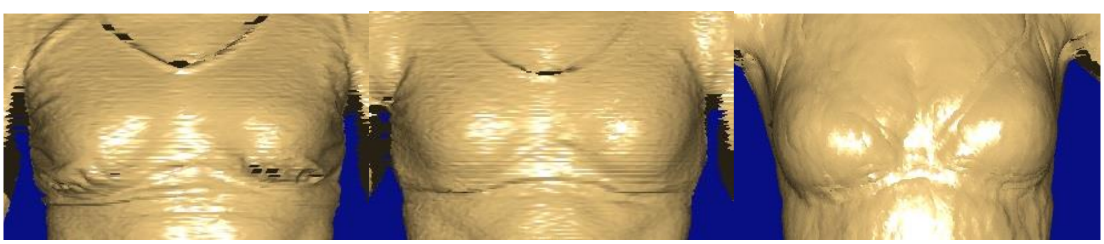


Figure 70: Examples of Bust Point Width, from left: Narrow, Average, Wide

GLBFP

Analysis of the greatest lower-body front prominence included waist indentation, GLBFP identification, GLBFP description, GLBFP alignment and understanding whether the GLBFP extended further than the bust. The fit model's waist was barely indented, the abdomen was her greatest lower-body front prominence, which was rounded, and aligned with her high-hip. Her abdomen did not extend past her bust.

Analysis of waist indentation yielded four categories: none, barely, slight, and indented (Figure 71 & Figure 72).

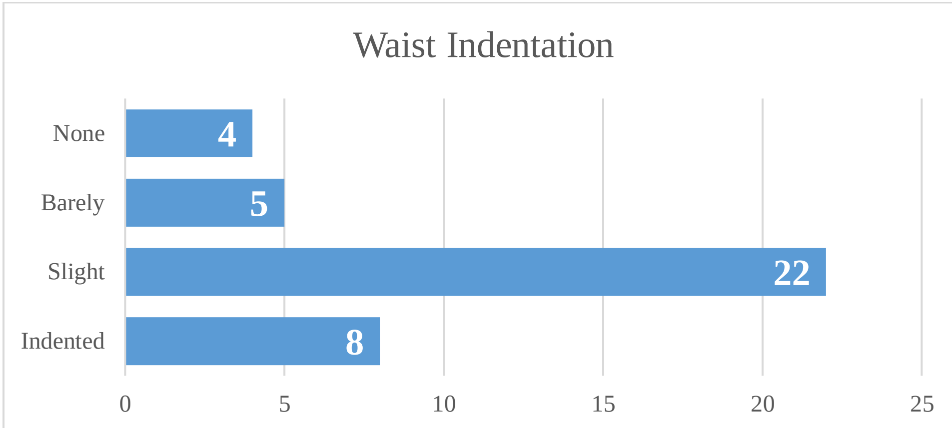


Figure 71: Waist Indentation

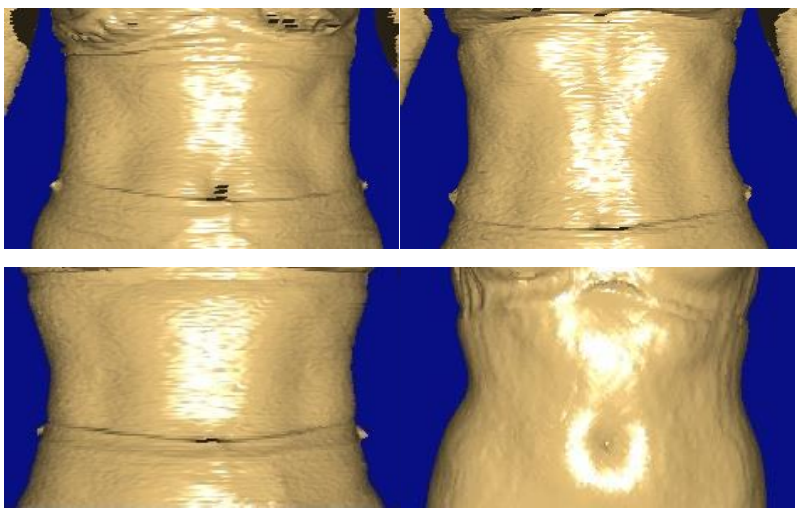


Figure 72: Examples of Waist Indentation, from top left: None, Barely, Slight, Indented

To identify the greatest lower-body front prominence a frontal plane was positioned against the body at the abdomen. If the stomach aligned with this plane the abdomen and stomach were considered equally prominent. If the stomach extended past the plane, the stomach was deemed the greater prominence. The GLBFP was the abdomen for thirty-five subjects and the stomach for two. Two subjects had equal stomach and abdomen prominences. Examples are presented in Figure 73.

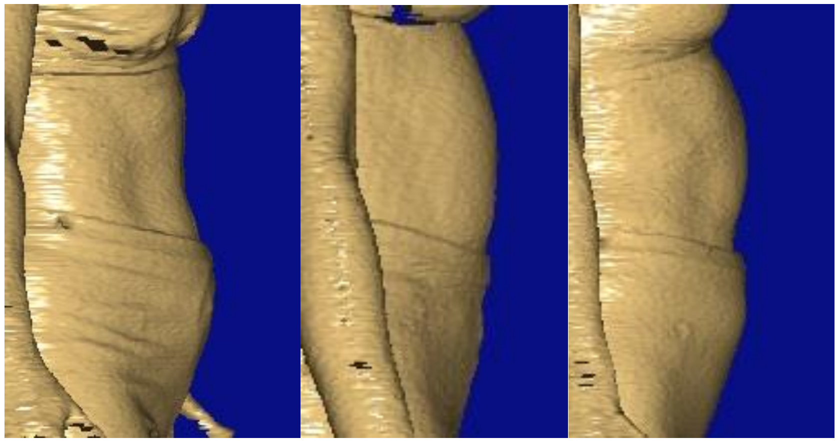


Figure 73: Examples of GLBFP Identifier, from left: Abdomen, Stomach, Both

Descriptions of the GLBFP included: flat, oval, softly pointed, softly rounded, and rounded (Figure 74 & Figure 75). Alignment of the GLBFP occurred at: the waist, below the waist, above the high-hip, at the high-hip, slightly below the high-hip, and below the high-hip (Figure 76). The plane used to identify the GLBFP extended the height of the subject. In some cases, it passed through the bust, meaning that the GLBFP was more prominent than the bust. Twenty-two subjects had GLBFP's that extended past the bust, four were aligned with the bust, and thirteen did not extend past the bust (Figure 77).

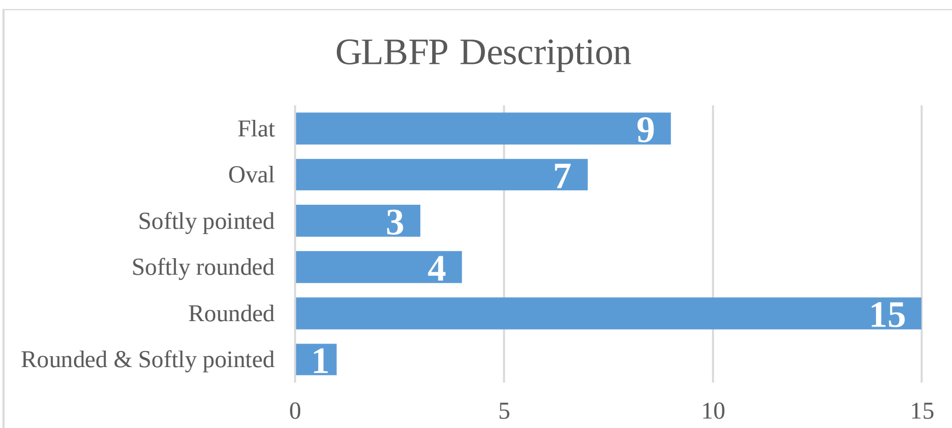


Figure 74: Greatest Lower-Body Front Prominence Description

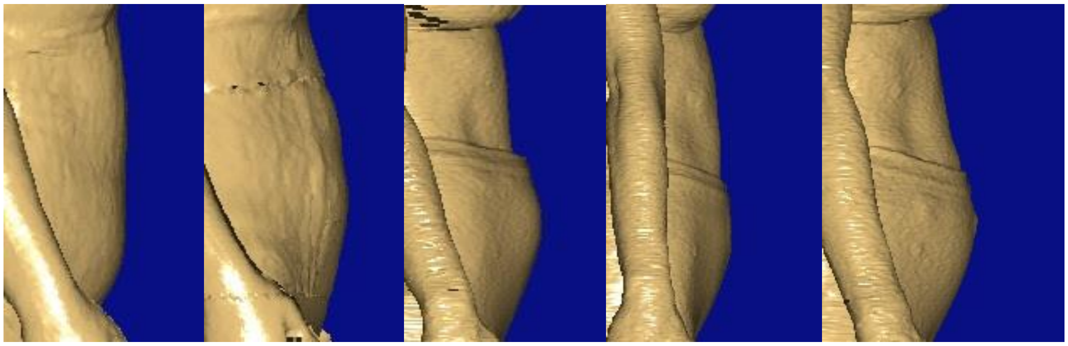


Figure 75: Examples of GLBFP Description, from left: Flat, Oval, Softly Pointed, Softly Rounded, Rounded

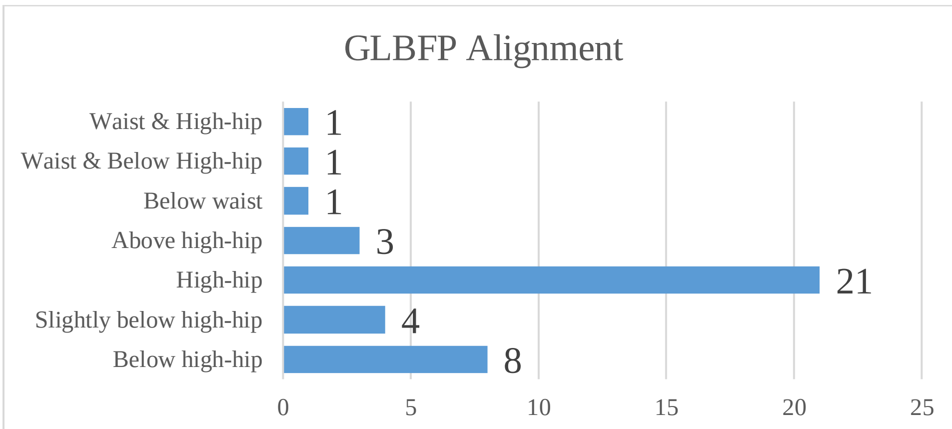


Figure 76: Greatest Lower-Body Front Prominence Alignment

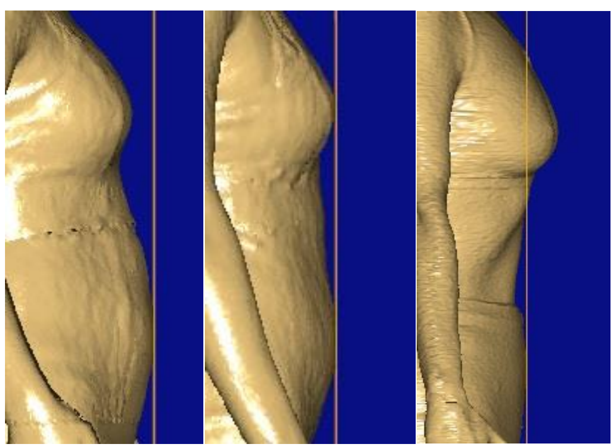


Figure 77: Examples of Past Bust Extension, from left: Yes, Aligned, No

Buttocks

Analysis of the buttocks included description of the prominence and length, a notation of where the fullest part of the buttocks was in relation to the buttocks length, and alignment. The fit model had a prominent buttock, of long length, where the fullest part falls in the middle of the buttocks, and is aligned with the true hip.

Buttocks prominence description consisted of two categories: flat and prominent (Figure 78). The farther from the body, the more prominent. Fifteen subjects had flat buttock prominences and twenty-four had prominent ones.

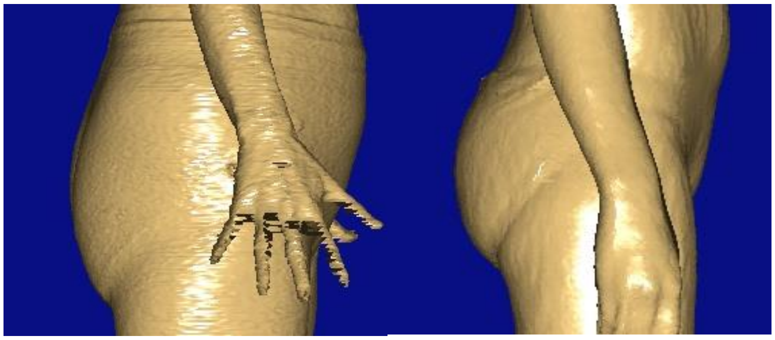


Figure 78: Examples of Buttocks Prominence, from left: Flat, Prominent

The more space the buttocks took up between the crotch and the waist, the longer it was deemed. Buttocks length had two categories: short and long (Figure 79). Ten subjects had short buttocks lengths, while twenty-nine had long ones.

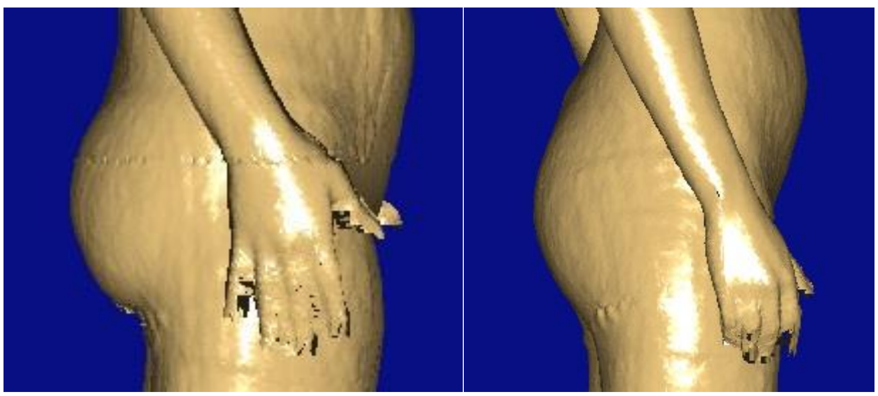


Figure 79:Examples of Buttocks Length, from left: Short, Long

Placing transverse planes at the top, bottom and fullest part of the buttocks allowed determination of where the fullest part fell in relation to the top and bottom planes. This variation was comprised of three categories: low, middle and high (Figure 80). Twelve subjects had the fullest part of their buttocks lower than the middle, twenty-three had it at the middle, and four had it higher than the middle.

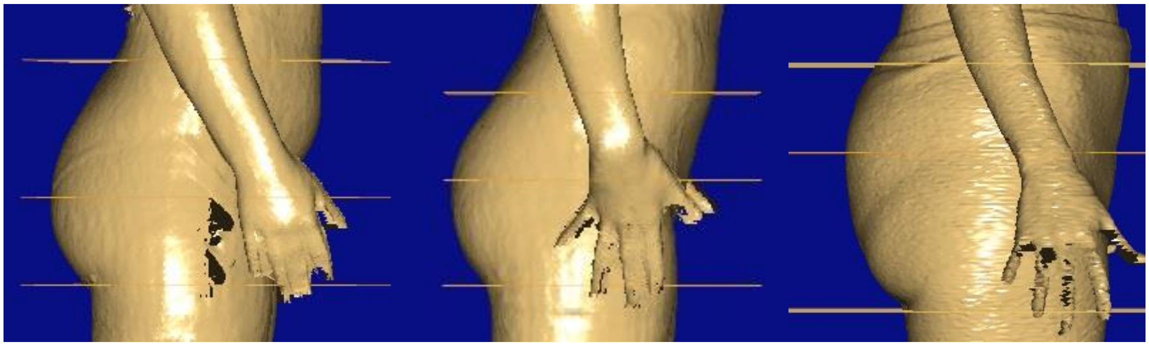


Figure 80: Examples of Buttocks Fullest Part Location, from left: Low, Middle, High

The buttocks alignment was determined by placing a transverse plane at the fullest part of the buttocks. Since the plane bisected the entire body, alignment was determined by viewing where the plane bisected the hips. Alignment occurred at: the true hip, slightly below the true hip, below the true hip, and far below the true hip (Figure 81).

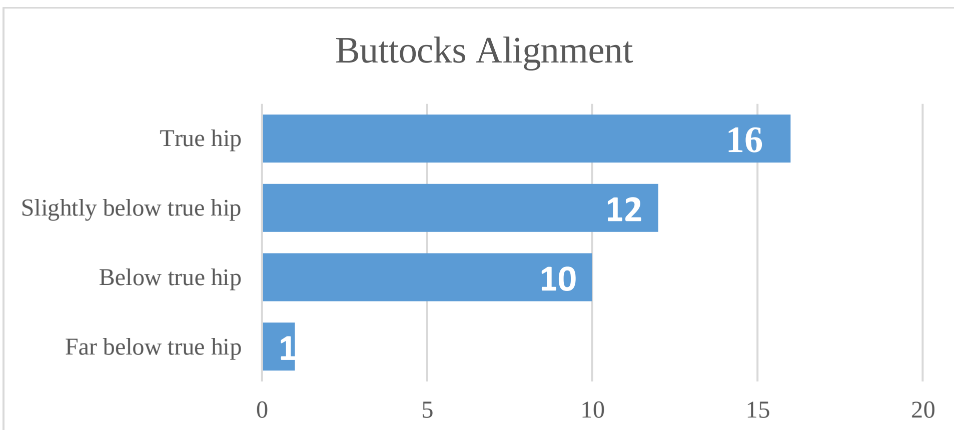


Figure 81: Buttocks Alignment

GLBSP

Analysis of the greatest lower-body side prominence included location and alignment identification, and description of the prominence. The fit model's GLBSP location was the thigh, which was aligned above the crotch and was rounded in description.

GLBSP location categories were: the high-hip and thighs (Figure 82). Four subjects had their greatest lower-body side prominence at the high-hip, and thirty-five at the thighs.

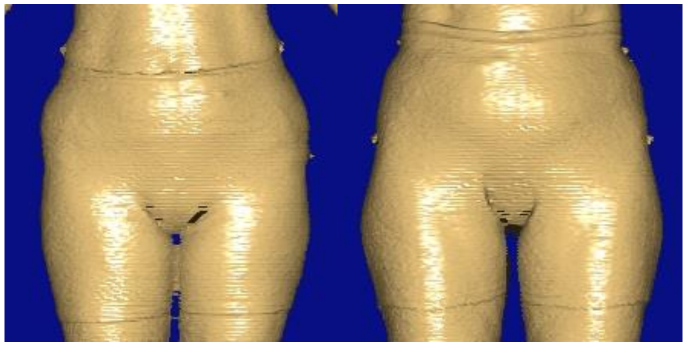


Figure 82: Examples of GLBSP Location, from left: High-hip, Thighs

GLBSP alignment categories included: below the crotch, at the crotch, above the crotch, below the abdomen, and at the abdomen (Figure 83).

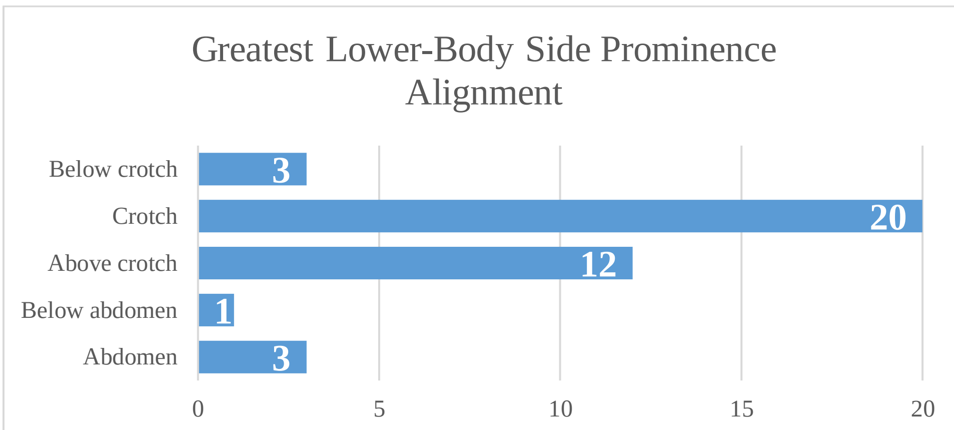


Figure 83: Greatest Lower-Body Side Prominence Alignment

Description categories included: flat, softly pointed, pointed, softly rounded, and rounded (Figure 84 & Figure 85).

