ANALYSIS OF PANT PATTERN SHAPES FOR TWEEN GIRLS BASED ON 3D

BODY SCANS

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ANALYSIS OF PANT PATTERN SHAPES FOR TWEEN GIRLS BASED ON 3D BODY SCANS

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ANALYSIS OF PANT PATTERN SHAPES FOR TWEEN GIRLS BASED ON 3D

BODY SCANS

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Angelina Louise Calabro, daughter of Louis and Jama Calabro, was born December 9, 1981 in Lexington Park, Maryland. She grew up in Stafford, Virginia and graduated from North Stafford High School with Distinguished Honors. She attended the University of Delaware from 2000-2004. After studying abroad during winter session in London, England, she graduated in May 2004 with a Bachelor of Science degree in Apparel Design. In August 2004 she began graduate studies at Auburn University.

THESIS ABSTRACT

ANALYSIS OF PANT PATTERN SHAPES FOR TWEEN GIRLS BASED ON 3D BODY SCANS

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The purpose of this study was to analyze and compare pant patterns for normal, overweight, and obese tweens in order to develop a better understanding of variations in pattern dimensions and shape. The goal was to evaluate the needs of the tween body so that apparel manufacturers, patternmakers, and other researchers can improve the overall fit quality of clothing made for this age group.

Subjects were selected from 151 body scans of girls aged 9-14 from Auburn University's body scan database. The scans were divided into three age subgroups (9-10, 11-12, and 13-14), then were classified by Body Mass Index scores as 'normal', 'overweight' and 'obese' and lastly sorted into body shape subgroups. Average height, weight and BMI were calculated for each age and size group. One scan was chosen to represent each subgroup. Selected scans approximated the average height, weight, and BMI numbers, and appeared, according to visual analyses, to be representative of the body shape characteristics of the subgroup. Pattern development software ($[TC]^2$ 3D-to-2D) was used to create pant patterns for each representative scan. To answer the research questions, full-scale, printed pant patterns were measured, and pattern shapes were visually analyzed using smaller pattern printouts.

Through visual analysis and comparison of pattern measurements including direct linear measurements, proportions, differences and patterns shapes and angles, differences and similarities were found among the three groups: age, body shape and body size.

For pattern shapes, age and body size seemed to change pattern shapes the most. The body shape subgroups differed which may indicate the need for three body shape apparel size categories. The greatest variation for age group was between the 9-10 year old and 11-12 year old subgroups. For body size group the largest differences occurred between normal and obese subgroups. The rectangle body shape group differed most from the hourglass and pear. Direct linear measurements showed that though crotch depth means did not increase with age, crotch length for the 9-10 year old group was 3" smaller than either of the older age groups. Pattern shapes changed and waistlines became more curved with body size increase. The normal subgroup had largest center front angle range. This study contributed an exploratory understanding of pattern shapes and sizing in pants for the tween market.

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I. INTRODUCTION

The American public is aware that there has been a rise in childhood obesity as it has become a constant topic in popular media. The changing size and shape of American adult women's bodies have been examined, but children's and teens' body shapes have been overlooked. There is no known, up-to-date anthropometric data for girls aged 8-14 or what is referred to as the tween consumer. The U.S. Center for Disease Control (CDC) reported that 14.7% of girls aged 6-11 and 15.4% aged 12-19 are overweight (CDC, 2006). This niche market is growing in population size and buying power, but also expanding in body size.

The tween is an emerging market segment coming to be recognized as was the teen market around 1941, when the term teen-ager was believed to be coined in *Popular Science Monthly* (Gibbs, 2005). A tween is generally defined as being between the ages of 8 and 14, prepubescent, and when "he/she rejects more childlike images and association and aspires to be more like a teen" (de Mesa, 2005, ¶ 1). Tweens are undergoing many different developmental (emotional, social, mental, and physical) changes. All of these changes affect how they think and act; one day they may act like an adult and the next like a child (Pennsylvania State University, 2002). They are in the process of developing personal identities and sense of self (Media Awareness Network, 2005).

Advertisers have tuned in to this developmental stage and have started marketing directed to these young consumers. This is not surprising; the tween market of more than 25 million is the most powerful since the baby boom (Brzezinski, 2004). They reportedly spend $51 billion of their own money and about $170 billion more of their parents' money (de Mesa, 2005); depending on the source, these amounts fluctuate. Some marketers are trying to cut parents out of tweens' decision-making by treating the tweens as "independent, mature consumers" (Media Awarness Network, 2005, ¶ 4) and portray them as capable of making adult decisions.

Women of all ages complain about not being able to find clothes that fit, but for the tween consumer, the task can be twice as daunting. Tweens have two options when shopping in most retail outlets: the children's department and the junior department. If the tween needs a larger size, then they may have to shop in the Misses' or Plus-Size departments. The difference between the consumer and the product being offered is a large one. Many girls approaching the teen years believe they are too old to shop in the children's department and have a desire to wear junior styles, which may not be age appropriate. The Misses' or Plus-Sizes do not usually offer styling that is similar to what the tweens' peers are wearing, but is normally geared to a more mature woman's tastes and figure.

Marshal Cohen, chief analyst for The NPD Group division Fashionworld, points out that plus-sized kids' apparel sales account for about 12% of the children's clothing market (Puente, 2004). Many retailers, including Old Navy, Delia's, Gap, Kohl's, Wal-Mart, Target, Lands' End, and J.C. Penney, offer plus-size fashion and understand that plus-sized consumers want clothes that fit their body size but are hip and in style. As one writer put it, “No muumuus, please” (Puente, 2004, p. D6). All tweens want fashion choices to show their individuality. Retailers are becoming more careful with the nomenclature used to refer to the plus-sized market, using words like “curvy” instead of “plus.” Some retailers are offering boutique type departments while others merchandise the same style on the same rack in a larger range of sizing (Haskell, 2002). Tim Waziak, trend manager of Torrid, a store for specifically plus-sized teens, says, “the plus-sized woman wants to feel sexy and beautiful just like a size 2 girl would […] To look like every other girl on the street is a feeling that everyone deserves” (Pliagas, 2005, p. 61). It is interesting to note that when talking about a larger girl, he refers to her as a ‘woman,’ but when referencing a size 2, he uses ‘girl.’ This suggests the way sizes are differentiated, thinking that a larger developed body belongs to a woman and a small undeveloped body belongs to a girl.

Statement of Problem

Tween girls’ bodies change because of puberty. This niche market is also outgrowing the available clothing sizes or clothing choices that are offered because of the increasing number of them who are overweight or obese. The additional implication of fitting girls whose bodies are changing and who are larger than their counterparts, but still want to wear the same clothing as their peers, makes it difficult to develop patterns and set sizing standards for this moving target market that already has varying body types and sizes. Pants, particularly fitted styles, are a hard garment to fit any female; tweens are no exception. Very little published research is available on tween sizing, pattern shapes for different figures, pant pattern shapes, and guides to changing patterns to fit the tween girl.

Purpose of Study

The purpose of this study was to analyze and compare pant patterns for normal, overweight, and obese tweens in order to develop a better understanding of pattern dimensions and shape. The goal of this study was to evaluate the needs of the tween body so that apparel manufacturers, patternmakers, and other researchers can improve the overall fit quality of clothing made for this age group.

Research Questions

1. Does the proportional relationship between crotch depth and overall length change in relation to age, body size, and body shape?
2. Does the crotch point width differ among age, body size, and body shape groups?
3. Is there a difference in crotch length for different age, body size, and body shape groups?
4. Does the proportional relationship between hip depth and overall length change in relation to age, body size, and body shape groups?
5. a. Does the hip-to-waist circumference difference change in relation to age, body size, and body shape groups?

   b. Does the shape of the side seam between the hip and waist change in relation to age, body size, and body shape groups?
6. Does the waistline shape differ in relation to age, body size and body shape groups?

7. Is the center back line angle different in relation to age, body size, and body shape groups?

8. Is the center front line angle different in relation to age, body size, and body shape groups?

Definitions of Terms

Anthropometry**: "**The study of measurement of humans, used in anthropology for classification and comparison, and in apparel and equipment design for identifying size and shape variation in the population" (Cornell University, 2003, ¶ 2). Greek origin, term literally meaning, "measurement of humans" (Anthropometry, 2006, ¶ 1). Many devices are used for measurement: a caliper, a pressure-sensing tape measure, anthropmeters and regular tape measures. Three-dimensional body scanners are the newest tool used in anthropometry.

Body Mass Index (BMI): A number calculated from a person's weight and height. BMI gives a dependable indicator of body fatness and is used to determine a weight category to determine if there are any health risks. For children and teens, BMI is age- and sex-specific (BMI-for-age). The formula for calculating BMI:

$$\frac{weight(lbs)}{[height(in)]^2} * 703 = BMI$$

(CDC, 2006).

Body Scanner: “The three-dimensional body scanner is a tool that captures information about the surface of the body using multiple laser or white lights and CCD (Charge-Coupled Device) cameras. Electronic circuitry and a microprocessor unload the data which are processed, saved as a file, and visualized as a three-dimensional image on a computer monitor” (Cornell University, 2003, ¶ 4). This image is a dimensionally accurate copy of the subject and can be manipulated and viewed on a computer screen. The one used in this study is the $[TC]^2$ NX12 Body Scanner developed by Textile/Clothing Technology Corporation ($[TC]^2$).

Computer-Aided Design (CAD): “A broad term that refers to software that assists in a variety of tasks” (Cornell University, 2003, ¶ 5). The apparel industry uses CAD programs to draft patterns, design textiles patterns, develop color schemes and other technical processes.

Ease: The extra amount of fabric added to a garment allowing for room of movement. Style ease or design ease: “is the extra amount added to create the desired silhouette for the garment” (Cornell University, 2003, ¶ 7) and is usually added to fit the target consumer’s preference.

Fit: “This term is used to describe the correspondence in three-dimensional form and in placement of detail between the figure and its covering in order to suit the purpose of the garment, to provide for activity, and to fulfill the intended style” (Fu, 2004).

Fit preference: Varies from person to person and is very subjective, the amount of ease in a garment may vary from a little to a lot. “The snugness or ease a person desires in clothing depends on one’s personal preferences, attitudes”, or what the consumer desires (Alexander, Connell, & Presley, 2005, p. 53).

Grading: Incrementally changing a pattern shape in certain locations to create a new size. "Patterns are increased and decreased (or graded up and down) from the base size to make a set of different sizes. Most grading is done proportionally, so that the basic proportions are kept the same across the full range of sizes" (Cornell University, 2003, ¶ 10). Also referred to as grade rules or grading system.

Scan Data: "Data take the form of XYZ coordinate points, about 300,000 points per body scan. The … accuracy of the data is about 1 mm in the horizontal plane and 2 mm in the vertical plane" (Cornell University, 2003, ¶ 17). The data are combined by the computer so that they can be visualized on a computer screen.

Size Categories: "Size categories are generated to suit different portions of the population, and these provide some variation in proportions in the size sets. Examples of size categories are Misses, Juniors, Petites, and Plus-Size" (Cornell University, 2003, ¶ 18).

Size Range: "The size range defines the smallest and the largest sizes available for a garment. Some apparel companies will provide clothing in a wider range of sizes than others" (Cornell University, 2003, ¶ 19). For example, one apparel company may offer junior sizes from size small to large while another company may offer sizes extra small to extra-extra large.

Sizing Systems: "The method or system used to create a set of clothing for a variety of people in the target market described. The most common sizing system in the apparel industry today uses a base size designed for a fit model and a graded set of proportionally similar sizes derived from this base size" (Cornell University, 2003, ¶ 20).

Sloper: The basic set of patterns without seam allowances or style lines that are used to create working patterns. Slopers are also called foundation blocks, master patterns or standard patterns (Fu, 2004, Joseph-Armstrong, 2006).

Target Market: Sample from a population of people towards whom a company aims their products and advertising. "Target markets are typically defined by demographic information such as age, income level, ethnicity, or interests, and not by body size or shape" (Cornell University, 2003, ¶ 21).

Tween Consumer: "Tweens is a relatively new marketing term used to describe adolescents approaching and just entering the teenage years … tweens are defined as 9 to 14 years old" (Ulrich, Connell, Simmons, Pasco & Bruner, 2006, ¶ 2). This age group is at a stage marked by many different changes, both physical and emotional.

II. REVIEW OF LITERATURE

The purpose of this study was to analyze pant pattern shapes and human measurements to determine if a better sizing system could be developed to better fit the tween girl. The review of literature is an overview of existing published studies applicable to this study's main focus. Topics covered in this chapter include: who the tween consumer is, improving apparel fit, anthropometrics, body scanning and computer-aided design, sizing and patternmaking.

The Tween Consumer

It is hard to define exactly what a tween is since this niche market has been described anywhere from 8 to 13 years old. Not yet a teenager but no longer a child, this age range is going through many emotional, physical and social changes. *Time* magazine describes it as, "the age of childhood leaning forward and adulthood holding back" (Gibbs, 2005, p. 41).

These girls are adjusting to the changes going on inside them and the changing world outside. Emotional changes in tweens can seem out of control; one day they act like a child; on another they appear mature. Social development includes increased peer pressure and sexual awareness. Along with that comes physical changes representing "one of the most rapid and dramatic periods of physical change" (Pennsylvania State University, 2002, ¶ 9) and the need to mentally cope with the changes. Tweens and teens start to view themselves differently as their body takes on a new appearance (Lerner, 2002). A survey done by the Unilever/Girl Scout Self Esteem Program showed that tweens were worried about homework (71%), grades (59%), and pleasing their parents (43%). Over 800 pre-teens (boys and girls) aged 8-12 took part in the survey, and among the top three things that concerned them was peer pressure. Tween girls were shown to be greatly satisfied with school and friends, but a major source of discontent was their looks. In another survey, over half the girls (54%) liked their weight "a little" or "not at all"; 15% were "completely dissatisfied" (Market Wire, 2003, ¶ 2). Many different life changes and social characteristics contribute to the uniqueness of this target market.

It is hard to pinpoint exactly when the term teen, let alone tween, came into our vocabulary. *Time* magazine credits an article written in 1941 for *Popular Science Monthly* (Gibbs, 2005) with first using the term in print. Massoni (2006) agreed that around the 1940s a "teenager" was better described as a consumer group and the term came into popular culture language. Of course, the teen girl in the 1940s and 1950s was much different than a teen girl in 2006. A girl of 12 or 13 in the mid-50s flipping through a magazine would see "ads for furniture because she reasonably expected to be married and starting a family within a few years" (Gibbs, 2006, p. 43); today a girl of 12 or 13 would see makeup, clothing, or shoe ads, with marriage as a distant thought. In the 1940s, *Seventeen* helped to create the teen girl as a consumer by selling the concept of Teena (the prototypical teenage girl) to retail and advertising industries, in order to humanize the large teen population for promotional campaigns. One *Seventeen* print ad pointed out that Teena (thus all teenage girls) had money and wanted to spend it. This is still true today where many tweens are given an allowance or have an after school job so that they can purchase the newest fashion or electronic (Massoni, 2006).

Spending Power

Five years after *Seventeen's* first publication, a change was occurring in the economy "as retailers and merchandisers rushed to meet the 'needs' of the teenage girl" (Massoni, 2006, p. 40). Over 60 years from its inception, *Seventeen* creators never could have imagined the influence of their marriage of the advertiser and teen girl. In the past few years, marketing and products aimed at 8-12 year olds have climbed quickly, leaving some wondering how savvy this new consumer group really is. Many advertisers play to the child's imagination where they "reign supreme" (Hymowitz, 2001, p. 16). The advertisers seduce tweens by showing and telling them that they are just as grown up as their teen counterparts or even their parents. Hymowitz (2001, p. 18) explained that American tweens "have simply learned to expect a lot of stuff" either because their parents had more established careers and were trying to compensate with material things, or the children were spending time between separated or divorced parents and needing two of everything, like two beds, two sets of toys, and two sets of clothes.

Business Week online reported that tweens spend about $51 billion, with an additional $170 billion spent by parents and family members on products for the tween (de Mesa, 2005). From an NPD group study, *Children's Business* reported that in a three-month period, parents spent an average of $100 on clothing and an average of $79 on accessories and room décor, making the monthly tab of a tween parent around $220. It was also reported that tweens themselves spent an average of $69 on entertainment in the three month time period (Clack, 2004). This consumer group, reported to be 25 million strong, has been called the largest and most influential since the baby boom (Brzezinski, 2004).

This demographic is hard for marketers to pin down since they are constantly changing with personal growth occurring each year. There is also the power struggle between tween consumers and their parents. A piece in *Time* magazine gave the following example: Claudia Wallis and her daughter had different views when underwear shopping; the teen wanted to buy thongs to wear to school, and her mother wanted to buy regular underwear, like packaged Hanes. Wallis was told, “besides the locker-room scene, girls like to wear their overpriced thongs with a silky strap showing” (Wallis, 2003, p. 94). Tweens yearn to be older and more sophisticated, but can only push the line so far since parents are still very much involved in their lives. One estimate was that only 8% of tween purchase decisions are made on their own, and 72% of purchases are decided by both parent and child (Clack, 2004). This is tough for marketers since they want to pull the tween in but not push the parent away.

Culture, Gender, and Age

The tween market is hard to satisfy since many tween girls are just looking to fit in with their peer group. Approval of being deemed “cool” by their friends is a cue of social acceptance to the tween (Pennsylvania State University, 2002). In her study, Simpson (1998, ¶ 3) listed approximately 10 authors who agreed that wearing brand name apparel or other types of clothing “is a way of ‘fitting in’ for both tweens and teenagers”. It was also suggested that not being able to dress like other teens could be a “barrier to social participation” (Simpson, 1998, ¶ 4). Added social pressure comes from a culture that constantly bombards women and girls with the image of the perfect or ideal body. Since Barbie was first introduced to the market, she has been credited for “everything from girls’ negative body images to materialism” (Cook & Kaiser, 2004, p.

212). Kay Hymowitz, a social critic, reported that "mothers without exception *hated* Barbie. They believed she was too grown up for their 4-to-12-year-old daughters" (Hymowitz, 2001, p. 16). She used Barbie to symbolize "the moment when the media and the businesses it promoted dropped all pretense of concern about maintaining childhood" (Hymowitz, p. 16); it was the point when the media destroyed parents' attempts to delay growing up and the "teening of childhood" began (Hymowitz, p. 16). Then there was Brooke Shields and her Calvin Klein jeans, which Cook and Kaiser (2004, p. 215) credited with "spark[ing] the failing preteen market." Again, the line between childhood and teenage years had been erased "by anchoring age aspiration, femininity and quite explicit sexuality onto the bodies of young girls" (Cook & Kaiser, p. 215). An article in *Inc. Magazine* discussed how today girls are dominated by images of pop stars (e.g., Britney Spears or Jessica Simpson) and celebrities (e.g., Paris Hilton or the Olsen twins), making "little girls grow up awfully fast […] and recoil from anything they deem childish" (Heintz, 2005, p. 44).

Tweens view images of the perfect body every time they shop; Abercrombie and Fitch, American Eagle, and even Victoria's Secret have huge posters of models in their stores portraying the ideal customer. These thin and toned models are sending the message of this is what you want to look like. "Contemporary popular media are replete with messages that emphasize the desirability of a well-maintained body" (Ballentine & Ogle, 2005, p. 281). Using articles from *Seventeen* magazine (1992-2003) that focused on body characteristics (shape, size, or weight) or ways of changing body characteristics, Ballentine and Ogle (2005) found that "this desirable body was described as smooth, trim, toned, tight, long, lean, flat, strong, young, sexy, healthy" (p. 290). The message was showing the body is a flexible object; teens could use methods of changing their bodies (exercise, dieting, self control). If an attempt at changing their body failed, however, teens might acquire negative self-feelings or develop unhealthy eating habits. At the same time Ballentine and Ogle (2005) found that *Seventeen* was encouraging girls to "embrace their bodies 'as is' and to appreciate and 'make the most of' their natural bodies" (p. 300). Ballentine and Ogle reported in some articles, readers were directed to focus on improving themselves inside and living life.

Tweens and Weight

Obesity is a national epidemic that has grown in media attention as much as it has grown in America. Newman (2004) for *National Geographic* reported, "today one out of three Americans is obese, twice as many as three decades ago" (p. 48). The most troubling statistic looks at obesity in children saying that; "15 percent of children and teens are overweight, a nearly three-fold jump from 1980" (Newman, p. 48). These statistics worry many in the heath care field since many health problems that overweight children develop will stay with them into adulthood and progressively get worse. Overweight and obese young people are seen as needing attention by health care professionals because "of the continued focus on biomedical constructions of appropriate body size and its relationship to 'good health' " (Wills, Backett-Milburn, Gregory & Lawton, 2006, p. 396).

Tweens who are overweight may have problems fitting in with their peers who think that the ideal body is the norm. Wills, Backett-Milburn, Gregory and Lawton (2006) conducted a study of 13 to 14 year-old teens in Scotland and their perceptions of obese, overweight and normal peers. Focus groups included questions about teens' everyday lives, including “perceptions about health, food and eating, weight, body image and appearance” (Wills et al., 2006, p. 398); the interviewer avoided the use of ‘fat’ or ‘big’ to let the teens use their own vocabulary. The idea of fatness and body size was found to be complex and individualized by the teens. The participants in the study said the word ‘fat’ most often when talking about peers who were teased about their weight. About half of the overweight and obese teens surveyed reported that they had been teased or bullied because of their weight, and some said it made them “unhappy or upset” (Wills et al., p. 401). The overweight girls pointed out that they felt limited in shopping for clothes; weight or body shape affected what they could wear. Some girls even said that it limited social situations, such as shopping with friends, because they were worried about “trying on clothes in front of other (thinner) peers” (Wills et al., p. 401). The feeling of not being able to go shopping with friends can have a mental impact on these girls, telling them they are not good enough to wear what their peers do (Wills et al.). Social acceptance is important to a tween, and the feeling of rejection that many overweight and obese tweens experience may lead to dieting, eating disorders, or mental health problems. With the trouble of finding clothes that fit and are similar to what their peers are wearing, it could be difficult to be an overweight or obese tween.

Apparel Fit

Fit Issues

Fit is often hard to define since each individual and each expert has their own definition. The most frequently described elements of fit are ease, line, grain, balance, and set. To a consumer, these terms may sound like a foreign language; their only concern is how they look and feel in the garment. A study done by Kurt Salmon Associates reported that 50% of women can never find apparel that fits (Loker, Ashdown, & Schoenfelder, 2005).

Alexander, Connell, and Presley (2005) pointed out that consumers use clothing to identify who they are and no longer view clothes as just a basic necessity. It has been shown that fit is an important factor in a consumer's comfort and confidence. Garments that fit well are regarded as influencing a consumer's psychological and social well-being. Dissatisfaction with fit is repeatedly reported as the biggest problem when shopping for clothing. Since consumers' fit preferences differ, clothing manufacturers need to examine body measurements and find the fit that satisfies their customer base. Even if manufacturers have data from body scans, it is not enough for the production of garments; they need to understand how their target market defines fit. New sizing systems could be developed from the consumers' view of fit (Alexander et al., 2005).

Terry (1968) pointed out that the techniques used for fitting are circumference measurements, specifically bust, waist, and hips, and those measurements do not take irregular figures into account. Irregularities, such as uneven hips, poor posture, or a prominent abdomen, need to be addressed when fitting a garment. The bust and hip measurements in the ideal figure should be about the same circumference, with the waist being somewhat smaller. This 'ratio' gives a proportional figure that is appealing in appearance. "This idealized proportion may frequently be unrealized in real life situations" (Terry, p. 8). People often use clothing to achieve this appealing proportion and hide the irregularities in their physique.

As fashions change, so does the definition of fit; over time it is difficult to say what the ideal fit is. Erwin, Kinchen, and Peters (1979) used five clues for identifying good fit: ease, line, grain, set, and balance. These five criteria for fit are interconnected; usually, if one is corrected, it may solve other problem areas or create another problem area. An unsatisfactory garment may be caused by poor fit or poor construction, although more often than not it is poor fit. Fit affects the silhouette of a garment, which then affects the overall look. Terry explained that "the silhouette is recognized as the most important aspect of a garment" (1968, p. 8) since it can be used to achieve a pleasing appearance.

There are many factors other than fit which can influence the silhouette and appearance of clothing; two of them, "figural and postural variations" and "proportions of the garment as related to the figure," take the body into consideration (Terry, 1968, p. 15). With the technology of body scanning, these factors can be better investigated as they pertain to answering fit problems. Loker, Ashdown and Schoenfelder (2005) studied one target market's sizes. They addressed body shape and measurements as factors in a sizing system.

Fit Testing

Ashdown, Loker, Schoenfelder and Lyman-Clarke (2004) defined a well-fitted garment as one that hangs smoothly and evenly on the body, has no pulls or gaping, has straight seams, is proportioned well, and has ample ease. For this research, fit experts were chosen because "the human senses used as a testing instrument can identify and process complex stimuli more effectively than other measurement devices, particularly when complex forms of pattern recognition are needed" (Ashdown et al., 2004, p. 3).

Conclusions from this study indicated that the 3D scanner is an effective tool in fit analysis; it can capture and store the fit information and is more effective than photographs (used by Douty, 1968) or videotapes (used by McCulloch, Paal, & Ashdown, 1998). Participants can be scanned in mass produced pants or other garments which can later be viewed for fit analysis.

In the Ashdown et al. study (2004), measurements were taken from scan data and evaluated for size ranges, measurement specifications, and grading rules in hopes of improving the fit of pants for a specific female target market. In order to give suggestions on improving fit, “it was necessary to identify the pants and the portions of the pants that fit well and those that fit poorly” (Ashdown et al., 2004, p. 4). Scans were viewed from every angle on a horizontal or vertical axis; it was also possible to zoom so that a specific location could be more closely examined. The experts selected to assess fit were given 13 critical fit locations: waist front, waist back, waist placement front, waist placement back, abdomen front, abdomen back, hip front, hip back, crotch front, crotch back, below buttocks, thigh front, and thigh back. The overall front and back fit were assessed, with the worst rated area being the crotch back “indicating a general patternmaking problem” (Ashdown et al., 2004, p. 7). Misfit of the crotch back affected the overall fit of the pant back, resulting in lower fit ratings from the fit experts. The authors pointed out that after analysis of the ratings, the scans could be reviewed to explore certain patternmaking problems that could be solved to provide better fit. Visual analysis with body scans is very similar to fit tests with live models, yet with new options. The scans also made it possible to view the minimally clothed body to “determine body configuration factors contributing to fit problems” (Ashdown et al., 2004, p. 9).

With the use of electronically stored body scans, researchers now have the capability to review a scan many times. This is beneficial to apparel manufacturers and researchers since the data can easily be accessed whenever needed. “The ability to easily scan and organize a database representing the fit of target market members in specific garment styles will provide information necessary to adjust patterns and sizing systems to better fit our population” (Ashdown et al., 2004, p. 11). Terry (1968, p. 2) stated it best: saying that, “because the human figure cannot be standardized, adjustments for figural and postural variation must be made” in sizing and patternmaking.

