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Sheath Dress Analysis and Body - Garment Relation

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Abstract- The apparel industry is replete with assumptions regarding the body-garment relationship. Traditional anthropometry focuses on linear body measurements, which are inadequate to describe and classify the human body-form for apparel pattern development. To enable the development of a body-form based block system, this case study explored the body-garment relationship for a sheath dress to determine if apparel block shapes could be categorized based on distinct body-form variations. A modified version of Gazzuolo's (1985) body-garment relationship theory guided the development and analysis of the study. Pattern blocks were fit to 39 female subjects, with 16 dimensions extracted from specific pattern components and graphed to reveal between one and five groups per dimension. Visual analysis of the sample's body scans revealed 27 body-form variations with 99 categorical descriptions. Categorical descriptions were compared to the dimensional values resulting in ten suggestions for a body-form based block system, and seventeen assumptions that require further analysis. In conclusion, this case study discovered multiple body-form variations across a single size, but block shapes could not be identified due to the wide variation in the sample. Future studies should assess a statistically significant sample of individuals within-depth analysis of a single body region to determine if there are generalizable body-form variations across the population.

Indexed Terms- Fit, Body–garment relationship, Theory, Patternmaking, CAD, Body scans

I. INTRODUCTION

This case study explores the relationship between the human body and the clothing that covers it by empirically testing the common apparel assumption: If ten women of the same size wear the same dress, it will fit them all differently. Anyone who shares their clothing with a sibling/friend of the same size can state this fact, but their stories constitute disparate anecdotal evidence affected by individual fit preference. Empirical, objective assessment of the body–garment relationship for women who share the same size has not been conducted. The body–garment relationship covers interactions between objective and subjective measures of fit, as well as the design features of a garment. Each area requires separate research prior to assessing the associations between them. This study focused on objective measures of fit for American women aged 18 to 54.

Apparel is traditionally a trial-and-error industry, basing decisions on assumptions orideals rather than on empirical data anchored in content analysis. In addition, sizing and fit are considered competitive advantages and treated as trade secrets in the industry, requiring every manufacturer to define their own body type and sizing system based on their own individual experiences and beliefs. The US government has attempted to alleviate this by offering standardized sizing systems, but research has shown that these systems fail to fit the US female population well (ex. Salusso-Deonier et al. 1985; Goldsberryet al. 1996; Ashdown 1998; Alexander et al. 2005).

II. BODY FORM

Body-form classification systems can be split into two main categories: sizing systems and form assessment. 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). The best sizing systems are based on anthropometric data taken from a large, representative population. Only six anthropometricsizing surveys have been conducted in the US in the past 75 years: The O'Brienand Shelton survey (1941), ANSUR (1988), NCTRF (1990), the Reich and Golds berry survey (1993), CAESAR (1998), and Size USA (2002). These surveys partially influenced the following US government standards for women's apparel: CS215-58, PS 42–70, ASTM D5585, D5586, D6829, D6960, D7197, and D7878.

Most research on sizing systems focuses on illustrating how poorly the government standards fit the US population, which is generally accomplished by testing linear measurements from the standard against the linear measurements from a population to discover statistically significant differences (ex. Patterson and Warden 1983; Simmons et al. 2004; Salusso et al., 2006; Alexander et al. 2012). The focus of these studies was on the linear measurements, not on the body-form or how the body-form could impact pattern-shape, suggesting a gap in the literature related to body-form.

The second most common body-from classification system focuses on body-form assessment. Body-form assessment (aka 'figure evaluation') scales classify human bodies into specific categories, such as: sizes, numbers, heights, volumes, letters, and shapes. Figure evaluation relies on comparisons between an observed form and a standard form and can be broken down into four categories: Proportions, Posture, Whole Body, and Body Components.

Whole body assessment in pattern-making and fitting texts typically flatten the human body to assess for shape instead of form (ex. Maehren and Meyers 2005; Rasband and Liechty 2006). This practice ignores the height, weight, volume, angle, and arc variations intrinsic to the human body and limits the applicability of body-form classification to pattern-making practice. Common body shapes include: average/hourglass, triangle, inverted triangle, rectangular, tubular, oval/rounded, elliptical, and diamond (Latzke and Quinlan 1940; Maehren and Meyers 2005; Rasband and Liechty 2006).

One study that does not reduce the human body to a two-dimensional shape for whole-body classification was conducted by Olds et al. (2013). Twenty-nine dimensions were extracted from 301 Australian adult body scans and clustered into groups described by the ecto-, endo-, and mesomorph classification system. This approach focused on overall volume, revealing markedly different forms (i.e., oval vs. top hourglass) when comparing the group's average and most extreme subjects. Simmons et al. (2004) ran into this problem when developing the FFIT for Apparel classification system and disregarded K-means cluster analysis as a viable option for sorting body shapes. These studies indicate that body form can vary across similar volumes, indicating that it may also vary within a single size.