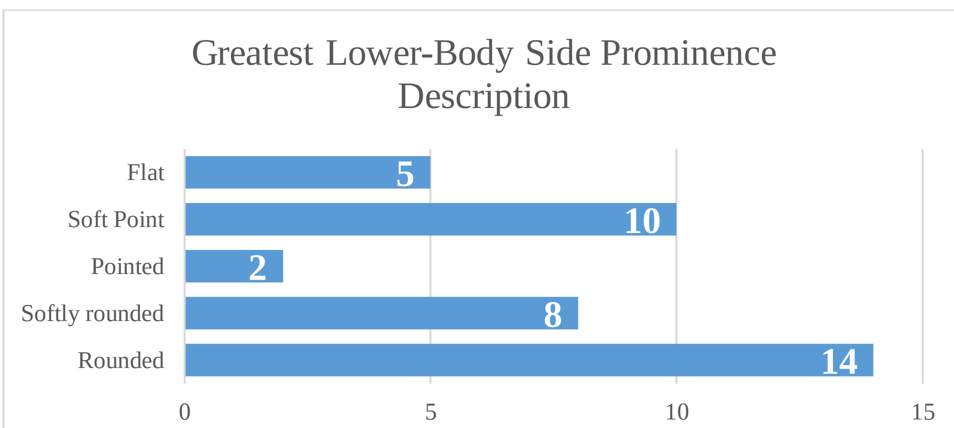


Figure 84: Greatest Lower-Body Side Prominence Description

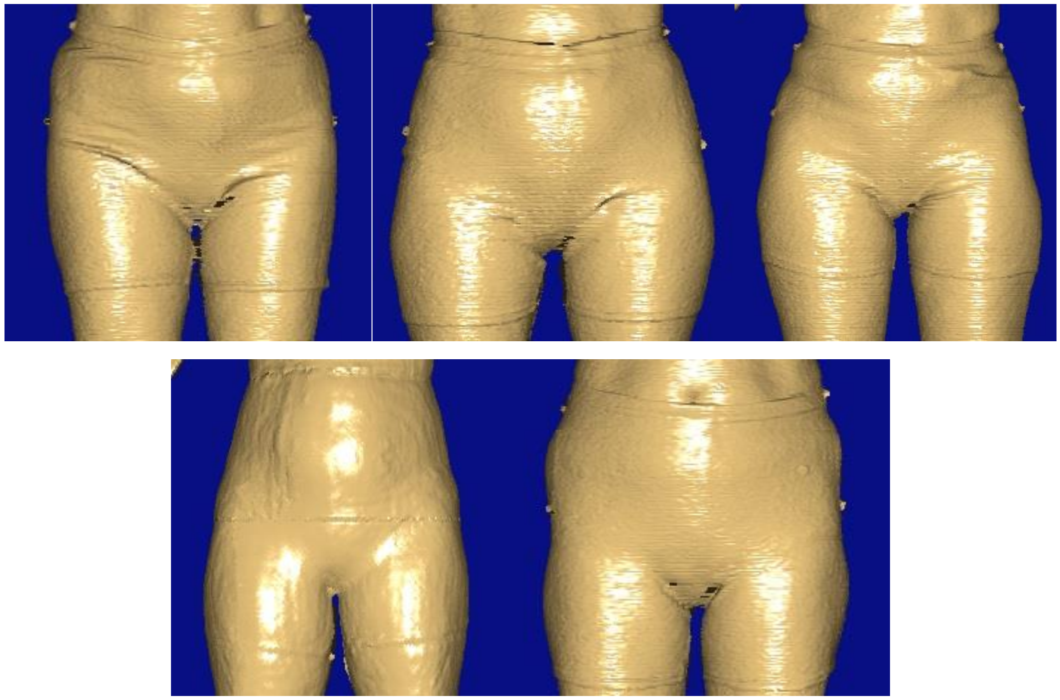


Figure 85: Examples of GLBSP Description, from top left: Flat, Softly Pointed, Pointed, Softly Rounded, Rounded

Physiological

This section describes the interaction between pattern dimensions and body-form variables. Analysis of each pattern dimension included at least one body-form variable. Each body-form variable included at least two categories, which were color-coded for ease of analysis.

Body-form variables were matched to pattern dimensions. Using Excel, pattern dimension measurements were sorted from smallest to largest, sorting the body-form variables at the same time. Tallies of each category within each body-form variation were calculated to see how many of each category fell within each group (identified during the dimensional component). For pattern dimensions that did not suggest groups, tallies were calculated to see how many of each category fell below and above the mean.

Neck

The pattern dimensions for the neck included the neck circumference and front neck drop. Body-form variables tested against the neck included neck thickness, the neck-to-shoulder transition, collarbone visibility, and neck tilt.

Neck circumference was compared to neck thickness, the neck-to-shoulder transition, and collarbone visibility. There were nineteen subjects below the mean, and twenty subjects above for neck circumference. Thin necks were the majority below the mean, at 56.2%, while thick necks were the majority above, at 50%. A sharp neck-to-shoulder transition was the majority both above and below the mean, at 68.4% and 75% respectively. The 'nearly flat' collarbone category was the majority below the mean, at 52.6%, while the visible collarbone category was the majority above, at 45%. Summaries of the data are displayed in Table 18.

Neck Thickness

Below Mean

Thin	10	52.6%
Thick	4	21.1%
Not thick or thin	5	26.3%
Total	19	100%

Above Mean

Thin	3	15%
Thick	10	50%
Not thick or thin	7	35%
Total	20	100%

Neck-to-Shoulder Transition

Below Mean

Sharp	13	68.4%
Smooth	6	31.6%
Total	19	100.00%

Above Mean

Sharp	15	75%
Smooth	5	25%
Total	20	100%

Collarbone Visibility

Below Mean

Flat	1	5.3%
Nearly Flat	10	52.6%
Visible	7	36.8%
Prominent	1	5.3%
Total	19	100.0%

Above Mean

Flat	1	5%
Nearly Flat	5	25%
Visible	9	45%
Prominent	5	25%
Total	20	100%

Table 18: Neck Circumference vs. Neck Thickness, Neck-to-Shoulder Transition, and Collarbone Visibility

Front neck drop was compared to neck tilt. Five groups were identified during the dimensional component. There were eight subjects in group 1, six in group 2, seven in group 3, eleven in group 4 and seven in group 5. Straight neck tilt was the majority for group 1, at 50%. Forward neck tilt was the majority for groups, 2, 3 and 4, at 66.7%, 71.4% and 54.5% respectively. Group 4 also had a large number of subjects with slightly forward neck tilt (36.4%) evenly spaced throughout. Far forward neck tilt was the majority for group 5, at 71.4%. A summary of the data is displayed in Table 19.

Shoulder

The pattern dimensions for the shoulder included shoulder seam and averaged shoulder slope. Body-form variables tested against the shoulder included the shoulder length description, shoulder point sharpness, shoulder point alignment, shoulder slope description, and the neck-to-shoulder transition.

Shoulder seam was compared to shoulder length description, shoulder point sharpness, and shoulder point alignment. Five groups were identified during the dimensional component. There were four subjects in group 1, seven in group 2, twenty-three in group 3, three in group 4 and two in group 5.

Neck Tilt

Group 1

Straight	4	50%
Slightly Forward	2	25%
Forward	2	25%
Far Forward	0	0%
Total	8	100%

Group 2

Straight	1	16.7%
Slightly Forward	1	16.7%
Forward	4	66.7%
Far Forward	0	0%
Total	6	100%

Group 3

Straight	1	14.3%
Slightly Forward	1	14.3%
Forward	5	71.4%
Far Forward	0	0.0%
Total	7	100%

Group 4

Straight	1	9.1%
Slightly Forward	4	36.4%
Forward	6	54.5%
Far Forward	0	0.0%
Total	11	100%

Group 5

Straight	1	14.3%
Slightly Forward	0	0.0%
Forward	1	14.3%
Far Forward	5	71.4%
Total	7	100%

Table 19: Front Neck Drop vs. Neck Tilt

Shoulder Length Description

Group 1

Short	4	100%
Long	0	0%
Average	0	0%
Total	4	100%

Group 2

Short	3	42.9%
Long	1	14.3%
Average	3	42.9%
Total	7	100%

Group 3

Short	4	17.4%
Long	12	52.2%
Average	7	30.4%
Total	23	100%

Group 4

Short	0	0%
Long	3	100%
Average	0	0%
Total	3	100%

Group 5

Short	0	0%
Long	2	100%
Average	0	0%
Total	2	100%

Table 20: Shoulder Seam vs. Shoulder Length Description

For the shoulder length description, group 1 consisted entirely of short shoulders, while groups 4 and 5 consisted entirely of long shoulders. Groups 2 and 3 included all three categories. The short and average categories tied for the majority in group 2, at 42.9%, while the long category was the majority for group 3, at 52.2%. A summary of the data is displayed in Table 20.

For shoulder point sharpness, groups 1 and 2 had a majority of sharp shoulder points, at 75% and 71% respectively, while groups 3 and 4 had a majority of soft shoulder points, at 73.9% and 66.7% respectively. Group 5 was split equally between sharp and soft shoulder points. A summary of the data is displayed in Table 21.

Shoulder Point Sharpness

Group 1

Sharp	3	75%
Soft	1	25%
Total	4	100%

Group 2

Sharp	5	71%
Soft	2	29%
Total	7	100%

Group 3

Sharp	6	26.1%
Soft	17	73.9%
Total	23	100%

Group 4

Sharp	1	33.3%
Soft	2	66.7%
Total	3	100%

Group 5

Sharp	1	50%
Soft	1	50%
Total	2	100%

Table 21: Shoulder Seam vs. Shoulder Point Sharpness

For shoulder point alignment, groups 1 and 3 had a majority of the ‘outside bust, inside high-hip and thigh’ category, at 75% and 39.1% respectively. The ‘aligned with bust, inside high-hip and thigh’ category was the majority for group 2, at 42.9%. Group 4 was split evenly between three categories. Group 5 was split evenly between the two categories. A summary of the data is in Table 22.

Shoulder Point Alignment

Group 1

Inside bust, high-hip & thigh	0	0%
Aligned w/bust, outside high-hip, inside thigh	0	0%
Aligned w/bust & high-hip, inside thigh	0	0%
Aligned w/bust; inside high-hip & thigh	1	25%
Outside bust & high-hip, inside thigh	0	0%
Outside bust, aligned w/high-hip, inside thigh	0	0%
Outside bust, inside high-hip & thigh	3	75%
Total	4	100%

Group 2

Inside bust, high-hip & thigh	0	0%
Aligned w/bust, outside high-hip, inside thigh	1	14.3%
Aligned w/bust & high-hip, inside thigh	0	0%
Aligned w/bust; inside high-hip & thigh	3	42.9%
Outside bust & high-hip, inside thigh	1	14.3%
Outside bust, aligned w/high-hip, inside thigh	0	0%
Outside bust, inside high-hip & thigh	2	28.6%
Total	7	100%

Group 3

Inside bust, high-hip & thigh	1	4.3%
Aligned w/bust, outside high-hip, inside thigh	0	0%
Aligned w/bust & high-hip, inside thigh	0	0%
Aligned w/bust; inside high-hip & thigh	6	26.1%
Outside bust & high-hip, inside thigh	6	26.1%
Outside bust, aligned w/high-hip, inside thigh	1	4.3%
Outside bust, inside high-hip & thigh	9	39.1%
Total	23	100%

Group 4

Inside bust, high-hip & thigh	0	0%
Aligned w/bust, outside high-hip, inside thigh	0	0%
Aligned w/bust & high-hip, inside thigh	1	33.3%
Aligned w/bust; inside high-hip & thigh	0	0%
Outside bust & high-hip, inside thigh	0	0%
Outside bust, aligned w/high-hip, inside thigh	1	33.3%
Outside bust, inside high-hip & thigh	1	33.3%
Total	3	100%

Group 5		
Inside bust, high-hip & thigh	0	0%
Aligned w/bust, outside high-hip, inside thigh	0	0%
Aligned w/bust & high-hip, inside thigh	0	0%
Aligned w/bust; inside high-hip & thigh	0	0%
Outside bust & high-hip, inside thigh	1	50%
Outside bust, aligned w/high-hip, inside thigh	0	0%
Outside bust, inside high-hip & thigh	1	50%
Total	2	100%

Table 22: Shoulder Seam vs. Shoulder Point Alignment

Averaged shoulder slope was compared to shoulder slope description, shoulder point sharpness, shoulder length description, and the neck-to-shoulder transition. Five groups were identified during the dimensional component. There were three subjects in group 1, five in group 2, twenty-five in group 3, five in group 4 and one in group 5.

For shoulder slope description, the flat category was the majority for group 1, at 66.7%. The sloped category appeared in groups 1, 2, 3 and 4, and was the majority for groups 2 and 3, at 40% and 64% respectively. The steep category made up the majority of group 4, at 60%, and comprised the entirety of group 5. A summary of the data is displayed in Table 23.

For shoulder point sharpness, both the sharp and soft categories appeared in groups 1, 2, 3 and 4. Sharp shoulder points comprised the entirety of group 1 and the majority of group 2, at 60%. Soft shoulder points were the majority for groups 3, and 4, at 68% and 60% respectively, and comprised the entirety of group 5. A summary of the data is displayed in Table 23.

For shoulder length description, short shoulders comprised the entirety of group 1, and were the majority for group 2, at 80%. Long shoulders were the majority for groups 3 and 4, at 48% and 80% respectively, and comprised the entirety of group 5. Average shoulders appeared in groups 3 and 4 as the second largest contingent, at 36% and 20% respectively. A summary of the data is displayed in Table 24.

Shoulder Slope Description

Group 1

Flat	2	66.7%
Slightly sloped	0	0%
Sloped	1	33.3%
More sloped	0	0%
Steep	0	0%
Total	3	100%

Group 2

Flat	1	20%
Slightly sloped	1	20%
Sloped	2	40%
More sloped	0	0%
Steep	1	20%
Total	5	100%

Group 3

Flat	0	0%
Slightly sloped	3	12%
Sloped	16	64%
More sloped	5	20%
Steep	1	4%
Total	25	100%

Group 4

Flat	0	0%
Slightly sloped	0	0%
Sloped	1	20%
More sloped	1	20%
Steep	3	60%
Total	5	100%

Group 5

Flat	0	0%
Slightly sloped	0	0%
Sloped	0	0%
More sloped	0	0%
Steep	1	100%
Total	1	100%

Shoulder Point Sharpness

Group 1

Sharp	3	100%
Soft	0	0%
Total	3	100%

Group 2

Sharp	3	60%
Soft	2	40%
Total	5	100%

Group 3

Sharp	8	32%
Soft	17	68%
Total	25	100%

Group 4

Sharp	2	40%
Soft	3	60%
Total	5	100%

Group 5

Sharp	0	0%
Soft	1	100%
Total	1	100%

Table 23: Averaged Shoulder Slope vs. Shoulder Slope Description and Shoulder Point Sharpness

For the neck-to-shoulder transition, the sharp transition comprised the entirety of group 1, and was the majority for groups 2, 3 and 4, at 60%, 72% and 80% respectively. The smooth neck-to-shoulder transition comprised the entirety of group 5. A summary of the data is displayed in Table 24.

Shoulder Length Description

Group 1

Short	3	100%
Long	0	0%
Average	0	0%
Total	3	100%

Group 2

Short	4	80%
Long	1	20%
Average	0	0%
Total	5	100%

Group 3

Short	4	16%
Long	12	48%
Average	9	36%
Total	25	100%

Group 4

Short	0	0%
Long	4	80%
Average	1	20%
Total	5	100%

Group 5

Short	0	0%
Long	1	100%
Average	0	0%
Total	1	100%

Neck-to-Shoulder Transition

Group 1

Sharp	3	100%
Smooth	0	0%
Total	3	100%

Group 2

Sharp	3	60%
Smooth	2	40%
Total	5	100%

Group 3

Sharp	18	72%
Smooth	7	28%
Total	25	100%

Group 4

Sharp	4	80%
Smooth	1	20%
Total	5	100%

Group 5

Sharp	0	0%
Smooth	1	100%
Total	1	100%

Table 24: Averaged Shoulder Slope vs. Shoulder Length Description and Neck-to-Shoulder Transition

Shoulder Blades

The pattern dimensions for the shoulder blades included the bodice back waist dart depth, the bodice back waist dart width and the between bodice back waist darts distance. Body-form variables for the shoulder blade included prominence point alignment, blade prominence, blade description, and blade width.

The bodice back waist dart depth was compared to prominence point alignment. Five groups were identified during the dimensional component. There were three subjects in group 1, sixteen in group 2, twelve in group 3, six in group 4 and two in group 5.

The 'at arm join' category occurred in every group, was the majority for groups 2, 3 and 4 (81.3%, 83.3% and 83.3% respectively), and tied for majority for groups 1 and 5 (33.3% and 50% respectively). The armpit category was spread throughout the sample and the 'above arm join' category only appeared in group 2. A summary of the data is displayed in Table 25.

Prominence Point Alignment

Group 1

Armpit	1	33.3%
At arm join	1	33.3%
Above arm join	0	0%
Obscured	1	33.3%
Total	3	100%

Group 2

Armpit	2	12.5%
At arm join	13	81.3%
Above arm join	1	6.3%
Obscured	0	0%
Total	16	100%

Group 3

Armpit	2	16.7%
At arm join	10	83.3%
Above arm join	0	0%
Obscured	0	0%
Total	12	100%

Group 4

Armpit	1	16.7%
At arm join	5	83.3%
Above arm join	0	0%
Obscured	0	0%
Total	6	100%

Group 5

Armpit	1	50%
At arm join	1	50%
Above arm join	0	0%
Obscured	0	0%
Total	2	100%

Table 25: Bodice Back Waist Dart Depth vs. Prominence Point Alignment

The bodice back waist dart width was compared to blade prominence and blade description. Four groups were identified during the dimensional component. Three subjects were in group 1, six in group 2, fourteen in group 3, and sixteen in group 4.

For blade prominence, the flat category occurs in every group, and was the majority for group 1, at 66.7%. The visible category was the majority for groups 2, 3 and 4, at 66.7%, 50%, and 56.3% respectively. For blade description both the flat and rounded categories appeared in every group. The flat category was the majority for group 1, at 66.7%. The soft point category was the majority for group 2, at 50%. The rounded category was the majority for groups 3 and 4, at 50% for both. Summaries of the data are displayed in Table 27.

The distance between the bodice back waist darts was compared to blade width. Three groups were identified during the dimensional component. Twenty-one subjects were in group 1, sixteen in group 1 and two in group 3.

For blade width, the narrow category was the majority for group 1, at 57.1%. The wide category was the majority for group 2, at 62.5% and comprised the entirety of group 3. The average category only appeared in group 1, and comprised 33.3% of the group. A summary of the data is displayed in Table 26.

Blade Width

Group 1

Narrow	12	57.1%
Wide	2	9.5%
Average	7	33.3%
Obscured	0	0%
Total	21	100%

Group 2

Narrow	3	18.8%
Wide	10	62.5%
Average	0	0%
Obscured	3	18.8%
Total	16	100%

Group 3

Narrow	0	0%
Wide	2	100%
Average	0	0%
Obscured	0	0%
Total	2	100%

Table 26: Between Bodice Waist Darts Distance vs. Blade Width

Blade Prominence

Group 1

Flat	2	66.7%
Almost Flat	0	0%
Visible	0	0%
Prominent	1	33.3%
Total	3	100%

Group 2

Flat	1	16.7%
Almost Flat	1	16.7%
Visible	4	66.7%
Prominent	0	0%
Total	6	100%

Group 3

Flat	4	28.6%
Almost Flat	1	7.1%
Visible	7	50%
Prominent	2	14.3%
Total	14	100%

Group 4

Flat	3	18.8%
Almost Flat	2	12.5%
Visible	9	56.3%
Prominent	2	12.5%
Total	16	100%

Blade Description

Group 1

Flat	2	66.7%
Soft Point	0	0%
Pointed	0	0%
Softly Rounded	0	0%
Rounded	1	33.3%
Total	3	100%

Group 2

Flat	1	16.7%
Soft Point	3	50%
Pointed	0	0%
Softly Rounded	1	16.7%
Rounded	1	16.7%
Total	6	100%

Group 3

Flat	4	28.6%
Soft Point	1	7.1%
Pointed	1	7.1%
Softly Rounded	1	7.1%
Rounded	7	50%
Total	14	100%

Group 4

Flat	4	25%
Soft Point	2	12.5%
Pointed	2	12.5%
Softly Rounded	0	0%
Rounded	8	50%
Total	16	100%

Table 27: Bodice Back Waist Dart Width vs. Blade Prominence & Blade Description

Bust

The pattern dimensions for the bust included the bust dart depth and the between bodice front waist darts distance. Body-form variables for the bust included bust fullness, ribcage containment, and bust point width.

The bust dart depth was compared to bust fullness and ribcage containment. Four groups were identified from the dimensional component. Eighteen subjects were in group 1, four in group 2, eleven in group 3, and six in group 4.

For bust fullness, the full category appeared in all four groups. The small category was the majority for group 1, at 61.1%. The full category comprised the entirety of group 2, and was the majority for groups 3 and 4, at 54.5% and 50% respectively. A summary of the data is displayed in Table 28.

Bust Fullness

Group 1

V. Small	0	0%
Small	11	61.1%
Average	2	11.1%
Full	5	27.8%
V. Full	0	0%
Total	18	100%

Group 2

V. Small	0	0.0%
Small	0	0.0%
Average	0	0.0%
Full	4	100.0%
V. Full	0	0.0%
Total	4	100%

Group 3

V. Small	0	0%
Small	3	27.3%
Average	1	9.1%
Full	6	54.5%
V. Full	1	9.1%
Total	11	100%

Group 4

V. Small	1	16.7%
Small	1	16.7%
Average	0	0%
Full	3	50%
V. Full	1	16.7%
Total	6	100%

Table 28: Bust Dart Depth vs. Bust Fullness

For ribcage containment, the majority of groups 1 and 3 had their breasts contained within their torso, at 77.8% and 72.7% respectively. The majority of group 4 had breasts that were not contained within their torso, at 66.7%. Summaries of the data are displayed in Table 29.