Loker et al. (2005) worked with stored body scans of an apparel company’s target market to provide data for improving ready-to-wear sizing. They visually compared body scans of women between the ages of 34 and 55 years old; they had minimally clothed subjects next to the same subject in a pair of pants. Each subject tried on the best fit pant that the apparel company had to offer, and then fit ratings were assigned to each scan. The analysis of fit ratings by size was used to explore the connection between body size and pants. Researchers found that below the buttocks and the crotch area were mostly unacceptable across all sizes, thus showing a basic flaw in the pant pattern. It was also shown that the sizes closer to the fit model size generally had higher fit ratings than the larger sizes. Through this study, it was concluded that for the 34 to 55 year-old female target market, “current sizing systems offer an acceptable fit to about only half of the 156 participants” (Loker et al., 2005, p. 12). LaBat and DeLong (1990) also found that, in a study of younger women, there was discontent with the fit at the waist, hip, and thigh area. Their subjects rated pants as the most unsatisfactory fit over all other apparel items. Focus groups conducted by Schofield, Ashdown, Hethorn, LaBat, and Salusso (2006) of women over the age of 55 found that most participants were unhappy with seat shape in relation to fit. In order to fit the target market, two seat shapes were designed to fit the same lower body circumference measurements but different body shapes. Schofield et al. (2006) suggested that the relationship between the variability of body measurements within each size has an effect on fit.

There is unsatisfactory fit in pants for women of all ages and in order to fit a certain target market, most of the studies done suggested using real human bodies of varying sizes instead of the ideal fit model traditionally used by the apparel industry. Apparel companies can not only look to fit experts to help improve the fit of their clothing. They must also keep in mind the fit preferences of their target market.

Anthropometrics and Body Measurement

Not many people make the connection between anthropometrics and clothing design, even though anthropometrics play an important role in the study of body dimensions and sizing. The statistical distribution of body dimensions is regularly used to improve merchandise offered to consumers (Anthropometry, 2006). Manufacturers may use this information to establish a range of sizes for production. For example, car manufacturers may use the data to determine how far away a steering wheel should be from the driver's seat or the necessary width of the driver's seat. Heiner Bubb (2004) explained that the need for body measurements came about because "the direct contact between producer and customer no longer existed […] Mass production led to a simplification of the production" (p. 155).

Historically, human body measurements have been taken by hand with a tape measure, weight scale, anthropometer, caliper, sliding compass, and head spanner (Simmons & Istook, 2003). Those measurements were taken as circumferences, distances, and weight, which are all one-dimensional (Bubb, 2004). Traditional measurements did not consider the human body as a three-dimensional object. Helen Douty (1954) was an initiator of seeing the body "as three-dimensional, geometric forms made up of a pattern of planes and solids, curves and flat areas" (p. 24). There were no longer only flat circumference measurements to consider. The body has many concave and convex curves that constantly change as a person moves.

"The precision and accuracy of measurements taken with a tape measure are often not sufficient to detect small, but important differences in body dimensions" (Heisey, 1984, p. 9). Bye, LaBat, and DeLong (2006) reviewed and evaluated three different methods of measurement to help in the improvement of fit. These methods include: linear methods, multiple probe methods, and body form methods. Each method has different types of measuring tools as seen in Table 1, which also shows what type of measurement is taken. Bye, LaBat, and DeLong (2006) found linear methods only took length measurements, and the multiple probe methods could take point, length, surface and shape measurements. The only body form method, body scanning, was able to take into account point, length, surface, shape, and volume measurements (see Table 1).

Table 1

Body Measurement Methods

	Point	Length	Surface	Shape	Volume
Linear Methods					
Tape Measure		X			
Direct Measure		X			
Proportional Measure		X			
Anthropometer		X			
Calipers		X			
Multiple Probe Methods					
Comples Anthropometer	X	X		X	
Somatography	X	X		X	
Minott Method		X		X	
Planar Method	X	X	X		
CIAM	X	X		X	
Photography	X	X		X	
Body Form Methods					
Draping			X	X	
Casting			X	X	X
Body Scans	X	X	X	X	X

(Bye, LaBat, & DeLong, 2006, p. 67)

With the technology of the 3D body scanner, the study of the 3D human figure differences in body dimensions has become much easier. The body scanner is, "beneficial for the anthropometrist, in that they can use this to extract any measurement at any time" (Anthropometry, 2006, ¶ 2). These measurements and body shapes can be analyzed again and again without the subject ever coming back. Body scanning has also made the process of collecting body data faster simply because "the individual does not have to wait for each measurement to be taken separately" (Anthropometry, 2006, ¶ 2). Three dimensional body scanning has made anthropometric studies such as Size USA less intrusive to the subject and easier on the anthropometrist.

In the first known US anthropometric study, O'Brien and Shelton (1941) could not identify one body measurement that could be used to calculate all other body measurements (Schofield & LaBat, 2005). O'Brien and Shelton (1941) suggested that the population be divided by vertical measurements and then divided into three weight classes to cover a wider range of people. Today, those two measurements are used to calculate a person's Body Mass Index (BMI) and the Center for Disease Control has different charts to break the population into normal, overweight, and obese body size categories (CDC, 2006).

Body Shape Measurement

To reduce bias in studying human shape, Douty (1954) took photographs of her students using somotography, a method of photography she developed for classroom use to improve her students' eye for different body shapes. In order to obtain an idea of a student's shape, Douty needed an objective and unbiased way to look at figures. By showing students silhouettes of themselves, discussion varied on shapes, postures, proportions, and weight distribution and how these characteristics affected the way clothing draped and fit on the body. With further analysis and more somatographs, Douty (1968) developed the Douty Body Build and Posture Scales which used side and front views of subjects to categorize their figures.

Connell, Ulrich, Brannon, Alexander, and Presley (2006) developed a body shape assessment scale based on 14 body shape templates created by other researchers. The final product was the Body Shape Assessment Scale (BSAS©) with Body Build, Body Shape, Hip Shape, Shoulder Shape, Front Torso Shape, Bust Shape, Buttocks Shape, Back Shape, and Posture as the element scales. Six of the nine BSAS© components affect the fit of lower body garments. This system of identifying different body shapes was programmed to be compatible with [TC]^2's Body Measurement Software (BMS) to evaluate body scans. The study samples focused on adult female figures, one-fourth of whom fell in the plus-size category (Connell et al., 2006). Hutton, Bayley, Broadhead, and Knox (2002) "suggested that the side silhouette was possibly the single most important indicator of a person's posture and shape" (Connell et al., 2006, p. 83).

With the improved technology and adoption of body scanners, anthropometric studies have become faster and easier to accomplish. The accuracy of the scanner is point accuracy <1mm (0.0394 in.) and circumferential accuracy <3mm (0.1181 in.), which is much more accurate than any hand measurement could be ([TC]^2, 2006). Instead of a subject standing and waiting for a person to measure them by hand, measurements are taken by the scanner and are non-invasive. The anthropometrist can extract any measurement at any time and use the measurements as many times as needed. The accuracy and accessibility of body scan data is an invaluable tool in the field of anthropometry.

Body Scanning and Computer-Aided Design

Technology has vastly improved since Douty (1954) used her method of somatography, photographing subjects behind a screen to analyze and understand body shape. To capture a silhouette photograph, Douty blocked off a bed sheet into six-inch squares "with braid heavy enough to make definite lines when photographed" (1954, p. 25). The subject would first face front and have her photograph taken, then turn to the side with the last photograph taken of the back view. Since Douty (1954), Terry (1968) and others used this method, which was long and meticulous, and the sample sizes were generally small. Researchers used somatography until 3D body scan technology became available. With the faster processing times of computers, 3D body scanning does not take nearly as much time as setting up for a somatography photograph. Scans are done in mere seconds, and the researcher has the ability to call up and study the three-dimensional figure many times.

In Terry's (1968) study identifying figure and posture differences that could help alter commercial garments, a main objective was "to utilize silhouette photographs as graphic evidence in order to clarify and make more accurate the perception of changes required for optimum fit" (p. 3). This objective can be applied today with 3D body scans as a virtual model to compare and contrast standard methods of pattern drafting and how those methods relate to real bodies. The 3D body scans and computer-generated patterns allow researchers to compare the shape of the person to the shape of the pattern. Today, we have the ability to pull a pattern of a skirt, bodice, or pant off a 3D form and visually display how the two relate to one another.

One main concern for the apparel industry is the variety and availability of 3D whole body scanners. Simmons and Istook (2003) compared three body scanners from different companies to see which took the best measurements for application in the apparel field. They found that the [TC]^2 scanner "had the most measures identified [...] and also had the capability of producing many more with specific application for apparel" (Simmons & Istook, 2003, p. 306). The [TC]^2 scanner uses white light technology which is, "considered to be the safest body scanning technology" ([TC]^2, 2006). The subject has a fully private environment to change from street clothing into scanwear and to move from the dressing area into the scan room. Scanwear usually consists of briefs for guys and bike shorts and sports bras for ladies. The entire scan time of eight seconds is done without the operator touching the subject. The [TC]^2 scanner has the largest scan volume of 2.1 meters tall (6.8 feet) and 1.2 meters wide (3.9 feet). The compatible software package can create a 3D body model from the 3D data point cloud produced by the scanner. This technology can also extract critical anthropometric measurements and link those measurements with key garment sizing measurements (Carrere, Istook, Little, & Hong, 2000). In addition, the software has the capability of producing patterns directly off the 3D data point cloud. Heisey (1984) suggested that "forming the pattern directly on the figure allows the three-dimensional form of the body to be automatically incorporated into the pattern" (p. 7).

A human body survey called Civilian American and European Surface Anthropometer Resource (CEASAR) of approximately 6,000 subjects used 72 body landmarks per scan. Previous research concluded that to find and identify landmarks manually would take about 60 minutes per scan, but with a fully automated process about 30% of landmarks detected were incorrect. Goals of the CAESAR project were “to convert marked locations on a subjects body into 3D named points” and “to accomplish this using less than 15 minutes per scan” (Burnsides, Boehmer, Robinette, 2001, p. 393). The scanner used in the North America study was the Cyberware WB4, which had two sets of cameras with two types of physical markers. In the landmark extraction process, three steps were used: detection of the markers, identification of each marker, and verification that the landmark was correct. The detection process involved using operators to pick out and select the landmarks for a batch of subjects. Then a fully automated identification process turned the detected landmarks into three-dimensional coordinates. Next, in the identification step, each landmark was matched with its landmark name. Lastly in verification, a human operator viewed each scan for accuracy in placement and correct identification. Through this semi-automated method, it was found that accuracy of landmark identification increased from about 80% to 96%. With visual examination, it was determined that the “entire process missed approximately 1 identification error for every 100 datasets, for a dataset reliability of 99%” (Burnsides et al.., 2001, p. 397); the total time to process each scan was 10 minutes and 20 seconds.

Griffey and Ashdown (2006) developed a process to create a basic skirt block pattern from body scans. They used slices of body scan data to find the smallest and largest circumferences of the lower body. These measurements were used to help define the fullest part of the buttock or thighs, which made it possible to place seams and darts more accurately and at the most effective locations (Griffey & Ashdown, 2006). In theory, these methods seem like good solutions for the apparel industry, but the apparel industry may take some time to catch up to the available technology. Ashdown and Dunne (2006) looked at the readiness of technology in this field and if the industry was ready to produce custom fit products. Using CAD systems to gather body data and develop patterns, they found seven of the ten participants preferred the custom jacket made using CAD technologies over the same style jacket produced in a standard size. Overall they concluded that the technology was ready for implementation in the apparel industry (Ashdown & Dunne, 2006). Now it is the industry's job to realize and adapt these CAD technologies for use. Implementation of 3D body scanners and body scan software may differ between apparel companies, but the technology is available.

Apparel Sizing

Sizing systems have been in place for many years and many researchers (McCulloch et al., 1998; Newcomb & Istook, 2004; Hsu & Wang 2005; Loker et al., 2005; Schofield & LaBat, 2005; Ulrich et al., 2005) have tried improving sizing methods, suggested different approaches to creating a size chart, and have tried to make sense of the current sizing standards in place by the American Society for Testing and Materials (ASTM). Schofield and LaBat (2005) found evidence that size charts developed before the first U.S. anthropometric study by O'Brien & Shelton (1941), "claimed to include average body measurements, but did not explain where or how averages were obtained" (Schofield & LaBat, 2005, p. 17). Most sizing standards and sizing charts are created using old, outdated anthropometric data and old, outdated assumptions of human body proportions. Table 2 lists previous sizing studies.

Table 2

Sizing Studies

Year	Anthropometric Study
1941	Department of Agriculture (O'Brien and Shelton, 1941)
1971	National Bureau of Standards Commercial Standard PS42-70 (Department of Commerce, 1971)
1981	ISO Size designation of clothes, definition and body measurement procedures (International Organization for Standardization, 1981)
1988	U.S. Army anthropometric study (Gordon, Bradtmiller, Churchill, Clauser, McConville, Tebbetts, and Walker, 1989)
1990	Navy women's uniforms (Mellian, Ervin, Robinette, 1990)
1995	ASTM standards approved (ASTM, 1995)
2000	CAESAR
2001	SizeUK
2002	SizeUSA

Carrere et al. (2000) gave five dimensions on which US women's sizes are based: height range, bust girth range, waist girth range, hip girth range, and bust point to bust point. There is nothing that accounts for different shapes with those girth measurements. Schofield and LaBat (2005) gave three steps typical in the process of developing a sizing system: "(a) division of the population into categories (each to have its own size chart), (b) choice of a primary size interval for each chart, and (c) choice of intervals for remaining body measurements for each chart" (p. 17). Loker et al. (2005) pointed out that, “a sizing system is only as good as the method and creativity that go[es] into the development of the system” (p. 3). This suggests that the previous methods of sizing and grading based on proportions of the assumed human figure are not working, and new methods must be developed.

The “inadequacies of ASTM sizing standards in meeting the needs of consumers in three target groups, segmented by age: Juniors, Missy and Over 55” were reviewed by Newcomb and Istook (2004, p. 1). Cconsumers ranked apparel fit as one of the high areas of intense frustration, as did apparel manufacturers since fit is hard to measure. According to Sirvart Mellian, “quality control people at women’s and children’s apparel manufacturers report that the highest number of returns retailers get is because of size and fit” (Agins, 1994, B1). Focusing only on returns does not give a full scope of the entire sizing problem. It is widely known in the apparel industry that, “these standards are largely based on outdated, decades-old anthropometric data, the extent to which the standards fit current consumer body shapes is not fully known” (Newcomb & Istook, 2004, p. 2). The main research objective of the Newcomb and Istook study (2004) was to show that ASTM standards developed for the Junior, Missy, and over 55 markets use body shapes not predominately found in the U.S. The researchers took the body measurements from each of three standards and processed them through the FFIT for Apparel © software developed at North Carolina State University’s College of Textiles. The FFIT for Apparel © software uses measurement input to divide subjects into nine different body shapes: Hourglass, Bottom hourglass, Top hourglass, Rectangle, Diamond, Oval, Spoon, Triangle, and Inverted triangle.

The FITT for Apparel © software was used to find the body shapes the ASTM standards best fit for the Junior, Missy, and over 55 categories. Two shapes, diamond and oval, were excluded since the ASTM and SizeUSA measurements did not include population data required for classification into those shapes. Since the SizeUSA data replicates the population distribution of the U.S., "the results may be extrapolated to describe the entire U.S. population" (Newcomb & Istook, 2004, p. 2). Juniors' ASTM standard measurements correspond to an hourglass body shape, but SizeUSA data puts 52% of the sample as rectangular shape, 13.6% as spoon shape, and 12.5% as hourglass shape. The ASTM Missy sizes also correspond to an hourglass body shape, but SizeUSA data has over 80% of the sample with a rectangle, spoon or inverted triangle shape. Only 8% of the sample is an hourglass shape, which again shows that the ASTM Missy standard is highly inadequate to fit a Missy consumer. The results illustrated that the Junior and Missy ASTM Standards are not based on the dominate body shapes in the U.S. and do not fit the Junior or Missy target market. According to their classification system, half of the population is rectangular in shape, and the standard is aimed at an hourglass shape. Newcomb and Istook suggested, "revisions of the ASTM sizing standards based on this SizeUSA would improve the fit of clothes, improve customer satisfaction, and enhance the business performance of apparel retailers" (Newcomb & Istook, 2004, p. 6).

Patternmaking

"Due to the emphasis on the mass production of ready-to-wear, little innovative work has been done on specifically fitting patterns in the last 60 years" (Heisey, 1984, p.

12). Tables 3, 4, and 5 were organized to effectively compare body measurements used in drafting, pant pattern alteration instructions, and patternmaking solutions for fit problems. There are many different authors and methods of pattern drafting and altering. Heisey (1984) pointed out that, “traditionally there have been two major methods of producing a specifically fitted garment pattern, drafting and draping” (p. 3); now with the 3D to 2D patternmaking capability from body scanning technology there are three ways to produce a custom-fitted pattern.

Table 3 was developed to show various body measurements that different drafting methods use to make pant patterns. References were textbooks and sewing industry publications. There are differing opinions on which measurements to use for pant patterns, but many of the suggested measurements overlap. The most commonly suggested measurements were: waist circumference, crotch length, crotch depth, waist to ankle length, and hip circumference. Joseph-Armstrong (2006) and Hollen and Kundel (1999), the two most recent textbooks, used the most measurements to draft a simple pant pattern, which is evidence that in recent years patternmakers have come to the conclusion that not everybody is proportionally the same. They not only use circumferences, but also lengths of waist to knee, waist to floor, and waist to ankle, which helps with placement of the knee line. Thus, by taking more measurements, a pattern is made with the intended person’s proportions taken into account. It is interesting to find that Hollen and Kundel (1999) draft the pant from a commercial straight skirt pattern, which in theory has already been altered to fit the wearer. They reason that if the skirt sloper fits, the pant sloper will also fit. To those who have fitting experience, this does not usually hold true. The crotch

Table 3

Body Measurements Used in Drafting Pant Patterns

Body Measurement	Minott 1974	Layton 1980	Singer 1989	McCalls 1963	Readers Digest 1999	Brackelsberg and Marshall 1999	Joseph-Armstrong 2006	Hollen and Kundel 1999
Hip Type (Shape)	X							
Hip Circumference		X	X	X	X		X	
Hip Depth			X					
Waist Circumference		X	X	X	X	X	X	
Waist to Knee Length	X		X				X	X
Waist to Floor Length							X	
Waist to Ankle Length	X		X	X	X		X	X
Thigh		X						X
Inseam		X						
Outseam		X						
Crotch Depth	X	X	X	X	X	X	X	X
Crotch Length (F, B, or Total)	X	X	X		X	X	X	X
Knee to Ankle Length								X
Knee Circumference							X	X
Calf Circumference							X	X
Ankle-Heel Circumference				X			X	X

depth and crotch length are difficult areas of fit and normally go through a few fittings and pattern changes before the final pant sloper is perfected.

Layton (1980), Singer Corporation (1989), McCalls (1963), and Readers Digest (1999) are more commercial sewing books than sewing textbooks. All four have the general measurements that should be taken to draft (or adjust) a pant pattern, with a few exceptions. Layton (1980) was the only resource that takes the inseam and outseam measurements into account, instead of measuring pant length from waist to floor. The curvature of the waist seam may throw off this measurement. Singer Corporation (1989) called for the hip depth measurement, which helps in placing the widest part of the hip circumference on the pattern, and, thus, the person's greatest girth is in the correct place. McCalls (1963) defined the crotch length as sitting down and measuring from the waist to chair; this is normally the way the crotch depth is found. Crotch depth was defined as the distance from waist to floor minus the crotch line to floor. Unlike later authors, Minott (1974) took into account a person's body shape by looking at hip type, hip size, and posture type. She did not look at hip circumference like the majority of the other authors.

One author, Deckert (1999) was not added to the tables since her suggestions were specifically for plus sizes and not all patterns in general, but had some important points for that body size. Deckert suggested that the crotch point for plus sizes be positioned forward on the body and that extra ease is needed in length and width since the body shifts as plus size women sit down.

The next table, Table 4, includes various fit problems and suggested solutions. These were taken from sources that had fit problems listed. Minott (1974) had the longest list of possible fit problems and how to change the pattern to correct the problem.

For example, if there is pulling below the back crotch, she called for lengthening the crotch depth. This allows for more distance from waist to crotch line and will release the pulling on the back of the leg. Most changes only discuss correcting a circumference measurement or a length change. None specifically say to check a shape of a hip curve or crotch curve to see if the correction can be made in the shape of the line.

The last table, Table 5, gives different pattern alteration methods. These methods vary from the slash and spread technique to adjusting the wedge at the abdomen, or to redraw a point in or out. For example, to make a correction to the crotch point, Singer Corporation (1989) suggested, lengthening the crotch line, then measuring and marking the point. They did not instruct how to adjust the crotch curve, e.g. making the curve more shallow or deepened.

Table 4

Various Fit Problems and Given Solutions by Different Authors

Fit Problem	Minott 1974	Layton 1980	Singer 1989	Readers Digest 1999	Joseph-Armstrong 2006
Wrinkles cupping crotch	Lengthen crotch depth	Add ease at SS and crotch	Lengthen F/ B equal amount above hipline		Add half measurement to each inseam
Pull below back crotch	Lengthen crotch depth			Enlarge area over buttocks, make darts shallower	
Back waist dips when seated	Check crotch point and depth				Add 1 to 2" in at CB blending to SS point
Excess fabric under seat	Shorten Crotch length				Slash at hip and overlap measured amount
Crotch too long or fold on front	Shorten crotch length		Shorten F and B equal amount above hipline		Measure and raise crotch point
Folds or extra fabric at front	Decrease hip circumference			Take in SS until smooth	
Excess fabric at side of hip	Decrease hip circumference		Lap lower sections along given slash line		
Pulls across front thighs	Lengthen B crotch point, check hip circumference		Lengthen front crotch point	Let out SS and taper to nothing at hip and knee	Add 3/4 measured amount at crotch point and 1/4 measured amount at SS
Pulls across back seat	Increase hip circumference	Adjust below crotch line			
Sagging below seat with ripples at SS	Check waist depth; change wedge relationship	Decrease crotch curve			

(Continued)

Table 4 (Continued)

Fit Problem	Minott 1974	Layton 1980	Singer 1989	Readers Digest 1999	Joseph-Armstrong 2006
Break below seat or Dent at Back Knee	Front wedge too wide				
Front crotch too long or high	Decrease front wedge or waist depth				Lower crotch point at F and B
Low CF/CB waist	Decrease waist depth, check wedges		Spread wedge and lengthen B crotch point		Slash at hip line and open up wedge
Legs fall against or pull from inside	Let inseam out and take in outseams		Move section below knee line toward inseam		
Inseam ripples below crotch	Adjust thighs let inseam out and SS in				
Loose on one side, tight on the other (diagonal pull at SS)	Adjust for asymmetric hip width and depth			Let out darts and SS, fit darts to contours, do both F and B	Reposition SS and back dart
Crease line swings to inside of foot	Adjust wedges, check waist depth		Move section below knee line toward SS		Add at waist SS point blend to hip and CF

Table 5

Pant Pattern Alteration Methods

Type/Placement of Alteration	Minott 1974	Layton 1980	Singer 1989	McCalls 1963	Readers Digest 1999	Brackelsberg and Marshall 1999
Crotch Depth	Redraw point in or out	Slash at line between bottom of crotch and adjust wedge	Adjust at line 5" down from waist	Overlap desired amount at widest point from crotch to SS	Slash at lengthen and shorten line then adjust	Slash and adjust at hip level
Hip Circumference	Increase or decrease same amount along lengthwise grain	Add or subtract at hip point	Slash on guidelines and spread or lap	Slash line parallel to grain, avoid darts and adjust	Add or subtract to hip at SS and taper to waist and thigh	Slash and spread on line parallel to grain and make adjustment at waist and hip line
Length	Adjust above and below knee line	Cut and add at knee line	Adjust above and below knee line	Adjust at line below knee	Use line on pattern to adjust	
Crotch Point	Draw new point in or out		Lengthen crotch line then measure and mark point			Take in or let out crotch curve
Waist Depth	Raise or lower waist seam at CF or CB					Slash near hip curve and use pivot point at SS hip line, spread to make adjustment
For Large Abdomen	Make front wedge larger	At alteration line cut in and make wedge open more at CF	Make wedge at fullest part of abdomen	Slash at center of waistline dart and slash 3" below waistline, spread needed amount	Add Length at front where needed	Let out inseam
For Large Seat	Adjust wedge	At alteration line make wedge open more at crotch line	Make wedge at hipline and lengthen crotch point	Make darts deeper and longer, add to SS and inseam on back		
Waist Line		Draw out from hip	Fold out darts, slash on guidelines then spread or lap	Adjust width of darts, if not enough adjust SS as well	Add or subtract from F or B crotch seams	
Waist Line		Adjust at line between bottom of crotch and waist	Make wedge and adjust		Adjust crotch point or crotch seam	Let out inseam and make wedge at hipline
For Small Seat		At alteration line overlap necessary amount	Lap wedge at hipline and shorten back crotch point	Remove extra length, decrease darts, and take out extra at waistline and hip		

III. METHODOLOGY

The purpose of this research was to compare pattern shapes and pattern measurements for tween girls across age, body size, and body shape categories. Research on this quickly growing target market is limited. There is no research comparing pattern shapes of real tween girls' bodies. Published information about pattern shapes focuses on adult women and often relates to commercial patterns. This research used normal, overweight, and obese tween girl 3D body scan data. Pattern shapes studied were created directly from body scan data and printed using CAD technologies. This chapter explains how the body scans were collected, the processes to print out the pant patterns, and the methods used to analyze and measure those patterns.

Sample

Subjects for this study were drawn from all available tween girl scans stored in Auburn University's body scan collection. The database of tween scans was collected in two different locations: $[TC]^2$ in Cary, NC, in October, 2004 and Auburn, AL, in November, 2005 using the $[TC]^2$ NX12 body scanner. As shown by Simmons and Istook (2003), the $[TC]^2$ scanner "is the choice among scanners for the needs of the apparel industry" (p. 328). The total number of available scans was 151, broken down by age as seen in Table 6.

Table 6

Break Down of Sample Size By Age

Age	Sample Size
9	17
10	21
11	26
12	28
13	28
14	31

Subject Grouping

At the time of scanning, research personnel measured the height and weight of each subject. These were used to calculate Body Mass Index (BMI) scores. Each of the 151 scans was printed and subject age, height, and BMI were recorded on the printout to categorize the groups. All scans were considered in identifying representative examples for comparative categories.

O'Brien and Shelton (1941) suggested breaking down the population by vertical and horizontal measurements. The vertical measurements were divided into three height classes and the horizontal measurements into three weight classes. "They recommended separate size charts for each of these resulting nine categories of women" (Schofield & LaBat, 2005, p. 17). These vertical and horizontal measurements are directly related to BMI since it is calculated using a person's height and weight.