Body component classification focuses on breaking the body into its component parts and evaluating each part separately from the others, though in some instances the same component is evaluated by multiple measures. Popular texts provide detailed descriptions of the average/ideal body component and possible deviations (Minott 1974, 1978; Liechty et al. 1986; Maehren and Meyers 2005). Major body components include: the neck, shoulders, back, chest/bust, arms, waist, abdomen, hips, buttocks, and thighs. Width, length, prominence, and fullness are the general types of classifications used, with shape used for the hips. Minott (1974) classifies six hip shapes: average, little difference, heart, semi-heart, diamond, and rounded diamond. Connell et al. (2006) developed the Body Shape Assessment Scale (BSAS©), which combines posture, whole-body form, and body component classification for nine subscales. Six subscales focus on body components: hip shape, shoulder slope, front torso shape, bust shape, buttocks shape, and back shape. The scale relies on subjective terminology, making it difficult to generalize. The researchers note that subjects who barely belong to one category are close to belonging to adjacent categories, which points to the fluidity of body form and marks one of the major difficulties involved with body-form classification.

These studies suggest that: (a) population lengths and widths, though not necessarily circumferences, vary more widely than assumed in government sizing standards (Salusso-Deonier et al. 1985), and (b) linear measurements from voluntary standards are inappropriate for fitting the general US population (Simmons et al. 2004; Alexanderet al. 2012). These findings indicate that even with similar circumference measurements, subjects may still vary in body-form, as linear measurements do not indicate the depth or volume of body features. In addition, findings from the Olds et al. (2013) study indicate that overall body volume alone does not adequately describe body-form variations.

III. PATTERN SHAPE

Historical analysis of patternmaking provides clues for why patterns poorly fit the irintended populations in the current market. Before the industrial revolution made ready-made apparel available cheaply, all clothing was custom-made. Dress makers and tailors analyzed their clients' body-form and movements to produce garments that fit them perfectly (Kidwell and Christman 1974). The shift from custom to readymade required a re-imagining of the pattern-drafting process. Tailors invented two drafting systems: direct and proportional. Direct systems were abbreviated versions of custom-made, while proportional systems relied on the principle that the human body is proportional, and that a single measurement could predict the rest (Kidwelland Christman 1974; Aldrich 2007). Proportional drafting led to proportional sizing, and in 1881, Charles Hecklinger combined the 'body' (a muslin fit to a specific client; origin of basic blocks) with proportional drafting, developing the first systematic adaptation for pattern blocks, which became the basis for applying size charts to patterns (Kidwell and Christman 1974; Aldrich 2007). These changes to the pattern making and grading systems essentially eliminated the complexity of the body form from the patternmaking process. The complexity of the body form must be considered during the patternmaking process if a garment is to fit its intended population, hence a need for studies such as this one that empirically assess the relationships between the body and the garment.

Schofield et al. (2006) explored satisfaction with pant seat shape (flat vs. full) for women aged 55 and older discovering through expert analysis the flat-seat pants fit the majority of the 176 subjects best. Song and Ashdown (2012) tested the final fit of a pair of custom-fit pants when the original pattern was drafted from pant pattern blocks using three lower-body hip variations (curvy, hip tilt, and straight), as well as a standard industry pattern, concluding that the basic blocks created using the hip variations generated better fitting customized pants. Sohn and Bye (2012) investigated changes in sheath dress patterns throughout three pregnancies; concluding that(a) grading for maternity sizing should not be proportional because humans do not grow proportionally, and (b) that different bodies change differently, and that these changes do affect pattern blocks. All of this research on pattern shape changes suggests that the body-form should be a key consideration during patternmaking and that specific body-form variations do affect patterns and grade rules.

IV. METHOD

- Sample selection

A self-sorting method was used to find an appropriate sample of female subjects who share a single size. Unlike the FFIT for Apparel (Simmons et al. 2004) system, the self-sorting method allowed for the deferment of body-form classification until after pattern block assessment, a crucial way for this study to retain its validity. By sorting into sizes using the most basic key measurements necessary for fitting clothing to the torso (bust, waist, and hips), more detailed body-form variations could be assessed after the garment was fitted to the body, but would ensure a similar basic body type. A total of 1036 available subjects were drawn from two body scan databases: CAESAR (821 subjects), and the University of Minnesota's Human Dimensioning Laboratory©'s Master Database (MDB; 215 subjects). To bound the study, six criteria were applied:(1) subjects are female, (2) subjects may not be pregnant, (3) one scan per subject, with all data available, (4) subjects are between 18 and 54 years of age, (5) height is between62.5″ and 70″, and (6) subjects within ± 1″ of each other's bust, waist, and hip girths constitute a size.

- Theoretical framework

A modified version of Gazzuolo's (1985) Body–Garment Relationship (BGR) frame work guided this research (Fig. 3). The original BGR is composed of four major components:

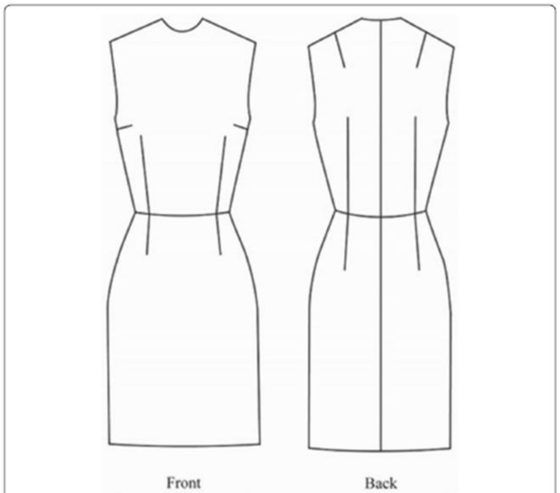

Fig. 4 Sleeveless sheath dress flats

[1] The analytical component abstracts the garment, determines the operational definitions of garment orientation, and identifies essential dimensions.
[2] The dimensional component uses the operational definitions from the analytical component to generate, collect, analyze, and sort data from the pattern blocks.
[3] The visual component analyzes critical values (lengths, widths, angles, and radii) of one subject's body to another's to understand the proportionate and spatial relationships between body sites and to uncover the extent of physical prominences.
[4] The physiological component focuses on in-depth analysis of the potential reasons why the body formed as it did, including heredity, nutrition, and the environment.