Ribcage Containment

Group 1

Yes	14	77.8%
No	4	22.2%
Total	18	100%

Group 2

Yes	2	50%
No	2	50%
Total	4	100%

Group 3

Yes	8	72.7%
No	3	27.3%
Total	11	100%

Group 4

Yes	2	33.3%
No	4	66.7%
Total	6	100%

Table 29: Bust Dart Depth vs. Ribcage Containment

The between front waist darts distance was compared to the bust points width description. Four groups were identified during the dimensional component. Eight subjects were in group 1, eight in group 2, six and group 3, and seventeen in group 4.

For bust point width, the narrow category was the majority for group 1, at 75%, and tied for majority with the average category for group 2, at 37.5%. The average category was the majority for group 3, at 66.7%, and the wide category was the majority for group 4, at 70.6%. A summary of the data is displayed in Table 30.

Bust Point Width

Group 1

Narrow	6	75%
Average	1	12.5%
Wide	1	12.5%
Total	8	100%

Group 2

Narrow	3	37.5%
Average	3	37.5%
Wide	2	25%
Total	8	100%

Group 3

Narrow	0	0%
Average	4	66.7%
Wide	2	33.3%
Total	6	100%

Group 4

Narrow	0	0%
Average	5	29.4%
Wide	12	70.6%
Total	17	100%

Table 30: Between Front Waist Darts Distance vs. Bust Point Width Description

GLBFP

The pattern dimensions for the abdomen included the waist circumference, the front waist width, the skirt front waist dart depth, and the skirt front waist dart width. The body-form variations included waist indentation, the GLBFP identifier, the GLBFP description, whether the GLBFP extended further than the bust, and GLBFP alignment.

The waist circumference was compared to waist indentation. Four groups were identified during the dimensional component. Thirty-six subjects were in group 1, with one subject in each of the remaining three groups.

For waist indentation, the slight category was the majority for group 1, at 58.3% and comprised the entirety of group 4. The indented category comprised the entirety of group 2. The 'none' category comprised the entirety of group 3. A summary of the data is displayed in Table 31.

Waist Indentation

Group 1

None	3	8.3%
Barely	5	13.9%
Slight	21	58.3%
Indented	7	19.4%
Total	36	100%

Group 2

None	0	0%
Barely	0	0%
Slight	0	0%
Indented	1	100%
Total	1	100%

Group 3

None	1	100%
Barely	0	0%
Slight	0	0%
Indented	0	0%
Total	1	100%

Group 4

None	0	0%
Barely	0	0%
Slight	1	100%
Indented	0	0%
Total	1	100%

Table 31: Waist Circumference vs. Waist Indentation

The front waist width was compared to the GLBFP identifier, the GLBFP description and whether the GLBFP extended further than the bust. Six groups were identified from the dimensional component. One subject was in group 1, four in group 2, twenty-seven in group 3, two each in groups 4 and 5, and three in group 6.

For the GLBFP identifier, the abdomen comprised the entirety of groups 1, 2, and 5, and was the majority for group 3, at 96.3%. The abdomen and both categories were tied for majority in group 4, at 50%. All three categories were tied in group 6. A summary of the data is displayed in Table 32.

GLBFP Identifier

Group 1

Abdomen	1	100%
Stomach	0	0%
Both	0	0%
Total	1	100%

Group 2

Abdomen	4	100%
Stomach	0	0%
Both	0	0%
Total	4	100%

Group 3

Abdomen	26	96.3%
Stomach	1	3.7%
Both	0	0%
Total	27	100%

Group 4

Abdomen	1	50%
Stomach	0	0%
Both	1	50%
Total	2	100%

Group 5

Abdomen	2	100%
Stomach	0	0%
Both	0	0%
Total	2	100%

Group 6

Abdomen	1	33.3%
Stomach	1	33.3%
Both	1	33.3%
Total	3	100%

Table 32: Front Waist Width vs. GLBFP Identifier

For the GLBFP description, the rounded category was the majority for groups 2, 3, and 6 (50%, 37% and 66.7% respectively), and tied for majority in group 4, at 50%. The softly rounded category comprised the entirety of group 1, and tied for majority with the oval category in group 5, at 50%. A summary of the data is displayed in Table 33.

GLBFP Description

Group 1

Flat	0	0%
Oval	0	0%
Softly pointed	0	0%
Softly rounded	1	100%
Rounded	0	0%
Rounded & Softly pointed	0	0%
Total	1	100%

Group 2

Flat	0	0%
Oval	1	25%
Softly pointed	1	25%
Softly rounded	0	0%
Rounded	2	50%
Rounded & Softly pointed	0	0%
Total	4	100%

Group 3

Flat	9	33.3%
Oval	4	14.8%
Softly pointed	2	7.4%
Softly rounded	2	7.4%
Rounded	10	37%
Rounded & Softly pointed	0	0%
Total	27	100%

Group 5

Flat	0	0%
Oval	1	50%
Softly pointed	0	0%
Softly rounded	1	50%
Rounded	0	0%
Rounded & Softly pointed	0	0%
Total	2	100%

Group 4

Flat	0	0%
Oval	0	0%
Softly pointed	0	0%
Softly rounded	0	0%
Rounded	1	50%
Rounded & Softly pointed	1	50%
Total	2	100%

Group 6

Flat	0	0%
Oval	1	33.3%
Softly pointed	0	0%
Softly rounded	0	0%
Rounded	2	66.7%
Rounded & Softly pointed	0	0%
Total	3	100%

Table 33: Front Waist Width vs. GLBFP Description

For the past bust extension, subjects with GLBFP's that extended past their bust comprised the entirety of groups 1 and 2 and were the majority for group 3, at 51.9%. Subjects that did not have GLBFP's extending past their bust were the majority of group 6, at 66.7%. A summary of the data is displayed in Table 34.

Past Bust Extension

Group 1

Yes	1	100%
Aligned	0	0%
No	0	0%
Total	1	100%

Group 3

Yes	14	51.9%
Aligned	4	14.8%
No	9	33.3%
Total	27	100%

Group 5

Yes	1	50%
Aligned	0	0%
No	1	50%
Total	2	100%

Group 2

Yes	4	100%
Aligned	0	0%
No	0	0%
Total	4	100%

Group 4

Yes	1	50%
Aligned	0	0%
No	1	50%
Total	2	100%

Group 6

Yes	1	33.3%
Aligned	0	0%
No	2	66.7%
Total	3	100%

Table 34: Front Waist Width vs. Past Bust Extension

The skirt front waist dart depth was compared to the GLBFP alignment. Five groups were identified during the dimensional component. Five subjects were in group 1, eight in group 2, thirteen in group 3, eleven in group 4, and two in group 5.

For the GLBFP alignment, the high-hip category appeared in groups 1, 2, 3 and 4. The high-hip category tied for majority with the above high-hip category in group 1, at 40%, tied for majority with the below high-hip category in group 2, at 37.5%, and was the majority for groups 3 and 4, at 69.2% and 63.6% respectively. The below waist and below high-hip categories tied for majority in group 5, at 50%. A summary of the data is displayed in Table 35.

GLBFP Alignment

Group 1

Waist & High-hip	0	0%
Waist & Below High-hip	0	0%
Below waist	0	0%
Above high-hip	2	40%
High-hip	2	40%
Slightly below high-hip	0	0%
Below high-hip	1	20%
Total	5	100%

Group 2

Waist & High-hip	0	0%
Waist & Below High-hip	0	0%
Below waist	0	0%
Above high-hip	0	0%
High-hip	3	37.5%
Slightly below high-hip	2	25%
Below high-hip	3	37.5%
Total	8	100%

Group 3

Waist & High-hip	0	0%
Waist & Below High-hip	1	7.7%
Below waist	0	0%
Above high-hip	1	7.7%
High-hip	9	69.2%
Slightly below high-hip	2	15.4%
Below high-hip	0	0%
Total	13	100%

Group 4

Waist & High-hip	1	9.1%
Waist & Below High-hip	0	0%
Below waist	0	0%
Above high-hip	0	0%
High-hip	7	63.6%
Slightly below high-hip	0	0%
Below high-hip	3	27.3%
Total	11	100%

Group 5

Waist & High-hip	0	0%
Waist & Below High-hip	0	0%
Below waist	1	50%
Above high-hip	0	0%
High-hip	0	0%
Slightly below high-hip	0	0%
Below high-hip	1	50%
Total	2	100%

Table 35: Skirt Front Waist Dart Depth vs. GLBFP Alignment

The skirt front waist dart width was compared to the GLBFP description. Three groups were identified during the dimensional component. One subject was in group 1, thirty-five in group 2, and three in group 3.

For the GLBFP description, the softly rounded category comprised the entirety of group 1. The rounded category was the majority for groups 2 and 3, at 37.1% and 66.7% respectively. The flat category is the second largest contingent in group 2, at 25.7%. A summary of the data is displayed in Table 36.

GLBFP Description

Group 1

Flat	0	0%
Oval	0	0%
Softly pointed	0	0%
Softly rounded	1	100%
Rounded	0	0%
Rounded & Softly pointed	0	0%
Total	1	100%

Group 2

Flat	9	25.7%
Oval	6	17.1%
Softly pointed	3	8.6%
Softly rounded	3	8.6%
Rounded	13	37.1%
Rounded & Softly pointed	1	2.9%
Total	35	100%

Group 3

Flat	0	0%
Oval	1	33.3%
Softly pointed	0	0%
Softly rounded	0	0%
Rounded	2	66.7%
Rounded & Softly pointed	0	0%
Total	3	100%

Table 36: Skirt Front Waist Dart Width vs. GLBFP Description

Buttocks

The pattern dimensions for the buttocks included the skirt back waist dart depth, and the skirt back waist dart width. The body-form variations included descriptions of the length, fullest part, prominence, and buttocks alignment.

The skirt back waist dart depth was compared to buttocks length and fullest part descriptions, as well as buttocks alignment. Three groups were identified during the dimensional component. There was one subject each in groups 1 and 2, and thirty-seven subjects in group 3.

For buttocks length, the long category comprised the entirety of group 1 and was the majority for group 3, at 75.7%. The short category comprised the entirety of group 2. For the description of the fullest part of the buttocks, the low category comprised the entirety of group 1. The high category comprised the entirety of group 2. The middle category was the majority for group 3, at 62.2%. Summaries of the data are displayed in Table 37.

Buttocks Length

Group 1

Short	0	0%
Long	1	100%
Total	1	100%

Group 2

Short	1	100%
Long	0	0%
Total	1	100%

Group 3

Short	9	24.3%
Long	28	75.7%
Total	37	100%

Fullest Part

Group 1

Low	1	100%
Middle	0	0%
High	0	0%
Total	1	100%

Group 2

Low	0	0%
Middle	0	0%
High	1	100%
Total	1	100%

Group 3

Low	11	29.7%
Middle	23	62.2%
High	3	8.1%
Total	37	100%

Table 37: Skirt Back Waist Dart Depth vs. Buttocks Length and Fullest Part of Buttocks

For buttocks alignment, the 'slightly below true hip' category comprised the entirety of group 1. The true hip category comprised the entirety of group 2, and was the majority for group 3, at 40.5%. Summaries of the data are displayed in Table 38.

Buttocks Alignment

Group 1

True hip	0	0%
Slightly below true hip	1	100%
Below true hip	0	0%
Far below true hip	0	0%
Total	1	100%

Group 2

True hip	1	100%
Slightly below true hip	0	0%
Below true hip	0	0%
Far below true hip	0	0%
Total	1	100%

Group 3

True hip	15	40.5%
Slightly below true hip	11	29.7%
Below true hip	10	27%
Far below true hip	1	2.7%
Total	37	100%

Table 38: Skirt Back Waist Dart Depth vs. Buttocks Alignment

The skirt back waist dart width was compared to buttocks prominence description. Four groups were identified during the dimensional component. Four subjects each were in groups 1 and 2, fifteen subjects were in group 3, and sixteen subjects were in group 4.

For the buttocks prominence, the flat and prominent categories tied for majority in group 1, at 50%. The flat category was the majority for group 2, at 75%. The prominent category was the majority for groups 3 and 4, at 80% and 56.3% respectively. A summary of the data is displayed in Table 39.

Buttocks Prominence

Group 1

Flat	2	50%
Prominent	2	50%
Total	4	100%

Group 2

Flat	3	75%
Prominent	1	25%
Total	4	100%

Group 3

Flat	3	20%
Prominent	12	80%
Total	15	100%

Group 4

Flat	7	43.8%
Prominent	9	56.3%
Total	16	100%

Table 39: Skirt Back Waist Dart Depth vs. Buttocks Prominence Description

GLBSP

The pattern dimension for the greatest lower-body side prominence was the skirt side seam curve length. Body-form variables included the greatest lower-body side prominence location, alignment and prominence description. Two groups were identified during the dimensional component. Four subjects were in group 1, and thirty-five were in group 2.

For the GLBSP location, the high-hip category comprised the entirety of group 1, while the thigh category comprised the entirety of group 2. For the GLBSP alignment, the abdomen category was the majority for group 1, at 75%; while the crotch category was the majority for group 2, at 57.1%. For the GLBSP description, the rounded category comprised the entirety of group 1, and tied with the softly pointed category for the majority of group 2, at 28.6%. Summaries of the data are displayed in Table 40.

GLBSP Location

Group 1

Thigh	0	0%
High-Hip	4	100%
Total	4	100%

Group 2

Thigh	35	100%
High-Hip	0	0%
Total	35	100%

GLBSP Alignment

Group 1

Abdomen	3	75%
Below Abdomen	1	25%
Above Crotch	0	0%
Crotch	0	0%
Below Crotch	0	0%
Total	4	100%

Group 2

Abdomen	0	0%
Below Abdomen	0	0%
Above Crotch	12	34.3%
Crotch	20	57.1%
Below Crotch	3	8.6%
Total	35	100%

GLBSP Description

Group 1

Flat	0	0%
Softly Pointed	0	0%
Pointed	0	0%
Softly Rounded	0	0%
Rounded	4	100%
Total	4	100%

Group 2

Flat	5	14.3%
Softly Pointed	10	28.6%
Pointed	2	5.7%
Softly Rounded	8	22.9%
Rounded	10	28.6%
Total	35	100%

Table 40: Skirt Curve Length vs. GLBSP Location, Alignment & Description

Summary

Nineteen measurements yielded sixteen pattern dimensions for analysis in the dimensional component. These sixteen dimensions suggested twenty-seven body-form variables for analysis in the visual component. The physiological component displayed the interaction between the pattern dimensions and body-form variables. The next chapter will discuss the body-form variations for this single size, as well as the what these findings suggest for the development of a body-form based block system.

Chapter 6 Discussion and Conclusion

Introduction

This chapter synthesizes the data reported in the previous chapter. The dimensional, visual, and physiological results were considered in terms of the two research questions:

1. What are the body form variations across a single size?
2. What do these findings suggest for the development of a body-form based block system?

Question One

There are numerous body-form variations in this sample. Every individual body component had one or more body-form variables to analyze. And every body-form variable had at least two categories. A visual content analysis was used to categorize each body-form variation. For each body-form variation, differences between subjects were considered and significant differences resulted in new categories. The results indicate that there are body-form variations in this single size.

In this study, the term “average” indicated that a variation did not belong in either the upper or lower categories of the body-form variable. It did not indicate that the variation matched the fit model or some other, outside standard. In the reviewed literature, sometimes the texts displayed images of what an “average” body-form variation looked like, but most commonly, they did not. Generally, the reviewed literature displayed only images of the variations from the average or ideal figure. Though, all texts preceded the variations section with a section on the “average” or “ideal” female body. Where the literature did not directly state that there was an “average” body-form variation, the researcher assumed there was one and that it represented each text’s “average/ideal” female body. This assumption was based on the understanding that there can be no variations without something to compare against. The term ‘a/i’ was used to indicate that a text did not specify an average, but did indirectly compare against one.

Neck

Four body-form variations with thirteen within-component categories were determined by analyzing the neck region of each subject: neck thickness, neck-to-shoulder transition, collarbone visibility, and neck tilt. For this sample, the most common neck variations were thick necks, sharp neck-to-shoulder transitions, visible collarbones, and forward neck tilts.

Neck thickness produced three categories: thin, average, and thick. Thick necks were the most common, at fourteen subjects. This number is essentially even with the thin (13) and average (12) categories. This may mean that any pattern blocks created from data in this sample may need to have three different neck circumference options.

Neck thickness was prevalent in the literature, though the terminology differed by text. Only Palmer and Alto (2005) shared the same terms as this study. Minott (1978) used synonyms, while Rasband and Liechty (2006), and Liechty, Rasband and Pottberg-Steineckert (2010) used terminology with a possibility for broader interpretation (Table 41). There are no measurements associated with this figure variation, which provides future researchers with an opportunity to determine what measurements or proportions match thin, average, and thick necks.

Two variations on neck thickness not accounted for in this study were the uneven and muscular neck variations from Palmer and Alto (2005). Observations of this sample noted uneven and muscular necks, but did not equate them with neck thickness, nor did they become categories for other neck variations. Future research may wish to include these variations to determine if they affect neck thickness or other neck variations.

Sample	**Thin**	**Average**	**Thick**
Minott (1978)	Narrow	Average	Wide
Palmer & Alto (2005)	Thin	a/i	Thick
Rasband & Liechty (2006)	Smaller	a/i	Larger
Liechty et al. (2010)	Smaller	a/i	Larger

Table 41: Neck Thickness - Sample vs. Reviewed Literature

The neck-to-shoulder transition produced two categories: sharp and smooth. A sharp neck-to-shoulder transition looked like a right angle between the neck and shoulder, while a smooth neck-to-shoulder transition looked like the muscles from the neck swept down gently into the shoulder, forming a curved ramp. Sharp neck-to-shoulder transitions were most prevalent in this sample, consisting of twenty-eight subjects, which was more than double the number of subjects in the smooth category (11).

The terminology used in this study differs from the terminology used in the reviewed literature. First, the transition is described differently, and second the number of categories within this variation is different (Table 42).

Sample	**Sharp**	**n/a**	**Smooth**
Rasband & Liechty (2006)	Low Neck Base	a/i	High Neck Base
Liechty et al. (2010)	Low Neck Base	a/i	High Neck Base

Table 42: Neck-to-Shoulder Transition - Sample vs. Reviewed Literature

The neck and shoulder are conjoined, thus there must always be a neck-to-shoulder transition. The Rasband and Liechty (2006) and Liechty et al. (2010) texts focus on the neck base, providing them with an "average/ideal" category. They state that neck angularity is based on neck muscle development: A low neck base has less muscle development than the ideal, while a high neck base has more. This study considered the transition itself, which must be described as a curve or angle, and does not afford an "average" definition.

This contrast in focus revealed a discussion point. If we accept that the muscle development of the neck base causes the neck-to-shoulder transition to behave in certain ways, then this study focused on the end result, rather than the cause. If this is so, then the neck-to-shoulder transition may not be the best body-form variation to use for the assessment of fit. Researchers should compare neck base muscle development to neck-to-shoulder transitions to see if there is a causal effect.

Collarbone visibility produced four categories: flat, nearly flat, visible, and prominent. Flat meant that the bones and hollow could not be seen; nearly flat meant the bones and hollow were barely visible; visible meant the bones and hollow could be easily identified; and prominent meant that the bones protruded from the body, with a deep hollow.

The most prevalent collarbone types found in the study were the visible (16) and nearly flat (15) categories, followed by the prominent (6) and flat (2) categories. Minott (1978) and Liechty et al. (2010) were the only texts to mention collarbone visibility, and they only mentioned a prominent collarbone (Table 43), which Liechty et al. defined as "larger and round out more than average/ideal" (p. 263). No definition of an ideal collarbone was given in either text.

Sample	Flat	Nearly Flat	Visible	Prominent
Minott (1978)	n/a	n/a	a/i	Prominent
Liechty et al. (2010)	n/a	n/a	a/i	Prominent

Table 43: Collarbone Visibility - Sample vs. Reviewed Literature

The fact that flat and nearly flat collarbones are not discussed in the reviewed literature may indicate (a) that they are not known, or (b) that they do not impact fit. If option (a) is true, then this study has added to the body of knowledge by adding two new categories to the body-form variation of collarbone visibility. If option (b) is true, then this researcher suggests that discussion of collarbone visibility should include all of the options before deciding on the relevancy of each option. Research into collarbone height and hollow depth should be conducted to more accurately define the categories presented in this study.