Since girls are physically changing in this period of their lives and an age range of 9-14 has different stages, the scans were categorized by age into three groups of 9-10 year olds, 11-12 year olds, and 13-14 year olds to try to cluster as closely as possible different developmental stages. Within each age group, body scans were classified into BMI groups based on scores from Figure 1, the CDC's BMI for Age chart (CDC, 2006)

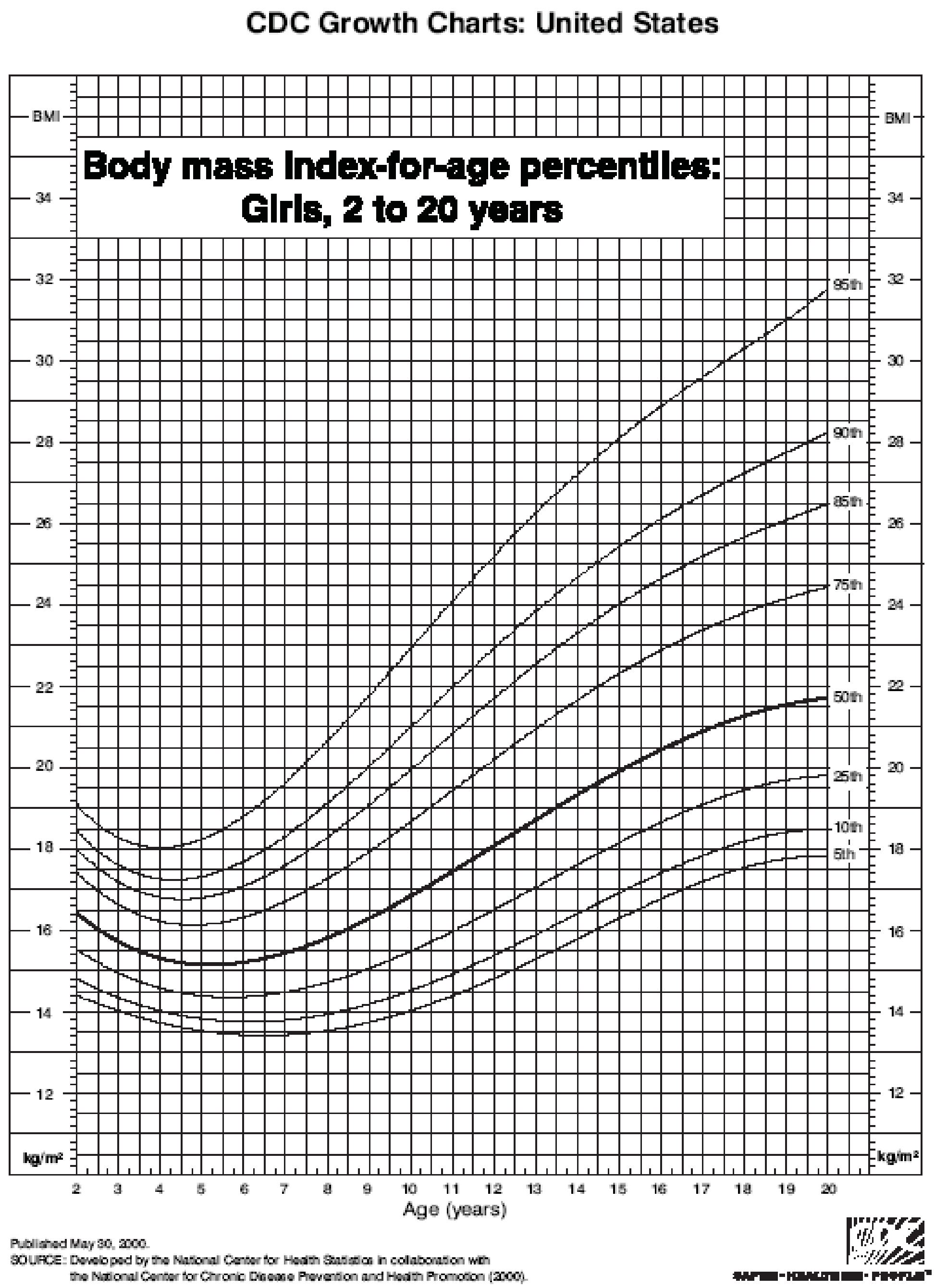

Figure 1. Center for Disease Control growth chart BMI for age

and Lee's (2006) derived version, Table 7. Body size was classified and recorded as 'normal', 'overweight' or 'obese'. The 'normal' girls are the 6th to 84th percentile, 'overweight' the 85th to 94th percentile, and 'obese' the 95th percentile and higher. The below 5th percentile is the underweight group, and there were no subjects in this sample. These body size groups are referred to as normal, overweight, or obese in the upcoming text. Table 8 shows the sample numbers resulting from sorting the 151 scans into age and body size groups.

Table 7

BMI Range by Age Derived From CDC

Age	BMI range under the 5th percentile	BMI range 6th to 84th percentile	BMI range 85th to 94th percentile	BMI range over the 95th percentile
9	Up to 13.6	13.7-19.1	19.2-21.8	Over 21.9
10	Up to 14.0	14.1-20.0	20.1-23.0	Over 23.1
11	Up to 13.9	14.0-20.8	20.9-24.1	Over 24.2
12	Up to 14.8	14.9-21.6	21.7-25.2	Over 25.3
13	Up to 15.2	15.3-22.6	22.7-26.2	Over 26.3
14	Up to 15.8	15.9-23.2	23.3-27.2	Over 27.3

(Lee, 2006, p. 59)

Table 8.

Body Size By Age

Body Size	Age	Sample
Normal	9-10	21
	11-12	33
	13-14	36
Overweight	9-10	10
	11-12	8
	13-14	10
Obese	9-10	7
	11-12	13
	13-14	13

After being broken down by age, each scan was sorted into body size groups, normal, overweight and obese, using Table 7 to determine the placement. The sample size groups for age and body size are seen in Table 8. Each age and body size group was broken down into body shapes. Shape analysis was visually determined by the researcher using the Body Shape Assessment Scale (BSAS ©) developed by Connell, Ulrich, Brannon, Alexander, Presley (2006). This scale was specifically designed for use with body scan data to evaluate the adult female figure. No similar scales are currently available for children or adolescents. Both front and side views were considered when categorizing body shape, as instructed in Connell et al. (2006) and as suggested by Ashdown et al. (2004) in their analysis of fit using 3D body scans. To determine body shape, the relationship between shoulders, waist and hip chart was used from the BSAS © see Figure 2. In each age and BMI group, the scans were sorted into the following four whole body shape groups: Rectangular, Hourglass, Pear, or Inverted Triangle (Connell et al., 2006)

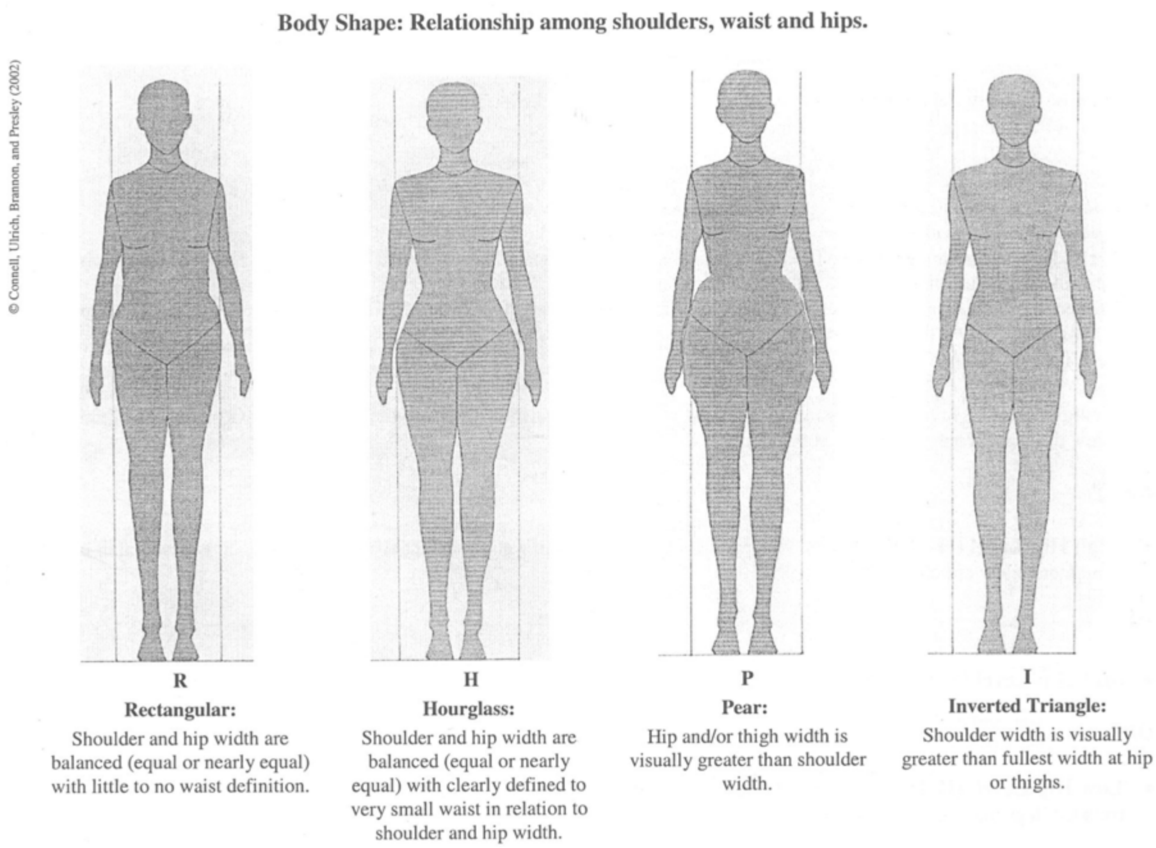

Figure 2. Body Shape Assessment Scale (BSAS ©) from Connell et al., 2006.

After being sorted by whole body shape, the scans were sorted into torso shape groups. The side view was used to determine the torso shape. Figure 3 shows torso shapes "b", "D", and "B" from the BSAS©. The "b" shape is fullness below a defined waist with the upper stomach relatively flat. The "D" shape is curved from below bust to lower abdomen, and has no waist indentation in the stomach area. The "B" shape has a defined waist with curvature above and below the waist.

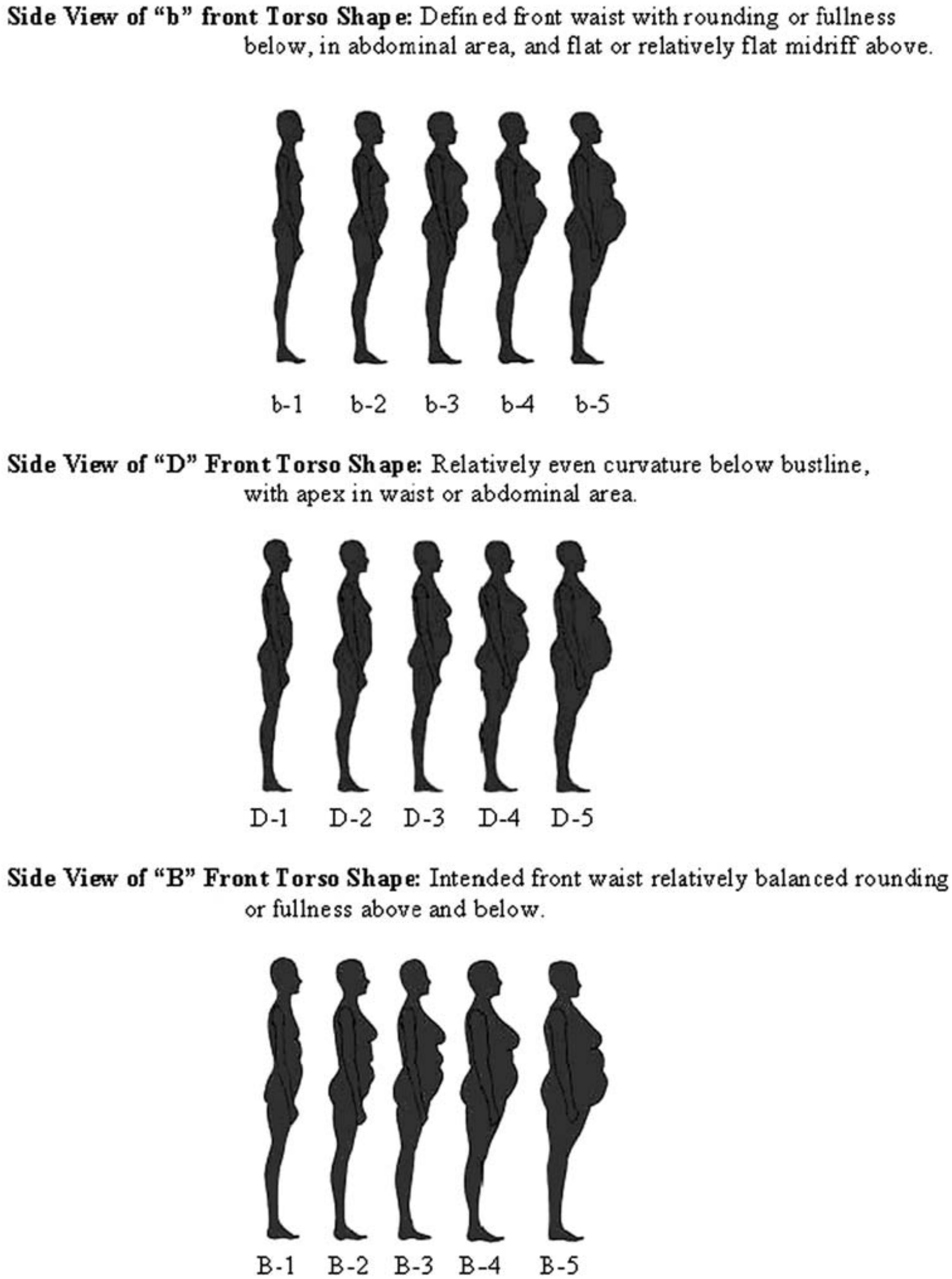

Figure 3. Side torso shapes from the Body Shape Assessment Scale (BSAS ©) (Connell et al., 2006)

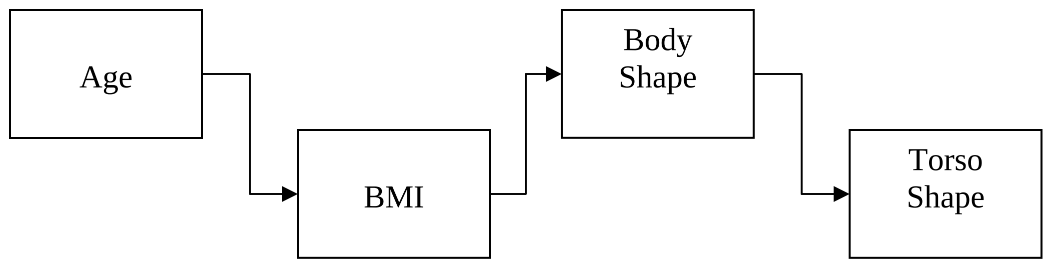

Figure 4. Flow of sorting method for body scans

Figure 4 reviews the complete sorting process. Once each scan was sorted, e. g., a 9-10 year old, normal body size, rectangle body shape, and “b” torso shape, averages were taken of height, weight, and BMI and shape was analyzed visually. To find an average shape in the visual analysis, the mathematical averages for height, weight, and BMI were used to determine which scans could be considered for the best representative of that group. The scans that best fit the mathematical averages were then visually analyzed to find the one closest to the BSAS © examples. From those averages, the scan that best illustrated the characteristics of the group was chosen to represent that group. A total of eighteen bodies were the representative of each age, body size and body shape group.

Gazzuolo (1985) had the foresight to predict that both 2D and 3D methods would be used to compare female body shape and pattern development (Connell et al., 2006). This study used the BSAS© to determine body shape, the 3D body scan data to obtain linear measurements, and the 3D to 2D pattern making software for pattern development.

Pattern Development

With the 3D to 2D patternmaking software developed by $[TC]^2$, it is possible to automatically extract garment blocks/slopers and finished patterns without using measurements. Instead, 3D to 2D conversion uses automatic land-marking and site location for darts, seams and other features to create slopers without ever touching an actual person ([TC]^2, 2006). The software version used in this study was the [TC]^2 NX 12 Body Scan software, Version 6.

To develop the 18 patterns for the age, BMI, body shape, and torso shape groups, each representative scan was viewed on the computer screen and analyzed to confirm the 3D body scan data point cloud had no incorrect or haphazard point that would affect measurements. Using the BMS, that is standard on the NX12 body scanner, measurements were extracted using a specified .mep file (measurement extraction profile). A .mep file consists of predetermined places on the body where measurements are taken. For example, the waist can be defined as being the distance between a point on the small of the back to between an upper and lower limit on the front, the narrowest circumference starting at the small of the back with a user-defined amount that will float up and down from that point, or by letting the program choose (See Figure 5). The parameters for measurements for this study were the options in the software chosen by the researcher (Table 9). The dart width and length were chosen by the program, but the minimum and maximum lengths, widths, number, and placement of darts was defined by the researcher, as well as the dart placement. Ease measurements are also defined in the pattern making software. The dart placement and ease measurements are both seen in Table 10.

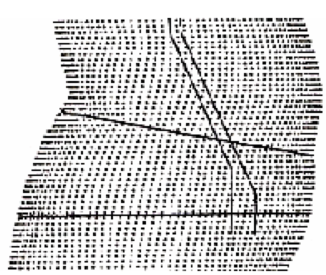

Figure 5. Visual of waistline placement (top line) by the .mep file.

Table 9

Parameters as Defined in .mep File

Measurement	Parameter
Waist	Small of back (center back point) to point on front with set upper limit of +1 in or above small of back and lower limit of -1 in below small of back
Hip	Largest circumference between the crotch and waist
Thigh	Largest circumference between the top of the knee and 2 inches below crotch point
Outseam	From waist to widest point above crotch (usually the hip level) and then straight down
Inseam	Straight down from crotch point to inside of foot, following the leg to the ankle bone

Table 10

Software Parameters as Defined by the Researcher

Ease		Darts	Front	Back
Waist	1"	Min Number	1	2
Abdomen	0.5"	Max Width	2"	2"
Seat	1.5"	Min Width	0.5"	0.5"
Hips	1.5"	Max Length	1"	1"
		Min Length	4"	4"

Once the .mep file was defined, measurements were extracted. When measurements were extracted, a .dxf file of the pant pattern was automatically generated and saved in a separate file folder. A .dxf file is a drawing interchange format used for computer aided design (CAD) work and is a format that is interoperable between different CAD systems (AutoCAD DXF, 2007). The .dxf file was then converted by using Gerber's .dxf file conversion software. The new pattern file was then opened in the Gerber workspace and checked for any stray lines or points. The patterns were labeled and then plotted using a Gerber Infinity plotter. Hip lines and crotch lines were drawn across the pattern perpendicular to the crease line. The dart fold line was also drawn by measuring the dart space and drawing a line from the mid-point to the dart point. The hip line and crotch line were used as reference places when comparing the pattern shapes (See Figure 6.)

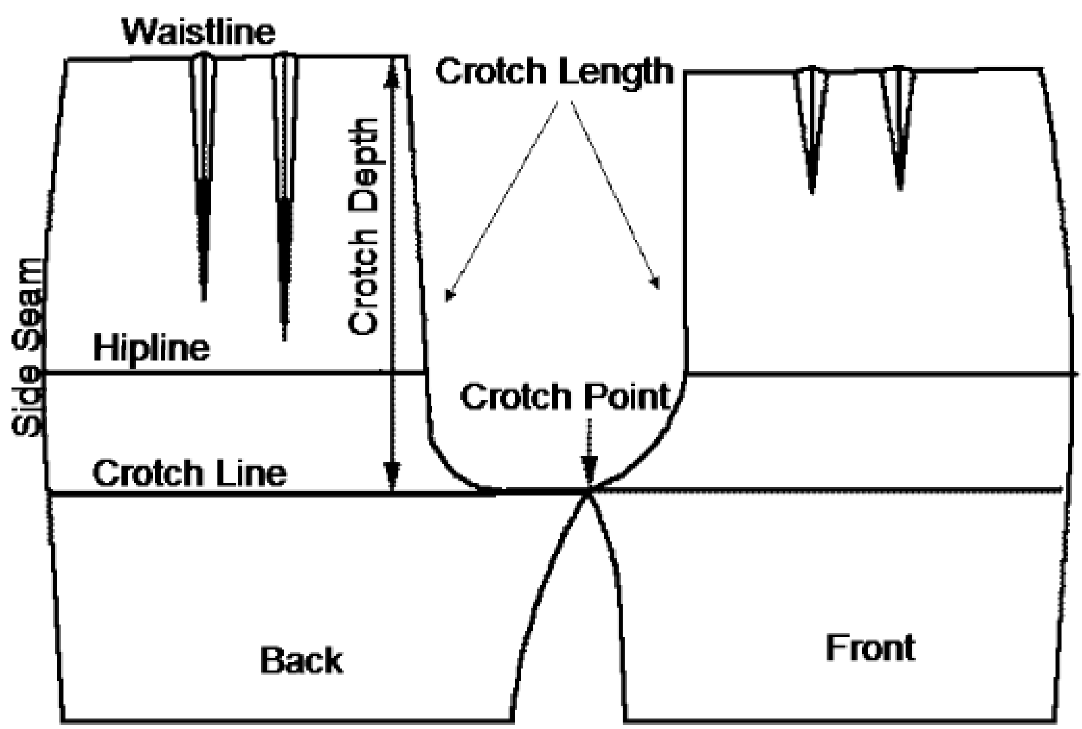

Figure 6. Visual of Pant Pattern Terminology. Edited image from Lindrix (2006).

Data Analysis

Pattern Assessment

Comparison of pant pattern differences was done by hand. Measurements were taken using a grid ruler. The researcher recorded and entered measurements into an Excel spreadsheet. Each comparison measurement was taken three separate times and averaged to account for human error. A protractor was used to determine the center front and center back angles. The angle was measured along a line that was drawn perpendicular to the crotch line and extended through the hipline. The protractor was lined up along the drawn line on the 180º line and the 90º mark was aligned with the hipline. The angle measurement was taken 3” up from the hipline because of the size of the protractor.

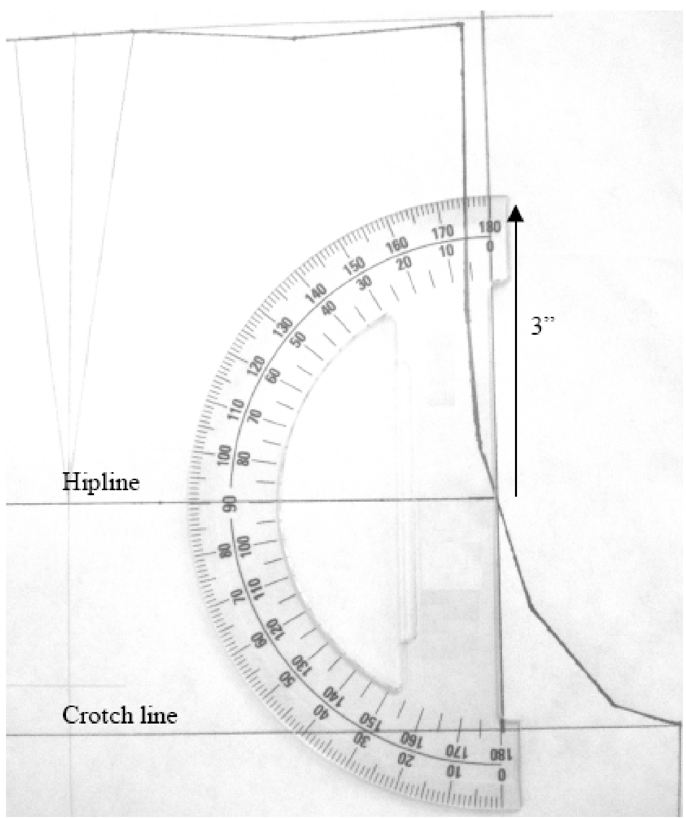

Figure 7. Set-up for measurement of center front and center back angles.

Research questions were answered using the data analysis that is described in the following section:

1. Does the proportional relationship between crotch depth and overall length change in relation to age, body size, and body shape?

This question was answered by determining the difference between the length of the side seam and the crotch depth measurement. The average crotch depth and overall side seam length was calculated and the range of the measurements recorded. The ratios were derived and compared among ages 9-10, 11-12, and 13-14. Data were tabled to compare among body size subgroups (normal, overweight and obese), and among three body shape subgroups (hourglass, rectangle, and pear).

2. Does the crotch point width differ among age, body size, and body shape groups?

This question was answered by measuring from the side seam to crotch point along the crotch line for front and back. The average crotch point width was calculated, and the range of the measurements identified. Those averages were compared among ages 9-10, 11-12, and 13-14. The averages were also compared across body shape and body size groups.

3. Is there a difference in crotch length for different age, body size, and body shape groups?

The crotch lengths were measured from waist point to crotch point along the crotch curve. Three measurements were used for front crotch length, back crotch length, and total crotch length, and these were compared across groups.

4. Does the proportional relationship between hip depth and overall length change in relation to age, body size, and body shape groups?

This question was answered by determining the proportion of the hip depth to the length of the side seam measurement. The average proportion was calculated and the range of the measurements noted. The proportion was taken from waist to hip divided into waist to hem compared across groups. The proportions were compared among ages 9-10, 11-12, and 13-14, among body sizes (normal, overweight and obese) and across three body shapes, hourglass, rectangle, and pear.

5. a) Does the hip-to-waist circumference difference change in relation to, age, body size, and body shape groups?

   b) Does shape of the side seam between the hip and waist change in relation to age, body size and body shape groups?

a) The total hip and total waist measurements were calculated to determine the difference between hip and waist circumferences.

b) For the shape of the side seam, a visual analysis was done along the hip curve. The curve was compared to a straight line drawn squared up from the hip line. Shapes were described as ‘none’/straight, ‘shallow’/flat, or ‘deep’/curved since there was no way to measure the difference in shape to compare across groups.

6. Does the waistline shape differ in relation to age, body size and body shape groups?

A visual analysis was done along the waistline. The curve was compared to a straight line drawn squared from the crease line. Shapes were described as ‘no curve’/straight, ‘shallow’/flat, or ‘deep’/curved since there was no way to measure the difference in shape to compare across groups.

7. Is the center back line angle different between age, body size, and body shape groups?

Angle measurements were taken using a protractor with the 180º line aligned with the crotch line and angle degree recorded and compared across groups. (see Figure 7)

8. Is the center front line angle different between age, body size, and body shape groups?

Angle measurements were taken using a protractor with the 180º line aligned with the crotch line and angle degree noted and compared across groups.

Analysis involved comparing and contrasting findings relative to current patternmaking practices in the field.

IV. DATA PRESENTATION AND ANALYSIS

The purpose of this research was to compare and contrast pant pattern shapes and measurements to help improve pant fit based on current anthropometric data for the tween girl target market. The study made use of the 3D-to-2D electronic patternmaking software that is associated with $[TC]^2$'s body scanner. Data presented in this chapter reflects measurements of pant patterns developed to represent selected body sizes and shapes for girls aged 9-14.

Sample and Procedures

The sample used in this study was drawn from the 151 tween girl scans stored in Auburn University's body scan collection. The database of tween scans was collected in two different locations: $[TC]^2$ in Cary, NC, in October, 2004, and Auburn, AL, in November, 2005, using the $[TC]^2$ NX12 body scanner. Eighteen scans were chosen as representative for comparison in this study.

To determine the scans that would be used in this study, all 151 scans were broken into the three variable groups of age, body size and body shape. First, the scans were sorted into age subgroups, 9-10, 11-12, and 13-14 year olds, in an attempt to cluster different developmental stages of growth. Then, within each age subgroup, the scans were divided by BMI into body size subgroups, with the subgroups being normal, overweight, or obese. Last, within each age and body size group, scans were sorted into body shape subgroups identified visually according to the BSAS© (Connell et al.., 2006). The three body shape groups of hourglass, pear, and rectangle were found. The scans were also analyzed for torso shape groups, with the majority of the scans having a "D" or "B" shape (as discussed in Chapter 3, Figure 3). Since minimal variance in torso shape was found, it was not included as a subgroup.