Major modifications to the original BGR included the use of virtual data (body scans) and virtual fitting (Optitex©) instead of photographs. The analytical component and the dimensional component were not altered. The visual component switched from collecting linear measurements of the body to categorical data of the body, due to the impracticability of using the planar methodology in current computer-aided design (CAD)software. In addition, since the basic blocks are empirical abstractions of each subject's body, the block dimensions were used in lieu of the body dimensions. To avoid data duplication, the visual component was changed to visual content analysis of the body to understand the physical variability of the sample. The physiological component was changed to a comparison between pattern-block dimensions and body-form variations, as the level of detail desired by Gazzuolo's framework is outside the scope of this study. To further bound the scope of the research, statistical analyses were not conducted.

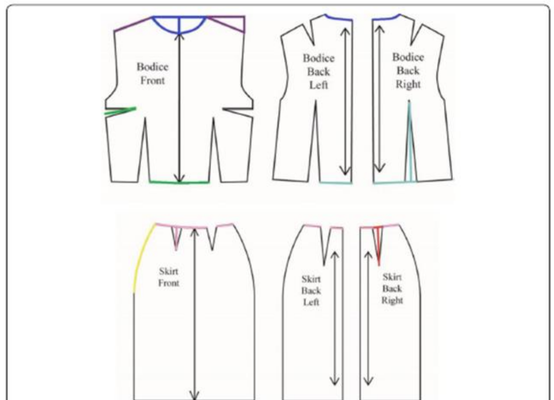

Fig. 5 Color-coded pattern-block dimensions

- Analytical component

The analytical component set the foundation and bounded the research; providing athorough description of the chosen garment (a sleeveless sheath dress, Fig. 4) and the fitting rules used to ensure consistent fit across the range of custom-fitted dresses. A sleeveless sheath dress was selected as it covers the body components most often associated with body-form: bust, waist, stomach, abdomen, high hip, hips, and thighs (Simmonset al. 2004; Lamport 2008, 2010). Basic blocks were chosen as they are the closest approximation of the body that is possible for a garment (Fig. 5). Garment abstraction is the specification of all the components of pattern-shape variance [level of abstraction (complexity), grain orientation, means of suspension, reduction/enlargement, division, and correspondence], such that all the elements of the body-form are considered and applied to the garment (Gazzuolo 1985). This is a correspondence-level garment (highest level of complexity for garment abstraction). The front and back of the dress are differentiated and the seamlines and darts are located relative to the body-form (Fig. 5). The grain falls vertically along the center front and back of each piece. Dress suspension occurred at the shoulders and the location of greatest lower-body prominence. Dimensional reduction/enlargement, used for increasing/decreasing a pattern-block component's value, could occur at seamlines, hem, and darts.

Table 2 Fitting rules for sheath dress, developed directly from analysis of correspondence
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
• 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

Contour reduction/enlargement, used to align the garment to the body's natural contours, could occur at the neckline, armhole, and skirt side seams. Each of the six block pieces had vertical divisions that occurred at the side-seam and center back, and horizontal divisions that occurred at the waist and shoulders.

Correspondence specified the anatomical locations of the major pattern points, which occurred at all block borders and the points of greatest prominence. The correspondence points and seams are: high-point shoulder, shoulder point, shoulder seam, center back neck point, center front neck point, neckline, shoulder blade apex, underarm point, armhole, bust apex, center back waist point, center front waist point, side waist points, waist seam, greatest lower-body front prominence, buttocks prominence, greatest lower body side prominence, knees, side seam, center back seam, and center front line. Analysis of correspondence led directly to the development of the eight fitting rules (Table 2). Visual analysis of fit was employed for fit evaluations and the principles of reduction and enlargement were used to achieve it.

- Block creation

Basic blocks created by the University of Minnesota were the basis for this pattern. The most representative size of blocks was chosen based on comparisons between the fit model's and block's bust, waist, and hip girth. The front shoulder dart was moved into the side seam, at bust level, allowing for more 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. The fit rules were then applied to the basic blocks, resulting in a custom set of blocks for the fit model. These blocks became the starting blocks for fitting the sample and were intended to reduce the amount of alterations and end with better fitting final garments (Song and Ashdown 2012).