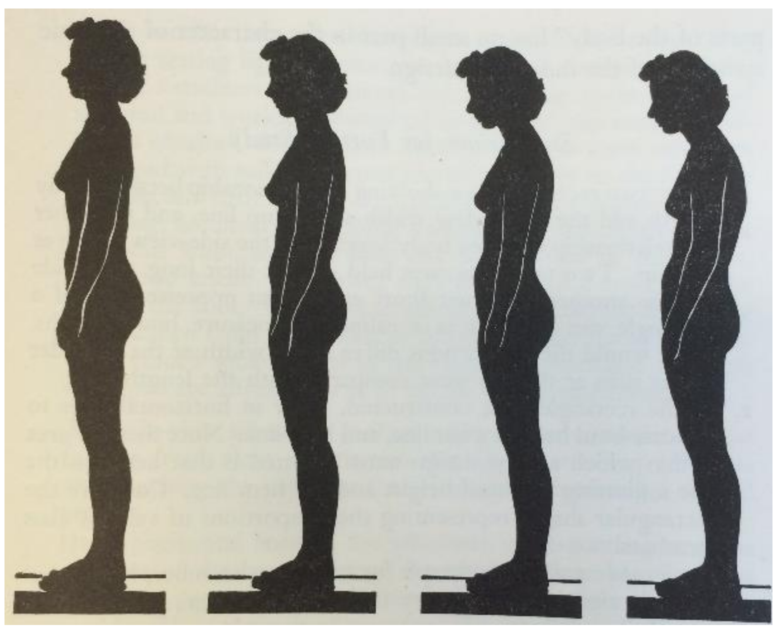


Figure 86: How posture affects neck tilt (from Latzke & Quinlan, 1940, Fig. 42, p. 73)

Neck tilt produced four categories: straight, slightly forward, forward, and far forward. The categories are a continuum of how forward the neck appeared in relation to the torso. The literature only suggested two options for neck tilt: average/ideal or forward. In this case, the term "forward" most likely covers any deviation from average, which would include the more specific terminology used in this study of "slightly forward", "forward", and "far forward" (Table 44).

Sample	Straight	Slightly Forward	Forward	Far Forward
Rasband & Liechty (2006)	a/i	n/a	Forward	n/a
Liechty et al. (2010)	a/i	n/a	Forward	n/a

Table 44: Neck Tilt - Sample vs. Reviewed Literature

This body-form variation may be caused by posture, as Liechty *et al*. (1986) note that a forward head may be caused by rounded back posture or slumped posture. Latzke and Quinlan (1940) showed that the neck tilts more and more forward as posture becomes worse and worse (Figure 86), though they do not specifically discuss neck tilt in their book. If we assume that the general term used in the literature ("forward") covers all deviations from the straight neck tilt, and that neck tilt results from poor posture, then 79.5% of this sample may have poor posture.

No other suggestions besides posture were found in the literature to explain forward neck tilt. As Latzke and Quinlan (1940) showed, posture can range from very poor to excellent (Figure 86). Overall posture was not evaluated in this study. Researchers should measure the angle at which the neck tilts forward at different postures to more clearly define the categories presented in this study. Additionally, while this study focused on adult women between the ages of 18 and 54, posture changes may also affect women 55 years and older, so analysis of neck tilt for women 55 years and older may provide helpful information with regards to apparel block production.

Shoulder

Four body-form variations with seventeen within-component categories were determined by analyzing the shoulder region of each subject: shoulder length description, shoulder point sharpness, shoulder point alignment, and shoulder slope description. For this sample, the most common shoulder variations were long shoulder lengths, soft shoulder points, shoulder point alignment outside the bust and inside the high-hip and thigh, and sloped shoulders.

Shoulder length produced three categories: short, average, and long. The long group was the most common, at eighteen subjects, while the short and average groups were just about equal at eleven and ten subjects each. Pattern blocks made for this sample should adjust the shoulder seam measurement for a long shoulder length, but also have options for short and average lengths.

The shoulder length description for this study focused on the distance from high-point shoulder to shoulder point, while the literature only discussed shoulder width (Table 45), which is the span from one shoulder point to the other and includes neck breadth within the measurement. The relationship between shoulder length and shoulder width should be tested as it relates to drafting and pattern alteration. Shoulder length may be more relevant to patterning the shoulder seam than shoulder width.

Sample: Shoulder Length	**Short**	**Average**	**Long**
Minott (1978): Shoulder Width	Narrow	Average	Wide
Maehren & Meyers (2005): Shoulder Width	Narrow	a/i	Broad
Palmer & Alto (2005): Shoulder Width	Narrow	Average	Broad
Rasband & Liechty (2006): Shoulder Width	Narrower	a/i	Wider/Broad
Liechty et al. (2010): Shoulder Width	Narrower	a/i	Wider/Broad

Table 45: Shoulder Length – Sample vs. Reviewed Literature

The shoulder point sharpness variation produced two categories: sharp and soft. The collarbone was followed to its natural end to locate a reference for the shoulder point. If the shoulder point was easy to see and the shoulder angled sharply into the arm, the shoulder point was sharp. If the shoulder point was difficult to see, or if the shoulder angled softly into the arm, then the shoulder point was soft. Soft shoulder points were the most common, at twenty-three subjects, while sharp shoulder points were around two-thirds the size, at sixteen subjects.

There was nothing in the literature about the sharpness of the shoulder point, though there were numerous descriptions of the shoulder that may account for differences in shoulder point softness (Table 46). Common themes among the possible variations noted in the literature included the size and placement of the shoulder bones, as well as muscle development at the shoulder joint.

Sample	Sharp	n/a	Soft
Minott (1978)	Prominent Collarbone	a/i	n/a
Maehren & Meyers (2005)	Forward Thrust Shoulders	a/i	n/a
Palmer & Alto (2005)	Forward Shoulders	a/i	n/a
Rasband & Liechty (2006)	Forward Shoulder Joint	a/i	Posterior Arm Joint
	Short Arm Joint	a/i	Long Arm Joint
Liechty et al. (2010)	Prominent Collarbone	a/i	n/a
	Forward Shoulder Joint	a/i	Posterior Arm Joint
	Shorter Shoulder Joint	a/i	Longer Shoulder Joint
	Smaller Shoulder Joint	a/i	Larger Shoulder Joint

Table 46: Shoulder Point Sharpness - Sample vs. Reviewed Literature

Minott (1978) and Liechty et al. (2010) were the only texts to note that the collarbone may impact the shoulder joint. Minott only includes an image (Figure 87), but this image does convey how the collarbone can cause sharpness of the shoulder point.

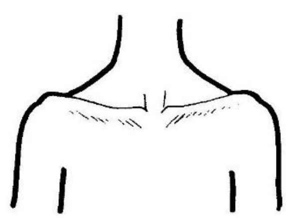


Figure 87: Prominent Collarbones, from Minott (1978), Fig. 7.1c, p. 52

Forward shoulders were found in four of the five reviewed texts and equate to the shoulder joint being rotated farther forward than is considered average or ideal. The opposite, a posterior arm joint, was only found in two texts, and equated to a shoulder joint positioned farther back on the body than average or ideal. Liechty et al. (2010) considered the forward or posterior positioning of the shoulder joint in connection with the collarbone, saying the collarbone bowed forward for the forward shoulder joint and lay flatter/straighter for the posterior shoulder joint. These variations may indicate that collarbone structure may influence the position of the shoulder point, though not the sharpness of the shoulder point.

Shoulder joint length, or the distance between the arm hinge and the shoulder point, was noted by Rasband and Liechty (2006) and Liechty et al. (2010) and was comprised of differences in bone length and muscle development. Longer joints resulted from longer bones and/or fleshier arms, and smaller joints resulted from shorter bones and/or less flesh at the arm joint. The length of the bone may or may not impact shoulder point sharpness, but more flesh may cover the bone, making the point soft, while less flesh may reveal the bone, making the point sharp.

Liechty et al. (2010) was the only text to discuss the general size of the shoulder joint. Larger shoulder joints had larger bones and/or more developed musculature, while smaller shoulder joints had smaller bones and/or less developed musculature. As with the length of the shoulder joint, more flesh may cover the bone and create a soft point, while less flesh may reveal the bone and create a sharp point.

As shoulder point sharpness is not discussed in the literature it may indicate that (a) it is not known, (b) it is known, but discussed in different ways, or (c) it does not impact fit. If option (a) is true, then this study added to the body of knowledge by providing a new body-form variation to describe the shoulder. If option (b) is true, then this study condensed discussion from multiple areas into one, which may speed up description and improve the pattern block alteration process. If option (c) is true, and shoulder point sharpness does not impact fit, then this researcher suggests studies be conducted on how bone structure and musculature development impact the shoulder joint.

Shoulder point alignment compared the relation of the shoulder points to the bust, high-hip, and thigh widths of the subjects in the sample. Alignment could have been inside, aligned, or outside each of the three body components, for a possible twenty-seven combinations. Alignment at the waist was not recorded, as all of the subjects' waists were inside the plane used to judge alignment. Seven combinations were seen in this sample. The most common combinations were a) outside the bust, inside the high-hip and thigh (16), b) aligned with the bust, inside the high-hip and thigh (10), and c) outside the bust and high-hip, inside the thigh (8). The remaining four categories had a combined total of five subjects; or about a third of the most common category.

Shoulder point alignment may indicate whole-body form, as it triangulates shape through four different body areas (Table 47). The only combination inside the bust, was also inside the high-hip and thighs, and so required a whole-body form that had narrow shoulders and a wider lower torso. Two whole-body forms accommodate these needs: the rectangular form and the oval form (Latzke & Quinlan, 1940; Simmons et al., 2004; Maehren & Meyers, 2005; Rasband & Liechty, 2006)

Combinations aligned with the bust required a whole-body form that had average to narrow shoulders and a wide lower torso. The only whole-body form that accommodates these needs is the triangular form (Simmons et al., 2004; Maehren & Meyers, 2005; Rasband & Liechty, 2006).

Combinations that were outside the bust required a whole-body form that had both a wide shoulder and a wide lower torso. The only whole-body form that accommodates these needs is the hourglass (Simmons et al., 2004; Maehren & Meyers, 2005; Rasband & Liechty, 2006).

Sample	Whole-Body Form	Shoulder Width
Inside b, hh & t	Rectangular or Oval	Narrow
Aligned w/b, outside hh, inside t	Triangular	Narrow
Aligned w/b & hh, inside t	Triangular	Narrow
Aligned w/b, inside hh & t	Triangular	Average
Outside b, inside hh & t	Hourglass	Broad
Outside b, aligned w/hh, inside t	Hourglass	Broad
Outside b & hh, inside t	Hourglass	Broad

Table 47: Shoulder Point Alignment - Whole-Body Form & Shoulder Width

The results suggest this sample may be made up of rectangular, oval, triangular and hourglass whole-body forms. The majority of the sample, 66.7%, falls into the hourglass category, while the second largest category, the triangular form was 30.8%. This was the only body-form variation to compare different body components in this study. As such, they provided a rough sketch of how alignment relates to the whole body-form. A larger sample may include body-forms for all 27 possible combinations, providing researchers with more detailed descriptions of whole body-form.

Shoulder point alignment may also indicate shoulder width, a common variation described in the literature, and compiled in Table 45. Shoulder width, the distance spanning from the left shoulder point to the right shoulder point, measured across the back of the body, can be either narrow, average, or wider/broad. Liechty et al. (2010) posit that shoulder width is influenced by bone structure, thus shorter bones equate to a narrower shoulder width, while longer bones equate to a wider/broader shoulder width. Shoulder width may also be influenced by posture, specifically curved or erect upper backs. As bone structure cannot be accurately assessed via body scans, a future study where a subject’s x-rays are overlaid on their body scan may be helpful in assessing this variation.

Shoulder slope produced five categories: flat, slightly sloped, sloped, more sloped, and steep. The categories are a continuum of how sloped the shoulders appeared. Sloped shoulders were the most common category at twenty subjects, one more subject than the remaining four categories combined.

Shoulder slope was discussed in the literature, though the terminology varied. The largest difference between the terminologies was the use of the term "sloped" instead of "average". The term "average" was avoided as much as possible in this study, as it does not adequately describe the body-form. The term "square" covers any deviation that slopes less than average, which was described as "flat" and "slightly sloped" in this study. Likewise, the term "sloped" covers any deviation that slopes more than average, which were described as "more sloped" and "steep" in this study (Table 48).

Sample	**Flat**	**Slightly Sloped**	**Sloped**	**More Sloped**	**Steep**
Minott (1978)	Square	n/a	Average	n/a	Sloped
Maehren & Meyers (2005)	Square	n/a	Average	n/a	Sloping
Palmer & Alto (2005)	Square	n/a	Average	n/a	Sloping
Rasband & Liechty (2006)	Square	n/a	a/i	n/a	Sloped
Liechty et al. (2010)	Square	n/a	a/i	n/a	Sloped

Table 48: Shoulder Slope - Sample vs. Reviewed Literature

Palmer and Alto (2005) also included an uneven category, for when the slope was different for the right and left shoulders. Subjects in this study were fit with symmetrical patterns, thus this body-form variation was not recorded. Future research should test left and right body symmetry.

Rasband and Liechty (2006) and Liechty et al. (2010) suggest that the slope is caused by the slant of the collar or shoulder bones. Less downward slant equates to square shoulders, while more downward slant equates to sloping shoulders. While the majority (51.3%) of this sample had "average" sloped shoulders, 30.7% had more sloped and steep shoulders and 18% had flat and slightly sloped shoulders. Slope should be measured so that ranges are more clearly defined. It is likely slope will need to be assessed on a continuum, rather than as a set of three broad categories.

Shoulder Blades

Four body-form variations with fifteen within-component categories were determined by analyzing the upper back region of each subject: shoulder blade prominence point alignment, blade prominence, blade description, and blade width. For this sample, the most common shoulder blade variations were prominence points aligned at the arm join, visible blade prominences, rounded shoulder blades, and narrow shoulder blade widths.

Shoulder blade prominence point alignment occurred at the armpit, arm join, or above the arm join. The most common alignment occurred at the arm join, with thirty subjects. This is over four times as many as the next alignment category (at the armpit, seven subjects). Arm join alignment shows a clear dominance in this sample, so any pattern created for this sample should align the bodice back waist dart tip with the arm join, which may or may not be above the underarm point.

None of the reviewed literature discussed shoulder blade prominence in terms of where it aligned with other body components (Table 49). The closest the literature came was in Minott (1978), where the author sketched shoulder blade "problems", which included blade prominence at either the top or bottom of the blades (Figure 88). Understanding where the prominence point aligns with other body components can help with the accurate placement of back darts in a pattern. While the shoulder blade prominence points were found to correspond to the lower part of the shoulder blades in this sample, future research should take into account that they may occur higher up on the back, in which case, the shoulder dart becomes more important.

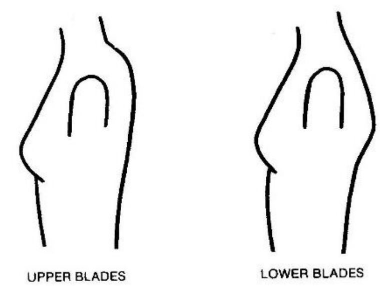


Figure 88: Shoulder Blade Prominence Types, from Minott (1978),Figure 7.1i, p. 54

Sample	Armpit	At Arm Join	Above the Arm Join
Minott (1978)	Lower Blades Prominent	a/i	Upper Blades Prominent

Table 49: Prominence Point Alignment - Sample vs. Reviewed Literature

Shoulder blade prominence produced four categories: flat, almost flat, visible, and prominent. Visible blades were the most common, at twenty subjects (51.3%). Flat blades were the next most common category, at ten subjects. The remaining subjects were almost evenly split between the prominent (5) and almost flat (4) categories.

Sample	Flat	Almost Flat	Visible	Prominent
Palmer & Alto (2005)	n/a	n/a	a/i	Prominent
Liechty et al. (2010)	Flat	n/a	a/i	Prominent
Alternative Explanations				
Palmer & Alto (2005)	Straight/Erect/Sway or Flat Back	n/a	a/i	Rounded Back
Rasband & Liechty (2006)	Erect Upper Back	n/a	a/i	Rounded Upper Back
Liechty et al. (2010)	Erect Upper Back	n/a	a/i	Rounded Upper Back

Table 50: Shoulder Blade Prominence - Sample vs. Reviewed Literature

Only two texts included direct mentions of shoulder blade prominence, and only one of those included a flat alternative (Table 50). Based on the data from this sample, a flat prominence should be included before a prominent option, as the flat category had double the number of subjects as the prominent category. The flat option may not be added because it does not affect pattern fit, or because it is classified as something else.

Explanations for the flat shoulder blade variation in Liechty et al. (2010) say it can be due to an overly erect posture. Three texts included an erect upper back category, which is defined as flat, resulting from an overly erect posture (Table 50). This definition confounds shoulder blade prominence with posture. Research needs to test if there is a difference between a flat shoulder blade due to an overly erect posture and a flat shoulder blade due to bone structure.

Likewise, explanations for the prominent shoulder blade variation in Liechty et al. (2010) say the back can appear rounded. A rounded back is a common postural variation amongst the literature (Table 50). The upper back becomes overly curved, and at the most extreme has been labeled "dowager's hump". Again, this confounds shoulder blade prominence with posture and research should test for a difference between prominent blades and rounded posture.

Both texts that discussed shoulder blade prominence indicated that there was an average/ideal blade prominence. The most common category for this sample was the visible blade prominence, which can equate to this average/ideal. Based on this sample, a case can be made that the average is in fact the most common type of blade prominence, and any pattern made for this sample should use the visible category as its guide.

Shoulder blade description produced five categories: flat, softly pointed, pointed, softly rounded and rounded. The most common category was the rounded category with seventeen subjects. This equals the next two categories added together, flat (11) and softly pointed (6). The smallest categories were pointed (3) and softly rounded (2). It is possible that these categories could have been combined with the softly pointed and rounded categories without repercussion.

The type of prominence (flat, pointed or rounded) is not present in the literature. It is possible that the type of prominence does not affect garment fit which may be why it has been left out. The other option is that it has been categorized as a postural variation, such as Palmer and Alto's (2005) three rounded back variations: slightly round, high round, and very round (Table 51). Future research should spend time separating the variations created by the shoulder blades from the variations created by the spine.

Sample	**Flat**	**Softly Pointed**	**Pointed**	**Softly Rounded**	**Rounded**
Palmer & Alto (2005)	n/a	n/a	High Round	Slightly Round	Very Round

Table 51: Shoulder Blade Description - Sample vs. Reviewed Literature

Shoulder blade width resulted in three categories: narrow, average, and wide. The narrow and wide categories were nearly even with fifteen and fourteen subjects, respectively. Both of these categories were double the average category (7), indicating that it may be more common to have a non-standard blade width than a standard one.

Analysis of the shoulder blade width focused on the distance between blades, while the literature only discussed total back width (Table 52), which spans from one arm join to the other, and includes shoulder blade width. Total back width was not assessed in this study, though future studies may wish to assess upper back width, shoulder blade width, and their proportional relationship.

Liechty et al. (2010) discuss upper back width in terms of muscle development; when there is more muscle back width increases and vice versa. With less muscle the back may appear overly erect (Liechty et al., 2010), a postural variation. As shoulder blades are part of the skeletal system, more or less musculature on the back should not affect their placement. As blade width may impact the depth, width, and placement of darts pointing towards the upper back, it is important for the literature to discuss the possible variations inherent to this body-form variation.

Sample – Blade Width	**Narrow**	**Average**	**Wide**
Minott (1978) – Back Width	Narrow	Average	Broad
Palmer & Alto (2005) – Back Width	Narrow	a/i	Broad
Maehren & Meyers (2005) – Back Width	Narrow	a/i	Broad
Rasband & Liechty (2006) – Upper Back Width	Narrower	a/i	Wider/Broad
Liechty et al. (2010) – Upper Back Width	Narrow	a/i	Wider

Table 52: Shoulder Blade Width - Sample vs. Reviewed Literature

Bust

Three body-form variations with ten within-component categories were determined by analyzing the bust region of each subject: bust fullness, ribcage containment, and bust point width. For this sample, the most common bust variations were full busts, busts contained within a subject's ribcage width, and wide bust point widths.

Bust fullness produced five categories: very small, small, average, full, and very full. The full category was the most common with eighteen subjects, followed closely by the small category (15). The remaining three categories accounted for six subjects total, which was a third the size of the full category. While the small number of subjects in the extreme categories may indicate that the five categories could be condensed into two or three, this would be a premature decision. If bust fullness relates to bra cup size (A, B, C, D, etc.) then finding five variations within our sample is not surprising.

The literature mostly discussed bust fullness in terms of bra cup size, indicating that a B-cup is average and that deviations from that result from smaller or larger busts (Table 53). Bra cup size is determined by taking the difference between the full bust circumference and the high bust circumference (Palmer & Alto, 2005). The larger the difference, the higher the bra cup size needed. But, as Palmer and Alto (2005) point out, bra cup labeling is not consistent across band size (determined by the underbust circumference); and a 38A may have the same cup size as a 32D. As such, bra cup size may not be appropriate for describing bust fullness. Researchers should consider a way to describe bust fullness that does not depend upon size labeling. A good start may be the categories presented herein.

An alternative description of bust fullness found in the Rasband and Liechty (2006) and the Liechty et al. (2010) texts is the prominent bust (Table 53). Prominent busts differ from larger busts by being conical in shape and usually a C-cup or larger. Bust shape was not noted during analysis, though future research may wish to compare how bust shape affects bust fullness.

Sample	Very Small	Small	Average	Full	Very Full
Minott (1978)	n/a	Small	Average	Large	n/a
Maehren & Meyers (2005)	n/a	Small/ <B	Average/ B	Full/ ≥C	n/a
Palmer & Alto (2005)	n/a	A	B	C/Full	D, DD
Rasband & Liechty (2006)	n/a	Smaller/ <B	a/i/B	Larger/ >B Prominent/ ≥C	n/a
Liechty et al. (2010)	n/a	Smaller/ <B	a/i/B	Larger Prominent/ ≥C	n/a

Table 53: Bust Fullness - Sample vs. Reviewed Literature

The bust was either contained within the upper ribcage or not. Ribcage containment was the most common variation in this sample. Twenty-six subjects had busts contained within their ribcage, while half that number (13) did not.