Once each scan was sorted into subgroups, e.g., a 11-12 year old, overweight body size, and rectangle body shape, averages were taken of height, weight, and BMI for each subgroup. From those averages and a visual analysis of shape, a scan was selected for each subgroup that best illustrated that subgroup's characteristics. Since every age subgroup did not have different body shapes, but did have different body sizes, the total number of representative scans came to 18. (See Appendix B) Of the three age subgroups, the 9-10 year old subgroup had only one body shape, the rectangle. A breakdown sample by age subgroup was three 9-10 year olds (16.7%), seven 11-12 year olds (38.9%), and eight 13-14 year olds (44.4%). The breakdown of the sample by body shape subgroups was eight rectangles (44.4%), four hourglasses (22.2%), and six pears (33.3%). The sample breakdown of body size subgroups was seven normal (38.9%), five overweight (27.8%), and six obese (33.3%). The age and body shape groups were skewed a bit since the 9-10 year olds only had rectangle body shapes. Across the body size subgroups (normal, overweight, and obese), there was at least one pear, one hourglass and one rectangle body shape within each subgroup.

Patterns were generated using the 3D-to-2D software from $[TC]^2$ and based on individual body scans. Pattern measurements for each pattern were taken by hand by the researcher. Each pattern was measured three times to account for human error. The waist, crotch and hip placement were double checked by the researcher to insure that they were identified correctly by the scanner using the defined parameters for placement.

Visual analyses of the patterns' linear shapes were also conducted by the researcher (Research Questions 5b and 6). Qualitative data analysis included comparing and contrasting measurements from the patterns across age, body shape, and body size subgroups.

Findings

Research Question 1: Does the proportional relationship between crotch depth and overall length change in relation to age, body size, and body shape?

Measurements were taken along the side seam to the crotch line for crotch depth and along the full length of the side seam for overall length.

Table 11

Crotch Depth and Overall Length Findings by Age Subgroups

Age	CD: Mean	CD: Range	SSL: Mean	SSL: Range	CD-to-SSL Proportion: Mean	CD-to-SSL Proportion: Range
9-10 (n=3)	9.708"	1.25" (9.125-10.375")	34.958"	2.125" (33.625-35.75")	3.606	0.242 (3.446-3.88)
11-12 (n=7)	11.071"	3.625" (8.125-13.75")	38.536"	3.25" (37.375-40.625")	3.566	1.782 (2.82-4.60)
13-14 (n=8)	10.906"	3.625" (9.125-12.75)"	39.156"	5.875" (36-41.875")	3.618	0.895 (3.12-4.01)

CD = Crotch Depth (along side seam)

SSL = Side Seam Length

Table 11 shows that both the means and ranges for side seam length increased across age subgroups; the biggest jump was between the 9-10 and 11-12 year olds subgroups' means. The widest range of side seam lengths was found in the 13-14 year olds subgroup. In looking at crotch depth means and ranges, the biggest change in means was also between the 9-10 and 11-12 year old subgroups, but the shortest and longest crotch depths were in the 11-12 year old subgroup, and the 13-14 year old subgroup's mean was slightly shorter than the 11-12 year old subgroup mean. The crotch depth increased only by about two inches between the youngest and oldest, and the net range of crotch depths was the same for 11-12 and 13-14 year old subgroups. When looking at crotch depth to side seam length proportions, the means were quite similar (3.606, 3.566, and 3.618). The 11-12 year old subgroup had the widest range of proportions.

Table 12.

Crotch Depth and Overall Length Findings by Shape Subgroups

Shape	CD: Mean	CD: Range	SSL: Mean	SSL: Range	CD-to-SSL Proportion: Mean	CD-to-SSL Proportion: Range
Pear (n=6)	11.167”	4” (9.75-13.75”)	38.521”	1.625” (37.625-39.25”)	3.489	1.041 (2.818-3.859)
Hourglass (n=4)	10.75”	2.875” (9.125-12”)	39.188”	5.875” (36-41.875”)	3.661	0.455 (3.49-3.945)
Rectangle (n=8)	10.484”	5.25” (8.125-13.375”)	37.5”	7” (33.625-40.625”)	3.644	1.563 (3.037-4.6)

CD = Crotch Depth (along side seam)

SSL = Side Seam Length

The crotch depth means increased from rectangle to hourglass to pear (see Table 12). All three means were within 0.7” of each other. The hourglass subgroup had the least variation or range in crotch depth measurements. The side seam length means increased from rectangle to pear to hourglass body shapes. Side seam length means were within 1.6” of each other; whereas the range of pear measurements was less than 2”, the range for the rectangle subgroup was 7”. Despite this variation, the crotch depth to side seam length proportions ranged by only 0.172”.

Table 13

Crotch Depth and Overall Length Findings by Size groups

Size	CD: Mean	CD: Range	SSL: Mean	SSL: Range	CD-to-SSL Proportion Mean	CD-to-SSL Proportion Range
Normal (n=7)	9.875”	2.875” (8.125-11”)	37.804”	3.5” (33.625-40.875”)	3.856	0.519 (3.494-4.6)
Overweight (n=5)	11.15”	1.625” (10.375-12”)	38.85”	6.125” (35.75-41.875”)	3.486	0.253 (3.34-3.593)
Obese (n=6)	11.5”	4.625” (9.125-13.75”)	38.167”	5.125” (35.5-40.625”)	3.384	1.127 (2.818-3.945)

CD = Crotch Depth (along side seam)

SSL = Side Seam Length

Table 13 shows that similar to the age subgroups, the size subgroup’s crotch depth means varied by less than 2”. The overweight and obese subgroups had similar crotch depth and side seam length means. The obese subgroup’s crotch depths ranged more widely than the side seam lengths. As body size increased, the crotch depth means increased, but the crotch depth to side seam length proportion means decreased.

In comparing all the groups, the age and size groups had the largest differences in crotch depth means. The 9-10 year old subgroup had the shortest side seam length mean and smallest crotch depth mean across all groups. The hourglass subgroup had the largest side seam length mean and the obese subgroup had the largest crotch depth mean.

Of all the subgroups, the largest crotch depth to side seam length proportion mean was the normal subgroup and the smallest crotch depth to side seam length proportion mean was the obese subgroup. It seemed age and body size had the biggest effect on crotch depth to side seam length proportion.

Research Question 2: Does the crotch point width differ among age, body size, and body shape groups?

Measurements for this research question were taken along the crotch line from side seam to crotch point.

Table 14

Crotch Point Width Findings by Age Subgroups

Age	Back CPW: Mean	Back CPW: Range	Front CPW: Mean	Front CPW: Range
9-10 (n=3)	11.979”	4.625” (9.5-14.125”)	12.188”	4.5” (10-14.5”)
11-12 (n=7)	13.188”	5.688” (10.188-15.875”)	13.188”	2.875” (11.875-14.75”)
13-14 (n=8)	13.688”	4.75” (11.125-15.875”)	13.414”	2.875” (11.875-14.75”)

CPW = Crotch Point Width

In comparing crotch point width means, both the back and front crotch point width means increased with age (see Table 14). The biggest jump in means occurred between the 9-10 and 11-12 year old subgroups. The 11-12 year old and 13-14 year old subgroups had similar back and front crotch point width means. The 11-12 year old subgroup had the exact same front and back crotch point width means, and the other two age subgroups had means that differed between front and back by approximately 0.2”. The back crotch point widths ranged approximately 0.5” more than the front widths (1.6” vs. 1.1”).

Table 15

Crotch Point Width Findings by Shape Subgroups

Shape	Back CPW: Mean	Back CPW: Range	Front CPW: Mean	Front CPW: Range
Pear (n=6)	13.406”	5.687” (10.188-15.875”)	13.417”	2.625” (12.125-14.75”)
Hourglass (n=4)	13.468”	4.75” (11.125-15.875”)	13.672”	2.875” (11.875-14.75”)
Rectangle (n=8)	12.406”	4.75” (9.5-14.25”)	12.625”	4.5” (10-14.5”)

CPW = Crotch Point Width

The pear and hourglass subgroups’ back and front crotch point widths were similar within and across subgroups, as seen in Table 15. The rectangle subgroup’s back and front crotch point width means were approximately one inch shorter than the other two subgroups. The pear subgroup had the widest back crotch point width range and the smallest front crotch point width range. All shape subgroups' crotch point width means, front or back, were within approximately 1" of each other.

Table 16

Crotch Point Width Findings by Size Subgroups

Size	Back CPW: Mean	Back CPW: Range	Front CPW: Mean	Front CPW: Range
Normal (n=7)	11.813"	6.375" (9.5-15.875")	12.232"	4.75" (10-14.75")
Overweight (n=5)	13"	1.813" (12.063-13.875")	13.263"	2.188" (12.063-14.25")
Obese (n=6)	14.313"	2.625" (13.25-15875")	14.042"	1.438" (13.313-14.75")

CPW = Crotch Point Width

Table 16 shows that similar to the age subgroups, the body size subgroups' back and front crotch point width means increased as the body size increased. There was a 2.5" difference in back crotch point width means and a 1.8" difference in front crotch point width means across size subgroups. The greatest range of measurements was observed for the normal subgroup's front and back crotch point widths.

The back and front crotch point width means increased as age and body size increased. A comparison of means for front and back crotch widths showed that they were within 0.5" of each other across each of the nine subgroups. Back crotch point width means changed the most across size subgroups. The normal body size subgroup had the smallest back crotch point width mean of all the groups and the obese body size subgroup had the largest mean. The 9-10 year old age subgroup had the smallest front crotch point width mean, while the obese subgroup had the largest back mean. It seemed that the body size affected front and back crotch point width means the most.

Research Question 3: Is there a difference in crotch length for different age, body shape, and body size groups?

Crotch lengths were measured from waist point to crotch point along the crotch curve.

Table 17

Crotch Length Findings for Age Subgroups

Age	Back CL Mean	Back CL Range	Front CL Mean	Front CL Range	Total CL Mean	Total CL Range
9-10 (n=3)	12.375”	2.625” (10.37-13.375”)	11.333”	3.125” (9.75-12.875”)	23.708”	5.75” (20.5-26.25”)
11-12 (n=7)	13.723”	5.875” (11.25-17.125”)	13.009”	8.5” (7.75-16.25”)	26.732”	13.375” (20-33.375”)
13-14 (n=8)	13.078”	5.688” (9.563-15.25”)	13.195”	3.563” (11.938-15.5”)	26.273”	8.688” (22.063-30.75”)

CL= Crotch Length

Table 17 showed that the back crotch and total crotch length means increased between ages 9-10 and 11-12 year old subgroups, but then decreased by less than 1” in comparison to the 13-14 year old subgroup. The front crotch length increased from youngest to oldest, but the difference between the 9-10 and 11-12 subgroups was greater than between the 11-12 and 13-14 year old subgroups. Looking at the differences among all of the crotch length means, the 11-12 old and 13-14 year old subgroups’ back crotch length means were within about 0.7” of each other; their front crotch length means were within about 0.19”, and their total crotch length means were within a ½” of each other. The 9-10 year old subgroup was 3” smaller in total crotch length mean than both older age subgroups. Of the three subgroups, the 11-12 year old subgroup had the longest back and total crotch length means; that subgroup’s crotch length measurements also ranged more widely than the other two subgroups. The 9-10 year old subgroup had the shortest back, front and total crotch length means and the narrowest ranges. When comparing the back and front crotch length means, the difference decreased across age subgroups from approximately 1” to ¾” to 1/8”; in the 13-14 age subgroup, the front crotch length mean was actually slightly shorter than the back one.

Table 18

Crotch Length Findings for Shape Subgroups

Shape	Back CL Mean	Back CL Range	Front CL Mean	Front CL Range	Total CL Mean	Total CL Range
Pear (n=6)	13.635”	5.875” (11.25-17.125”)	13.365”	4.313” (11.958-16.25”)	27”	10.188” (23.188-33.375”)
Hourglass (n=4)	12.625”	4.813” (9.563-14.375”)	13.141”	1.563” (12.5-14.063”)	25.766”	6.375” (22.063-28.438”)
Rectangle (n=8)	13.188”	4.875” (10.75-15.625”)	12.234”	11.188” (7.75-15.563”)	25.422”	11.188” (20-31.188”)

CL= Crotch Length

Of the body shape subgroups the pear body shape subgroup had the longest front, back and total crotch length means. The hourglass subgroup’s back crotch length mean was shorter than the pear’s back crotch length mean by approximately 1” and than the rectangle’s by approximately ½”. The rectangle subgroup had the shortest front and total crotch length means. The rectangle and hourglass subgroups’ total crotch length means were less than ½” different, but the pear subgroup’s total crotch length mean was more than 1” longer than both of them.

The back crotch length measurement ranges varied the least across subgroups. There was much greater variation across the subgroups for front length measurements, with the hourglass subgroup’s measurements varying by less than 2”, the pear subgroup varying by more than 4”, and the rectangle subgroup by more than 11”. Thus, in observing total crotch length measurement ranges, the hourglass subgroup had the smallest variation, and the other two subgroups varied much more.

Table 19

Crotch Length Findings for Size Subgroups

Size	Back CL Mean	Back CL Range	Front CL Mean	Front CL Range	Total CL Mean	Total CL Range
Normal (n=7)	12.170”	2.75” (10.75-13.5”)	11.330”	5.375” (7.75-13.125”)	23.5”	6.625” (20-26.625”)
Overweight (n=5)	13.713”	1.563” (12.938-14.5”)	13.350”	1.188” (12.875-14.063”)	27.063”	2.188” (26.25-28.438”)
Obese (n=6)	14.010”	7.563” (9.563-17.125”)	14.094”	4.875” (11.375-16.25”)	28.104”	11.313” (22.063-33.375”)

CL= Crotch Length

Across body size subgroups, the front and back crotch length means increased as the body size increased. The normal subgroup had the shortest back, front and total crotch length means. The overweight subgroup’s means were approximately 1.5”, 2”, and 3.5” longer than the normal subgroup’s means. The obese subgroup’s means were longer still, but by margins of an 1” or less. The normal and overweight subgroups’ back crotch length means were longer than their front means, but the obese subgroup’s two means were almost the same.

Out of all the age, body shape, and body size subgroups, the obese body size subgroup had the largest back, front and total crotch length means. The normal body size subgroup had the smallest back crotch length mean. The subgroups with the smallest front crotch means were the 9-10 year old subgroup and the normal body size subgroup, which also had the smallest total crotch length means. Among all the subgroups, the largest back crotch length range was the obese body size subgroup; the rectangle body shape subgroup had the widest front crotch length range, and the 11-12 year old subgroup varied the most in total crotch length range. The overweight body size subgroup had the smallest back, front and total crotch length range.

Research Question 4: Does the proportional relationship between hip depth and overall length change in relation to age, body size, and body shape groups?

Measurements for hip depth were taken along the side seam to the hipline and side length was measured the full length of the side seam.

Table 20

Hip Depth-to-Side Length Findings for Age Subgroups

Age	HD Mean	HD Range	SSL Mean	SSL Range	HD-to-SSL Proportion Mean	HD-to-SSL Proportion Range
9-10 (n=3)	6.313”	2.125” (33.625-35.75”)	34.958”	2.125” (33.625-35.75”)	5.906	3.513 (4.719-8.232)
11-12 (n=7)	6.786”	6.063” (3.938-10”)	38.536”	3.25” (37.375-40.625”)	6.169	5.588 (4.063-9.651)
13-14 (n=8)	6.305”	5.125” (3.938-9.063”)	39.156”	5.875” (36-41.875”)	6.85	5.774 (3.972-9.746)

HD = Hip Depth

SSL = Side Seam Length

As shown in Table 20, the hip depth varied by just under ½” from 6.305” to 6.786”. The side length increased by about 3 ½” from 9-10 (mean of nearly 35”) to 11-12 (mean of approximately 38 ½”), then only by 5/8” to 13-14 (mean of less than 39 ¼”). Thus, the proportions increased only slightly across age subgroups since the side length increased more than the hip depth. The hip depth and side length measurements varied more for the two older subgroups.

The 11-12 year old subgroup’s hip depth mean was slightly different from the 9-10 year old and 13-14 year old subgroups, which had similar means. Among the three subgroups, the hip depth means were within 0.4” of each other. The proportion mean for hip depth-to-side length increased as the age subgroups increased; this was possibly because the side seam length mean increased as the age subgroups increased. This increase did not hold true for the hip depth range as it did for the side length range and hip depth-to-side length proportion range. The 9-10 year old subgroup had the smallest hip depth, side length, and hip depth-to-side length proportion means. This subgroup also had the smallest ranges among the three subgroups.

Table 21

Hip Depth-to-Side Length Findings for Shape Subgroups

Shape	HD Mean	HD Range	SSL Mean	SSL Range	HD-to-SSL Proportion Mean	HD-to-SSL Proportion Range
Pear (n=6)	6.125”	5.063” (3.938-8.875”)	38.521”	1.625” (37.625-39.25”)	6.854	5.507 (4.239-9.746)
Hourglass (n=4)	6.484”	5.125” (3.938-9.063”)	29.188”	5.875” (36-41.875”)	6.606	5.679 (3.972-9.651)
Rectangle (n=8)	6.773”	6” (4-10”)	37.5”	7” (33.63-40.625”)	6.019	5.593 (4.063-9.656)

HD = Hip Depth

SSL = Side Seam Length

In Table 21, the hip depth varied across shape subgroups by 0.648”, and measurement ranges were less than 1” different. The hourglass subgroup had the shortest side length compared to the pear (9.3” difference) and rectangle (8.3” difference) subgroups. Hip depth-to-side length proportions were between 6 and 6.85 to 1. The rectangle subgroup had the largest hip depth, but the pear subgroup had the largest hip depth-to-side length proportion mean. Hip depth increased from the pear to the hourglass to the rectangle subgroup, but hip depth-to-side length proportion increased from the rectangle to the hourglass to the pear subgroup. The hip depth ranges were similar, and the side length ranges varied from 1.625” to 7”. The hip depth-to-side length proportion ranges were very similar to one another.

Table 22.

Hip Depth-to-Side Length Findings for Size Subgroups

Size	HD Mean	HD Range	SSL Mean	SSL Range	HD-to-SSL Proportion Mean	HD-to-SSL Proportion Range
Normal (n=7)	5.842”	4.938” (3.938-8.875”)	37.804”	7.25” (33.625-40.875”)	7.072	5.417 (4.239-9.656)
Overweight (n=5)	7.113”	0.938” (6.688-7.625”)	38.85”	6.125” (35.75-41.875”)	5.487	1.495 (4.767-6.262)
Obese (n=6)	6.833”	6.063” (3.938-10”)	38.167”	5.125” (35.5-40.625”)	6.36	5.774 (3.972-9.746)

HD = Hip Depth

SSL = Side Seam Length

The hip depths varied across subgroups by approximately ¼” (overweight and obese), 1” (normal and obese), 1 ¼” (normal and overweight), with the overweight subgroup having the greatest hip depth (See Table 22). The side length only varied at the most by barely more than 1” between the normal and overweight subgroups. Hip depth-to-side length proportions were 5.5 (overweight), 6.4 (obese), and 7.1 (normal) to 1.

The normal body size subgroup had the smallest hip depth and side length means, but highest hip depth–to-side length proportion mean, while the overweight subgroup had the greatest hip depth and side length mean but the smallest hip depth-to-side length proportion mean. The overweight subgroup had the smallest hip depth and hip depth-to-side length proportion ranges, while the obese subgroup had the smallest side length range. The largest hip depth and hip depth-to-side length proportion ranges were the obese subgroup. The normal subgroup had the largest side length range.

The body size subgroups’ hip depth means, as well as the hip depth-to-side length proportion means, varied the most out of the age, shape, and size groups. The largest hip depth mean was found in the overweight body size subgroup; the 13-14 year old subgroup had the largest side length mean, and the subgroup with the largest hip depth-to-side length proportion mean was the normal body size subgroup. The smallest hip depth mean was the normal body size subgroup; the smallest side length mean was the hourglass body shape subgroup. The smallest hip depth-to-side length proportion mean of all the subgroups was the overweight subgroup. Among all the subgroups, the hip depth-to-side length proportion means varied from 5.487 to 7.072.

Research Question 5 a: Does the hip-to-waist circumference difference change in relation to age, body size, and body shape groups?

Total hip and total waist circumferences were taken by measuring the front waistline on the pattern, multiplying it by two and adding that number to twice the back waist measurement.

Table 23

Hip-to-Waist Circumference Findings for Age Subgroups

Age	HC Mean	HC Range	WC Mean	WC Range	Difference	Difference Range
9-10 (n=3)	36.542”	10.75” (30.875-41.625”)	28.833”	12.75” (22.875-35.625”)	7.708”	3.125” (6-9.125”)
11-12 (n=7)	40.214”	8.625” (36.75-45.375”)	30.964”	15.875” (24.375-40.25”)	9.25”	7.5” (5.125-12.625”)
13-14 (n=8)	39.922”	10.625” (34.75-45.375”)	31.828”	14” (26-40”)	8.094”	7.5” (5.375-12.875”)

HC=Hip Circumference

WC=Waist Circumference

Table 23 displays hip and waist circumference pattern measurements (including allocated ease) by age subgroups. The 9-10 year old subgroup had the smallest hip and waist circumference means, and difference between the two. The 11-12 year old subgroup had the next largest mean waist circumference (2.131” larger than the younger subgroup) and the largest mean hip circumference, yielding the largest hip-to-waist difference (9.25”). The 13-14 year old subgroup’s mean waist circumference was less than 1” larger than the 11-12 year old subgroup, and the mean hip circumference was approximately ¼” smaller than that group; the 13-14 year old subgroup’s difference score was between those of the two younger groups. The hip-to-waist difference scores ranged more widely for the 11-12 and 13-14 year old subgroups than they did for the younger group.

Table 24

Hip-to-Waist Circumference Findings for Shape Subgroups

Shape	HC Mean	HC Range	WC Mean	WC Range	Difference	Difference Range
Pear (n=6)	40.667”	9.25” (36.125-45.375”)	31.104”	15.625” (24.375-40”)	9.563”	7.5” (5.375-12.875”)
Hourglass (n=4)	40.719”	10.625” (34.75-45.375”)	33.063”	14.25” (26-40.25”)	7.656”	5.625” (5.125-10.75”)
Rectangle (n=8)	37.953”	12” (30.875-42.875”)	29.875”	12.75” (22.875-35.625”)	8.078”	3.875” (6-9.875”)

HC=Hip Circumference

WC=Waist Circumference

In Table 24, the body shape subgroups the pear and hourglass subgroups had similar hip circumferences, with the rectangle group between 2 ½” and 3” smaller. The largest waist circumference mean (hourglass) was more than 3” larger than the smallest one (rectangle). The three shape subgroups’ hip-to-waist circumference difference scores were less than ½” to nearly 2” apart. The largest hip-to-waist circumference difference was the pear body shape subgroup and the smallest difference was the hourglass subgroup. The pear subgroup had the widest range of hip to waist circumference differences, and the rectangle subgroup had the narrowest range.

Table 25

Hip-to-Waist Circumference Findings for Size Subgroups

Size	HC Mean	HC Range	WC Mean	WC Range	Difference of the Means	Difference Range
Normal (n=7)	36.643”	10.625” (30.875-45.375”)	28.518”	17.375” (22.875-40.25”)	8.125”	7.5” (5.125-12.625”)
Overweight (n=5)	39.575”	6.25” (36.75-43”)	29.45”	2.625” (28-30.625”)	10.125”	5.125” (7.75-12.875”)
Obese (n=6)	42.688”	3.75” (41.625-45.375”)	35.167”	8.25” (31.75-40”)	7.521”	4.625” (5.375-10”)

HC=Hip Circumference

WC=Waist Circumference

Hip and waist circumferences increased as body size increased. From normal to overweight to obese, each subgroup's mean hip circumference was approximately 3" larger than the previous one (see Table 25). The separation was different for mean waist circumferences. The overweight subgroup's mean was less than 1" larger than the normal subgroup, but the obese subgroup's mean was nearly 6" larger than the overweight subgroup's mean. Thus, the obese subgroup had the smallest hip-to-waist circumference difference, and the overweight subgroup had the largest difference. The normal size subgroup's hip circumferences, waist circumferences, and hip-to-waist circumference differences varied more widely than the other two subgroups.

Comparing all age, shape, and size subgroups, the obese body size subgroup had the largest hip and waist circumference means. The normal body size subgroup had the smallest mean waist circumference, and the 9-10 year old subgroup had the smallest mean hip circumference. The largest hip-to-waist circumference difference overall was the overweight body size subgroup, and the smallest hip-to-waist circumference difference was the obese body size subgroup.

Research Question 5b: Does the shape of the side seam between the hip and waist change in relation to age, body size, and body shape groups?

Comparison for pattern shapes was done visually by the researcher.

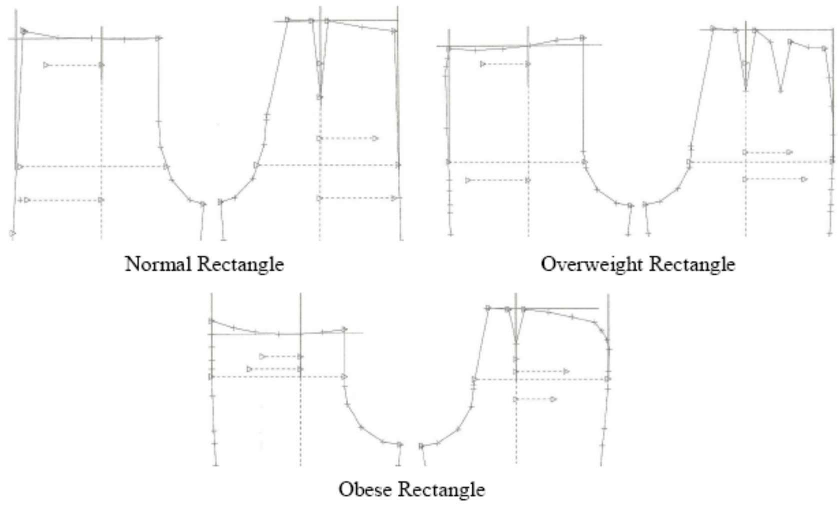

Figure 8. Side seam shape between hip and waist age subgroups: 9-10 year olds. (front pattern is on the left, back pattern is on the right).

There was little difference in the side seam shapes in this subgroup; there was either no curve like the normal rectangle (See Figure 8) or very shallow curves like the overweight rectangle. The obese rectangle was the only one to have a deep curve, which was along the back side seam.