Table 3 Dimensions and accompanying description; sorted by body region

Body region	#	Dimension	Description
Neck	1	Neck circumference	Curved line from center front neck point to the high-point shoulder and the high-point shoulder to the center back neck point, doubled
	2	Front neck drop	Vertical distance between the center front neck point and the high-point shoulder
Shoulder	3	Shoulder seam length	Straight line from the high-point shoulder to the shoulder point
	4	Averaged shoulder drop	Front and back vertical distance between the high-point shoulder and the shoulder point, averaged
Shoulder blade	5	Bodice back waist dart depth	Vertical distance between the dart point and the midpoint of the dart opening
	6	Bodice back waist dart width	Horizontal distance of the dart opening
	7	Back waist darts distance	A straight line from the center back waist point to the first dart leg, doubled
Bust	8	Bust dart depth	Distance between the dart point and the midpoint of the dart opening
	9	Front waist darts distance	A straight line from the first dart leg to the center front waist point, doubled
Greatest lower-body front prominence (GLBFP)	10	Front waist width	Distance from the right side waist point to the outside dart leg + the distance from the inside dart leg to the center front waist point, doubled
	11	Waist circumference Skirt front waist	Front waist width + back waist width, calculated same as for front, but with center back waist point
	12	Dart depth Skirt front waist	Distance from dart point to the midpoint of the dart opening
	13	Dart width	Horizontal distance of the dart opening
Buttocks	14	Skirt back waist dart depth	Distance from dart point to the midpoint of the dart opening
	15	Skirt back waist dart width	Horizontal distance of the dart opening
Greatest lower-body side prominence (GLBSP)	16	Skirt curve length	Curved line from right side waist point to the point of greatest lower-body side prominence

- Dimensional component

The goal of the dimensional component was to describe the major block-shape variations in this sample. The authors have worked extensively with both physical and virtual fitting and could accurately analyze the final fit of the garments without outside assistance. To generate data, the right-hand side of the blocks were altered until the fitting rules were met for each subject. Optitex's CAD system automatically mirrors changes made on the "working half" of the garment to the "mirrored half" of the garment, so that both halves of the garment are identical. Data collection consisted of gathering length and width dimensional values from the right-hand side of the blocks that directly corresponded to specific body-form variations, which are color-coded in Fig. 5. Dimensions needed to be directly comparable to the body-form so that they physiological component could be smoothly carried out (Table 3).

Dimension values were entered into a spreadsheet, sorted from smallest to largest, and graphed. Each subject received an identifier (a1–a44) to protect their identities. Descriptive frequencies were calculated for each dimension. The dot graphs were set so that the minimum and maximum y-axis values equated to the smallest and largest standard deviations 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

Content analysis of the body through in-depth inspection of the body scans resulted in categorical descriptions of multiple body-form variations. Coding terminology used in this study was subjective and relates only to the sample analyzed; it was not meant to be generalizable. 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. The term 'obscured' indicated that the body-form variation could not be assessed and does not count as abody-form variation categorical descriptor. Likewise, 'combo' designations in the GLBFPregion do not count as a categorical descriptor because they account for subjects with equally prominent stomachs and abdomens (stomach was determined to be higher on the body than the abdomen).

The analytical component defined seven key regions (neck, shoulder, shoulder blades, bust, GLBFP, buttocks, and GLBSP) for analysis, ensuring accurate and focused content analysis of the body scans. Body-form variation categorical data was organized in an Excel spreadsheet. Each variation had at least two categories, labelled by specific body part (i.e., shoulder or bust) and measurement entity (i.e., length or fullness). Tallies of how many subjects fell into each category allowed for comparisons within individual body-form variations.

- Physiological component

In the modified BGR, the physiological component compares the block-shape variances to the body-form variances. Twenty-seven assumptions were developed based upon consideration of how the body could affect the pattern blocks at specific locations (Table 4), guided by the garment abstraction analysis conducted during the analytical component. A strict one-to-one comparison was used to bound the research. By thinking of the pattern blocks as points connected by lines, the garment was more easily abstracted and each point and line were considered separately. Block points can move either horizontally or vertically, changing the length, steepness, and/or curvature of the connected lines.

V. RESULTS

The results from the dimensional, visual, and physiological components are presented in this section. Four of the 43 subjects were removed from the sample set due to extreme asymmetry which prevented the symmetrical fit of the garment on the avatars in Optitex©, resulting in 39 subjects for analysis. The fit model is the standard for this sample, and thus was not included in analysis of the sample, but information pertaining to the fit model is presented in the dimensional and visual results to show how the sample differs from the standard.

Table 4 Assumptions organized by body component and pattern dimension combinations

Body + pattern	#	Assumptions
Neck + neck circumference	1	The thicker the neck, the larger the neck circumference
	2	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
	3	The more prominent the collarbone, the smaller the neck circumference will be
Neck + front neck drop	4	The more forward tilted the neck is in relation to the torso, the longer the front neck drop measurement will be
Shoulder + shoulder seam	5	The longer the shoulder, the larger the shoulder seam measurement will be
	6	The softer the shoulder point, the longer the shoulder seam measurement will be
	7	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 drop	8	The more sloped the shoulder, the larger the shoulder drop measurement will be
	9	The softer the shoulder point, the larger the shoulder drop measurement will be
	10	The longer the shoulder, the larger the shoulder drop measurement will be
	11	A smooth neck-to-shoulder transition will produce a larger shoulder drop measurement, while a sharp neck-to-shoulder transition will produce a smaller shoulder drop measurement
Shoulder blade + bodice back waist dart depth	12	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	13	The more prominent the shoulder blade, the larger the bodice back waist dart width measurement will be
	14	The type of shoulder blade prominence will affect the measurement of the bodice back waist dart width
Shoulder blade + between back waist darts	15	The wider apart the shoulder blade back prominence points are, the larger the between back waist darts distance measurement will be
Bust + bust dart depth	16	The fuller the bust, the larger the bust dart depth measurement will be Busts contained within the ribcage will have smaller bust dart depth