Ribcage containment was not mentioned in the literature, though ribcage width was (Table 54). Liechty et al.'s (2010) wider and narrower rib cages, defined as wider or narrower than average/ideal, when combined with bust fullness may provide an explanation for ribcage containment. Fuller busts and a narrower rib cage may cause the bust to extend past the ribcage, while smaller busts and a wider rib cage may cause the bust to stay within the ribcage. Ribcage was not assessed in this study, but should be considered in conjunction with bust fullness in future research. In instances where the bust is wider than the ribcage, the pattern will need to reflect this, as there will be a hollow along the side of the body between the bust and the back.

Sample	No	n/a	Yes
Liechty et al. (2010)	Narrower Rib Cage	a/i	Wider Rib Cage

Table 54: Ribcage Containment - Sample vs. Reviewed Literature

Bust point width produced three categories: narrow, average, and wide. The wide category was the most common in this sample, with seventeen subjects, followed by the average (13), and narrow (9) categories. Liechty et al. (2010) was the only text to refer to bust point width, and they only indicated two categories: average/ideal and wide (Table 55). The fact that bust point width is not discussed in most of the literature may indicate (a) that it is not known, or (b) that it does not impact fit. If (a) is true, then this study has added to the body of knowledge by adding the narrow category and providing evidence that average and wide categories also exist. Option (b) is most likely untrue, as bust point width may impact the placement of waist darts pointing towards the bust. The front bust width dimension was not assessed in this research, but future research should compare the relationship between the total bust width and the bust point width.

Sample	**Narrow**	**Average**	**Wide**
Liechty et al. (2010)	n/a	a/i	Wide Bust Span

Table 55: Bust Point Width - Sample vs. Reviewed Literature

Greatest Lower-Body Front Prominence

Five body-form variations with twenty-one within-component categories were determined by analyzing the greatest lower-body front prominence region of each subject: waist indentation, GLBFP location, GLBFP description, GLBFP alignment, and past-bust extension. For this sample, the waist is slightly indented, the abdomen is where most people have their GLBFP, the prominence is rounded, aligns with the high-hip, and extends past the bust.

Waist indentation produced four categories: none, barely, slight, and indented. Slight indentation was the most common, at twenty-two subjects. The remaining three categories add up to seventeen subjects, indicating four categories may be too many to describe waist indentation variation. The 'none' and 'barely' categories can probably be combined. The subjects in this sample did not have significantly indented waists, which suggests the majority of this sample has thicker waists. Future research should measure the angle of the waist indentation for different categories and compare it to waist circumference, as waist circumference does not determine waist indentation.

Waist indentation is prevalent in the literature, though the terminology differed from this study (Table 56). While this study focused on describing the indentation, the literature focused on terms that would best describe waist thickness, but defined them as types of indentation. For example, Liechty et al. (2010) use the term “larger”, but define it as indenting less than average/ideal. This mixing of thickness and indentation is confusing, as terms such as “large” or “narrow” better express levels of thickness. This study proposes new terminology for the description of waist indentation that is not confounded with waist thickness.

Sample	**None**	**Barely**	**Slight**	**Indented**
Minott (1978)	n/a	n/a	Average	Indented
Maehren & Meyers (2005)	n/a	Thick	Average	Small
Palmer & Alto (2005)	n/a	Thick	a/i	Small
Rasband & Liechty (2006)	n/a	Larger/Wider	a/i	Smaller/Narrower
Liechty et al. (2010)	n/a	Larger	a/i	Smaller

Table 56: Waist Indentation - Sample vs. Reviewed Literature

Two locations for the greatest lower-body front prominence were posited in the dimensional phase of the methods chapter: the stomach and the abdomen. Observations revealed a third option: these locations could be equally prominent. Thirty-five subjects had the abdomen as the GLBFP, two had the stomach and two had both locations equally prominent. The location of the GLBFP has implications for front waist darts on pattern blocks. The abdomen location allows basic blocks for skirts and dresses with front waist darts to remain as is, but if the GLBFP the stomach, which is above the waist, then front waist darts pointing towards the abdomen may not be necessary. Additionally, if both locations are equally prominent, then basic blocks may not require front waist darts at all.

Given the implications of GLBFP location it was surprising to find so little about this body-form variation in the literature (Table 57). The dearth of information may be due to the literature considering the below-bust portion of the torso the “abdomen”, whereas this study split the below-bust portion of the torso into two parts (above the waist = stomach; below the waist = abdomen). The closest mention of differences in GLBFP location was of high abdominal contours, which protrude from directly under the bust, and low abdominal contours, which drop over the crotch (Rasband & Liechty, 2006; Liechty et al., 2010). The high abdominal contour may correspond to the stomach category from this study. An alternative option was presented in Liechty et al. (2010) whereby flared lower ribs may protrude and cause the stomach to appear to be a location for the GLBFP.

Body-form descriptions should be grounded in accurate terminology. Apparel should borrow terms from anthropometry or medicine to describe the body. Having a formal taxonomy of body-form variations will improve communication between designers, engineers, professors, and medical professionals.

Sample	Abdomen	Stomach	Both	n/a
Rasband & Liechty (2006)	a/i	High Abdominal Contour	n/a	Low Abdominal Contour
Liechty et al. (2010)	a/i	High Abdominal Contour	n/a	Low Abdominal Contour
	a/i	Flared Lower Ribs	n/a	n/a

Table 57: GLBFP Location - Sample vs. Reviewed Literature

Greatest lower-body front prominence description produced five categories: flat, oval, softly pointed, softly rounded, and rounded. The most common category was rounded, with fifteen subjects, followed by flat (9), and oval (7). The softly pointed and softly rounded categories added up to equal the oval category. The categories with 'softly' in front of them indicated that there was some prominence, but not enough to be labeled as 'pointed' or 'rounded'. It is possible that these distinctions are not necessary and the softly rounded category could be combined with the rounded category.

The literature distinguished between prominent, average, and flat abdomens, though the terminology differed among texts. None of the literature shared the terminology of this study, though descriptions of the terms indicated they held the same meaning. As the meanings from the literature are the same, this study proposes that the terms from this study be used to describe the GLBFP, as they are more descriptive.

There were no common terms for the softly pointed category in the literature, which could indicate that (a) it doesn't really exist, (b) it is so uncommon it doesn't need to be discussed, or (c) it has gone unnoticed. As shown in this study, softly pointed GLBFP's do exist, so option (a) is most likely untrue. Only three subjects from this study were categorized as softly pointed, so option (b) may be true; a larger sample will provide researchers with a greater understanding of the proportion of softly pointed GLBFPs in the population. If option (c) is true, then this study has added to the body of knowledge by discovering a previously unknown description for the GLBFP.

Alternative explanations for the GLBFP 'rounded' and 'oval' descriptions were found in the literature on posture (Table 58). The explanations for the rounded description contradict each other: the 'sway front' posture has the pelvis tilted backward (Rasband & Liechty, 2006; Liechty et al., 2010), while Minott (1974) has the pelvis tilted forward in the 'tilted hip forward' postural variation. As can be seen in Figure 89 both result in rounded abdomen, though the placement of the abdomen changes. The sway front places the abdomen lower, while the tilted hip forward posture places the abdomen higher, close to the waist. The contradiction in pelvis tilt does not inhibit description of the GLBFP; these postural variations may play a larger role in GLBFP alignment.

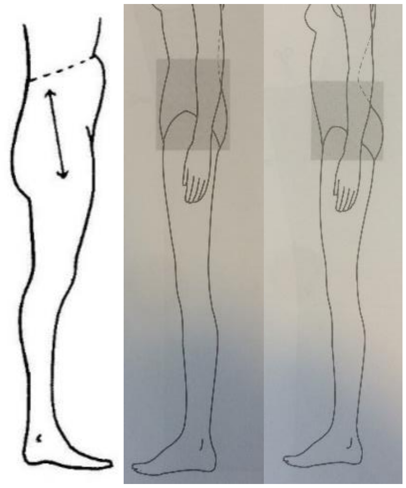


Figure 89: Tilted Hip Forward (Minott, 1974, Fig. 2.5, p. 11), Sway Front, Sway Back (Rasband & Liechty,2006, pp. 332 & 336)

Sample	**Flat**	**Oval**	**Softly Pointed**	**Softly Rounded**	**Rounded**
Minott (1978)	n/a	Large Front	n/a	n/a	n/a
Maehren & Meyers (2005)	Flat	n/a	n/a	Average	Full/Prominent
Palmer & Alto (2005)	n/a	Full Tummy	n/a	n/a	n/a
Rasband & Liechty (2006)	Smaller/Flat	n/a	n/a	a/i	Larger/Prominent
Liechty et al. (2010)	Smaller/Flat	n/a	n/a	a/i	Large/Prominent
Alternative Explanations					
Minott (1974)	n/a	n/a	n/a	a/i	Tilted Hip Forward
Liechty et al. (1986)	n/a	Swayed Back	n/a	a/i	n/a
Rasband & Liechty (2006)	n/a	Sway Back	n/a	a/i	Sway Front
Liechty et al. (2010)	n/a	Sway Back	n/a	a/i	Sway Front

Table 58: GLBFP Description - Sample vs. Reviewed Literature

The sway back posture, indicated by a forward tilt of the pelvis and increased abdominal curvature (Liechty et al., 1986) may produce the 'oval' GLBFP description. For the sway back, Figure 89 shows how the forward tilt produces a curve starting under the bust, extending over the waist, and ending in the groin. Posture was not analyzed in this study, but analysis of how posture affects the GLBFP may provide useful implications for front waist dart placement.

The greatest lower-body front prominence alignment variation produced six categories: at waist, below waist, above high-hip, at high-hip, slightly below high-hip, and below high-hip. The most common alignment occurred at the high-hip, with twenty-one subjects. A couple categories accounted for the same general area. The 'below waist' and 'above high-hip', and 'slightly below high-hip' and 'below high-hip' categories could be combined without repercussion. As these locations change depending upon an individual's waist and high-hip locations, when considering how GLBFP alignment affects pattern blocks, waist, and high-hip data will be necessary to draw conclusions.

While Rasband and Liechty (2006) and Liechty et al. (2010) note that there could be high or low abdominal contours, none of the reviewed literature related the GLBFP to other parts of the body (Table 59). It is possible for postural variations to change the alignment of the GLBFP, as seen in Figure 89; but this is not well established. Future research should consider how body parts relate to each other, especially for the skeletal system and the GLBFP.

Sample	**At Waist**	**Below Waist/ Above High-Hip**	**At High-Hip**	**Slightly Below/ Below High-Hip**
Rasband & Liechty (2006)	High Abdominal Contour	n/a	a/i	Low Abdominal Contour
Liechty *et al*. (2010)	High Abdominal Contour	n/a	a/i	Low Abdominal Contour
Minott (1974)	n/a	Tilted Hip Forward	n/a	n/a
Rasband & Liechty (2006)	Sway Back	n/a	a/i	Sway Front
Liechty *et al*. (2010)	Sway Back	n/a	a/i	Sway Front

Table 59: GLBFP Alignment - Sample vs. Reviewed Literature

An interesting finding from the study was that for the majority (22) of subjects the GLBFP extended farther forward than the bust prominence. Thirteen subjects did not have their GLBFP extend past the bust prominence, and four subjects had their GLBFP aligned with the bust.

This is a completely new body-form variation, the finding of which was made possible by the use of body-scanning technology. As none of the literature discussed past-bust extension, there is either (a) no knowledge of its existence, or (b) it does not affect apparel patterns. If it is (a), then this study has extended the body of knowledge for the apparel field by providing a new relationship to test among the body. If (b) is true, and the past-bust extension of the GLBFP does not affect apparel patterns, then this can be verified through research focused on the relationship. As front waist darts are meant to reduce the pattern from the bust to the waist, having the GLBFP extend past the bust may reduce or eliminate the need for front waist darts.

Buttocks

Four body-form variations with eleven within-component categories were determined by analyzing the buttocks region of each subject: buttocks prominence, buttocks length, buttocks fullest part, and buttocks alignment. For this sample, the most common buttocks variations were prominent and long, with the fullest part in the middle and aligned with the true hip.

Buttocks prominence produced two categories: flat and prominent. Prominent buttocks were the most common, at twenty-four subjects. Flat buttocks followed with fifteen subjects, indicating that any patterns made for this sample should have two types of skirt back patterns.

Buttocks prominence was prevalent in the literature, though the terminology differed slightly for the prominent category, and all of the literature included an average category (Table 60). Liechty et al. (2010) note that prominent buttocks may have greater muscle development, while flat buttocks may have less than average buttocks. Because muscle develops differently in each person, it would be beneficial to measure muscle tone and compare it to buttocks prominence. Plus, while this study did not have an average category, creating a continuum of flat to prominent would accommodate those subjects that do not easily fall into one category or the other.

Posture can also account for differences in buttocks prominence (Table 60). When the top of the pelvis tilts backwards (Sway Front, Tilted Hip-Forward) the buttocks protrude less, resulting in a flat seat (Minott, 1974; Rasband & Liechty, 2006; Liechty et al., 2010). When the top of the pelvis tilts forwards, the buttocks protrude more, resulting in a more prominent seat (Minott, 1974; Rasband & Liechty, 2006; Liechty et al., 2010). Posture was not assessed in this study, so future studies should consider how posture affects buttocks prominence and contrast that to muscle tone and fat deposits.

Sample	**Flat**	**n/a**	**Prominent**
Maehren & Meyers (2005)	Flat	Average	Full
Palmer & Alto (2005)	Flat	a/i	Full
Rasband & Liechty (2006)	Smaller/Flat	a/i	Larger/Prominent
Liechty et al. (2010)	Flat	a/i	Large Prominent
Alternative Explanations			
Minott (1974)	Tilted Hip-Forward	Average	Tilted Hip-Backward
Maehren & Meyers (2005)	n/a	n/a	Swaybacked
Palmer & Alto (2005)	n/a	a/i	Sway Back
Rasband & Liechty (2006)	Sway Front	a/i	Sway Back
Liechty et al. (2010)	Sway Front	a/i	Sway Back

Table 60: Buttocks Prominence - Sample vs. Reviewed Literature

Buttocks length produced two categories: long and short. Long buttocks were the most common, with twenty-nine subjects. This was nearly three times as many subjects as the short category (10). This suggests that pattern blocks created for this sample should have a longer waist to crotch length, and but also an option to shorten this length.

Only two texts mentioned the length of the lower torso in connection to the buttocks (Table 61). Both note that buttock length is due to the length of the pelvic area, indicating that the skeletal system may play a crucial role in this body-form variation. Length may also be affected by muscle tone or posture. Overlaying x-rays on scans will provide data on pelvis length and posture.

Sample	**Short**	**n/a**	**Long**
Rasband & Liechty (2006)	Shorter Lower Torso	a/i	Longer Lower Torso
Liechty et al. (2010)	Shorter Lower Torso	a/i	Longer Lower Torso

Table 61: Buttocks Length - Sample vs. Reviewed Literature

The fullest part of the buttocks was determined by placing transverse planes at the top, bottom, and fullest part of the buttocks. The fullest part fell at three locations: low on the buttocks, in the middle of the buttocks, and high on the buttocks. The most common location for the fullest part of the buttocks was in the middle, with twenty-three subjects. This is nearly twice the next largest category (low, twelve subjects), and six times the smallest category (high, four subjects). Patterns made for this sample should align dart lengths with the middle of the buttocks, but also provide an option to lengthen the darts for subjects in the low category.

Sample	**Low**	**Middle**	**High**
Rasband & Liechty (2006)	Low Contour	a/i	High Contour
Liechty et al. (2010)	Low Curve	a/i	High Contour

Table 62: Buttocks Fullest Part - Sample vs. Reviewed Literature

Rasband and Liechty (2006) and Liechty et al. (2010) were the only texts to discuss the height of the buttocks contour (Table 62). They describe two variations: high and low buttocks contours. High contours were described as having a shorter distance from the most prominent point to the waist. Low contours were described as dropping below the crotch. The low category from this study does not match the low category from these texts, as demonstrated by the four categories of buttocks alignment: true hip, slightly below true hip, below true hip, and far below true hip. In no instance did the most prominent point of the buttocks drop below the crotch. This discrepancy indicates that there may be another level to this body-form variation. A larger sample should provide evidence of whether this even lower buttocks contour exists or not.

Alignment of the buttocks prominence most commonly occurred at the true hip, with sixteen subjects. The second most common alignment occurred slightly below the true hip (12), followed by the below the true hip (10) category. The closeness of the top three categories indicates that patterns made for this sample should include three different dart lengths to match the different hip alignments.

Minott (1978) was the only text to equate hip type with buttocks prominence alignment (Table 63). Figure 90 shows three variations of buttocks prominence and hip alignment: heart, diamond, and standard. The buttocks appear to align below the hip for the heart-shaped hip. There is no distinction between how low the buttocks align below the true hip in Minott's illustration, which differs from this study. The buttocks appear to align at the true hip for the standard-shaped hip. The heart and standard hip shapes align with buttocks alignment categories from this study, but the diamond hip does not. The buttocks appear to align above the true hip for the diamond-shaped hip, which suggests there may be another category to add to the buttock alignment body-form variation. A larger sample may include a buttock alignment that occurs above the true hip. Overall, a continuum should be created for this body-form variation.

Sample	**n/a**	**True Hip**	**Slightly Below True Hip**	**Below True Hip**	**Far Below True Hip**
Minott (1978)	Diamond Hip	Standard Hip	n/a	Heart Hip	n/a

Table 63: Buttocks Alignment - Sample vs. Reviewed Literature

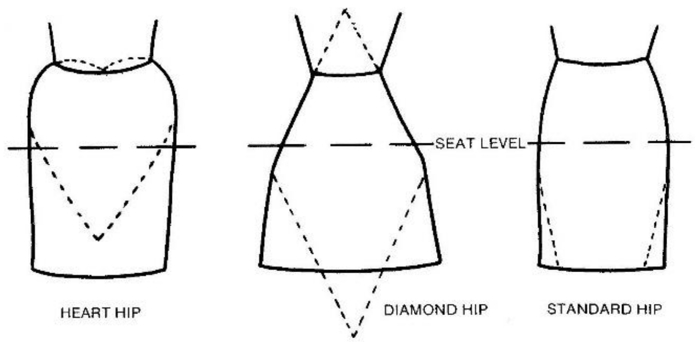


Figure 90: Seat level vs Hip Type (from Minott, 1978, Fig. 7.1k, p. 55)

Greatest Lower-Body Side Prominence

Three body-form variations with twelve within-component categories were determined by analyzing the greatest lower-body side prominence region of each subject: GLBSP location, GLBSP alignment, and GLBSP description. For this sample, the most common GLBSP variations were location at the thigh, alignment at the crotch, and rounded in prominence.

Three possible locations for the greatest lower-body side prominence were posited during the analytical phase of this study: the high-hip, true hip, and thighs. Only the high-hip and thighs were found during the visual analysis phase, with the thigh location being the most common, at thirty-five subjects. Four subjects aligned with the high-hip, indicating there were two distinct groups in this sample. Patterns for these two groups will require different starting locations for the hip curve.

There are many names for the GLBSP locations identified in this study, though they all indicate three locations for the greatest lower-body side prominence: high-hip, hip, and thighs (Table 64). The standard among all texts was that the hip is the most common GLBSP, and the high-hip and thigh locations are deviations from the norm. The results from this sample contradict this, indicating that the hip might not be the most useful location for fitting apparel. Due to the great variability in this body-form variation future research should attempt to describe all of the possible locations for the GLBSP, as well as any combinations of them. The GLBSP may be one of the clearest ways to sort subjects into groups.

Sample	**High Hip**	**n/a**	**Thighs**
Minott (1974, 1978)	Heart, Semi-Heart	Hips	Diamond, Rounded Diamond
Maehren & Meyers (2005)	n/a	Hips	n/a
Palmer & Alto (2005)	n/a	Hips	Full Thighs
Rasband & Liechty (2006)	High Hip Curve/Square	Hips	Low Hip Curve/Sloped, Large Thighs at Side
Liechty et al. (2010)	High Hip Curve	Hips	Low Hip Curve, Larger Thighs at Side

Table 64: GLBSP Location - Sample vs. Reviewed Literature

Five categories were produced by assessing the GLBSP alignment: below the crotch, at the crotch, above the crotch, below the abdomen, and at the abdomen. The below crotch, at crotch, and above crotch relate solely to the thighs; the most common alignment occurred at the crotch, with twenty subjects. Alignment above the crotch came second, at twelve subjects. Thigh alignment always occurred below buttocks alignment, indicating that while the buttocks may hold the largest circumference, aligning the hip curve point with the buttocks alignment may not lead to accurate patterns.

The below abdomen and at abdomen alignment locations relate solely to the high-hips; the most common alignment occurred at the abdomen, with three subjects. Conclusions on this variation cannot be made on such a small number of subjects and future research should attempt to find a sample where the majority of subjects have the high-hip as the GLBSP to determine alignment more clearly.