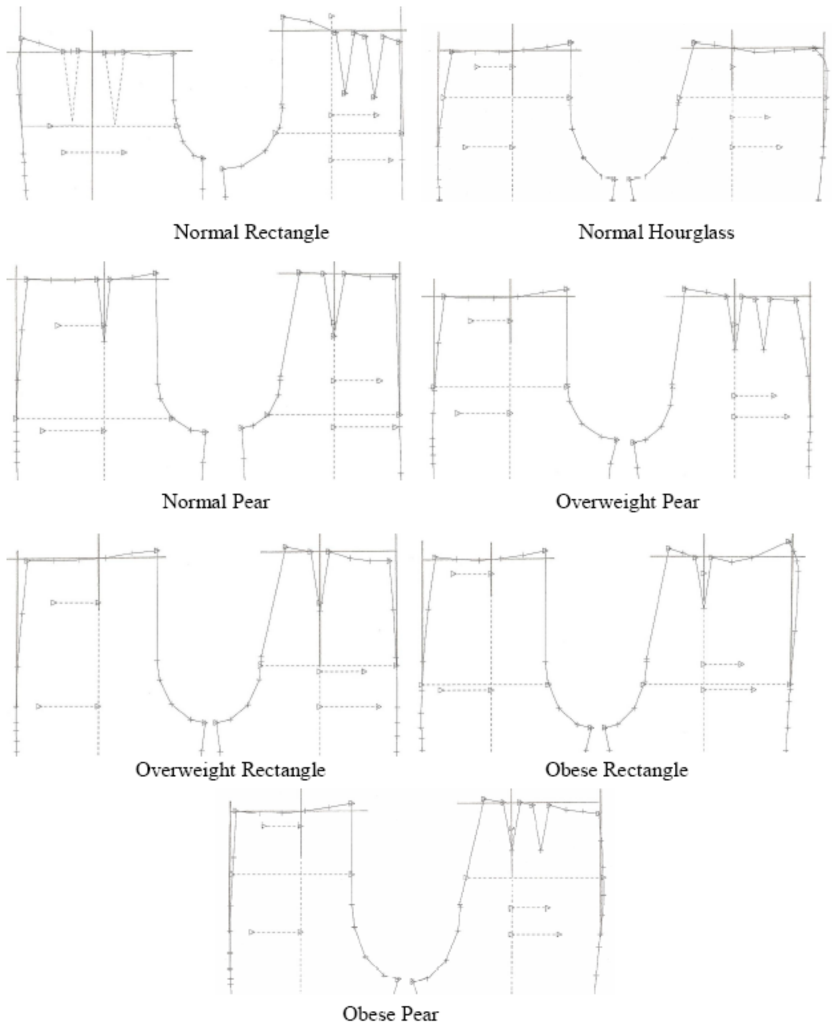

Figure 9. Side seam shape between hip and waist age subgroup: 11-12 year olds. (front pattern is on the left, back pattern is on the right)

In Figure 9, the majority of the 11-12 year old subgroup's patterns had shallow curves, as the overweight rectangle or a slight curve as the obese pear. The patterns that had the most curve along the side seam were the normal hourglass, overweight pear, and overweight rectangle. The normal rectangle had almost no curve.

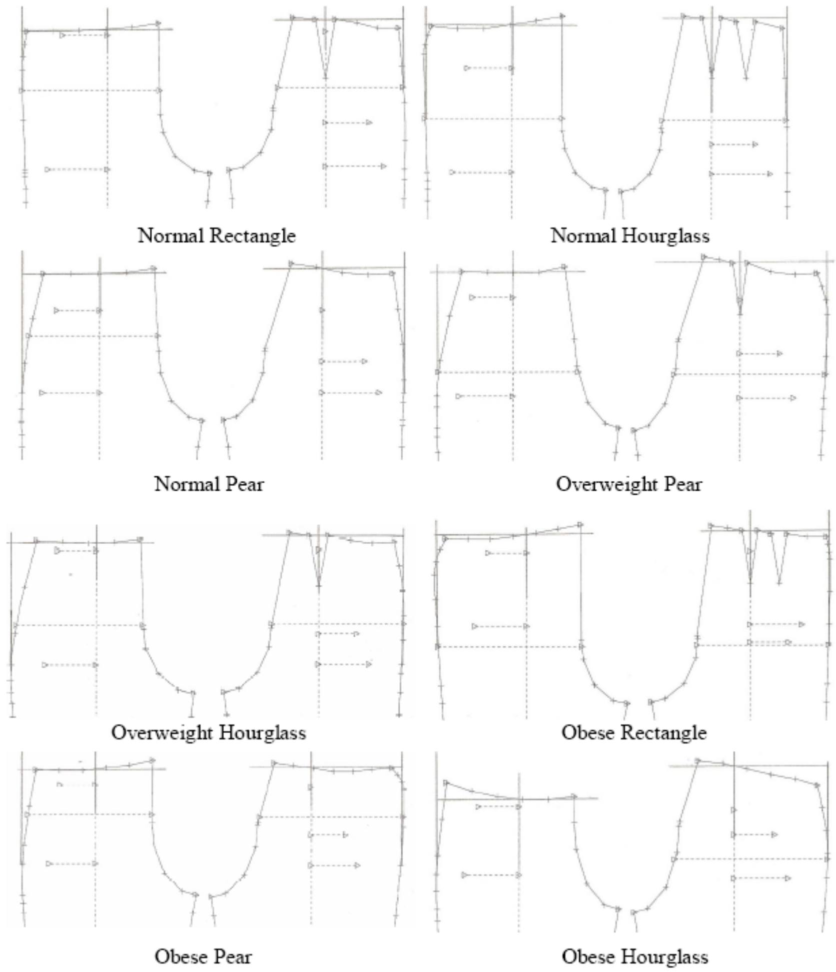

Figure 10. Side seam shape between hip and waist age subgroup: 13-14 year olds. (front pattern is on the left, back pattern is on the right).

The 13-14 year old subgroup (Figure 10) had five patterns that had similar hip curve shapes: normal pear, overweight pear, overweight hourglass, obese pear, obese hourglass. Three patterns were barely curved (normal rectangle, normal hourglass, and obese rectangle). The obese rectangle also had a very slight curved back side seam, but a more curved front side seam.

The age subgroup that had the most curved side seam was the 13-14 year old subgroup. It was visually evident that the side seam became more curved as age increased. The 9-10 year old subgroup had little or no curve, the 11-12 year old subgroup had shallow or slight curves and the 13-14 year old subgroup had curved side seams.

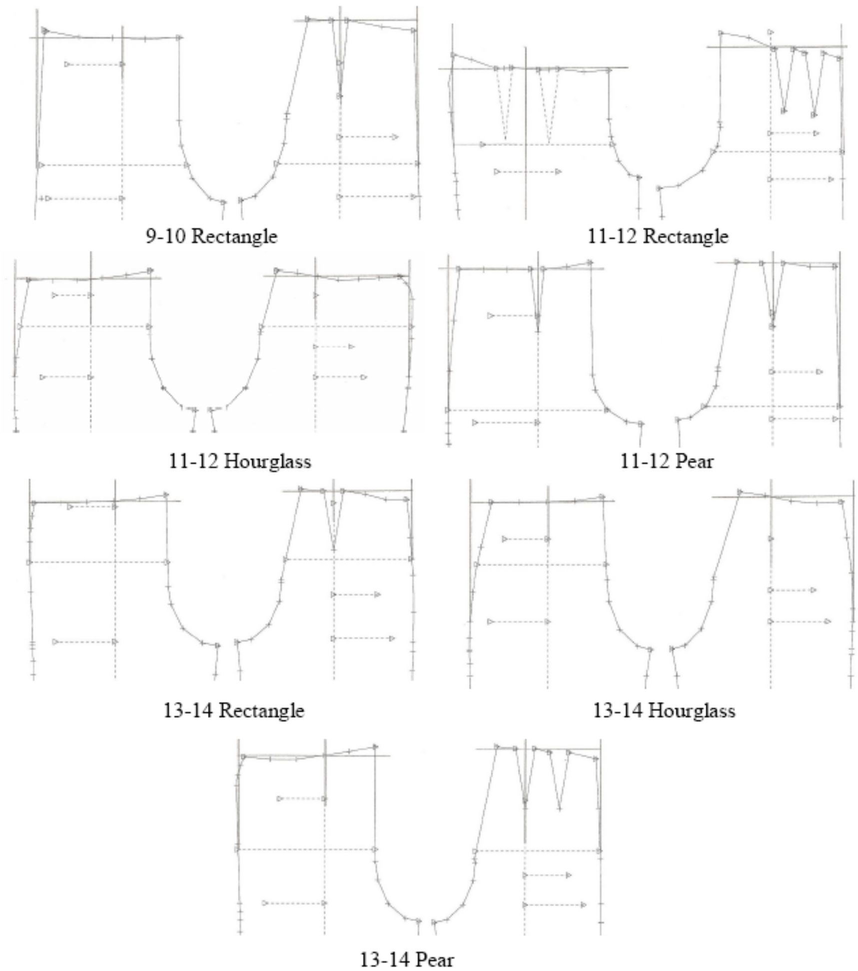

Figure 11. Side seam shape between hip and waist by body size subgroup: Normal. (front pattern is on the left, back pattern is on the right).

Figure 11 shows that across the normal body size subgroup there was not many curved side seams. Most patterns had no curve or a slight curve. The normal 11-12 hourglass and normal 13-14 hourglass were the only two patterns that had notably curved side seams.

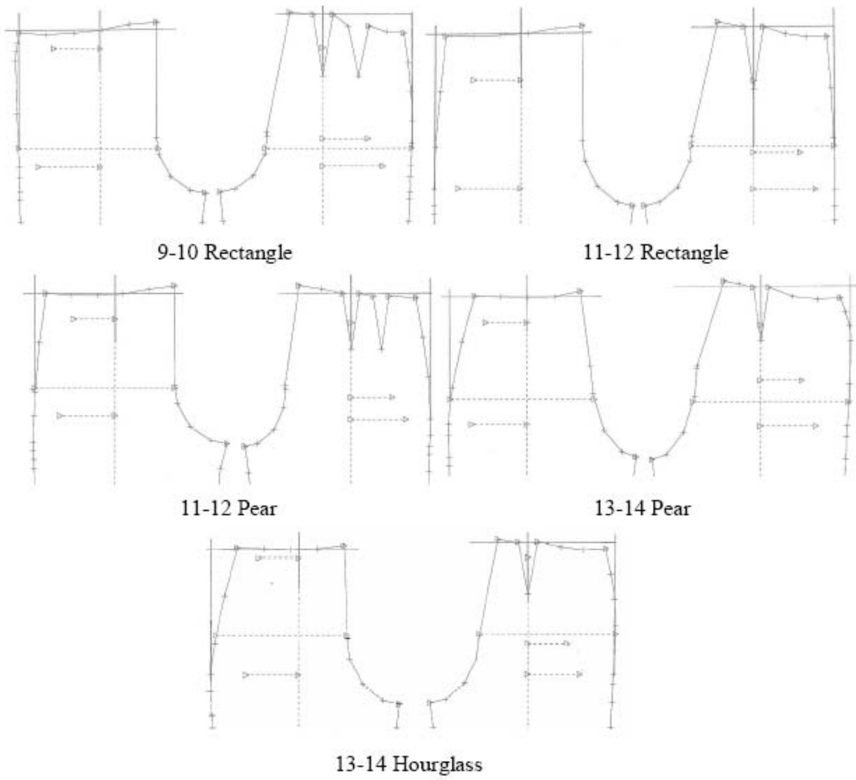

Figure 12. Side seam shape between hip and waist by body size subgroup: Overweight. (front pattern is on the left, back pattern is on the right).

The overweight body size subgroup (See Figure 12) had shallow or slight curved to moderate or curved side seams. The shallow or slight curves were very similar, 11-12 rectangle or 11-12 pear. The moderately curved or curved side seams, 13-14 pear and 13-14 hourglass, were also very similar. This subgroup overall had side seams that were curved.

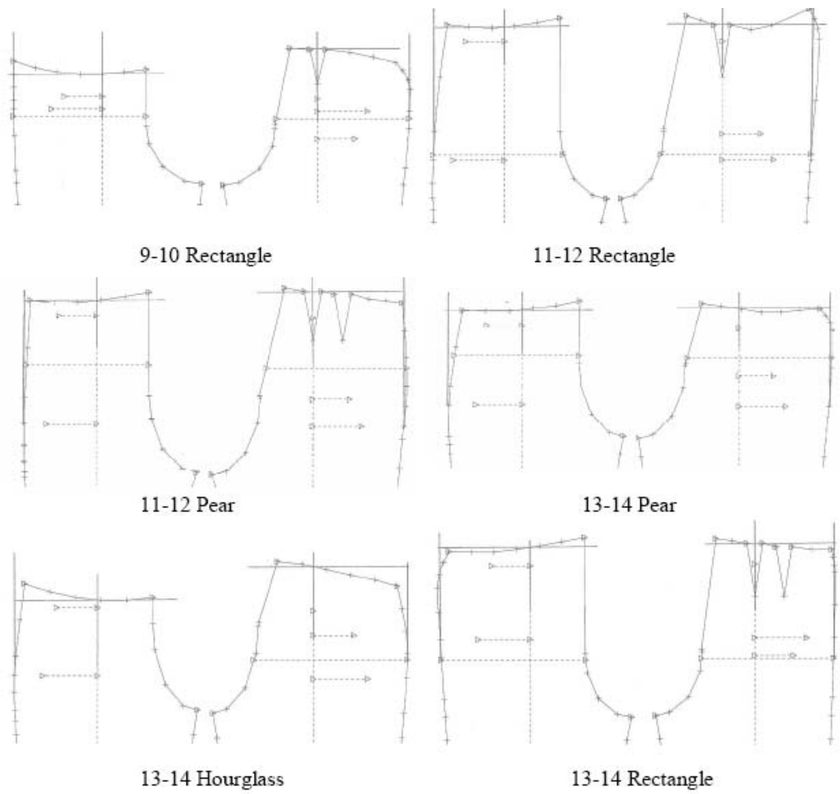

Figure13. Side seam shape between hip and waist by body size subgroup: Obese. (front pattern is on the left, back pattern is on the right).

In Figure 13, the side seams for the obese body size subgroup had slight to moderate curves. There were similar curves across this subgroup, front (left) or back (right) patterns.

Among the three body size subgroups, the normal subgroup had the fewest curved side seams and the obese subgroup had the most side seams that were curved. The overweight subgroup had the most varied side seam curves.

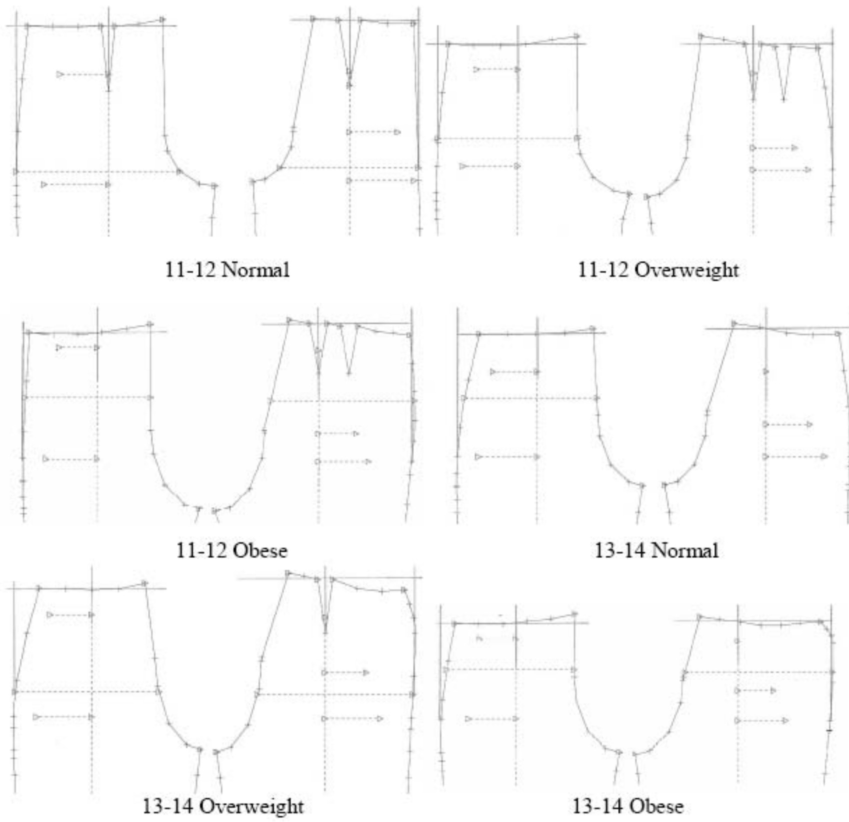

Figure 14. Side seam shape between hip and waist by body shape subgroup: Pear. (front pattern is on the left, back pattern is on the right).

The pear shaped body size subgroup had slight to moderately curved side seams (See Figure 14). The curves were very similar except for the 13-14 overweight and 13-14 obese which were more curved along the front and back side seams.

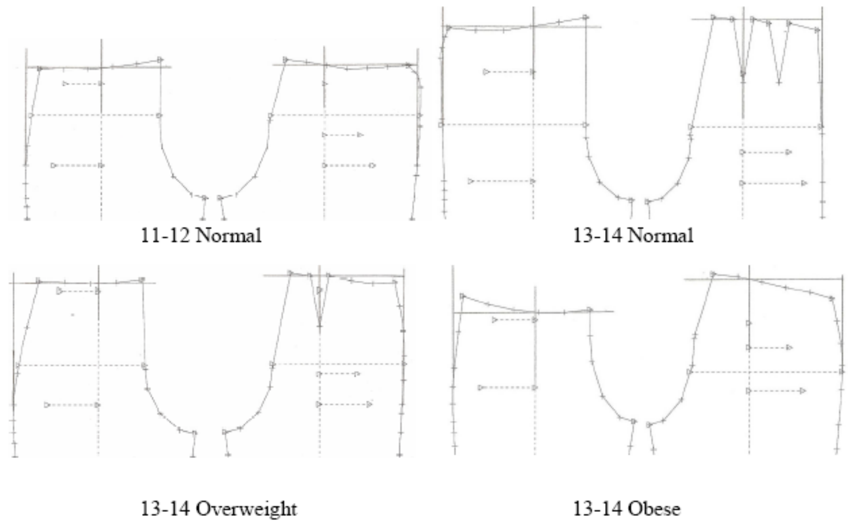

Figure 15. Side seam shape between hip and waist by body shape subgroup: Hourglass. (front pattern is on the left, back pattern is on the right).

In Figure 15, the hourglass body shape subgroup's side seams were curved (13-14 overweight), or moderately curved (13-14 obese) patterns. The 13-14 normal pattern was an exception, with little to no curve.

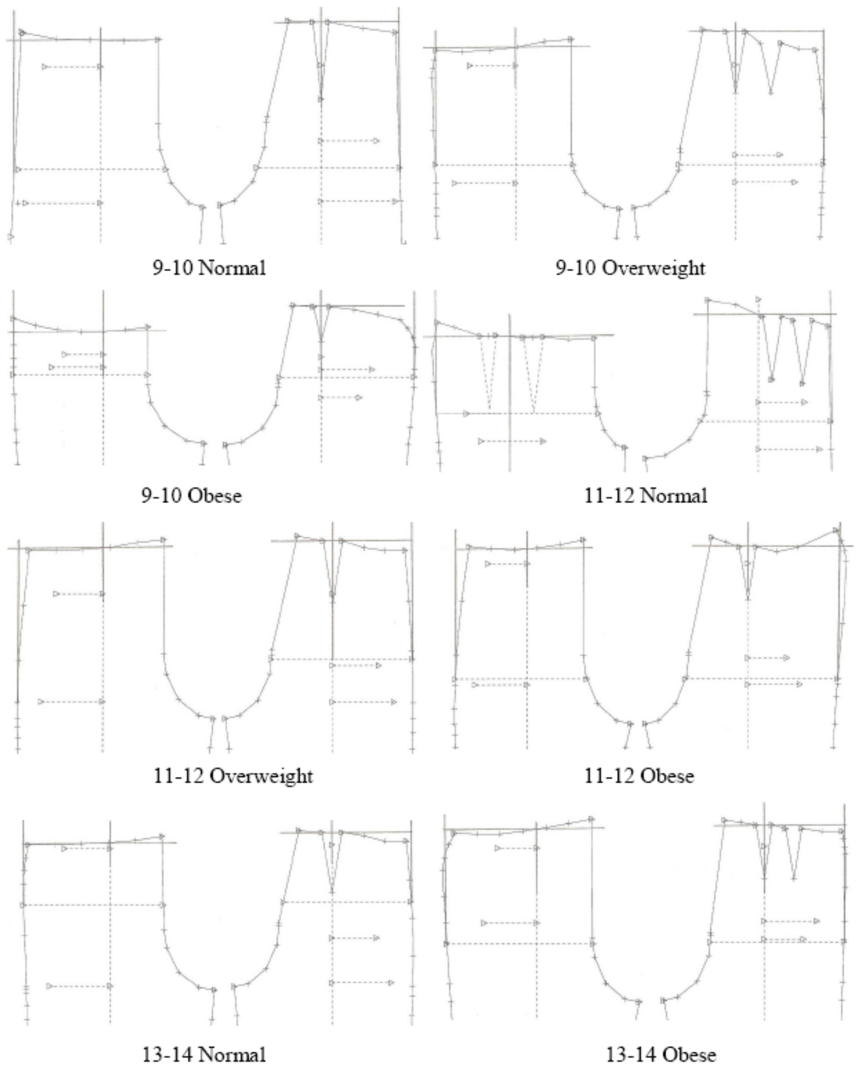

Figure 16. Side seam shape between hip and waist by body shape subgroup: Rectangle. (front pattern is on the left, back pattern is on the right).

The rectangle body shape subgroup patterns had little to slightly curved side seams (See Figure 16). The side seams had many similarities with the 11-12 overweight which had moderate to curved side seams.

Overall, there was not much difference between the three body shape subgroups. The hourglass body shape subgroup may have had slightly more curved side seams than the other two subgroups, but not enough to be a noteworthy difference.

Research Question 6: Does the waistline shape differ in relation to age, body size, and body shape groups?

Comparison for pattern shapes was done visually by the researcher.

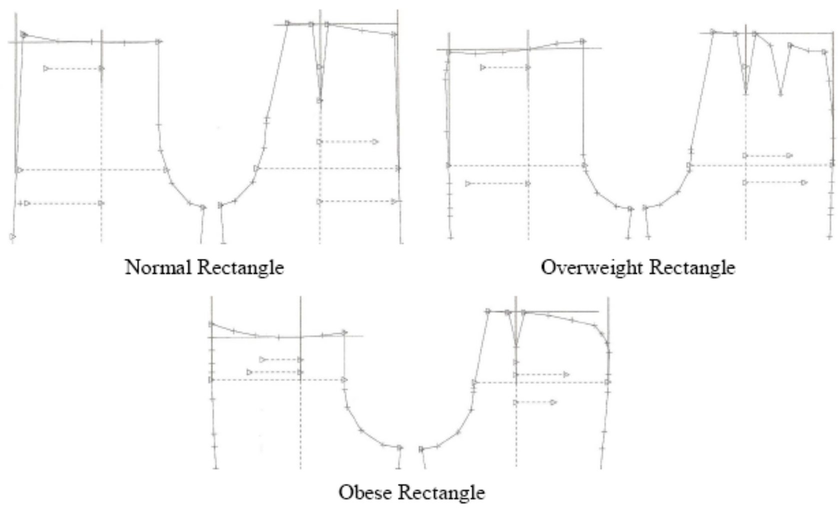

Figure 17. Waistline shape by age subgroup: 9-10 year old. (front pattern is on the left, back pattern is on the right).

In Figure 17, the 9-10 year old age subgroup had similar back waistline curves. The front waistline curves differed slightly. The back (pattern on right) waistlines curved up or angled up to the center back. Front (pattern on left) waistlines curved up to the side seam for the normal rectangle and obese rectangle, the exception was the overweight rectangle, the waistline curved up towards the center front.

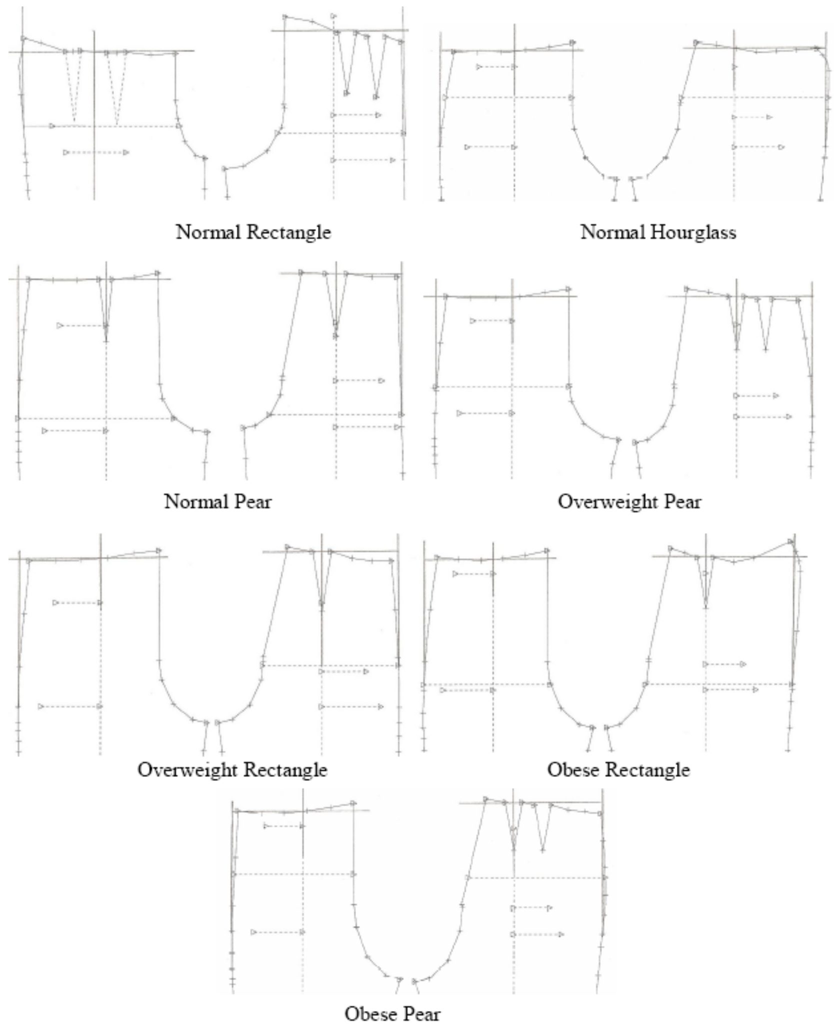

Figure 18. Waistline shape by age subgroup: 11-12 year old. (front pattern is on the left, back pattern is on the right).

The 11-12 year old age subgroup overall had moderately curved waistlines (See Figure 18). The majority of the front waistlines curved up towards the center front, and the back waistlines curved up towards the center back. The exception was the normal rectangle where the front waistline curved up towards the side seam. Also the normal pear's back waistline was flatter.

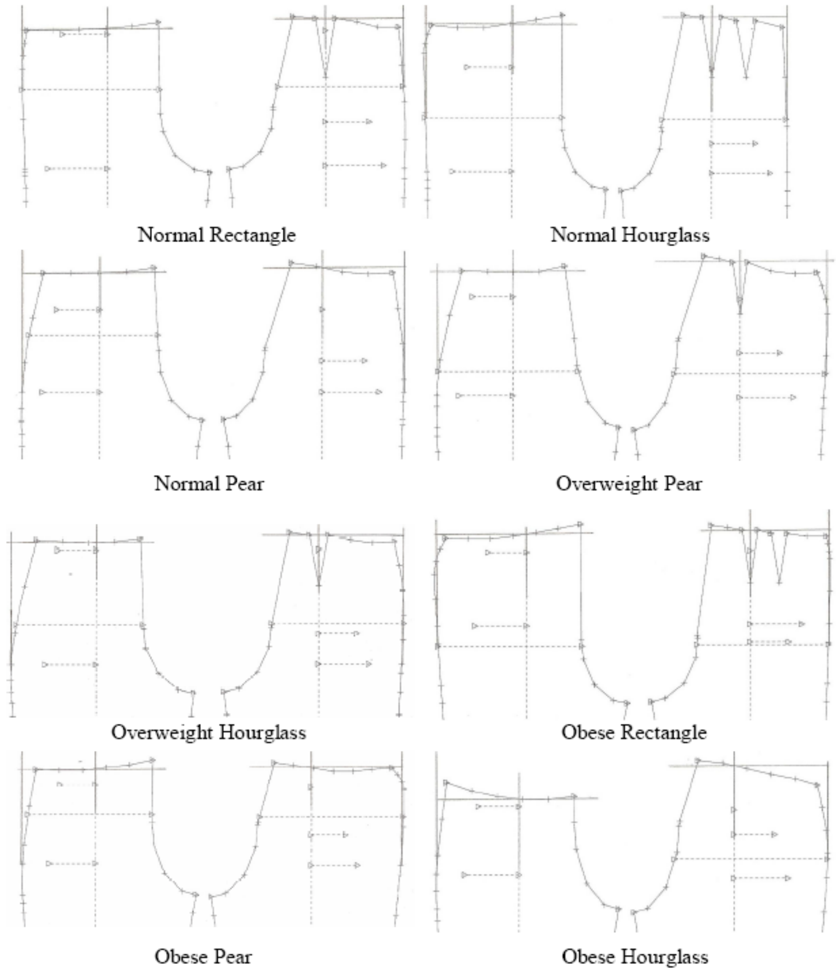

Figure 19. Waistline shape by age subgroup: 13-14 year old (front pattern is on the left, back pattern is on the right).