	17	Measurements than busts not contained within the ribcage
Bust + between front waist darts	18	The wider apart the bust points are, the larger the between front waist darts distance measurement will be
GLBFP + waist circumference	19	The more indented the waist, the smaller the waist circumference measurement will be
GLBFP + front waist	20	The type of GLBFP will affect the measurement of the front waist
	21	Certain types of GLBFPs will extend past the bust, while others will not
GLBFP + skirt front waist dart depth	22	The lower the GLBFP is aligned, the larger the skirt front waist dart depth measurement will be
GLBFP + skirt front waist dart width	23	The type of GLBFP will affect the measurement of the skirt front waist dart width
Buttocks + skirt back waist dart depth	24	The longer and lower the buttocks prominence, the larger the skirt back waist dart depth measurement will be
Buttocks + skirt back waist dart width	25	The more prominent the buttocks, the larger the skirt back waist dart width measurement will be
GLBSP + skirt curve length	26	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
	27	The type of prominence will affect the skirt side seam curve measurement

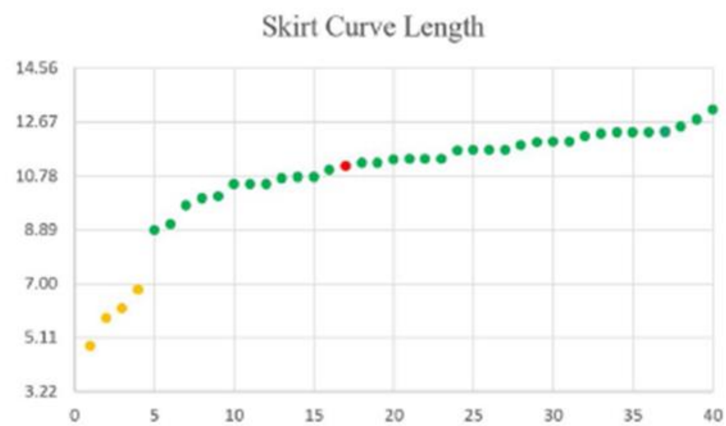

Fig. 6 Skirt Curve Length dimension dot graph. The red dot denotes the fit model. The two groups are clearly split by nearly a two-inch difference

- Dimensional component

Dimensional values were plotted on dot graphs to determine groupings; some groups

were more obvious than others. Dot graphs were chosen to allow the researcher to see how the sample dimensions ranged naturally (Fig. 6). The dot graphs were visually analyzed to discover where the groups split naturally, relying on long spaces between dots and locations where the dots levelled off to distinguish groups. Every attempt was made to eliminate subjectivity in group formation, though alternative methods for group formation should be assessed to ensure empirical objectivity.

While the range of some dimensions is quite small, the average measurements for those dimensions are also quite small, thus small differences have a big impact on the number of groups within a dimension. For example, even though the range for averaged shoulder drop is 0.70″, the dot graph suggests that for this sample, there are five distinct groups based on spaces between clusters of dots.

For the dot graphs, the y-axis values indicate the range of measurements for each dimension while the x-axis values indicate the individual subject number. Groupings were color coded, with a red dot denoting the fit model. The fit model was included in the graphs, but not in the calculations of descriptive frequencies or in the groups. Descriptive frequencies as well as the number of groups identified from the graphs are presented in Table 5.

Table 5 Dimensional component descriptive frequencies (in) and number of groups per pattern-block dimension

Pattern dimension	Mean (SD) (in)	Min (in)	Max (in)	Range (in)	# of groups
Neck circumference	15.75 (0.725)	14.41	17.13	2.72	1
Front neck drop	3.58 (0.35)	2.86	4.05	1.16	5
Shoulder seam	3.95 (0.22)	3.50	4.47	0.97	5
Averaged shoulder drop	1.24 (0.14)	0.875	1.57	0.70	5
Bodice back waist dart depth	7.36 (0.68)	5.50	8.75	3.25	5
Bodice back waist dart width	1.53 (0.25)	0.875	1.77	0.89	4
Between back waist darts distance	5.68 (0.80)	4.94	8.47	3.53	3
Bust dart depth	5.15 (0.37)	4.63	6.00	1.38	4
Between front waist darts distance	6.10 (0.45)	5.31	6.72	1.41	4
Waist circumference	32.28 (1.09)	30.94	35.94	5.00	4
Front waist width	17.41 (0.82)	15.66	19.78	4.13	6
Skirt front waist dart depth	4.17 (0.68)	3.00	6.00	3.00	5
Skirt front waist dart width	0.69 (0.08)	0.48	0.89	0.41	3
Skirt back waist dart depth	7.39 (0.75)	5.00	8.63	3.63	3
Skirt back waist dart width	1.84 (0. 26)	1.17	2.06	0.89	4
Skirt curve length	10.78 (1.92)	4.83	13.11	8.28	2

- Visual component

Twenty-seven body-form variations with ninety-nine variation categories were discovered during visual content analysis of the body scans. The inductive coding was developed by the researchers based on the scans in the sample and did not rely on other body classification methods since those were developed through deductive coding. This method is aimed at describing a specific population thoroughly, not on generalizing the findings of a specific population to the general population. Variation of body-form components was evident, even in such a small sample and had to be documented with as many categories per body-form variation as necessary. The number of groups per body-form variation ranged from two to seven.