There are no direct references to the greatest lower-body side prominence alignment in the literature, though inferences can be made from descriptions of hip types and thigh fullness (Table 65). Minott's (1974, 1978) heart and semi-heart hip types, and Rasband and Liechty (2006), and Liechty et al.'s (2010) high hip curve variation are described as occurring 3-4.5" below the waist, which may correlate to the abdomen area. Rasband and Liechty, and Liechty et al. describe the thighs as having extra weight at the crotchline and below the hips, which may correlate to the at crotch and above crotch categories from this study. Future research should categorize the different alignments of the GLBSP types, and compare them to buttocks body-form variations.

Minott's (1974, 1978) rounded diamond hip type is unique in that it has prominences at both the high-hip and thighs, thus the GLBSP could align at any of the five categories in this study. While not recorded in this study, there were subjects that appeared to have both prominent high-hips and thighs, though there was always one that was slightly more prominent. Considering combinations of GLBSPs may lead to more accurately fitting patterns, as it may be necessary to have hip curve points at multiple locations on patterns for subjects with dual GLBSPs.

Sample	**Below Crotch**	**At Crotch**	**Above Crotch**	**Below Abdomen**	**At Abdomen**
Minott (1974, 1978)				Heart, Semi-Heart	
	Rounded Diamond				
Rasband & Liechty (2006)		Large Thighs at Side		High Hip Curve/Square	
Liechty et al. (2010)		Larger Thighs at Side		High Hip Curve	

Table 65: GLBSP Alignment - Sample vs. Literature

The greatest lower-body side prominence descriptions produced five categories: flat, softly pointed, pointed, softly rounded, and rounded. Rounded GLBSPs were the most common, with fourteen subjects; followed by the softly pointed (10), softly rounded (8), and flat (5) categories. As with the greatest lower-body front prominence, designations of 'softly' indicated that there was some prominence, but not enough for the full rating of 'pointed' or 'rounded'. Only two subjects fell into the pointed category, indicating that the softly pointed and pointed categories could be combined.

The literature does not describe the greatest lower-body side prominence. Instead it describes the width of the pelvis (Table 66). Rather than describing the width of the lower body, it would be better to describe the side prominence itself. The flatness, pointedness, or roundness of the GLBSP may change the angle of the hip curve on the pattern. Future research should focus on creating clear description categories for the GLBSP.

Sample	**Flat**	**Softly Pointed**	**Pointed**	**Softly Rounded**	**Rounded**
Maehren & Meyers (2005)	Small	n/a	n/a	Average	Full
Palmer & Alto (2005)	Small	n/a	n/a	a/i	Full
Rasband & Liechty (2006)	Smaller/Narrower	n/a	n/a	a/i	Larger/Wider
Liechty *et al.* (20100	Smaller/Narrower	n/a	n/a	a/	Larger/Wider

Table 66: GLBSP Description - Sample vs. Literature

Fit Model vs. Sample

Fit models are commonly used in the apparel industry to simulate the body-form of targeted customers. Basic measurements, such as bust, waist, and hip girth are common considerations for fit models. As this study has shown, basic measurements do not fully describe the human body. The purpose of this section is to share how the differences in body-forms between the fit model and the sample may impact garment fit.

Throughout the results chapter, data on both the sample and the fit model were presented. The previous sections in this chapter have outlined the differences between the body-form variations found in this study and those present in the literature. This section will discuss the differences between the body-form variations of the fit model and the most common body-form variations in the sample, with implications for garment fit.

Twenty-seven total body-form variations, with ninety-nine within-component categories were determined for this sample. The fit model and the sample match for sixteen of the variations, but do not match for eleven. The focus of this section will rest on the eleven non-matches, as these are what will cause garments created for this sample to fit it poorly.

Neck Region	Fit Model	Sample
Neck Thickness	Average	Thick
Neck-to-Shoulder Transition	Smooth	Sharp
Collarbone Visibility	Visible	Visible
Neck Tilt	Slightly Forward	Forward
Shoulder Region	**Fit Model**	**Sample**
Shoulder Length	Average	Long
Shoulder Point Sharpness	Soft	Soft
Shoulder Point Alignment	Aligned w/b, inside hh & t	Outside b, inside hh & t
Shoulder Slope	Slightly Sloped	Sloped
Shoulder Blade Region	**Fit Model**	**Sample**
Prominence Point Alignment	Arm Join	Arm Join
Blade Prominence	Visible	Visible
Blade Description	Rounded	Rounded
Blade Width	Average	Narrow
Bust Region	**Fit Model**	**Sample**
Bust Fullness	Average	Full
Ribcage Containment	Yes	Yes
Bust Point Width	Wide	Wide
GLBFP Region	**Fit Model**	**Sample**
Waist Indentation	Barely	Slight
GLBFP Location	Abdomen	Abdomen
GLBFP Description	Rounded	Rounded
GLBFP Alignment	High-Hip	High-Hip
Past-Bust Extension	No	Yes
Buttocks Region	**Fit Model**	**Sample**
Buttocks Prominence	Prominent	Prominent
Buttocks Length	Long	Long
Buttocks Fullest Part	Middle	Middle
Buttocks Alignment	True Hip	True Hip
GLBSP Region	**Fit Model**	**Sample**
GLBSP Location	Thigh	Thigh
GLBSP Alignment	Above Crotch	At Crotch
GLBSP Description	Rounded	Rounded

Table 67: Body-Form Variations - Fit Model vs. Sample

As seen in Table 67, the neck and shoulder regions have the most non-matches between the fit model and the sample, with different categories for 75% of each region. The fit model has a smaller neck thickness than the sample which may cause the neck circumference of a pattern to be too small. As garment suspension for the upper torso is based on the neck circumference, a too small neckline will cause the shoulder seam to ride-up on the neck, affecting garment positioning and balance negatively. The fit model's smooth neck-to-shoulder transition may cause the neck circumference of a pattern to be larger than necessary, causing the shoulder seam to hang off the body at the shoulder point, affecting garment positioning and balance negatively. The outcomes of these two variations directly contradict each other. Because of this, the outcomes may equate to the outcomes a thick neck and sharp neck-to-shoulder transition creates for a pattern.

The fit model has a less tilted neck than the sample (Table 67), which may cause the center front neck point to rest above the center of the clavicle hollow, which would be too high for this sample. A higher center front neck point could cause a shorter front neck drop, which would alter the balance of the garment, potentially causing tightness over the bust, and raised waist- and hem-lines.

The fit model has a shorter shoulder length than the sample (Table 67), which may result in the shoulder point of the pattern not reaching the outside of the acromion on the body. Garment balance may be negatively affected, as the shoulder seam may pull the bust up, causing raised waist- and hem-lines. Additionally, garments made with sleeves will find the armhole too tight, and that the sleeve cap fits poorly over the shoulder.

Patterns drafted for the fit model will fit a triangular whole-body form (aligned with bust, inside high-hip and thigh), while the sample requires an hourglass whole-body form (outside bust, inside high-hip and thigh) (Table 67). This may result in garments poorly fitting the upper torso of the sample, which will affect total garment balance and cause garments that are drafted to fit the lower torso well appear to fit poorly.

The fit model has slightly sloping shoulders which are a little bit flatter than the sample (Table 67). Patterns drafted for a flatter slope may pull at the shoulder seam. The stress placed on the shoulder seam will lead to a shorter life for the garment. Balance may also be affected if the pulling raises the bustline of the garment, thereby raising the waist- and hem-lines too.

The remaining five regions have between 60% and 100% of body-form variation matches between the fit model and the sample (Table 67). The buttocks region has 100% agreement and will not be discussed.

The fit model has a wider blade width than the sample (Table 67), resulting in the bodice back waist darts placing further out on the pattern than necessary. As such, they will not point to the shoulder blade prominence of the sample. Large width between the shoulder blades may cause a garment to look too wide for the body, causing aesthetic issues.

The fit model has a smaller bust than the sample (Table 67). This will cause pulling around the bust and will negatively affect garment balance. Tightness at the bustline may pull other parts of the garment forwards and towards the bust, and out of correct alignment.

The fit model has less waist indentation than the sample (Table 67), resulting in a wider waistline, which hangs further from the body. The waistline is a suspension location for garments, which means that garment balance is affected by changes to the waistline. A larger waistline could cause a garment to hang lower on the body than intended, shifting all pattern components to the wrong place.

The sample has their greatest lower-body front prominence extend past the bust, while the fit model does not (Table 67). As this is a completely new body-form variation, there is no guidance on how this may affect patterns. Speculatively, this variation may impact the use of front waist darts. With the GLBFP not extending past the bust prominence, the pattern should need darts to reduce from the bust to the waist. Past-bust extension may eliminate the need for front waist darts. If this is the case, then patterns made for the fit model will have darts, while the sample may not need them. This would add an extra step to the production process that if eliminated would surely save apparel producers money and may lead to better fit for customers.

The fit model's greatest lower-body side prominence alignment occurs slightly higher on the body than the sample (Table 67). This places the hip curve point too high on the pattern for the sample. If the side seam starts curving early, the garment will be too tight at the GLBSP, causing the garment to wrinkle and ride-up the thighs. Balance will also be affected as the garment will bunch around the GLBSP, causing there to be excess fabric above the GLBSP and a raised hemline.

Overall, the major differences between the fit model and the sample occur in the neck and shoulder regions. The remainder of the body regions matched well, which makes sense as they were all impacted by the bust, waist, and hip girth measurements used to select the sample. Adding the neck circumference or shoulder length measurement to the sorting process may help move the fit model closer to the body-form variations of the sample.

Conclusion

Question one asked what the body-form variations were across a single size. Originally, the goal was to determine holistic body-form types, but due to the detailed information gleaned during content analysis this was changed to bound the scope of the study. The next step for this project is to compare across the sample to discover common combinations of body-form variations.

This section discussed the variations found in the sample as well as variations prevalent in the literature. Many of the body-form variations from this study differed from those found in the literature and some new variations were recorded. Many of the differences came from terminology. Synonyms abound in the literature, even in texts written by the same authors. Theorists should endeavor to define body-form variation terminology so that researchers and manufacturers have a standardized vocabulary for communication.

This section ended with a comparison of the fit model and the most common body-form variations for the sample. This exercise demonstrated how garments made for a fit model the same size as intended customers, may still not fit those customers due to body-form variations.

The next section will address the second research question by comparing body-form variations to pattern dimensions in an exploratory attempt to group subjects by variation.

Question Two

While there are numerous body-form variations in this sample, there were not always clear-cut groupings when comparing dimensions and body-form variations. Some dimensions and variation combinations were more apparent than others. This section discusses the implications for the development of a body-form based block system by assumption status, starting with the upheld assumptions.

Upheld

Ten of the twenty-seven assumptions were upheld (Table 68). Figure 91 shows the six dimensions associated with the assumptions. The neck, shoulder, shoulder blades, bust, and greatest lower-body side prominence regions were affected.

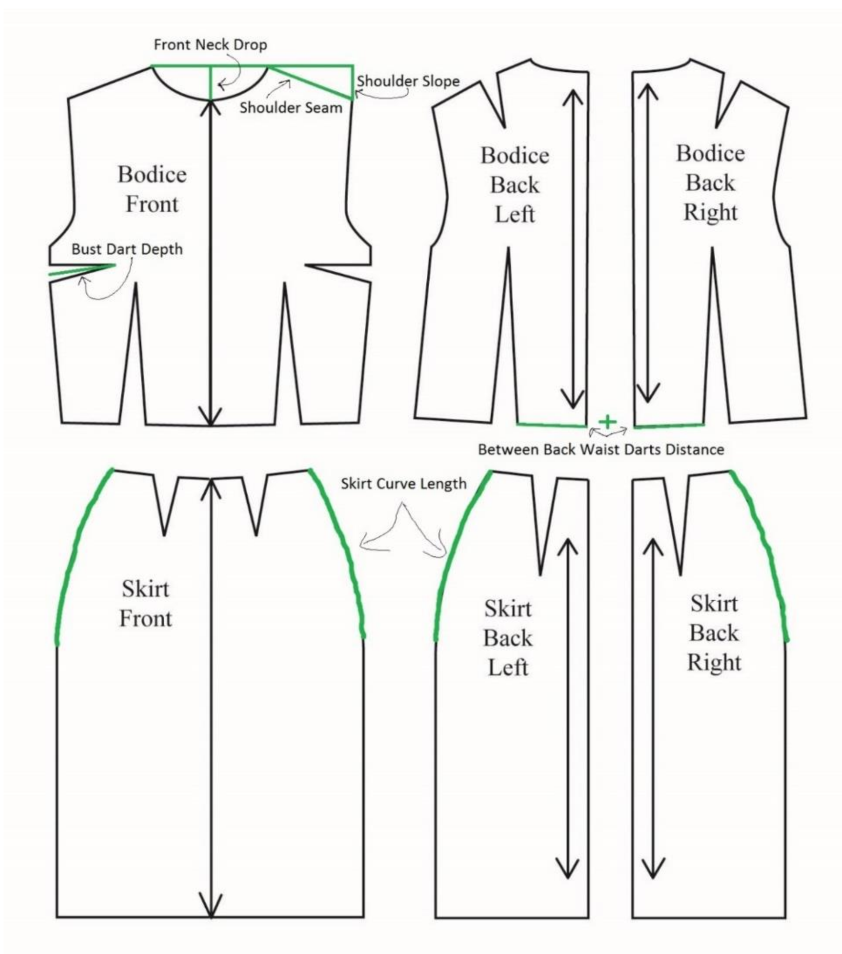


Figure 91: Upheld Assumptions, Dimension Locations

Body Region	Assumption
Neck	The more forward tilted the neck is in relation to the torso, the longer the front neck drop measurement will be.
Shoulder	The longer the shoulder, the larger the shoulder seam measurement will be. The softer the shoulder point, the longer the shoulder seam measurement will be. The more sloped the shoulder, the larger the shoulder slope measurement will be. The softer the shoulder point, the larger the shoulder slope measurement will be. The longer the shoulder, the larger the shoulder slope measurement will be.
Shoulder Blade	The wider apart the shoulder blade prominence points are, the larger the between back waist darts distance measurement will be.
Bust	The fuller the bust, the larger the bust dart depth measurement will be. Busts contained within the ribcage will have smaller bust dart depth measurements than busts not contained within the ribcage.
GLBSP	The lower the location of the GLBSP on the body, the longer the curved portion of the skirt side seam will be on the pattern.

Table 68: Upheld Assumptions

The only upheld assumption for the neck compared the front neck drop dimension to the neck tilt body-form variation. Four categories were identified for neck tilt: straight, slightly forward, forward, and far forward, and five groups were identified from the front neck drop graph (Figure 35Figure 34Table 18). Group 1 was made of primarily straight necks, while group 5 was primarily far forward necks. Groups 2, 3, and 4 were primarily composed of forward necks, indicating that it may be safe to combine the middle of the sample into one group. Slightly forward necks were spread out over groups 1 through 4, with the highest concentration in group 4. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed a progression from straight-to-far forward.

The data suggest that the more forward tilted the neck is, the longer the front neck drop dimension is. This finding suggests that pattern blocks based on body-forms may need at least four distinct neck drop lengths. As posture may play a role in neck tilt, pattern blocks may not need all four neck drop lengths if consumers all share similar posture.

Five assumptions from the shoulder were upheld; two focus on the shoulder seam dimension, and three focus on the averaged shoulder slope dimension. Shoulder length, shoulder point softness, and shoulder slope description were the three body-form variations tested. Five groups were identified from both the shoulder seam and averaged shoulder slope graphs (Figure 36 & Figure 37).

The first upheld shoulder assumption compared the shoulder seam dimension to the shoulder length description body-form variation. Three categories were identified for shoulder length: short, average, and long. Group 1 was comprised solely of short shoulder lengths, group 2 had a tie for majority between the short and average lengths, while long shoulder lengths comprised the majority of group 3, and the entirety of groups 4 and 5. Groups 4 and 5 could potentially be condensed into one group. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed a progression from short-to-long.

The data suggest that the longer the shoulder length is, the larger the shoulder seam dimension is. This finding suggests that pattern blocks based on body-forms may need three distinct shoulder seam lengths. Though, as there was a great amount of difference between the fit model and the sample for the shoulder region, choosing a fit model with a shoulder length that matches the target market may eliminate the need to pattern multiple shoulder seam lengths.

The second upheld shoulder assumption compared the shoulder seam dimension to the shoulder point softness body-form variation. Two categories were identified for shoulder point softness: sharp, and soft. Sharp shoulder points comprised the majority for groups 1 and 2, while soft shoulder points comprised the majority for groups 3 and 4; sharp and soft tied for majority in group 5 (at one person each). Averaging the measurements for each body-form category showed that shoulders with soft shoulder points were longer than shoulders with sharp shoulder points.

The data suggest that soft shoulder points equate to longer shoulder seam measurements. This finding, in conjunction with the previous finding on shoulder length, suggests that people with soft shoulder points may also have long shoulder lengths, while people with sharp shoulder points may have short or average shoulder lengths. As such, shoulder point sharpness may be an indicator of shoulder length. Future research may wish to test if there are degrees of softness/sharpness for the shoulder point, how the shoulder point softness body-form variation compares to the shoulder length description body-form variation, and if these comparisons lead to specific shoulder seam lengths.

The third upheld shoulder assumption compared the averaged shoulder slope dimension to the shoulder slope description body-form variation. Five categories were identified for shoulder slope description: flat, slightly sloped, sloped, more sloped, and steep. Flat slopes comprised the majority of group 1, while group 2 and 3 had the sloped category as the majority, group 4 had the steep category as the majority, and group 5 was comprised solely of one subject, who had a steep slope. The slightly sloped category was distributed throughout groups 2 and 3, mostly toward the smaller measurements, while the more sloped category was distributed in groups 3 and 4, mostly towards the larger measurements. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed a progression from flat-to-steep.

The data suggest that the more sloped the shoulder is, the larger the averaged shoulder slope dimension is. This finding suggests that pattern blocks based on body-forms may wish to use a sloped shoulder (average: 1.24”) as the base, but also have alternative slopes available, depending on the collarbone slant of target customers. Vertical changes in the shoulder point or the side neck point on the pattern block will affect the shoulder slope, thus this pattern dimension is tied to changes made to the neck circumference and front neck drop, as well as changes at the armscye. Future research should compare shoulder slope to neck and arm body-form variations and pattern dimensions.

The fourth upheld shoulder assumption compared the averaged shoulder slope dimension to the shoulder point sharpness body-form variation. Group 1 was composed solely of sharp shoulder points and sharp shoulder points comprised the majority for group 2, commensurate with the smallest averaged shoulder slope measurements. Soft shoulder points comprised the majority for groups 3 and 4, and were the sole inhabitants of group 5, commensurate with the largest averaged shoulder slope measurements. Averaging the measurements for each body-form category showed that shoulders with soft shoulder points had larger averaged shoulder slopes than those with sharp shoulder points. The data suggest that soft shoulder points equate to larger averaged shoulder slope measurements.

The fifth, and final, shoulder assumption compared the averaged shoulder slope dimension to the shoulder length description body-form variation. Group 1 was composed solely of short shoulder lengths, and group 2 had a majority of short shoulder lengths. Groups 3 and 4 had a majority of long shoulder lengths, and group 5 was comprised solely of long shoulder lengths. Average shoulder lengths were distributed throughout group 3, close to the mid-length measurements. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed a progression from short-to-long. The data suggest that the longer the shoulder length, the larger the averaged shoulder slope dimension.

The findings from shoulder assumptions one, two, four, and five are linked. Soft shoulder points equate to longer shoulder seam measurements, and to larger averaged shoulder slope measurements. The longer the shoulder length description, the longer the shoulder seam dimension and the larger the averaged shoulder slope dimension. These findings suggest that the shoulder length description and the shoulder point sharpness body-form variations may be correlated. Two suggestions for developing pattern blocks for a body-form based system derive from these findings:

1. When someone is assessed with soft shoulder points, she most likely needs a pattern with a longer shoulder seam.
2. When someone is assessed with sharp shoulder points, she most likely needs a pattern with a shorter shoulder seam.

Future research will need to determine exact lengths for short, average, and long shoulder seams, as well as classify soft and sharp shoulder points by the height of the acromion.

The only upheld assumption for the shoulder blade compared the between back waist darts distance dimension to the shoulder blade width body-form variation. Three categories were identified for blade with: narrow, average, and wide, and three groups were identified from the between back waist darts distance graph (Figure 40). Narrow blade widths comprised the majority of group 1, while wide blade widths comprised the majority of group 2, and were the only inhabitants of group 3. Average blade widths only occurred in group 1, but they were toward the larger measurements of this group.

Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, revealed that the wide category was greater than the narrow and average categories by nearly an inch, but the narrow category was greater than the average category by .06”. This is most likely due to the fact that subjects with average blade widths only occurred in group one, but three subjects with narrow blade widths occurred in group 2, increasing the value of narrow category’s average. As there was still a clear split between narrow, average, and wide, this assumption was upheld.

The data suggest that the wider the shoulder blade width is (as assessed by the distance between the shoulder blade prominence points), the larger the between back waist darts distance dimension is. This finding suggests that pattern blocks based on body-forms may need three alternative dart placement locations depending upon the width of the shoulder blade.

Two assumptions from the bust were upheld, both focused on the bust dart depth dimension. The body-form variations assessed were bust fullness and ribcage containment. Four groups were identified from the bust dart depth graph (Figure 41).