In Figure 19, the 13-14 year old age subgroup had slight or shallow front waistline curves that curved up towards the center front. The back waistlines were also slightly to moderately curved towards the center back. The only different pattern was the obese hourglass which curved up toward the side seam on the front pattern and had a sharp upward angle toward center back on the back pattern.

Of the three of the age subgroups, the 9-10 year old subgroup had the most varied waistline curves, while the 11-12 year old subgroup had the most similar waistline curves. The 13-14 year old subgroup were the most curved back waistlines and had very similar front waistline curves the 11-12 year old subgroup.

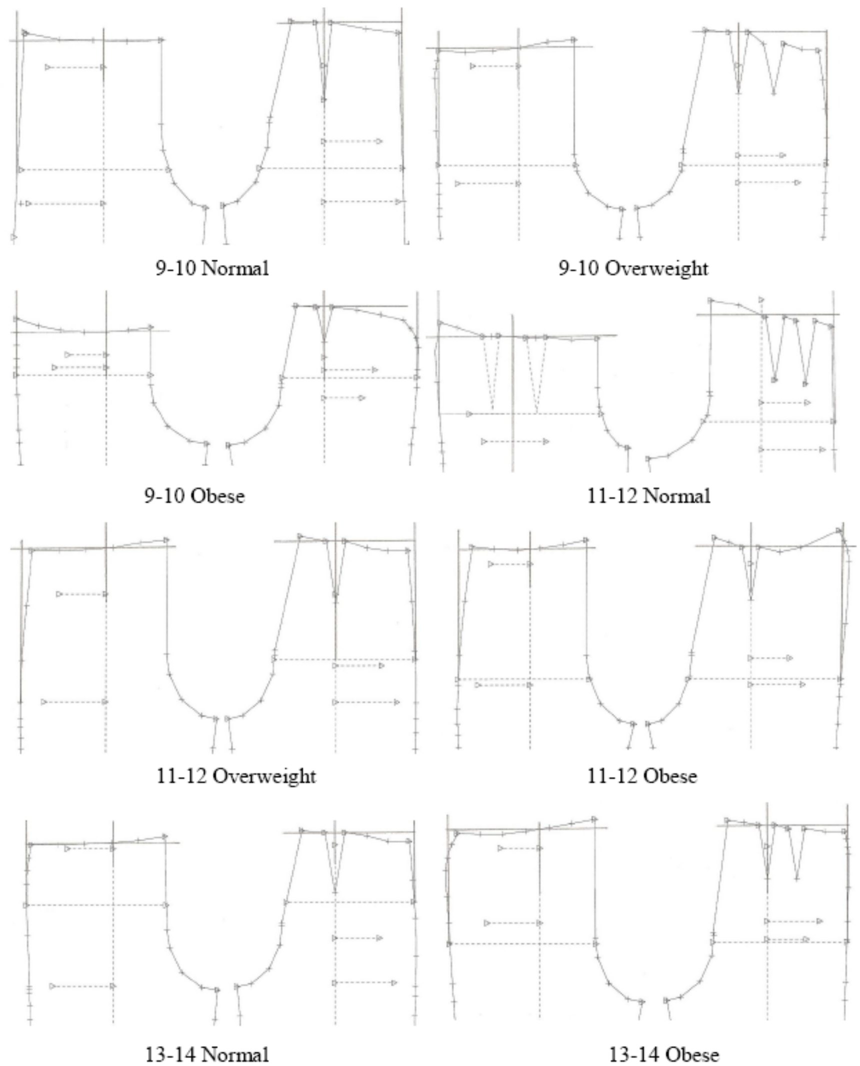

Figure 20. Waistline shape by body shape subgroup: Rectangle. (front pattern is on the left, back pattern is on the right).

For the rectangle body shape subgroup (See Figure 20), the front waistline curves varied. The majority of the patterns, five, curved up towards the center front, while three patterns curved up towards the side seam. Most of the front waistline curves were slight or moderate, with three curved, the 9-10 normal, 9-10 obese and 11-12 normal, which both curved towards the side seam.

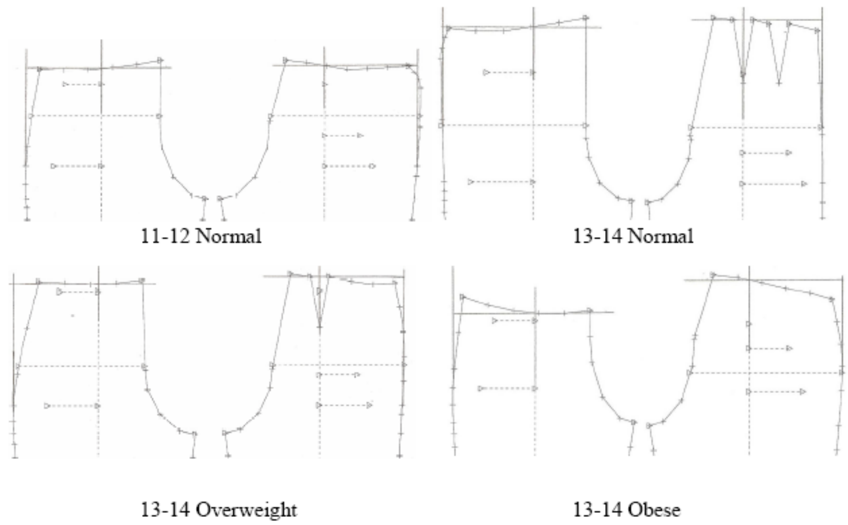

Figure 21. Waistline shape by body shape subgroup: Hourglass. (front pattern is on the left, back pattern is on the right).

In Figure 21, the hourglass body shape subgroup had similar waistline curves that had slight or very little curve to them. The exception was the 13-14 obese; its front waistline curved towards the side seam, and both the front and back had a substantially more curved waistlines than the other hourglass subgroup patterns.

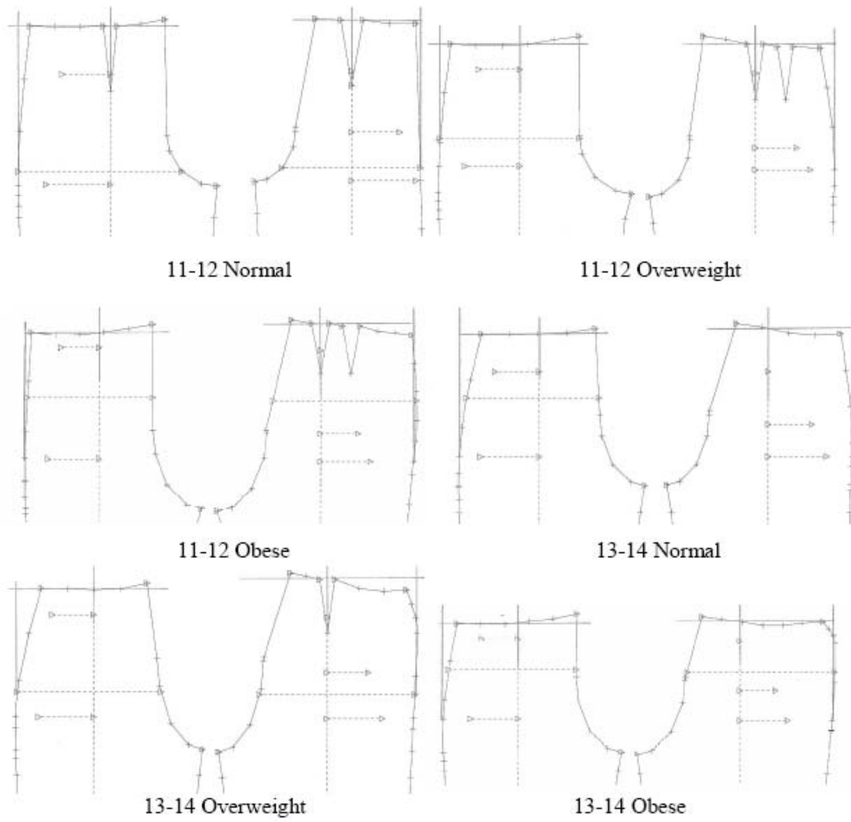

Figure 22. Waistline shape by body shape subgroup: Pear. (front pattern is on the left, back pattern is on the right).

The pear body shape subgroup (See Figure 22) had very similar waistline shapes. All of the front waistlines had a similar slight curve towards the center front. The back waistline curves all had more curve compared to the front, except for the 11-12 normal which had only a slightly curved back waistline.

For the body shape subgroups, the rectangle subgroup had the most varied waistline curves, while the pear group had very similar waistline curves. The hourglass subgroup waistlines were close to the pear subgroup's waistlines. Overall the front waistlines were slightly curved while the back waistlines had slight to moderate curves.

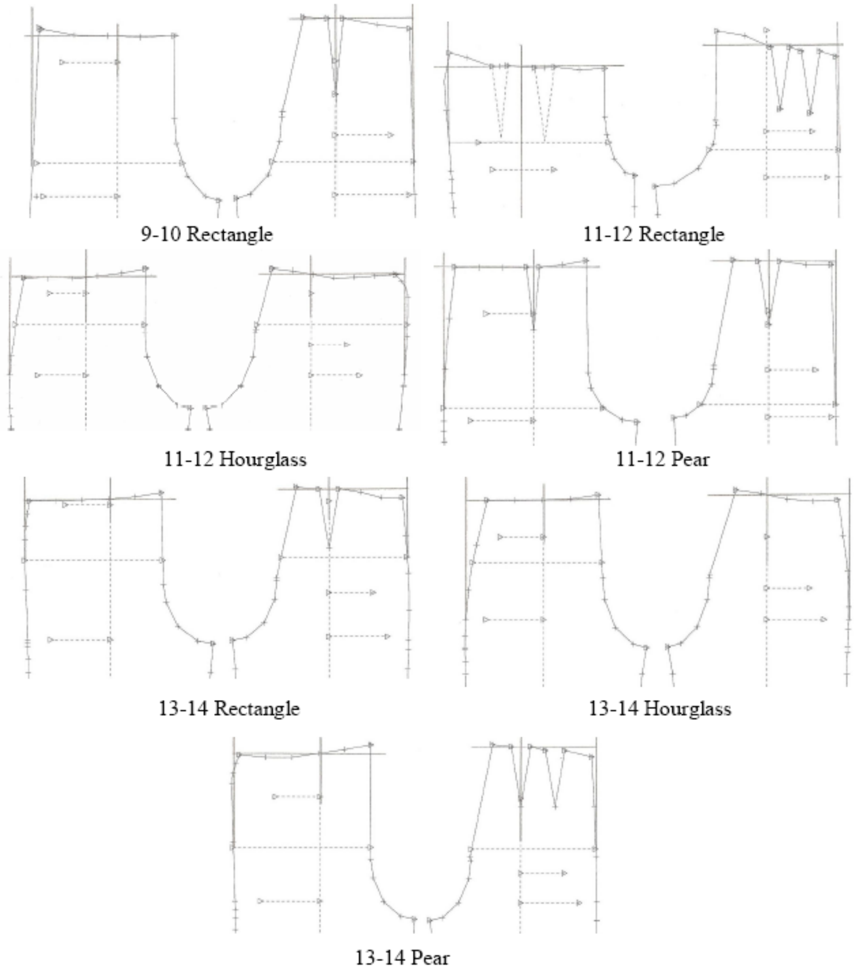

Figure 23. Waistline shape by body size subgroup: Normal. (front pattern is on the left, back pattern is on the right).

In Figure 23, the normal body size subgroup had similar front waist curves except for the 9-10 rectangle and 11-12 rectangle. Both of those patterns front waistlines curved towards the side seam. The back waistline curves were generally shallow except for the 11-12 pear and 11-12 hourglass which had only a little curve.

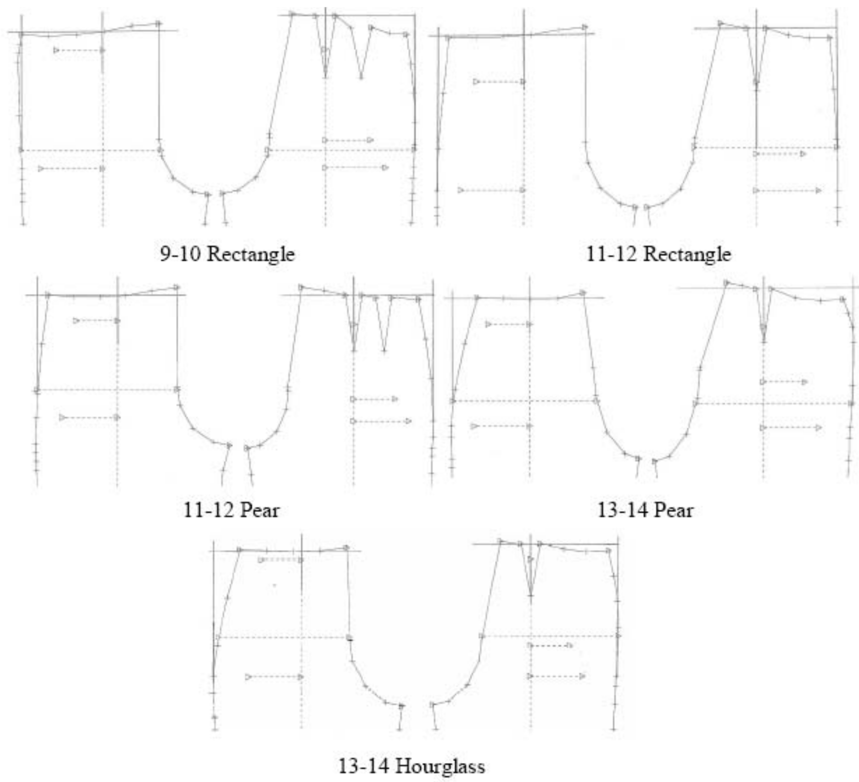

Figure 24. Waistline shape by body size subgroup: Overweight. (front pattern is on the left, back pattern is on the right).

The overweight body size subgroup all had similar curves (See Figure 24). The front waistline curved slightly up towards the center front. The back waistline curves were moderately curved up towards the center back.

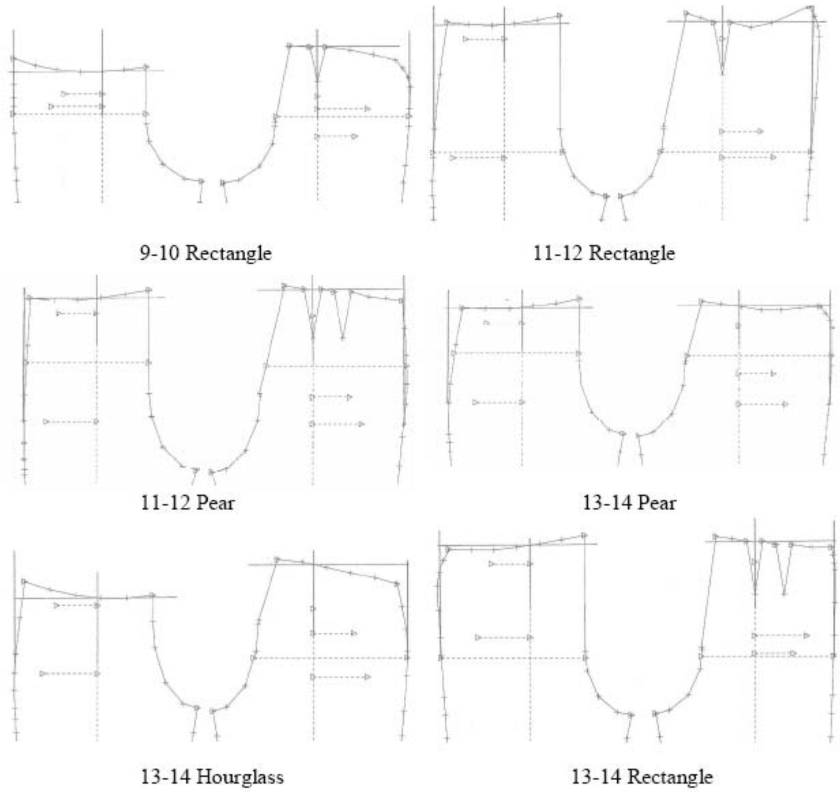

Figure 25. Waistline shape by body size subgroup: Obese. (front pattern is on the left, back pattern is on the right).

In Figure 25, the obese body size subgroup had curved front and back waistlines that were moderate to very curved. All the front curves were generally going in the same direction (up towards the center front or center back). The back waistline curves all curved down towards the side seam except for the 11-12 rectangle which curved up towards the side seam.

As body size increased the waistline curves became more pronounced. The obese subgroup waistline curves varied the most among the three groups, while the normal and overweight subgroups had similar curves, especially on the front patterns.

Research Question 7: Is the center back line angle different between age, body size, and body shape?

Angle measurements were taken with a protractor along a line drawn perpendicular to the crotch line and extended up through the hipline (see Figure 7).

Table 26

Center Back Line Angle Findings for Age Subgroups

Age	CB Angle Mean	CB Angle Range
9-10	170º	2.5º
(n=3)		(169-171.5º)
11-12	169º	9.5º
(n=7)		(163.5-173º)
13-14	169.13º	11º
(n=8)		(163.5-174.5º)

CB=Center Back

There was not much difference, only about 1º, in the center back angle means across the age subgroups, but there was an important difference in the ranges for each subgroup (see Table 26). The center back angle range increased as age increased. The largest jump in range was from the 9-10 year olds to the 11-12 year olds, with a 7º difference.

Table 27.

Center Back Line Angle Findings for Shape Subgroups

Shape	CB Angle Mean	CB Angle Range
Pear	167.67º	9.5º
(n=6)		(163.5-173º)
Hourglass	168.63º	5.5º
(n=4)		(166-171.5º)
Rectangle	170.69º	6.5º
(n=8)		(168-174.5º)

CB=Center Back

In Table 27, among the shape subgroups, there was only about a 3º difference. The pear subgroup had the smallest mean but the largest range; the hourglass subgroup had the smallest range, and the rectangle subgroup had the largest center back angle mean. The largest difference in center back angle means was between the pear and rectangle subgroups.

Table 28

Center Back Line Angle Findings for Size Subgroups

Size	CB Angle Mean	CB Angle Range
Normal	167.21º	8.5º
(n=7)		(163.5-172º)
Overweight	171.1º	4º
(n=5)		(169-173º)
Obese	170º	9º
(n=6)		(165.5-174.5º)

CB=Center Back

Across the three body size subgroups there was about a 4º difference in center back angle means (see Table 28). The obese subgroup had the largest range of angles, and the overweight subgroup had the smallest range. The obese and overweight subgroups had similar center back angles, with the normal subgroup having a smaller center back angle than the other two subgroups.

Among all the age, body shape, and body size subgroups, the largest center back angle range was the 13-14 year old subgroup with the 9-10 year old subgroup having the smallest center back angle range. All group means were within 3.99º of each other (167.21º-171.1º).

Research Question 8: Is the center front line angle different between age, body size, and body shape?

Angle measurements were taken with a protractor along a line drawn perpendicular to the crotch line and extended up through the hipline (see Figure 7).

Table 29

Center Front Line Angle Findings for Age Subgroups

Age	CF Angle Mean	CF Angle Range
9-10	176.5º	9.5º
(n=3)		(171-180.5º)
11-12	176.14º	20º
(n=7)		(161-181º)
13-14	177.63º	8º
(n=8)		(173-181º)

CF=Center Front

In Table 29, there was a very slight difference of about 1.5º among the age subgroups' for the center front angle means. The largest angle mean was the 13-14 year old subgroup with the 11-12 year old subgroup having the smallest center front angle mean. Even though the 11-12 year old subgroup had the smallest center front angle mean, it had the largest center front angle range, and the 13-14 year old subgroup had the smallest center front angle range.

Table 30

Center Front Line Angle Findings for Shape Subgroups

Shape	CF Angle Mean	CF Angle Range
Pear	175.25º	20º
(n=6)		(161-181º)
Hourglass	178.5º	7º
(n=4)		(174-181º)
Rectangle	177.25º	9º
(n=8)		(171-180º)

CF=Center Front

Of the three body shape subgroups, the hourglass subgroup had the largest angle mean, but the smallest angle range and the pear subgroup had the largest angle range, but smallest angle mean (See Table 30). The rectangle subgroup and the hourglass subgroups were the closest to each other in center front angle means and center front angle ranges. The pear subgroup's center front angle range was larger than both the hourglass and rectangle subgroups. The difference among the body shape subgroups was about 3.25º.

Table 31

Center Front Line Angle Findings for Size Subgroups

Size	CF Angle Mean	CF Angle Range
Normal	174.93º	20º
(n=7)		(161-181º)
Overweight	177.7º	7º
(n=5)		(173-180º)
Obese	178.42º	7º
(n=6)		(174-181º)

CF=Center Front

Among the body size subgroups, the center front angle mean increased as body size increased (See Table 31). The largest center front angle mean was the obese subgroup, and the smallest center front angle mean was the normal subgroup. The largest angle range was the normal subgroup and the overweight and obese subgroups had the same range. The difference of the center front angle means was about 3.5º. The normal subgroup's center front angle range was significantly larger than the other two subgroups' ranges.

The largest center front angle mean among all the subgroups was the hourglass body shape subgroup, and the smallest center front angle mean was the normal body size subgroup. The subgroups that had the largest center front angle range were the normal body size, pear body shape and 11-12 year old subgroups with a 20º range. The overweight, obese and hourglass subgroups had the same angle ranges at 7º. The 13-14 year old, rectangle, and 9-10 year old subgroups had similar center front angle ranges, 8º, 9º, and 9.5º respectively. All group center front angle means were within 3.57º of each other with the smallest being 174.93º and the largest being 178.5º.

V. SUMMARY, DISCUSSIONS, CONCLUSIONS, IMPLICATIONS, & RECOMENDATIONS

Summary

The purpose of this research was to compare pant pattern shapes for tween girls across age, body size and body shape groups. This study was done in order to understand the impacts of differences in tween girls' bodies to help guide the patternmaking process. This study used 3D body scans to create pant patterns to analyze body shapes and create pant patterns which were used to evaluate differences among patterns based on shape and to measure differences as a basis for understanding pattern development for this target market.

The sample for this study came from two different locations: $[TC]^2$ in Cary, NC, in October, 2004 and Auburn, AL, in November, 2005. Body scans were derived using the $[TC]^2$ NX12 body scanner. All 151 scans in Auburn University's tween girl body scan data base were included. Those scans were grouped first by age, then body size, and finally by body shape. Body size was determined by BMI using the CDC's BMI for Age chart. Body size was classified as normal, overweight or obese. The normal size girls fall into the 6^{th} to 84^{th} percentile, overweight girls into the 85^{th} to 94^{th} percentile, and obese girls into the 95^{th} or higher percentile. The CDC uses the term overweight for the largest group, termed obese in this study, and the term "tending towards overweight" for the next largest group, termed overweight in this study. The below 5^{th} percentile on the

CDC chart is the underweight group, and there were no underweight girls in this study (CDC, 2000)

The scan that best illustrated the average characteristics of each of the nine subgroups was chosen to represent that group and to create a pattern from that scan. The three groups and nine subgroups were: groups - age, body shape and body size; subgroups - 9-10 year olds, 11-12 year olds, 13-14 year olds, hourglass, rectangle, pear, normal, overweight and obese. A total of nine sets of patterns (each set consisting of a front and a back pattern) represented the age, body size and body shape subgroups when the 151 scans were sorted. These patterns were measured by hand three times to account for human error. Actual patterns, not body measurements, provided the data. Most of the data was in the form of pattern measurements, expressed as direct inch and angle measurements, proportional relationships of measurements, and differences between measurements. Curve shapes were also analyzed visually. The following section discusses relationships and disparities between the subgroups.

Discussion

This research supplements and expands on previous studies of pant fit and tween girls. Results showed the different tween girl body shape and body size groups and that across the three groups there were differences in the pant patterns. The findings were broken down by group, age, body shape, and body size, focusing on three major themes, direct linear measurements, proportions and differences, pattern shapes and angle measurements.

Age Related Findings

The age subgroups were some of the most varied groups overall. It was found that as age increased, measurements, such as side length means, crotch point width means, hip depth means, center front and center back angle means, hip circumference and waist circumference, increased as well.

Direct Linear Measurements

One would expect the crotch depth mean to increase with age since the side seam length and hip depths did. The 9-10 year old subgroup had a 9.7” crotch depth mean, then the 13-14 year old subgroup was the next largest with a 10.9” crotch depth mean and the 11-12 year old subgroup was the largest with a 11.07” crotch depth mean. The crotch point width means, front and back, increased with age, but among the three age subgroups the back crotch point width means varied by approximately 0.5” more than the front crotch point width means. For crotch length, the 9-10 year old subgroup was about 3” shorter than both the older age subgroups. It was also interesting to see that the 13-14 year old subgroup’s front crotch length mean was 13.195”, which was slightly larger than the back crotch length mean of 13.078”. The hip depth means increased from the 9-10 to 11-12 year old subgroups by 0.4” and then decreased from the 11-12 to 13-14 year old subgroup of the same amount.

Proportions and Differences

Crotch depth to side seam length proportion means are quite similar (3.606, 3.566, 3.618), but the hip depth to side seam length proportion means increased with age (5.906 to 6.169 to 6.85). The 11-12 and 13-14 year old subgroups were with in 1” of each other for hip circumference and waist circumference with the 9-10 year old subgroup being about 4” smaller in the hip circumference and 2” smaller in the waist circumference. The difference between hip circumference and waist circumference varied from 7.7” for 9-10, 9.25” for 11-12, and 8.09” for 13-14 year old subgroup.

Pattern Shapes

Similarly, the side seam curves and waistlines curves became more curved as age increased. Although the 13-14 year old subgroup had curved side seams, there was only a slight or shallow curve along the waistline. That subgroup’s front waistline was also similar to the 11-12 year old subgroup front waistline.

Angle Measurements

Compared to a 180º line, a 178º angle (2º difference) is considered smaller than a 168º angle (12º difference) for this study. The age subgroups center front and center back angles were very similar, the back angles with only about a 1º difference and the front angles with only about a 1.5º difference. Center front angle means for the 11-12 year old subgroup had the largest center front angle range (20º), while the 9-10 and 13-14 year old subgroups had closer ranges (9.5º and 8º, respectively). The center back angle ranges increased with age, 9-10 year old subgroup with a 2.5º range, 11-12 with a 9.5º range and the 13-14 year old subgroup with an 11º range.

For the age subgroups, generally the biggest difference in circumference and depth measurements was between the 9-10 and 11-12 year old subgroup, but the biggest difference in angle measurements was between 11-12 and 13-14 year old subgroups, where it might be expected that the same pattern of the biggest difference being between the 9-10 and 11-12 year old subgroups.