Analysis of the neck included neck thickness, the neck-to-shoulder transition, collarbone visibility, and neck tilt. Neck thickness produced three groups: thin (13), average (12), and thick (14). The neck-to-shoulder transition produced two groups:sharp (18) and smooth (11). Collarbone visibility ranged from flat (2), nearly flat (15), visible (16), and prominent (6). Neck tilt ranged from straight (8), slightly forward (8), forward (18), and far forward (5) (Fig. 7).

Analysis of the shoulder included shoulder length description, shoulder points harpness, shoulder point alignment, and shoulder slope description. Shoulder length description produced three groups: short (11), average (10), and long (8). Shoulder point sharpness produced two groups: sharp (16) and soft (23) (Fig. 8). 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, with alignment either inside, aligned, or outside of each body component. Shoulder point alignment produced seven groups: inside bust, high-hip, and thigh (1), aligned with bust, outside high-hip, inside thigh (1), aligned with bust and high-hip, inside thigh (1); aligned with bust, inside high-hip and thigh (10), outside bust and high-hip, inside thigh (8), outside bust, aligned with high-hip, inside thigh (2), outside bust, inside high-hip and thigh (16). Shoulder slope description ranged from flat (3), slightly sloped (4), sloped (20), more sloped (6), and steep (6).

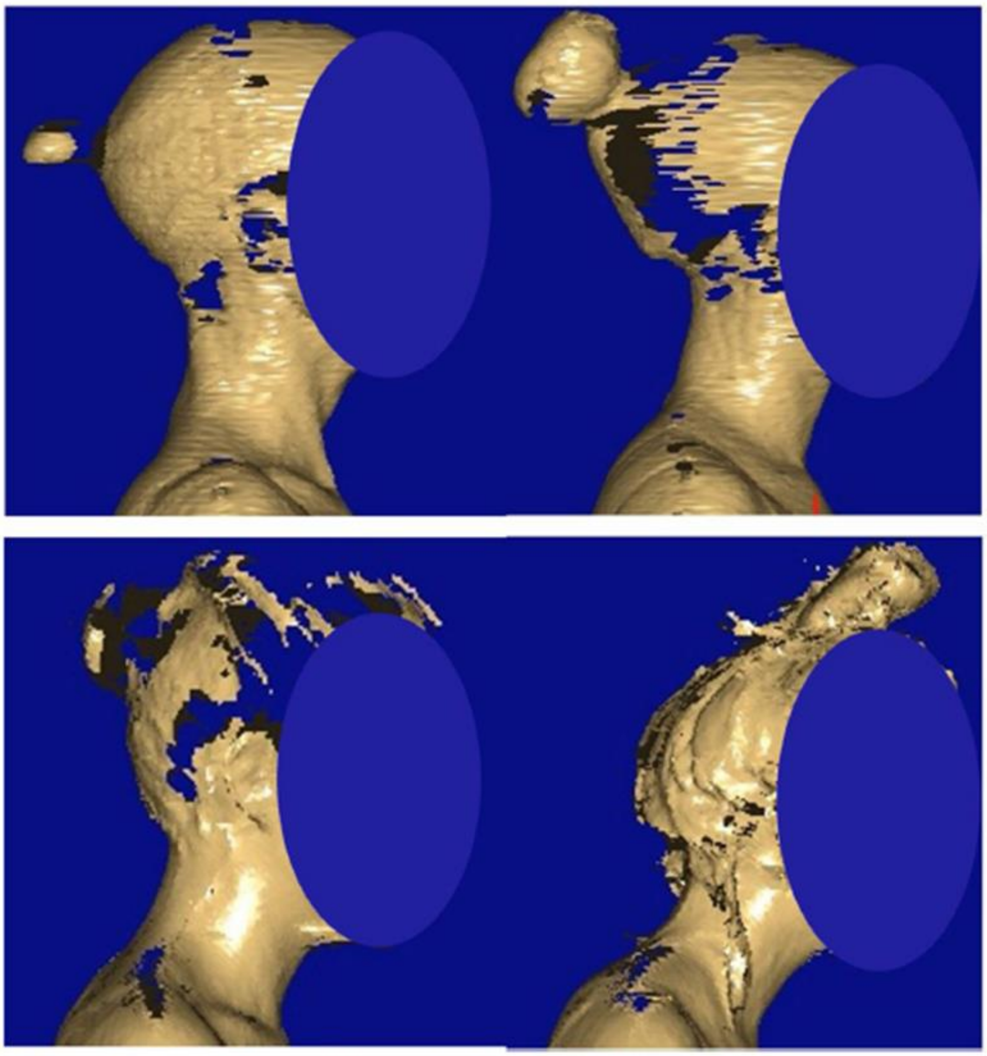

Fig. 7 Examples of neck tilt, from top left, straight, slightly forward, forward, far forward