The first upheld bust assumption compared the bust dart depth dimension to the bust fullness body-form variation. Five categories were identified for bust fullness: very small, small, average, full, and very full. The small category comprised the majority of group 1, while the full category comprised the majority of groups 2, 3, and 4. The average category appeared in groups 1 and 3; and the very full category appeared in groups 3 and 4. The very small category comprised one subject and had the largest bust dart depth measurement of the sample. This may have been a patterning error, or the subject may have a very deep upper ribcage, which when combined with very small breasts and an average bust point width, produced a long dart. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, revealed that the small and average categories had the same average (5”), but that they are both smaller than the full category, which is smaller than the very full category.

Aside from the single subject in the very small category, the data suggest that the fuller the bust, the larger the bust dart depth measurement. This finding suggests that pattern blocks based on body-forms may need multiple bust dart depths depending upon bust fullness. Currently, bra sizing is used to define bust fullness, but sizing standards differ by company, and also within companies by band size (Palmer & Alto, 2005). Future research should quantify the levels of bust fullness by measuring breast depth, width, length, and volume.

The second upheld bust assumption compares the bust dart depth dimension with the ribcage containment body-form variation. The breasts were either contained within the ribcage width or not. Group 1 covered about half the sample, while groups 2, 3, and 4 covered the remainder. The majority of groups 1 and 3 had busts contained within their ribcage width, while the majority of group 4 did not. Averaging the measurements for each body-form category showed that subjects with ribcage containment had shorter bust dart depths than subjects without ribcage containment.

The data suggest that ribcage containment does affect bust dart depth, with containment leading to smaller bust dart depth measurements than non-containment. This finding suggests two things:

1. When someone is assessed has having her busts contained within her ribcage, she should be assigned to patterns with smaller bust dart depths.
2. When someone is assessed as having her busts not contained within her ribcage, she should be assigned to patterns with larger bust dart depths.

Taking the findings from both upheld bust assumptions suggests that bust fullness may not be the only factor involved in bust dart depth. Since all the subjects in this study have a bust circumference within two inches of each other, the body-form variations witnessed at the bust are most likely a combination of ribcage depth and bust fullness. Future research should assess ribcage depth, and assess how much of the bust dart covers the ribcage, and how much covers the breast. It is possible that smaller busts have wider and/or deeper ribcages, while fuller busts have narrower and/or shallower ribcages.

The only upheld assumption for the greatest lower-body side prominence compared the skirt curve length dimension to the GLBSP location and alignment body-form variations. Two groups were identified from the skirt curve length graph (Figure 49).

GLBSP locations included the high-hips and the thighs. Group 1 was comprised solely of the high-hip category, while group 2 was comprised solely of the thigh category. Averaging the measurements for each body-form category showed that the thigh category had a much longer skirt curve length than the high-hip category (11.34” vs. 5.89”).

GLBSP alignment produced five categories: at the abdomen, below the abdomen, above the crotch, at the crotch, and below the crotch. Categories pertaining to the abdomen only appeared in group 1, corresponding to the high-hip body-form location category. Categories pertaining to the crotch only appeared in group 2, corresponding to the thigh body-form location category. The above the crotch category corresponded to the smaller measurements in group 2, while the at the crotch category corresponded to the larger measurements. Two of the three below-crotch subjects corresponded to the larger measurements, while one corresponded to the smaller measurements in group 2. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed that aside from the below crotch category, the other categories showed a progression from alignment at the abdomen to alignment at the crotch.

The data suggest that the lower the location of the GLBSP is on the body, the longer the skirt curve length dimension is. This finding suggests that pattern blocks based on body-forms may need at least two different locations for the skirt curve point. One will need to be much higher on the body, centered around the abdomen, with a steeper curve between the waist and high-hip, while the other will need to be lower on the body, centered around the crotch, with a gentler curve over the lower torso.

Another aspect of this finding is the lengths associated with the GLBSP location categories. Standard practice places the hip at 7” to 9” below the waist (Maehren & Meyers, 2005; Minott, 1974), and Minott (1974) places the high-hips 3” to 4.5” below the waist. The average skirt curve lengths for both groups are longer than the upper limits for both of these by at least an inch. Pattern blocks based on body-forms may need longer skirt curve lengths than traditionally used.

Partially Upheld

Eight of the twenty-seven assumptions were partially upheld, meaning there were indications of possible connections between body-form variations and pattern dimensions, but more research is needed to confirm their presence (Table 69). Figure 92 shows the seven dimensions associated with these assumptions. All seven body regions were affected. In general, there were many more categories in each of the tested body-form variations for the partially upheld assumptions than for the upheld assumptions. This created difficulty in assessing data patterns with such a small sample size.

Body Region	**Assumption**
Neck	The thicker the neck, the larger the neck circumference.
Shoulder	A smooth neck-to-shoulder transition will produce a larger shoulder slope measurement, while a sharp neck-to-shoulder transition will produce a smaller shoulder slope measurement.
Shoulder Blade	The type of shoulder blade prominence will affect the measurement of the bodice back waist dart width.
Bust	The wider apart the bust points are, the larger the between front waist darts distance measurement will be.
GLBFP	The type of GLBFP will affect the measurement of the front waist. Certain types of GLBFPs will extend past the bust, while others will not.
Buttocks	The longer and lower the buttocks prominence, the larger the skirt back waist dart depth measurement will be.
GLBSP	The type of prominence will affect the skirt side seam measurement.

Table 69: Partially Upheld Assumptions

The only partially upheld assumption for the neck compared the neck circumference dimension to the neck thickness body-form variation. Three categories were identified for neck thickness: thin, average, and thick. As no groups were produced from the neck circumference graph (Figure 34) the data were analyzed by splitting the sample at the mean. The majority of subjects below the mean had thin necks, while the majority above had thick necks. Average necks were evenly distributed through the sample, with 26.3% below the mean, and 35% above. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed a progression from thin-to-thick.

The data suggest that the thicker the neck, the larger the neck circumference dimension, but the fact that the average neck thickness category defied grouping indicates that this assumption cannot be fully validated.

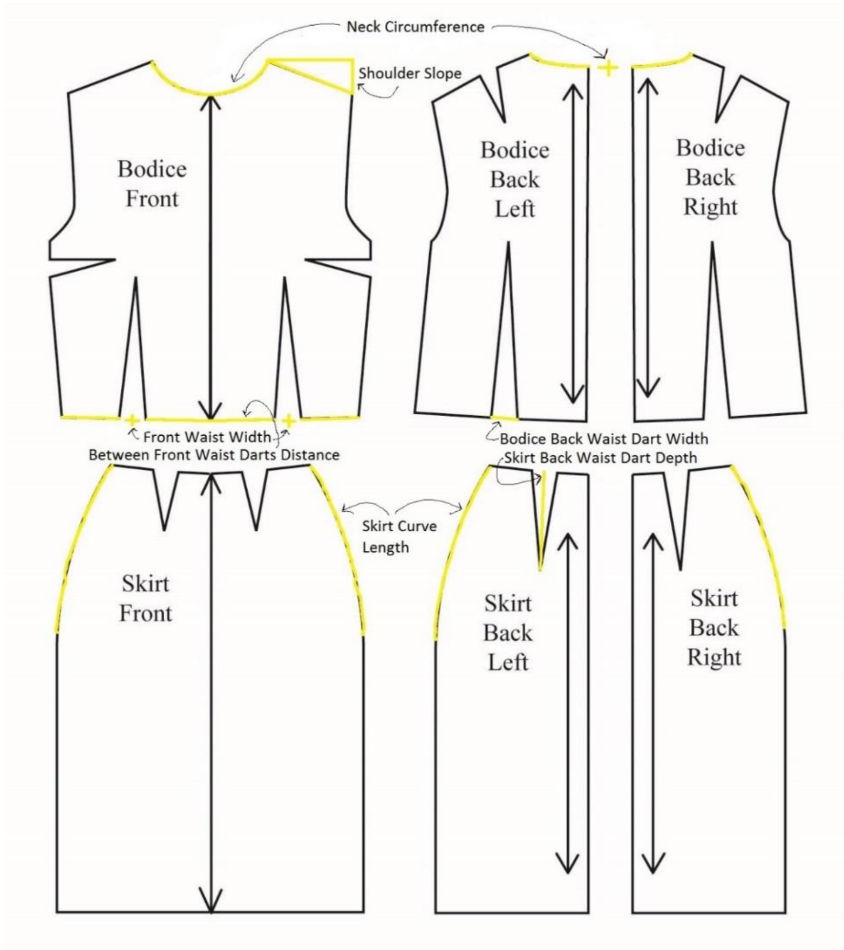


Figure 92: Partially Upheld Assumptions – Dimension Locations

The only partially upheld assumption for the shoulder compared the averaged shoulder slope dimension to the neck-to-shoulder transition body-form variation. Two categories were identified for the neck-to-shoulder transition: smooth and sharp, and five groups were identified from the averaged shoulder slope graph (Figure 37). There was a loose grouping of smooth neck-to-shoulder transitions around the larger measurements, and only sharp neck-to-shoulder transitions appeared at the smallest measurements.

Though the sharp neck-to-shoulder transitions were the majority for the sample (70%) and spanned the whole measurement range. Averaging the measurements for each body-form category showed that the smooth category was larger than the sharp category by .05”.

The data suggest that a smooth neck-to-shoulder transition may produce steeper slopes, while a sharp neck-to-shoulder transition may produce flatter slopes. Because the difference between the averages is so small, the wide range of measurements for the sharp neck-to-shoulder transition, and the loose grouping for the smooth neck-to-shoulder transition, this assumption cannot be fully validated.

The only partially upheld assumption for the shoulder blade compared the bodice back waist dart width dimension to the shoulder blade description body-form variation. Shoulder blade description produced five categories: flat, softly pointed, softly rounded, pointed, and rounded; and four groups were identified from the bodice back waist dart width graph (Figure 39). Group 1 comprised a majority of flat blades, correspondent with the smallest width measurements. Group 2 comprised a majority of softly pointed blades, correspondent with the second smallest width measurements. Groups 3 and 4 comprised a majority of rounded blades, correspondent with the largest width measurements.

Averaging the measurements for each body-form category showed that the flat category was the smallest, the soft categories were in the middle, and the fullest categories were the largest. Additionally, the pointed category was larger than the softly pointed category, and the rounded category was larger than the softly rounded category.

The data suggest that the type of shoulder blade prominence may affect the bodice back waist dart width dimension, but not all of the categories grouped. The softly rounded and pointed categories had so few members that they did not group, and the flat and rounded categories spanned the entire measurement range. A larger sample size is needed to fully validate this assumption.

The only partially upheld assumption for the bust compared the between front waist darts distance dimension to the bust point width body-form variation. Bust point width produced three categories: narrow, average, and wide; and four groups were identified from the between front waist darts distance graph (Figure 42). The narrow category was the majority for group 1, and only appeared in groups 1 and 2, correspondent with the smallest measurements. The average category was the majority for group 3, had the four largest measurements in the sample, and appeared in all four groups. The four subjects with the largest measurements may have wider waists than the rest of the sample, causing the between darts distance to be wider. The wide category appeared in all four groups, but was the majority for group 4. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed a progression from narrow-to-wide.

The data suggest that the wider the bust points are, the larger the between front waist darts distance dimension may be. Due to both the average and wide categories appearing in all of the categories, as well as four average subjects holding the largest measurements in the sample, this assumption cannot be fully validated.

Two assumptions from the greatest lower-body front prominence were partially upheld, and both focused on the front waist width dimension. The GLBFP location, GLBFP description, and past-bust extension were the body-form variations tested. Six groups were identified from the front waist width graph (Figure 44).

The first partially upheld GLBFP assumption compared the front waist width dimension to the GLBFP location and description body-form variations. Three categories were identified for the GLBFP location: abdomen, stomach, and both. The abdomen category was the majority for the sample, and dominated the smaller front waist measurements. The stomach category was evenly split between group 3 and group 6. The both category occurred in groups 4 and 6. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed that the abdomen had the smallest average, and the both category had the largest average.

Five categories were identified for the GLBFP description: flat, oval, softly pointed, softly rounded, and rounded. There were no clear groupings for this comparison, though the rounded category clustered loosely around the mid-to-large measurements in group 3. The stomach location had only oval descriptions, but the both category had one rounded and one combination (rounded + softly pointed). Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed that the there was no real order.

The data suggest that GLBFP location has a stronger influence on the front waist width dimension than the GLBFP description body-form variation does. But, since the abdomen category comprised 90% of the sample, a larger sample is needed to more accurately understand how the stomach and both categories affect front waist width. Due to this and the unclear groupings from the GLBFP description, this assumption cannot be fully validated.

The second partially upheld GLBFP assumption compared the front waist width dimension to the past-bust extension and GLBFP description body-form variations. Three categories were identified for the past-bust extension: yes, aligned, and no. Groups 1 and 2 were comprised solely of the yes category, and the majority of group 3 was comprised of the yes category. The aligned category only occurred in group 3. The no category clustered around the smaller measurements in group 3 and around the largest measurements in groups 4, 5, and 6. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed the yes category had the smallest average, while the no category had the largest.

Five categories were identified for the GLBFP description: flat, oval, softly pointed, softly rounded, and rounded. There were not clear groupings when comparing this body-form variation to the front waist width dimension, but comparisons of this body-form variation to the past-bust extension body-form variation provided some interesting data. The flat category aligned with the no category for seven subjects, and the aligned category for two subjects. The oval and softly pointed categories both aligned with the yes category for all subjects. The softly rounded category aligned with the yes category for half of its subjects, and the no category for the other half. The rounded category aligned with the yes category for nine subjects, the aligned category for two subjects, and the no category for four subjects. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed there was no clear order; the softly rounded category had the smallest average, while the rounded category had the largest.

The data suggest that subjects with the smallest front waist measurements had their GLBFP extend past their bust, while subjects with the larger front waist measurements did not have their GLBFP extend past the bust. Additionally, while there were no groups identified from a comparison of the GLBFP description body-form variation and the front waist width dimension, description categories grouped by past-bust extension categories. The data from this comparison suggests that the oval, softly pointed, and rounded description categories do extend past the bust, while the flat category does not. Because there are not clear groupings by dimension, but there are by body-form variation, this assumption cannot be fully validated. It does indicate a possible correlation between past-bust extension and GLBFP description though.

The only partially upheld assumption for the buttocks compared the skirt back waist dart depth dimension to the buttocks length, and buttocks fullest part body-form variations. There were three groups identified from the skirt back waist dart depth graph (xx). Two categories were identified for buttocks length: short and long. The long category was the majority for this body-form variation (75.7%) and the long and short categories were evenly spaced throughout the measurement range, forming no groups. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed that the short category was smaller than the long category.

Three categories were identified for buttocks fullest part: low, middle, and high. The middle category was the majority for this body-form variation (59%), but the low category loosely clustered around the mid-to-large measurements, and the high category clustered around the smaller measurements. Comparing the buttocks fullest part variation to the length variation showed that the low and long categories corresponded strongly, and the middle and long categories corresponded strongly, though not as strongly as the low and long categories. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed a progression from high-to-low.

The data suggest that the longer and lower the buttocks prominence, the larger the skirt back waist dart depth measurement. Due to the loose clustering, and the fact that the middle and long categories also correspond strongly, this assumption cannot be fully validated. A larger sample should provide more concrete evidence.

The only partially upheld assumption for the greatest lower-body side prominence compared the skirt curve length dimension to the GLBSP description body-form variation. Five categories were identified for the GLBSP description: flat, softly pointed, pointed, softly rounded, and rounded; two groups were identified from the skirt curve length graph (Figure 49). Group 1 was comprised entirely of the rounded category. Group two had loose clusters: the flat category was close to the smaller measurements, the rounded was close to the small-to-mid measurements, and the softly pointed category was around the mid-to-large measurements. The rounded and softly pointed categories tied for the majority of group 2.

Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed that the rounded category had the lowest average, followed by the flat category, the pointed category, the softly rounded category, and the softly pointed category. The soft categories had the largest averages, about one to one and a half inches larger than the full categories. The rounded category comprises the entirety of group 1, which holds the high-hip subjects who have much smaller measurements, this may partly account for why the average is so low.

The data suggest there may be some prominences that affect the skirt curve length dimension, for example the rounded category and the high-hip side prominence body-form category, but the data are not conclusive. The small number of subjects with high-hip's as the greatest lower-body side prominence, the looser groupings for the thigh prominence category, and the mixed-up averages indicate that this assumption cannot be fully validated.

Not Upheld

Nine of the twenty-seven assumptions were not upheld, meaning there were either no groupings, or groups were opposite from what was expected (Table 70). Figure 93 shows the eight dimensions associated with these assumptions; five of these dimensions deal with darts. The neck, shoulder, shoulder blades, greatest lower-body front prominence, and buttocks regions were affected.

Body Region	Assumption
Neck	A smooth neck-to-shoulder transition will produce a larger neck circumference, while a sharp neck-to-shoulder transition will produce a smaller neck circumference. The more prominent the collarbone, the smaller the neck circumference will be.
Shoulder	The farther the shoulder point is outside the bust, high-hip, and thigh widths, the longer the shoulder seam measurement will be.
Shoulder Blade	The further the shoulder blade prominence is from the waist, the larger the bodice back waist dart depth measurement will be. The more prominent the shoulder blade, the larger the bodice back waist dart width measurement will be.
GLBFP	The more indented the waist, the smaller the waist circumference measurement will be. The lower the GLBFP is aligned, the larger the skirt front waist dart depth measurement will be. The type of GLBFP will affect the measurement of the skirt front waist dart width.
Buttocks	The more prominent the buttocks, the larger the skirt back waist dart width measurement will be.

Table 70: Not Upheld Assumptions

Two assumptions for the neck were not upheld, and both focus on the neck circumference dimension. The neck-to-shoulder transition and collarbone visibility were the two body-form variations tested. No groups were identified from the neck circumference graph (Figure 34); thus, the data were analyzed by splitting the sample at the mean.

The first not upheld neck assumption compared the neck circumference dimension to the neck-to-shoulder transition body-form variation. Two categories were identified for the neck-to-shoulder transition: smooth and sharp. Both categories were equally distributed below and above the mean, though there were mostly sharp subjects for the largest neck circumferences. Averaging the measurements for each body-form category showed that the sharp category was greater than the smooth category.

The data suggest that sharp neck-to-shoulder transitions produce larger neck circumferences, while smooth neck-to-shoulder transitions produce smaller neck-to-shoulder transitions. Rasband and Liechty (2006) and Liechty et al. (2010) suggest that the neck-to-shoulder transition is affected by neck muscle development. Extrapolating from their definitions, the sharp transitions should have less muscle development, while the smooth transitions should have more. This should indicate that smooth transitions be larger, as there is more mass around the neck. As this finding is opposite from what was expected, future research should attempt to understand why.

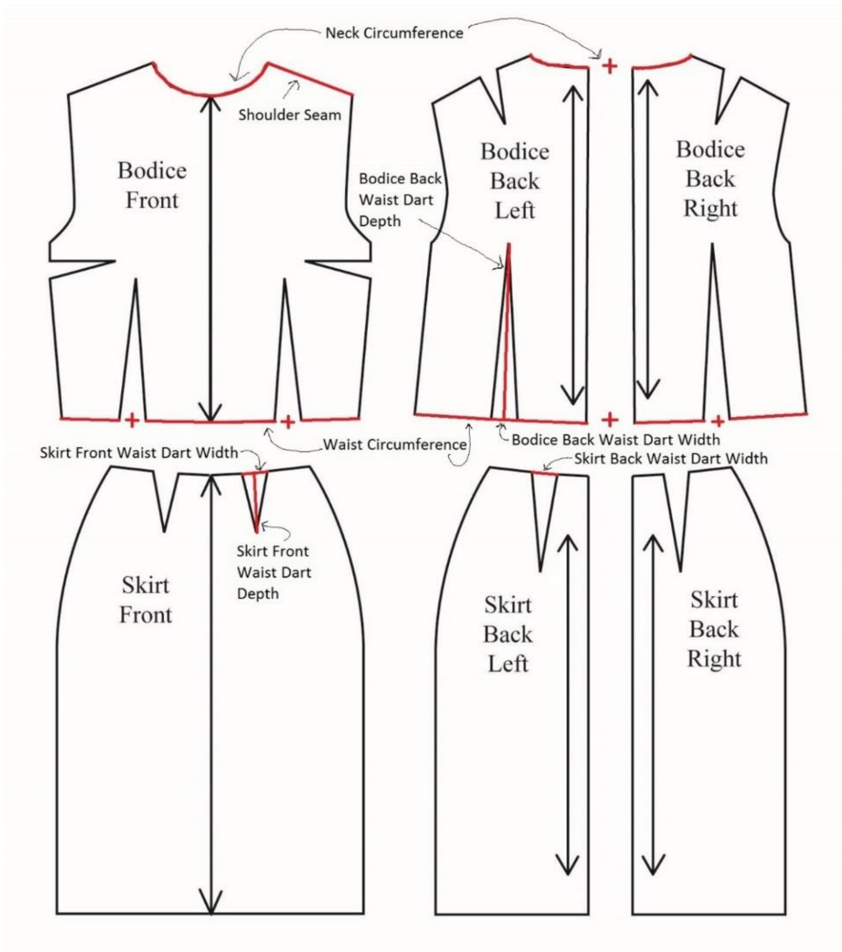


Figure 93: Not Upheld Assumptions – Dimension Locations

The second not upheld neck assumption compared the neck circumference dimension to the collarbone visibility body-form variation. Four categories were identified for collarbone visibility: flat, nearly flat, visible, and prominent. Groupings were loose clusters, with the nearly flat category the majority below the mean, and the visible category the majority above. The flat category was equally distributed below and above the mean, and the prominent category stayed close to the mean. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, generally showed that there was a progression from flat-to-prominent.