Body Shape Related Findings

Overall, there were not many repetitive patterns in the shape subgroups for measurements. The crotch depth means increased from the rectangle to hourglass to pear subgroup, but the hip depth means increased from the pear to the hourglass to the rectangle subgroup. The pear subgroup has the largest front, back and total crotch point width means, and also has the largest crotch depth mean. The pear subgroup also had the largest hip-to-waist circumference difference and the largest crotch point width. It was surprising that the hourglass group had the smallest hip-to-waist difference; one would expect the rectangle to have the smallest hip-to-waist difference.

Direct Linear Measurements

The rectangle subgroup's back and front crotch point width was approximately 1" shorter than the other two subgroups' whose front and back crotch point widths are with in 0.2" of each other (pear and hourglass). The total crotch length mean for the rectangle and hourglass subgroups are less than ½" different, but the pear body shape subgroup total crotch length mean was more than an 1" larger than the other two. The hip depths across the three body shape subgroups vary by only 0.648" which is surprising since the pear body shape usually has a lower hip than the other two shapes. The hip circumferences were similar for pear and hourglass with the rectangle subgroup between 2 ½" and 3" smaller. This could be expected since the body shape rectangle has most of its weight distributed evenly on the body, while the pear and hourglass body shapes usually carry more of the weight in the hip area. It was interesting though that the hourglass had the largest waist circumference (33.06") compared to the 3" difference from the rectangle (29.8").

Proportions and Differences

The crotch depth-to-side seam length proportion range for the three shape subgroups by only 0.172. The hip depth-to-side length proportions fell between 6 and 6.85 to 1. The proportions increased from the rectangle to the hourglass to the pear shape subgroups. Among the three subgroups, the hip depth-to-side length proportion ranges were very similar.

The largest hip-to-waist difference was the pear subgroup which was to be expected, but the unexpected was the least difference for the hourglass subgroup.

Pattern Shapes

For side seam shapes, the pear was slight to moderately curved, the rectangle had little or slight curves and the hourglass patterns were moderately curve. The rectangle subgroup's waistlines varied the most, while the hourglass and pear subgroups stayed similar. The rectangle's waistline curves generally curved up to the center front with slight or moderate curves. The hourglass subgroup had similar waistline curves that had very little or a slight curve up to center front and for this subgroup the back waistlines had more curve than the front waistlines. Among the three subgroups, the front waistlines were slightly curved while the back waistlines were slight to moderate curve which follows a general patternmaking rule of thumb.

Angle Measurements

The pear subgroup had the largest center front and center back angle ranges (20º and 9.5º respectfully), with the front angle range being much larger than the hourglass (7º) or rectangle (9º) ranges. The pear had the largest center back angle mean (167.67º, 12.33º difference from 180) and the rectangle had the smaller center back angle mean

(170.69º) which would be expected since the pear body shape generally has more curves that the rectangle body shape. The center front angle means vary with the hourglass subgroup not having much of a front angle (178.5º) to the pear with a larger angle (175.25º).

Body Size Related Findings

Similar to age groups, measurements generally increased with body size increases. The crotch depth means, crotch point width means, hip and waist circumferences increased as body size increased.

Direct Linear Measurements

It was interesting to find that the crotch depth means varied by less than 2" across the body size subgroups. The overweight and obese groups had similar crotch depth means, but the overweight subgroup had the largest hip depth. Among the three body size subgroups, the back crotch point width means varied by 2.5" and the front crotch point width means varied by 1.8". The normal and overweight subgroups' back crotch length means were longer than the front crotch length means, but the obese front and back crotch length means were almost the same. This could possibly have something to do with weight distribution, the normal and overweight subgroups have more weight distributed on the back than the obese, whose weight is distributed front and back. For all the body size subgroups, the hip circumferences were approximately 3" apart, but the waist circumference differences were from normal to overweight about 1" and from overweight to obese nearly 6". The hip and waist circumferences increased with age with a 3" jump from normal to overweight and then overweight to obese.

Proportions and Differences

As body size increased, the crotch depth-to-side seam length proportion decreased because as body size increased, so did the crotch depth. The hip depth-to-side length proportions varied; the normal subgroup's was 7.072, the overweight subgroup's was 5.487, and the obese subgroup's was 6.36. The difference of the means for hip circumference-to-waist circumference went from 8.125" for the normal body size subgroup to 10.125" for the overweight subgroup and then decreased to 7.521" for the obese group.

Pattern Shapes

For side seam shape, the pattern of the curves increasing with body size increase parallels the body size and measurement increases. It was also visually evident that as body size increased, the waistline curve increased. The normal body size subgroup's front waistlines were slightly curved and the back waistlines were generally shallow curves compared to the obese subgroup's curves which were moderately to very curved on the front and back waistlines. The overweight subgroup had the most varied side seam curve, but the obese subgroup had the most varied waistline curves. It was interesting that the waistline curves for the normal and overweight subgroups were similar, especially on the front.

Angle Measurements

For the center front and center back angle ranges, the overweight and obese had similar ranges (7º for both center front and 8.5º and 9º for center back). Center front angle mean decreased with body size; the normal subgroup had the largest center front angle range.

Conclusions

General Findings

When comparing all of the pattern data, a few generalized findings appeared. Within the groups (age, body shape, or body size), there were very similar pattern measurement means or radically different measurements. The most varied pattern shapes across subgroups seemed to be in the crotch curve and center front/back line angles. These differences emerged as the data was being compiled and after the patterns were visually analyzed.

Specific Findings

For pattern shapes, age and body size seems to make a difference. Not only does the obese subgroup differ from the normal subgroup, but the middle body size, overweight, differs from the other two subgroups. This may indicate the need for three size categories rather than just the traditional 'girls' and 'plus-size girls'. It also appears that the greatest variation in each group is the 11-12 year old subgroup for age, normal and obese subgroups for body size, and the rectangle shape varies the most followed by the pear. For proportions, it could be said that as body size increases, generally the proportions decrease and that there is not much difference in the ratios for age.

One might expect that the rectangle subgroup should have the least difference in hip-to-waist for body shape subgroups and the pear have the greatest difference. Here the hourglass has the least difference, by just under ½". It would also be expected that the hourglass waist would be smaller than the rectangle. Here the rectangle subgroup was more heavily weighted because of the 9-10 year old subgroup only having rectangle body shapes.

Limitations

Several limitations could have influenced the findings in this study. Of course, human error is always possible when measuring and visually analyzing patterns and was possible in this study. The exact placement of body locations (hip, waist, crotch) was governed by parameters set in the BMS software, although each scan was visually checked for correct placement. The study was also limited by the small sample size of scans to choose the representative scan from and only having one representative scan for each group, thus not being able to analyze more patterns. There were also an uneven number of shapes in each age or body size group since the 9-10 year old subgroup only had rectangle body shapes. The small sample size also limited possibilities of other body shapes and body sizes. The sample could also be skewed by the fact the scans were only of tweens in the southeast part of the United States. It could also be said that BMI does not account for active girls with more muscle mass when classifying body size subgroups. Also, since the patterns were derived from body scans, it was assumed that they would fit the bodies. However, since it was impossible to construct the pants for the individuals scanned, it cannot be known for sure that the patterns correctly fit.

Implications

This research lays the ground work for future studies on fit for tween girls or studies on pattern shapes. It was shown that there were some differences in pattern shapes and proportions to consider when developing patterns. With traditional patternmaking, you are limited to the proportions and shapes set forth by the author of whichever instructions you are following. Using 3D body scan software to create a pattern, the process is much faster and the pattern is developed directly from the subject's real body, taking not only circumference and vertical measurements into account, but also the actual 3D shape. Findings support Brock's (2006, p. 174) research that there are differences in the subgroups of tween consumers, especially between age subgroups and body size subgroups.

The method used in this study can be applied to future 3D body scan patternmaking studies. The findings may help traditional patternmakers in re-thinking the way they draft and create patterns, especially when working with different body size and shapes. This research will help future researchers studying patternmaking, pattern shapes, or the tween girl market. It could also help inform the study and analysis of sizing and grading specification for this target market.

Recommendations

Since there are few studies investigating the tween consumer, their apparel needs, and, more specifically fit, for this target market, there are many opportunities for future research. Recommendations include further analysis of the age, body shape and body size groups and subgroups, and gathering a larger sample of tween girls. More specific suggestions include:

1) Looking at patterns and construction the pants for fit tests.
2) Fit tests should be conducted to see if patterns developed from the 3D data fit the consumer.
3) Data should be collected in different regions.
4) Different parameters for hip and waist placement can be explored to see if there is any effect in the change of placement.

5) Patterns can be drafted using traditional methods using body scan data and compare those patterns to the ones generated by the body scan software.
6) The apparel industry should explore the use of 3D generated patterns to improve fit of their garments.
7) The apparel industry could investigate the possibility of having three size categories for normal, overweight and obese body sizes for tween girls.
8) Researchers could further investigate the different body shapes of tween girls.

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APPENDICES

APPENDIX A

TABLE OF REPRESENTATIVE BODY SCANS

9-10 Year Olds

Body Size	Body Shape	Age	Height (in.)	Weight (lbs.)	BMI	Hip (in.)	Waist (in)
Normal	Rectangle	10	54.5	71	16.8	30.01	22.85
Overweight	Rectangle	10	55	96.4	22.4	34.64	28.30
Obese	Rectangle	9	57.75	145	31.4	41.37	36.54

11-12 Year Olds

Body Size	Body Shape	Age	Height (in.)	Weight (lbs.)	BMI	Hip (in.)	Waist (in)
Normal	Hourglass	11	58.5	83	17	32.16	24.35
	Rectangle	12	60	90	17.6	32.59	24.52
	Pear	12	62	96	17.6	33.78	25.23
Overweight	Rectangle	11	62.3	120	21.8	36.17	28.22
	Pear	11	63.3	139.6	23.7	39.96	32.18
Obese	Rectangle	11	60.5	136	26.1	39.53	33.11
	Pear	12	58	147.2	30.8	41.66	32.75

13-14 Year Olds

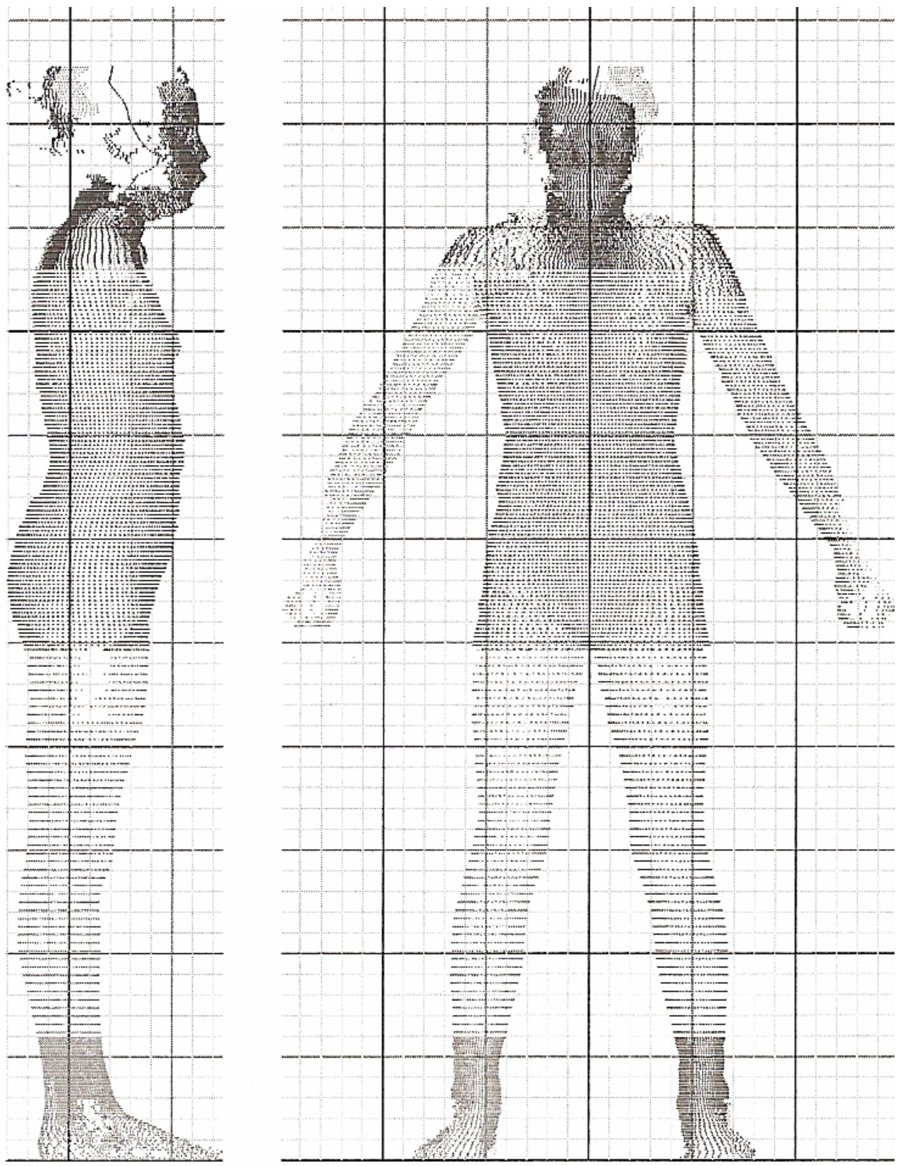
Body Size	Body Shape	Age	Height (in.)	Weight (lbs.)	BMI	Hip (in.)	Waist (in)
Normal	Hourglass	13	63.3	104.6	18.4	33.75	26.90
	Rectangle	13	62.5	121	21.8	36.34	28.18
	Pear	14	64	120	20.6	37.34	29.82
Overweight	Hourglass	13	65	143	23.8	40.36	30.93
	Pear	14	63.8	142.4	24.6	41.07	29.90
Obese	Hourglass	13	64	154	26.4	40.46	36.33
	Rectangle	14	62.5	166.8	30	40.33	35.10
	Pear	13	64	181	31.1	44.87	41.49

APPENDIX B

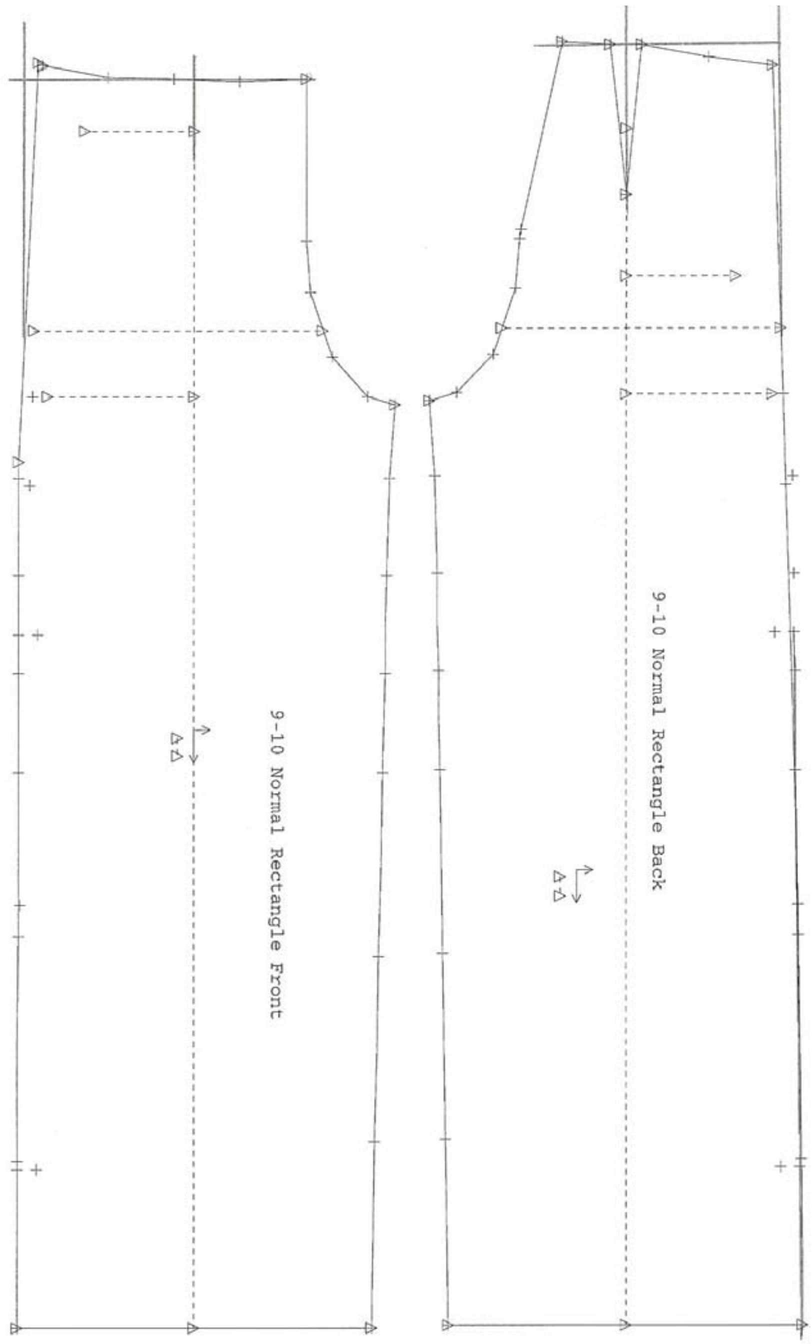
REPRESENATIVE BODY SCANS

AND

3D-TO-2D PANT PATTERNS



9-10 Normal Rectangle



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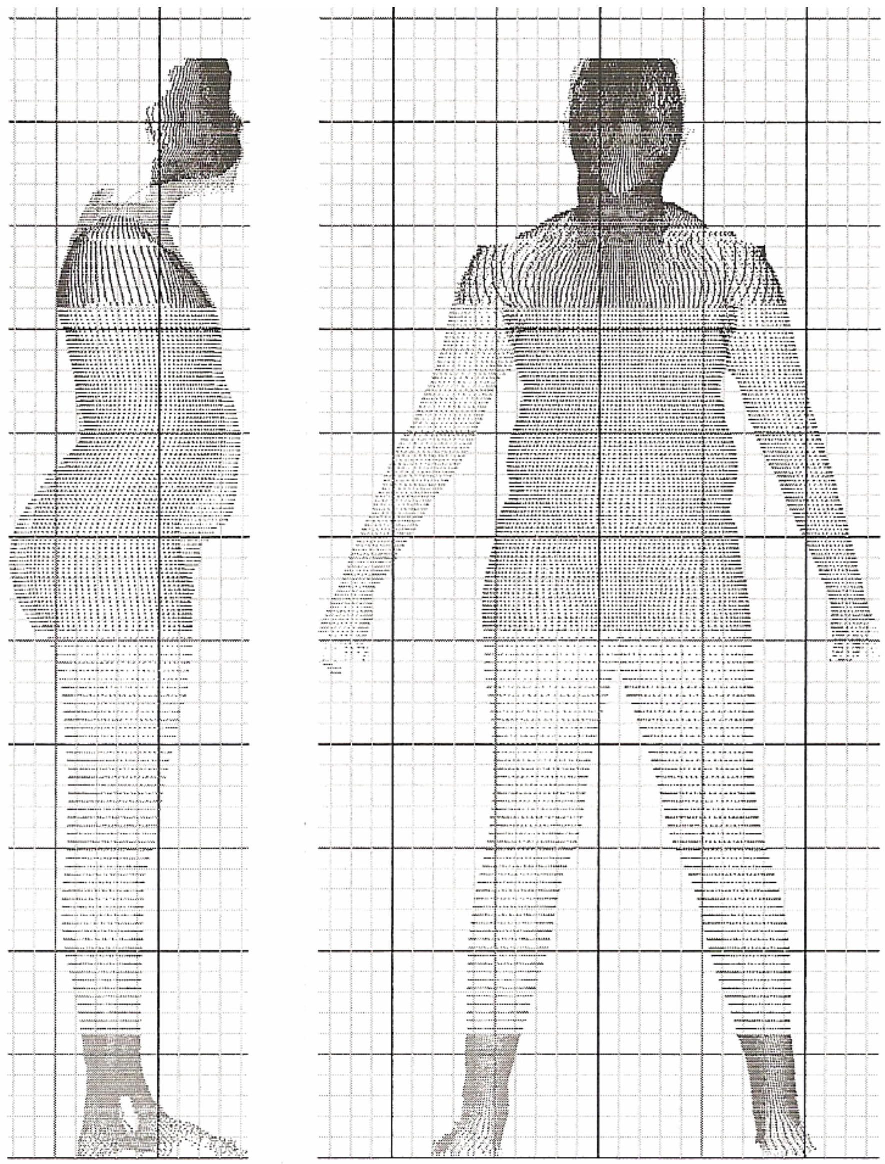

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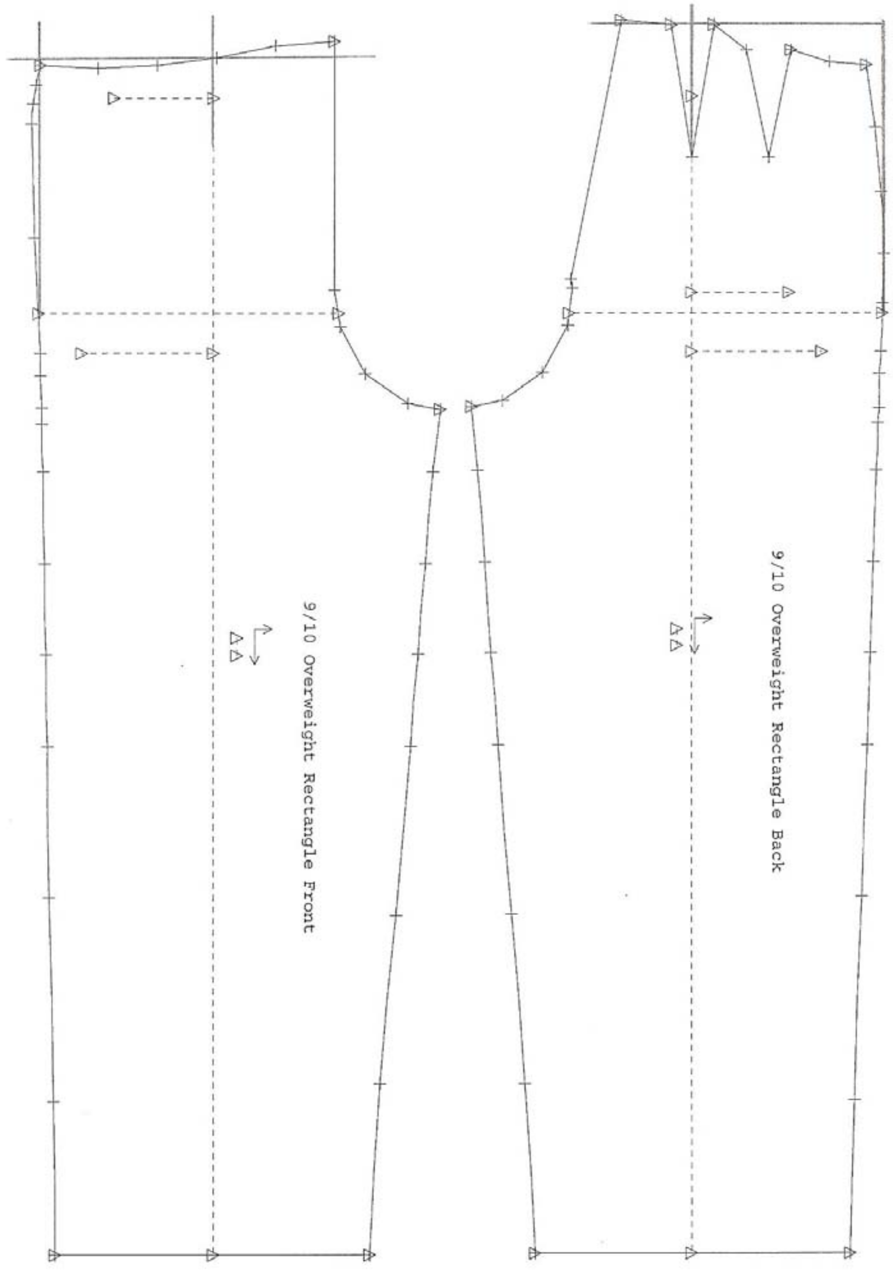

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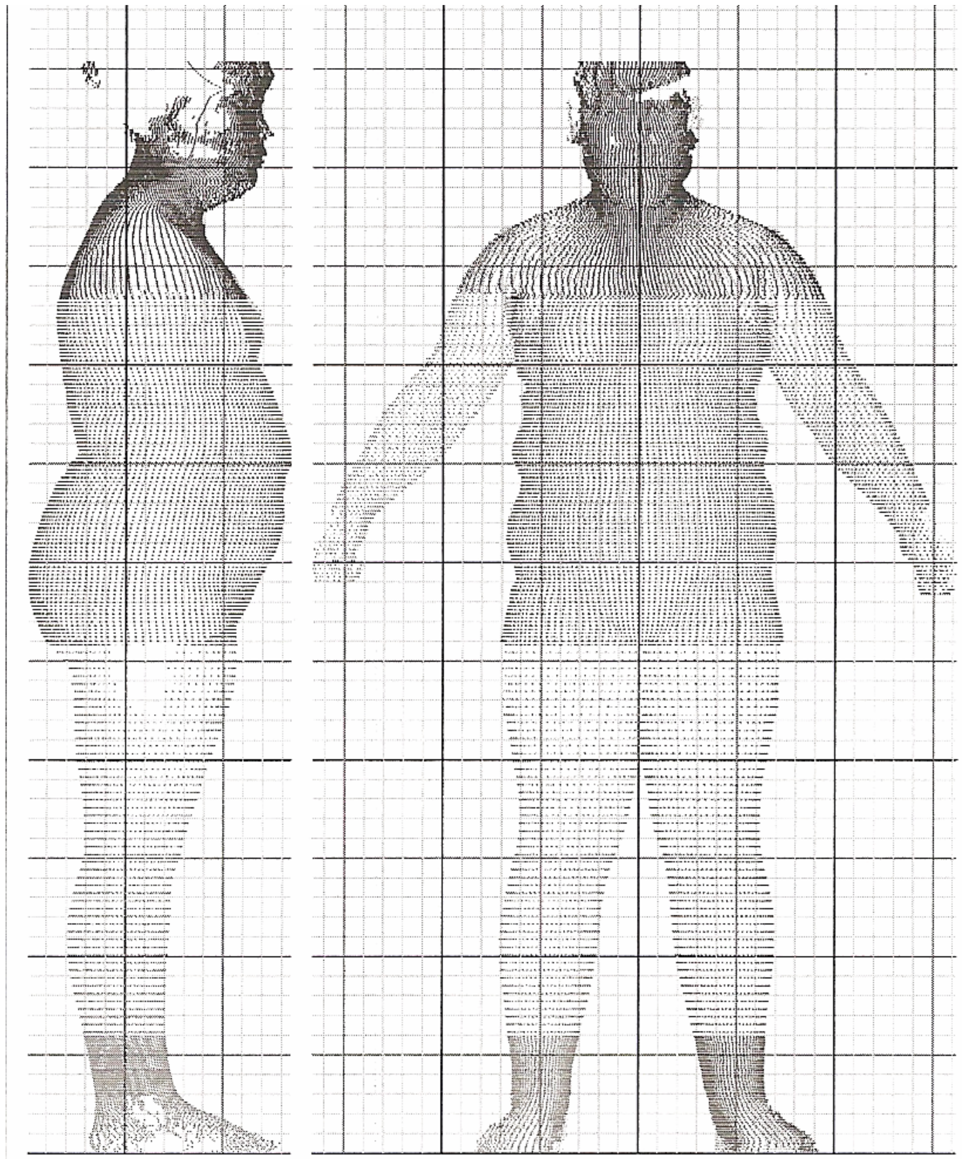