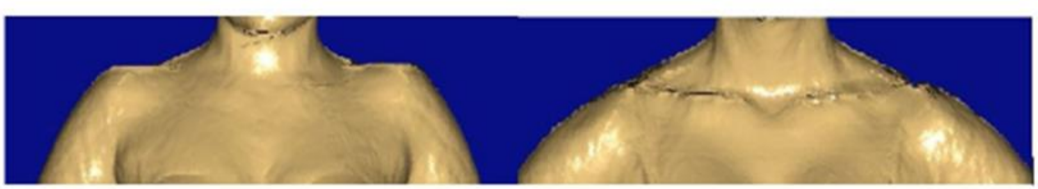

Fig. 8 Examples of shoulder point sharpness, from left: sharp, smooth

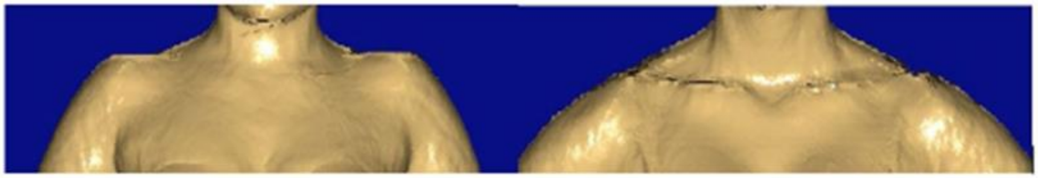

Fig. 8 Examples of shoulder point sharpness, from left: sharp, smooth

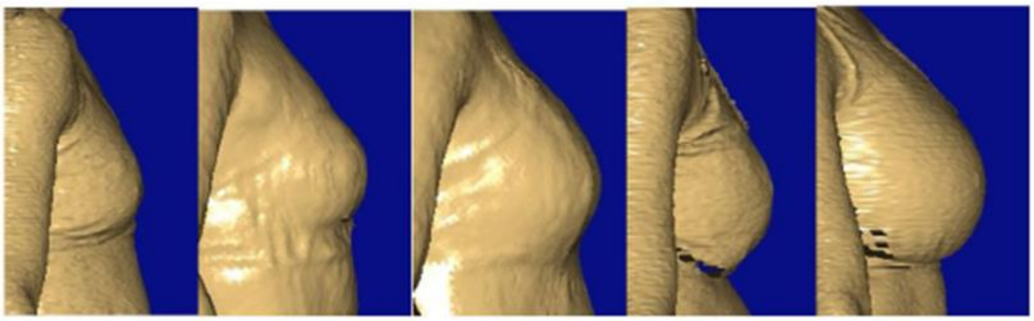

Fig. 10 Examples of bust fullness, from left: very small, small, average, full, very full

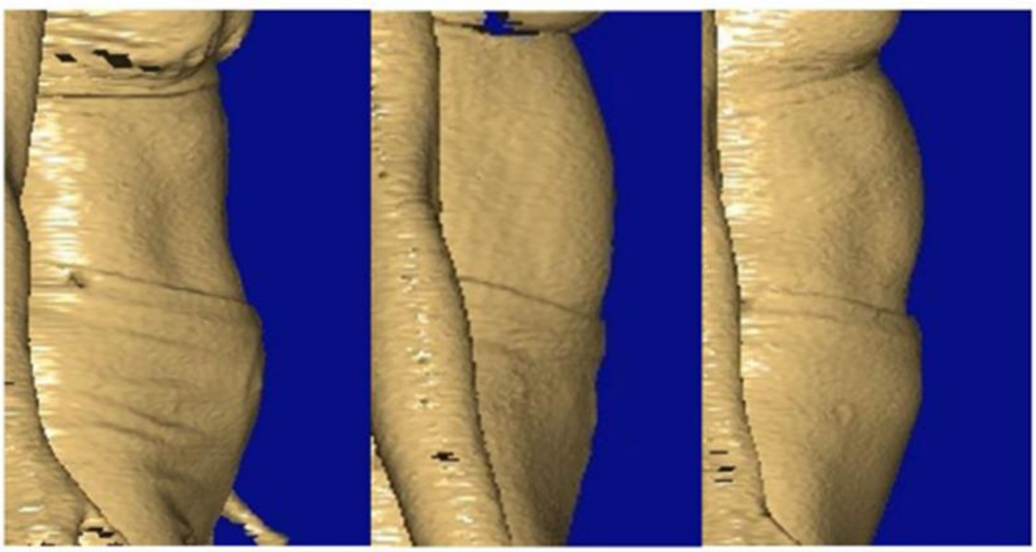

Fig. 11 Examples of the GLBFP identifier, from left: abdomen, stomach, and both

- Physiological component

Each body-form variation corresponded to a pattern dimension. In Excel, pattern dimension values were sorted from smallest to largest, simultaneously sorting he body-form variations. Tallies of each category within each body-form variation were calculated to see how many of each category fell within each group. For pattern dimensions with only one group, the group was split at the mean and the upper half was compared to the lower half.

Neck circumference was compared to neck thickness, the neck-to-shoulder transition, and collarbone visibility. There were 19 subjects below the mean and twenty subjects above the mean for neck circumference. Thin necks were the majority below the mean (56.2%), while thick necks were the majority above (50%). A sharp neck to-shoulder transition was the majority above and below the mean at 68.4% and 75%respectively. The ‘nearly flat’ collarbone category was the majority below the mean (52.6%), while the visible collarbone category was the majority above (45%).

Front neck drop was compared to neck tilt. Five groups were identified for front neck drop during the dimensional component. Straight neck tilt was the majority for group 1 (50%), forward neck tilt was the majority for groups 2 (66.7%), 3 (71.4%), and4 (54.5%). 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(71.4%).

The skirt front waist dart depth was compared to the GLBFP alignment. Five groups for skirt front waist dart depth were identified during the dimensional component. For the GLBFP alignment, the high-hip category tied for majority with the above high-hip category in group 1 (40%), tied for majority with the below high-hip category in group2 (37.5%) and was the majority for groups 3 (69.2%) and 4 (63.5%). The below waist and below high-hip categories tied for majority in group 5 (50%).