The data suggest that the more prominent the collarbone, the larger the neck circumference dimension. This is opposite what was assumed in this study, but provides an opportunity for future research. It was assumed that prominent collarbones were due to a subject having less fat and muscle mass, making the skeletal system easier to view, and, by extension, the neck thinner. Testing the interactions between the skeletal and muscular systems for the neck against pattern dimensions, such as neck circumference, should provide more detailed information on how body-form variations affect pattern dimensions.

The only not upheld shoulder assumption compared the shoulder seam dimension to the shoulder point alignment body-form variation. Seven categories were identified for shoulder point alignment: Inside the bust, high-hip, and thigh; aligned with the bust, outside the high-hip, inside the thigh; aligned with the bust and high-hip, inside the thigh; aligned with the bust, inside the high-hip and thigh; outside the bust, inside the high-hip and thigh; outside the bust, aligned with the high-hip, inside the thigh; and outside the bust and high-hip, inside the thigh. Five groups were identified from the shoulder seam graph (Figure 36). There were no clear patterns among the alignment categories. The most common variation, ‘outside bust, inside high-hip and thigh’, occurred in all five groups, was the majority for groups 1 and 3, tied for majority in groups 4 and 5, and was the second largest contingent of group 2. Averaging the measurements for each body-form category also produced no clear groups.

The data suggest the shoulder seam dimension cannot be categorized using the shoulder point alignment body-form variation. With seven categories, this sample may not have been large enough to show distinctive groupings. Alternatively, the shoulder seam dimension may not be the correct pattern dimension to compare with shoulder point alignment. This was the only body-form variation that compared different body components, thus, those components may be more useful in categorizing this variation.

Two assumptions for the shoulder blade were not upheld; they both focused on the bodice back waist dart. Prominence point alignment and shoulder blade prominence were the two body-form variations tested.

The first not upheld shoulder blade assumption compared the bodice back waist dart depth dimension to the shoulder blade prominence point alignment body-form variation. Three categories were identified for prominence point alignment: at the armpit, at the arm join, and above the arm join, and five groups were identified from the bodice back waist dart depth graph (Figure 38). There were no groupings. Additionally, averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed that subjects with prominence point alignment at the armpit had the largest average, while subjects with prominence point alignment above the arm join had the smallest average.

The data suggest that the closer shoulder blade prominence is to the waist, the larger the bodice back waist dart depth measurement. This is opposite from what was expected and may be due to differences in overall back length. As the majority of the sample has their shoulder blade prominence in essentially the same place on the body, placing the bodice back dart tip at the location of the arm join allows for pattern standardization. Depending on overall back length, the depth of the dart will differ by subject group, but now only one aspect of the pattern has to change, rather than two.

The second not upheld shoulder blade assumption compared the bodice back waist dart width dimension to the shoulder blade prominence body-form variation. Four categories were identified for shoulder blade prominence: flat, almost flat, visible, and prominent, and four groups were identified from the bodice back waist dart width graph (Figure 39). There were no groupings, as all categories were distributed throughout the range of measurements. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, showed that the flat category was smallest, the prominent category came next, followed by the almost flat category, and ended with the visible category.

The data suggest that there may be no correlation between the shoulder blade prominence body-form variation and the width of the bodice back waist dart. This goes directly against accepted pattern-drafting practice, which states that the fuller and more prominent the body prominence, the deeper and wider the corresponding dart. Alternatively, the bodice back waist darts may be a reduction device to eliminate excess material between the upper torso and the waist, rather than as a way to accommodate the shoulder blade prominences. This indicates darts may serve more than one purpose in a garment: prominence accommodation and reduction.

Three assumptions from the greatest lower-body front prominence were not upheld; one focused on the waist circumference dimension, and the other two on the skirt front waist dart. Waist indentation, GLBFP alignment, and GLBFP description were the three body-form variations tested.

The first not upheld GLBFP assumption compared the waist circumference dimension to the waist indentation body-form variation. Four categories were identified for waist indentation: none, barely, slight, and indented; four groups were identified from the waist circumference graph (Figure 43). The none and barely categories were spaced evenly throughout the measurement range, forming no groups. The slight category clustered around the smallest and the largest measurements, while the indented category clustered loosely around the mid-to-large measurements. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, resulted in the following order: slight (32.21”), barely (32.28”), indented (32.36”), and none (32.5”).

The data suggest that waist indentation may not impact the waist circumference dimension. The subjects in this study all shared a similar waist circumference, as well as thicker waists, with minimal indentation. Before concluding that there is no connection between waist indentation and waist circumference in a size, future research should consider testing other populations, as well as other body-form variations that may impact waist indentation, such as ribcage width and length, and high-hip prominence.

The second not upheld assumption for the GLBFP compared the skirt front waist dart depth dimension to the GLBFP alignment body-form variation. Six categories were identified for GLBFP alignment: below the high-hip, slightly below the high-hip, at the high-hip, above the high-hip, below the waist, and at the waist; five groups were identified from the skirt front waist dart depth graph (Figure 45). There were no groups found in the data, though the below high-hip and slightly below high-hip categories seemed to cluster together, indicating there need not be two separate groups to identify this area. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, revealed no groupings either.

The data suggest that greatest lower-body front prominence alignment alone cannot account for the skirt front waist dart depth. There is not enough known about the distance between the waist and high-hip, or how the GLBFP and these body-form variations interact. The high-hip may occur at different locations for each woman, and may have greater or lesser prominence for each woman. Closer inspection of the lower-body front prominence is necessary before drawing conclusions about how it relates to pattern dimensions.

The third, and final, not upheld GLBFP assumption compared the skirt front waist dart width dimension to the GLBFP description body-form variation. Five categories were identified for GLBFP description: flat, oval, softly pointed, softly rounded, and rounded; three groups were identified from the skirt front waist dart width graph (Figure 46). No groupings were found during analysis of the data. Averaging the measurements for each body-form category, and arranging them in order of smallest-to-largest, revealed that the softly rounded category was smaller than the rounded category, but that the flat category and the rounded category had the same value. The oval category had the largest value.

The data suggest that the GLBFP descriptions may not be the best body-form variation to compare against the skirt front waist dart width. It is possible that five body-form categories were too many for this sample size. It may also be the case, as with the bodice back waist dart, the skirt front waist dart is primarily for reducing the pattern from the greatest lower-body circumference to the waist, and not for accommodating the shape of the lower-body front prominence.

The only not upheld assumption for the buttocks compared the skirt back waist dart width dimension to the buttocks prominence body-form variation. Two categories were identified for the buttocks prominence: flat and prominent; four groups were identified from the skirt back waist dart width graph (Figure 48). The flat category appeared around both the smallest and the largest measurements in the range. The prominent category clustered loosely around the middle of the measurement range. Averaging the measurements for each body-form category revealed that the flat category was smaller than the prominent category, but only by .04”.

The data suggest that greater buttocks prominence did not result in larger skirt back waist dart width measurements. Since all of the subjects had hip circumferences that were within 2” of each other, the discrepancy in skirt back waist dart width for the flat buttocks prominence subjects may be due to some of the flat category subjects having wide hips. Hip, or pelvis, width was not assessed in this study, by may be an important indicator to help explain the skirt back waist dart width dimension. Due to the skirt back waist dart acting as a reduction device as well as a prominence accommodating device, the width of the pelvis may be of greater importance than the prominence of the buttocks. Researchers may find that buttocks prominence is a better indicator of skirt back waist dart width when the pelvis is narrow, but that pelvis width is a better indicator when it is wide.

Conclusion

Question two asked what the findings from this study suggest for the development of a body-form based block system. The aim of this second question was to empirically show that apparel block shapes can be categorized based on distinct body-form variations. Twenty-seven assumptions were discussed and ten led to specific suggestions for how specific body-form variations affect specific pattern dimensions. The remaining seventeen assumptions require further analysis before suggestions can be created. The overall aim for question two was not reached, but a start has been made.

Many of the seventeen unanswered assumptions indicated that either a different body-form variation should be tested, or that more than one body-form variation impacted the pattern dimension. The next step for this project is to run statistical analyses, such as ANOVA or t-tests, on all twenty-seven assumptions, and to start comparing multiple body-form variations against single pattern dimensions.

Conclusion

This case study explored the relationship between the human body and the clothing that covered it, aiming to make a case for why body form variations need to be integrated into pattern block development. Assumptions abound about what women's bodies look like, as well as what pattern blocks should look like, but little research has empirically tested this relationship. Knowing how body-form variations affect the pattern block will provide manufacturers with the means to tailor their products to specific customers, improving the end product and ensuring a competitive advantage in a crowded market.

Research into body-form variation has either focused on how poorly women's sizing standards fit the current population, or classifying female bodies using pre-conceived notions of how bodies look. The literature on body-form variation suggested that people have unique and distinctive body forms, leading to the question: What are the body-form variations across a single size?

Research into patterning practice generally explores the relationships between grading and sizing. Some of the research compared patterns created for different body forms, though they did not compare specific body-form variations to pattern dimensions. The literatures suggested that body-form variation does affect apparel block shapes, leading to the second question: What do these findings suggest for the development of a body-form based block system?

This study concludes that there are multiple body-form variations across a single size, and that the findings from comparing body-form variations to pattern dimensions can provide important suggestions for the creation of a body-form based block system.

Based on the results and discussion of the two research questions, a body-form based block system may be quite complex, and require a new mode of thinking about pattern-drafting. If each body-form category requires different pattern dimensions, this may cause the system to become overly complex. For example, having multiple dart lengths and widths, combined with multiple neck circumferences and shoulder slopes will make a pattern unreadable. Instead, if patterns are considered more like puzzles, with many separate pieces, then only the specific pattern dimensions needed for a specific body can be combined. This necessitates a large library of pattern dimension pieces, but once compiled, can be combined in infinite ways. This would not only allow large manufacturers, such as The Gap or Target, to create better fitting garments for their target markets, but it would allow small manufacturers to specialize in custom design.

This study provided the research community with a base on which to explore the body-garment relationship in terms of pattern block generation. While many relationships were tested in this study there are many more that still need to be analyzed. Next steps include testing each region of the body, determining exact dimensions for each body-form category, comparing multiple sizes, and finding combinations of body-form variations.

Chapter 7 References

Aldrich, W. (2007). History of sizing systems and ready-to-wear garments. In S. Ashdown (Ed), *Sizing in clothing: Developing effective sizing systems for ready-to-wear clothing* (pp. 1-56). Cambridge: Woodhead Publishing Limited.

Alexander, M., Connell, L. J. & Presley, A. B. (2005). Clothing fit preferences of young female adult consumers. *International Journal of Clothing Science and Technology, 17*(1), 52-64.

Alexander, M., Pisut, G. R. & Ivanescu, A. (2012). Investigating women's plus-size body measurements and hip shape variation based on SizeUSA data. *International Journal of Fashion Design, Technology and Education*, *5*(1), 3-12.

Ashdown, S. (1998). An investigation of the structure of sizing systems: A comparison of three multidimensional optimized sizing systems generated from anthropometric data with the ASTM standard D5585-94. *International Journal of Clothing Science and Technology*, *10*(5), 324-341.

ASTM International. (2001). *D5586-01: Standard tables of body measurements for women aged 55 and older (All Figure Types)*. ASTM International, 1-20.

ASTM International. (2001). *Standard table of body measurements for adult female misses figure type, sizes 2-20: D5585-95 (2001)*. ASTM International, 1-4.

ASTM International. (2004). *D6960-04: Standard table of body measurements relating to women's plus size figure type, sizes 14W-32W*. ASTM International, 1-4.

ASTM International. (2006). *D7197-06: Standard table of body measurements for misses maternity sizes two to twenty-two (2-22)*. ASTM International, 1-4.

ASTM International. (2010). *Standard tables of body measurements for women aged 55 and older (all figure types): D5586/D5586M-10*. ASTM International, 1-20.

ASTM International. (2011). *Standard tables of body measurements for adult female misses figure type, size range 00-20: D5585-11^{e1}*. ASTM International, 1-7.

ASTM International. (2013). *Standard tables for body measurements for adult female misses petite figure type, size range 00P-20P: D7878/D7878M-13^{e1}*. ASTM International, 1-7.

Bergh, R. (2006). *Make your own patterns: An easy step-by-step guide to making over 60 dressmaking patterns*. London: New Holland Publishers (UK) Ltd.

Bye, E., LaBat, K. L. & DeLong, M. R. (2006). Analysis of body measurement systems for apparel. *Clothing and Textiles Research Journal*, 24(2), 66-79.

Bye, E., LaBat, K., McKinney, E. & Kim, D. (2008). Optimized pattern grading. *International Journal of Clothing Science and Technology*, *20*(2), 79-92.

Connell, L. J., Ulrich, P. V., Brannon, E. L., Alexander, M. & Presley, A. B. (2006). Body shape assessment scale: Instrument development for analyzing female figures. *Clothing and Textiles Research Journal*, *24*(4), 80-95.

Devarajan, P. (2003). *Validation of 'Female Figure Identification Technique (FFIT) for apparel' methodology* (Unpublished master's thesis). North Carolina State University, Raleigh.

Gazzuolo, E. B. (1985). *A theoretical framework for describing body form variation relative to pattern shape* (Unpublished master's thesis). University of Minnesota, St. Paul.

Goldsberry, E., Shim, S. & Reich, N. (1996a). Women 55 years and older: Part I. Current body measurements as contrasted to the PS 42-70 data. *Clothing and Textiles Research Journal*, *14*(2), 108-120.

Heisey, F. L., Brown, P. & Johnson, R. F. (1988). Three-dimensional pattern drafting: A theoretical framework. *Clothing and Textiles Research Journal*, *6*(3), 1-9.

Hemmis, P. (2016). *The elements of design, shape and form* [PowerPoint slides]. Retrieved from https://ay15.moodle.umn.edu/pluginfile.php/1508461/mod_resource/content/1/DES%201101w%20Sp16%20Elements%20Shape%20and%20Form.pdf

Istook, C. L., Simmons, K. P. & Devarajan, P. (2004). *Female figure identification technique (FFIT) for apparel*. 147-173. Retrieved from http://www.iffti.com/downloads/past_conferences/HKPU,%202002/A/147-173.pdf

Jaffe, H. & Relis, N. (2005). *Draping for fashion design* (4th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Joseph-Armstrong, H. (2006). *Patternmaking for fashion design* (4th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Kidwell, C. B. & Christman, M. C. (1974). *Suiting everyone: The democratization of clothing in America.* Washington, D.C.: Smithsonian Institution Press.

Kim, D-E., LaBat, K., Bye, E., Sohn, M. & Ryan, K. (2014). A study of scan garment accuracy and reliability. *The Journal of the Textile Institute*, *106*(8), 1-9.

LaBat, K. L. (2007). Sizing standardization. In S. Ashdown (Ed), *Sizing in clothing: Developing effective sizing systems for ready-to-wear clothing* (pp. 88-107). Cambridge: Woodhead Publishing Limited.

LaBat, K. L. & Sokolowski, S. L. (1999). A three-stage design process applied to an industry-university textile product design project. *Clothing and Textiles Research Journal*, *17*(1), 11-20.

Lamb, J. M. & Kallal, M. J. (1992). A conceptual framework for apparel design. *Clothing and Textiles Research Journal*, *10*(2), 42-47.

Lamport, I. (2008, August 22). To belt or not to belt? [Web log post]. Retrieved from https://insideoutstyleblog.com/2008/08/to-belt-or-not-to-belt.html.

Lamport, I. (2010, November 2). Body shapes explained – Defining points [Web log post]. Retrieved from https://insideoutstyleblog.com/2010/11/body-shapes explained-defining-points.html.

Latzke, A. & Quinlan, B. (1940). *Clothing: An introductory college course*. Chicago: J. B. Lippincott Company.

Le Pechoux, B. & Ghosh, T. K. (2002). Standard sizing and fit testing applied to women's hosiery. *Textile Progress*, *32*(1), 1-59.

Lee, J. Y., Istook, C. L., Nam, Y. J. & Park, S. M. (2007). Comparison of body shape between USA and Korean women. *International Journal of Clothing Science and Technology*, *19*(5), 374-391.

Liechty, E. G., Pottberg, D. N. & Rasband, J. A. (1986). *Fitting and pattern alteration: A multi-method approach.* New York: Fairchild Publications.

Liechty, E., Rasband, J. & Pottberg-Steineckert, D. (2010). *Fitting & pattern alteration: A multi-method approach to the art of style selection, fitting and alteration* (2nd ed.). New York, NY: Fairchild Books.

Maehren, B. & Meyers, S. (Eds.) (2005). *The perfect fit: The classic guide to altering* *patterns.* Chanhassen, MN: Creative Publishing International.

Minott, J. (1974). *Pants and skirts: Fit for your shape* (2nd ed.). Minneapolis, MN: Burgess Publishing Company.

Minott, J. (1978). *Fitting commercial patterns: The Minott method*. Minneapolis, MN: Burgess Publishing Company

Nayak, R., Padhye, R., Wang, L., Chatterjee, K. & Gupta, S. (2015). The role of mass customization in the apparel industry. *International Journal of Fashion Design, Technology and Education, 8*(2), 162-172.

Olds, T., Daniell, N., Petkov, J. & Steward, A. D. (2013). Somatotyping using 3D anthropometry. A cluster analysis. *Journal of Sports Sciences, 31*(9), 936-944.

Palmer, P. & Alto, M. (2005). *Fit for real people: Sew great clothes using any pattern!* (2nd ed.). Portland, OR: Palmer/Pletsch Incorporated.

Patterson, C. A. & Warden, J. (1983). Selected body measurements of women aged 65 and older. *Clothing & Textiles Research Journal, 2*, 23-31.

Petrova, A. (2007). Creating sizing systems. In S. Ashdown (Ed), *Sizing in clothing: Developing effective sizing systems for ready-to-wear clothing* (pp. 57-87). Cambridge: Woodhead Publishing Limited.

Pisut, G. & Connell, L. J. (2007). Fit preferences of female consumers in the USA. *Journal of Fashion Marketing and Management: An International Journal, 11*(3), 366-379.

Rasband, J. A. & Liechty, E. L. G. (2006). *Fabulous fit: Speed fitting and alteration* (2nd ed.). New York, NY: Fairchild Publications, Inc.

Robinette, K. M., Blackwell, S., Daanan, H., Boehmer, M., Fleming, S., Brill, T., Hoeferlin, D. & Burnsides, D. (2002). *Civilian American and European surface anthropometry resource (CAESAR) final report, Volume 1: Summary* (Report #AFRL-HE-WP-TR-2002-0169). Wright-Patterson AFB, OH: United States Air Force Research Laboratory.

ScanWorX [Computer Software]. Cary, NC: Human Solutions of North America, Inc.

Salusso, C. J., Borkowski, J. J., Reich, N. & Goldsberry, E. (2006). An alternative approach to sizing apparel for women 55 and older. *Clothing and Textiles Research Journal, 24*(2), 96-111.

Salusso-Deonier, C. J., DeLong, M.R., Martin, F. B. & Krohn, K. R. (1985). A multivariate method of classifying body form variation for sizing women's apparel. *Clothing and Textiles Research Journal, 4*(1), 38-45.

Schofield, N. A., Ashdown, S. P., Hethorn, J., LaBat, K. & Salusso, C. J. (2006). Improving pant fit for women aged 55 and older through an exploration of two pant shapes. *Clothing and Textiles Research Journal*, *24*(2), 147-160.

Schofield, N. A. & LaBat, K. L. (2005a). Exploring the relationships of grading, sizing, and anthropometric data: Table 1. Comparison of sizing charts from 1873 to 2000. *Clothing and Textiles Research Journal, 23*(1) 14.

Schofield, N. A. & LaBat, K. L. (2005b). Defining and testing the assumptions used in current apparel grading practice. *Clothing and Textiles Research Journal, 23*(3), 135-150.

Simmons, K. P., Istook, C. L. & Devarajan, P. (2004). Female figure identification technique (FFIT) for apparel, Part I: Describing female shapes. *Journal of Textile and Apparel, Technology and Management, 4*(1), 1-16.

Sohn, M. & Bye E. (2012). Visual analysis of body shape changes during pregnancy. *International Journal of Fashion Design, Technology and Education*, *5*(2), 117-128.

Song, H. K. & Ashdown, S. P. (2012). Development of automated custom-made pants driven by body shape. *Clothing and Textiles Research Journal, 30*(4), 315-329.

U.S. Census Bureau. (2015). *Annual estimates of the resident population for selected age groups by sex for the United States, states, counties and Puerto Rican Commonwealth and municipios: April 1, 2010 to Jul 1, 2015.* Retrieved from http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk.

United States Air Force Research Laboratory. (2002). *Civilian American and European surface anthropometry resource* (CAESAR) [Data set].

Yu, W. (2004). Human anthropometrics and sizing systems. In J. Fan, W. Yu, & L. Hunter (Eds), *Clothing appearance and fit: Science and Technology* (pp. 174-183). Cambridge: Woodhead Publishing Limited.