The skirt front waist dart width was compared to the GLBFP description. Three groups for the skirt front waist dart width were identified during the dimensional component. For the GLBFP description, the softly rounded category comprised the entirety of group1. The rounded category was the majority for groups 2 (37.1%) and 3 (66.7%), while the flat category was the second largest contingent in group 2 (25.7%).

The skirt back waist dart depth was compared to buttocks length, buttocks fullest part, and buttocks alignment. Three groups for skirt back waist dart depth were identified during the dimensional component. For buttocks length, the long category comprised the entirety of group 1 and was the majority for group 3 (75.7%). The short category comprised the entirety of group 2. For buttocks fullest part, the low category comprised the entirety of group 1 the high category comprised the entirety of group 2, and the middle category was the majority for group 3 (62.2%). For buttocks alignment, the ‘slightly below true hip’ category comprised the entirety of group 1, the hip category comprised the entirety of group 2 and was the majority for group 3 (40.5%).

VI. DISCUSSION

Results from the visual component provide the answer to the first research question: What are the body-form variations across a single size? All seven torso regions had multiple body-form variables, and each body-form variable had at least two categorical descriptors.

While many of the categorical descriptions of the body-form variations can be found in popular sewing literature (indicating many of these variations are known), this study provides a method for systematic analysis of a group of individuals missing from the literature. While Simmons et al. (2004) and Connell et al. (2006) provide methods for systematic body-form analysis, this study provides a method for deeper analysis of the body and relates body-form variations to specific pattern block components. Body-form analysis in the apparel industry is only useful in the context of pattern block generation or alteration.

Interestingly, the sample differed in many ways from the fit model’s categorical descriptions of the body-form variations, with sixteen matches and eleven non-matches. As seen in Table 6, the neck and shoulder regions have the most non-matches with different categories for 75% of each region. This means that garments that fit the upper torso of the fit model well, fit the sample’s upper torso poorly. Differences in neck thickness, neck tilt, shoulder length, and shoulder point alignment affected total garment balance and caused the lower section of the garment to appear poorly fitted on most of the sample. The remaining five body regions matched well, which makes sense as the sample was sorted by bust, waist, and hip girths, and these measurements directly impacted the shoulder blade, bust, GLBFP, buttocks, and GLBSP regions of the pattern blocks. This suggests that the addition of the neck circumference or shoulder length linear measurements to fit model designation for a target market may improve garment fit and speedup the garment sampling process.

Table 6 Body-form variations—fit model vs. most common variations in the sample

Body-form variation	Fit model categorical descriptors	Sample categorical descriptors
Neck region		
Neck thickness	Average	Thick
Neck-to-shoulder transition	Smooth	Sharp
Collarbone visibility	Visible	Visible
Neck tilt	Slightly forward	Forward
Shoulder region		
Shoulder length	Average	Long
Shoulder point sharpness	Soft	Soft
Shoulder point alignment	Aligned w/b, inside hh and t	Outside b, inside hh and t
Shoulder drop	Slightly sloped	Sloped
Shoulder blade region		
Prominence point alignment	Arm join	Arm join
Blade prominence	Visible	Visible
Blade description	Rounded	Rounded
Blade width	Average	Narrow
Bust region		
Bust fullness	Average	Full
Ribcage containment	Yes	Yes
Bust point width	Wide	Wide
GLBFP region		
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		
Buttocks prominence	Prominent	Prominent
Buttocks length	Long	Long
Buttocks fullest part	Middle	Middle
Buttocks alignment	Hip	Hip
GLBSP region		
GLBSP location	Thigh	Thigh
GLBSP alignment	Above crotch	At crotch
GLBSP description	Rounded	Rounded

The assumptions from the physiological component provide answers to the second research question: What do these findings suggest for the development of a body-form based block system? Assumptions were split almost into thirds: ten were upheld, eight were partially upheld, and nine were not upheld. The upheld assumptions provide specific suggestions for how specific body-form variations affect specific pattern components. The remaining seventeen assumptions require further analysis before suggestion scan be created. While not all assumptions provided concrete suggestions for the creation of a body-form based block system, a promising start has been made.

CONCLUSION

This study concludes that for this sample 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 development of a body-form based block system. Unfortunately, complete pattern block shapes could not be found from this sample, as there was too much variation in body-form. A body-form based pattern block system will be complex and require a new mode of thinking about pattern-drafting. Patterns should be thought of as puzzles, with the body-form variation-based pattern components making up the puzzle pieces. Such a system necessitates a large library of pattern components, but once compiled, they can be combined in infinite ways. This would allow not only traditional ready-to-wear manufacturers to create better fitting block patterns for their target markets, but also designers who wish to specialize in customization to more easily create block patterns for individual customers.

Due to the subjective nature of visual analysis, the results from studies such as this one cannot be generalized. New objective methods for describing body-form variation must be developed. Potentially useful body-form description may come from Gazzuolo's(1985) original visual analysis strategy of comparing the linear measurements from a subject's body against the linear measurements from their pattern blocks, but depth and volume calculations will be necessary to fully describe the body as purely linear measurements do not adequately describe body-form variation, as shown in this study. Due to the scope of the current study, statistical analysis could not be performed on the dimensional values, nor on the physiological comparisons between dimensional and categorical variables. Statistical analysis should be performed to validate the conclusions made herein. Next steps include testing each region of the body separately, determining exact dimensions for each body-form variation category in multiple sizes, and discovering common combinations of body-form variations in the population.

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