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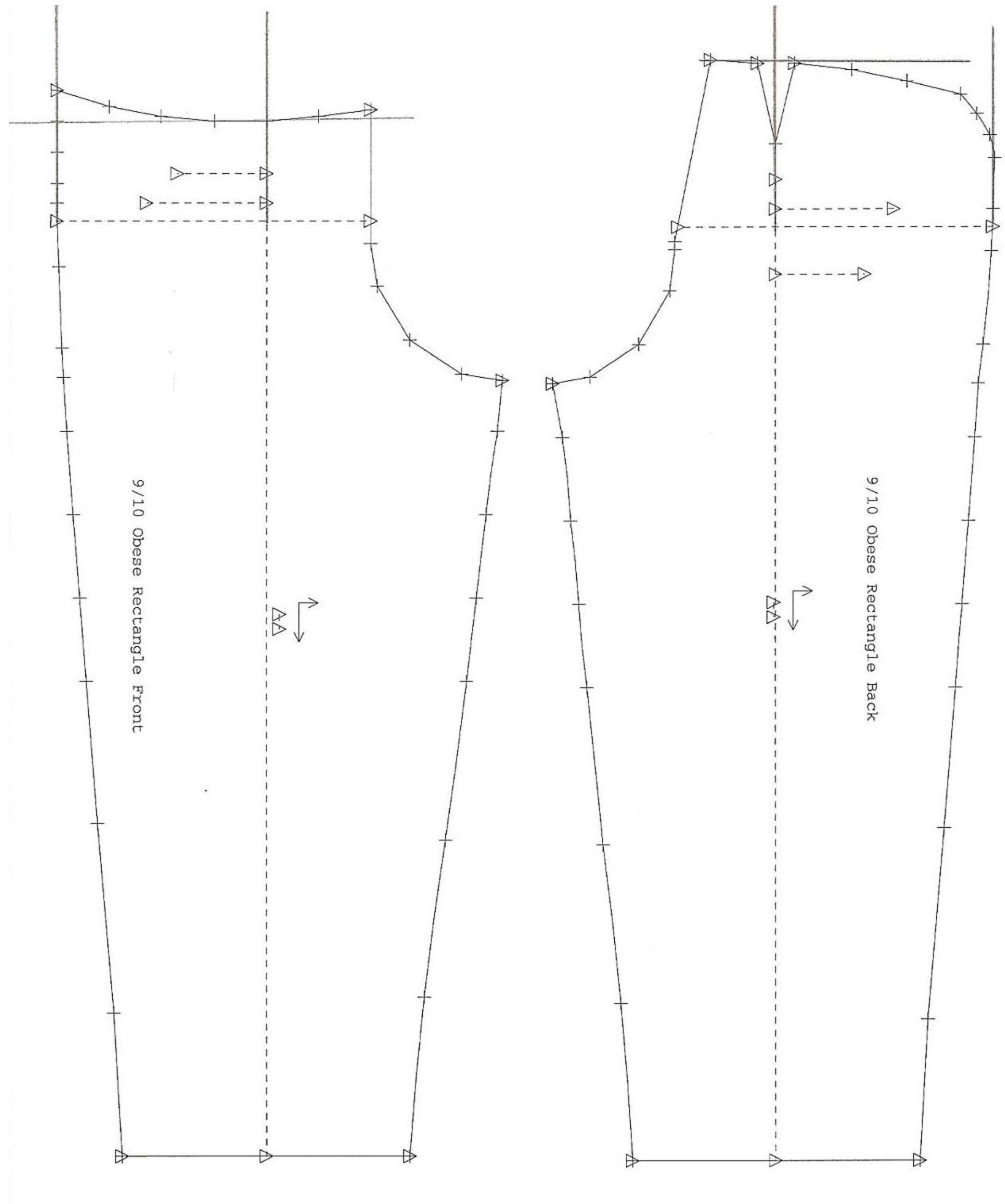

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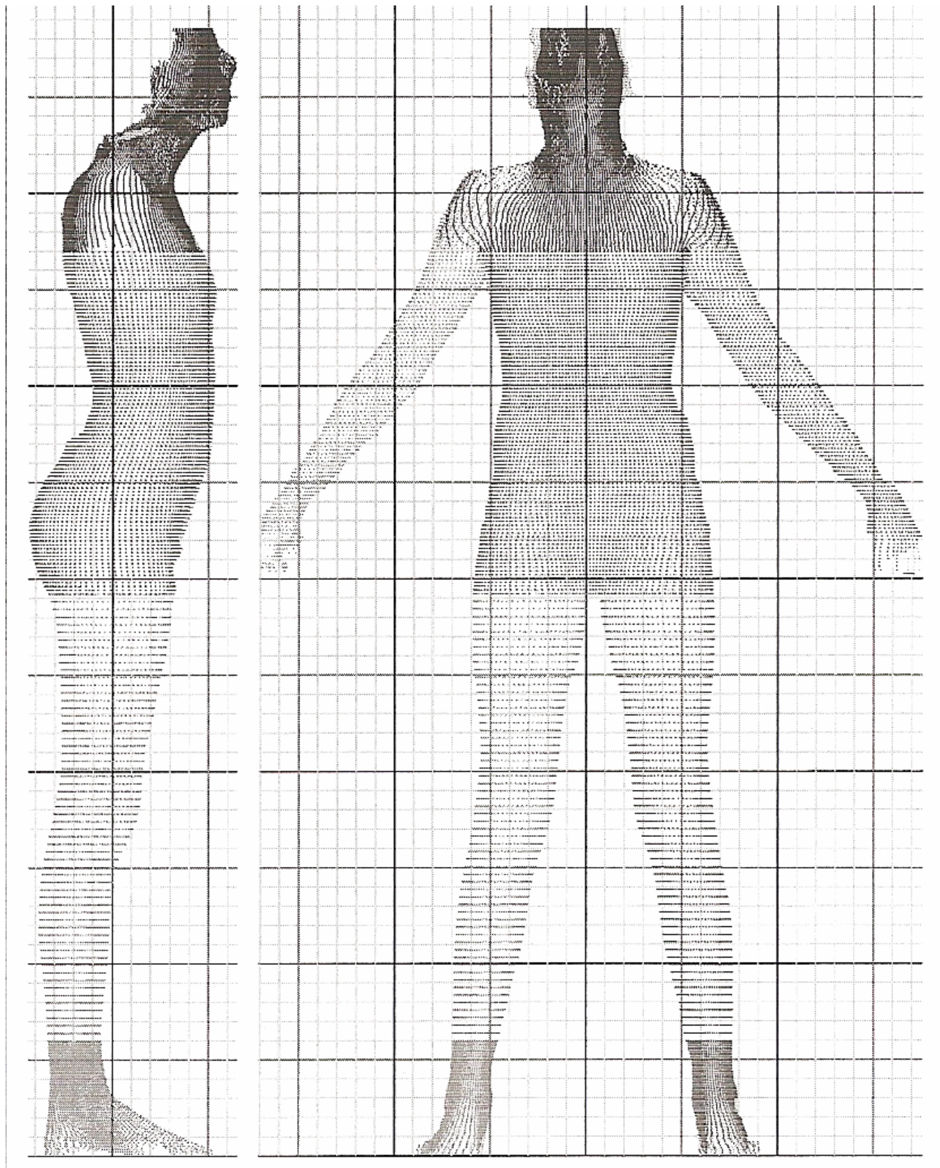

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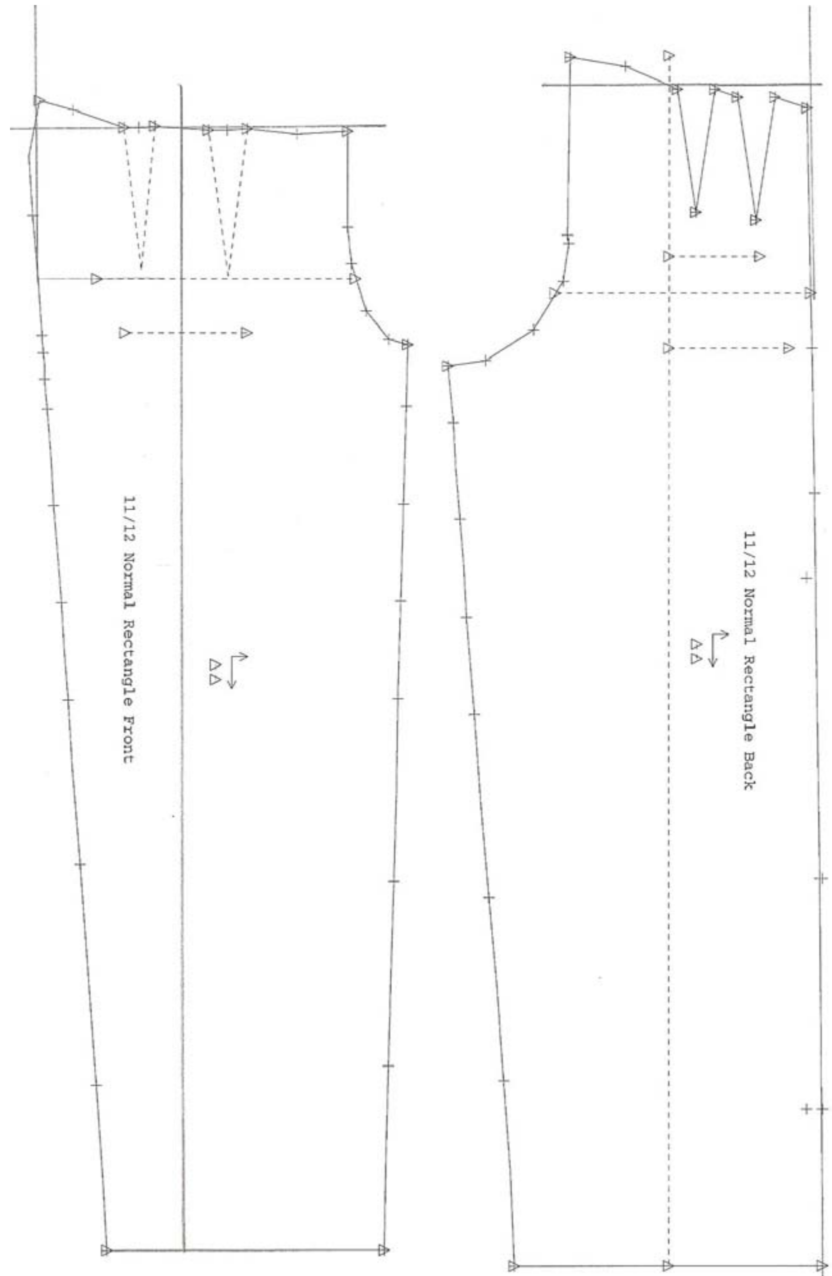

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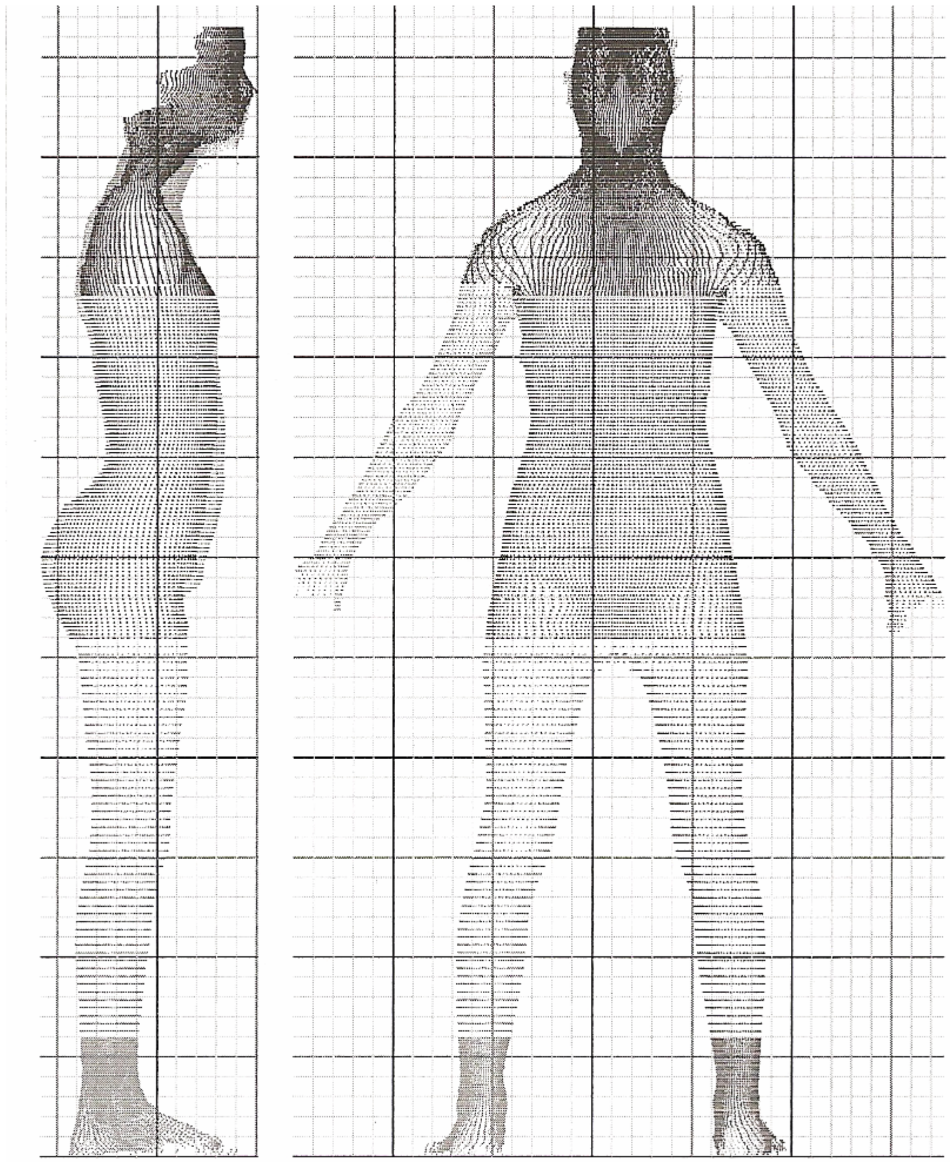

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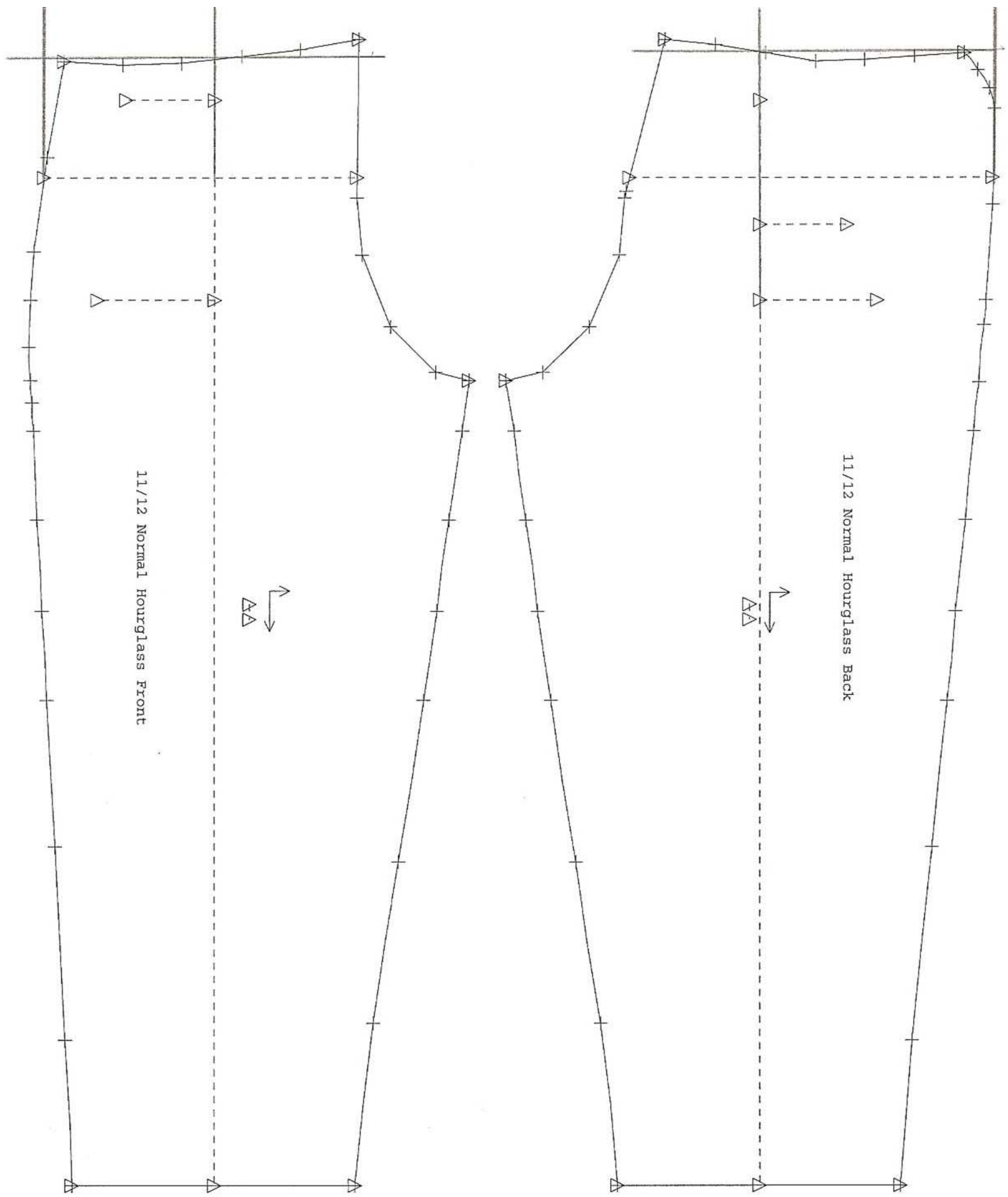

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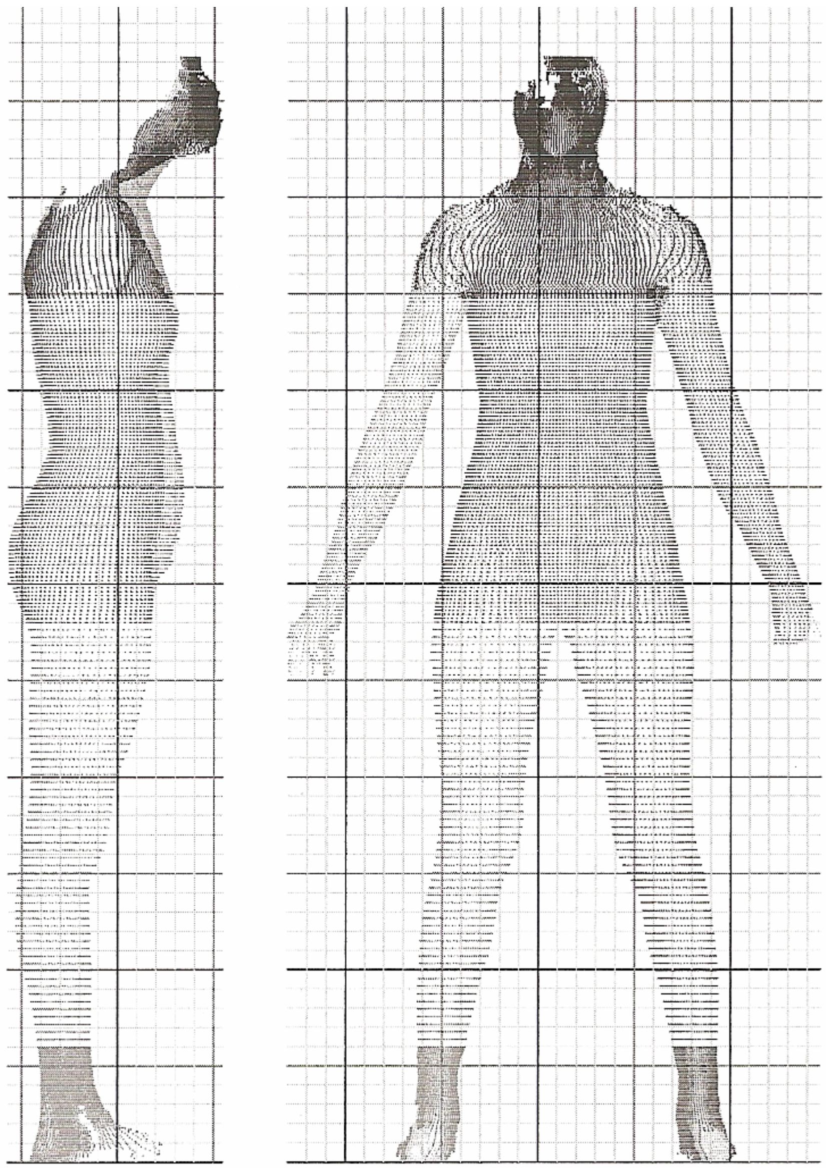

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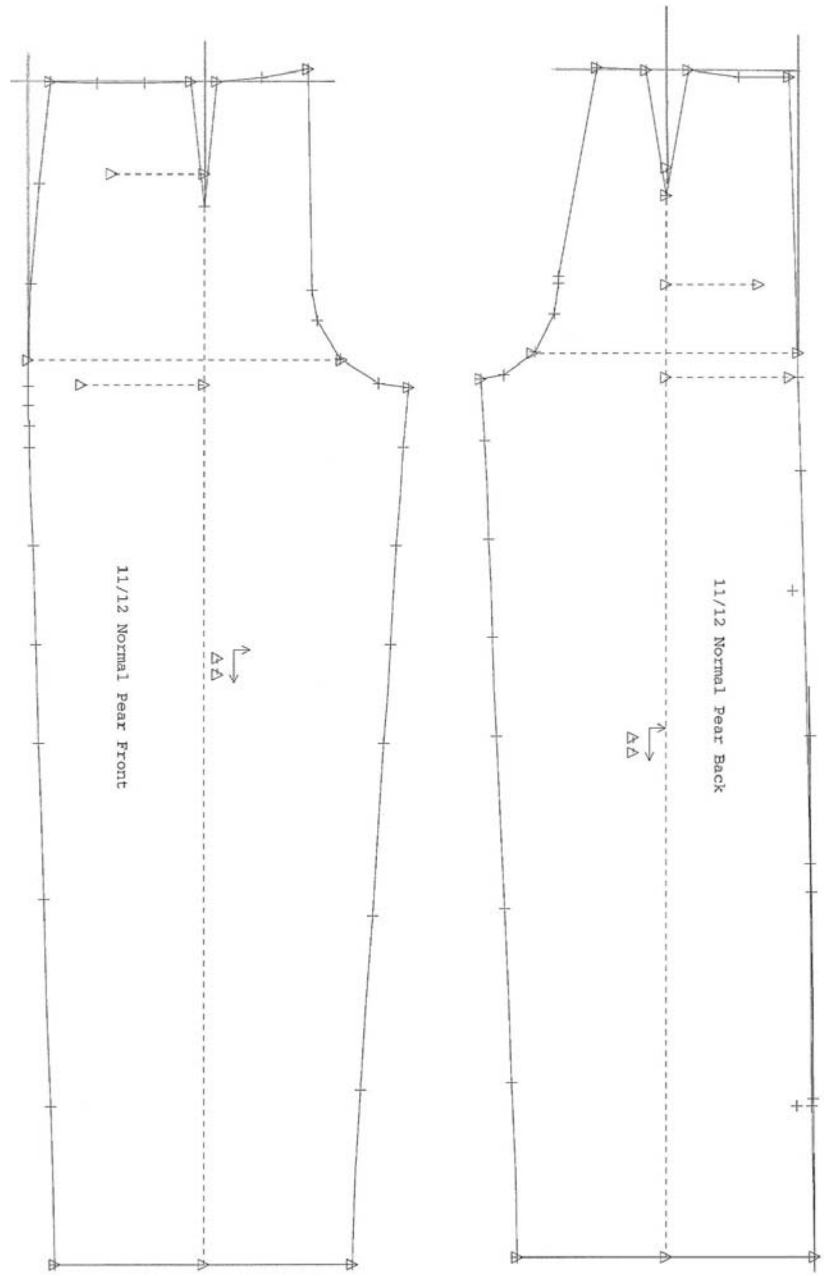

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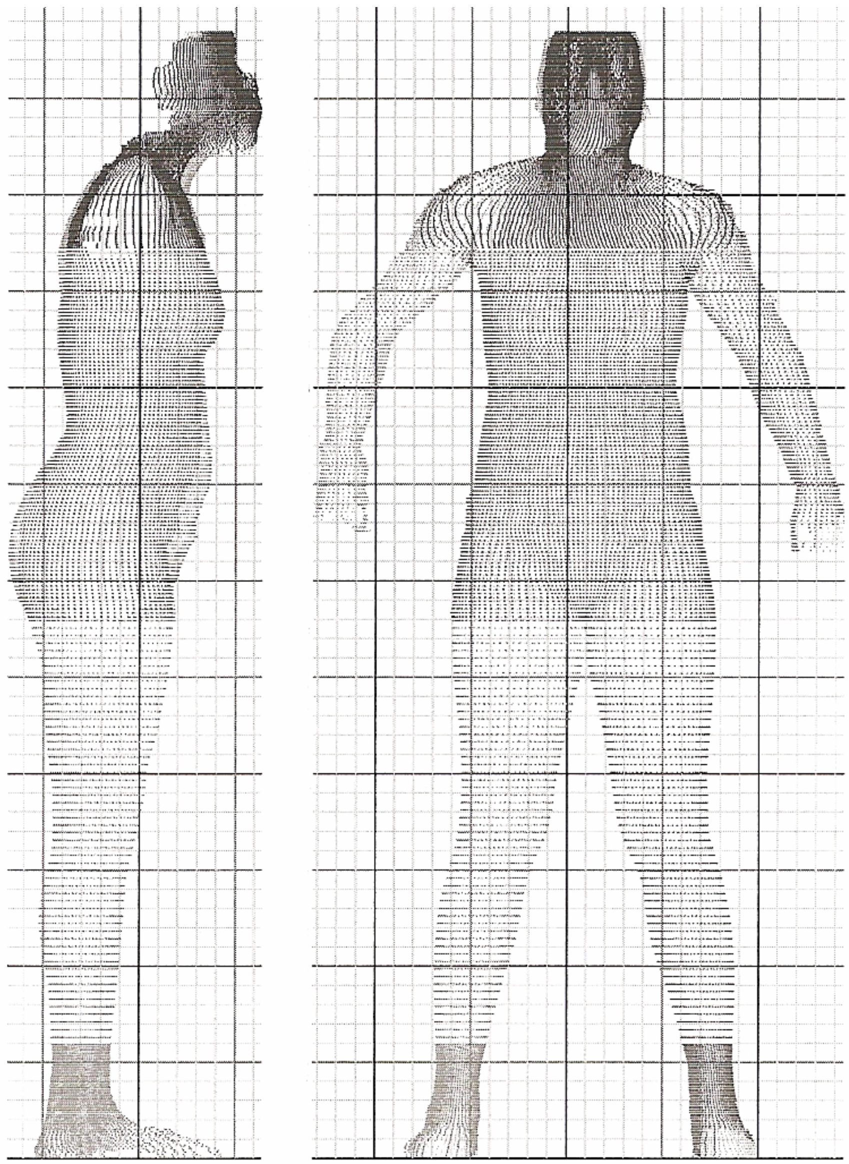

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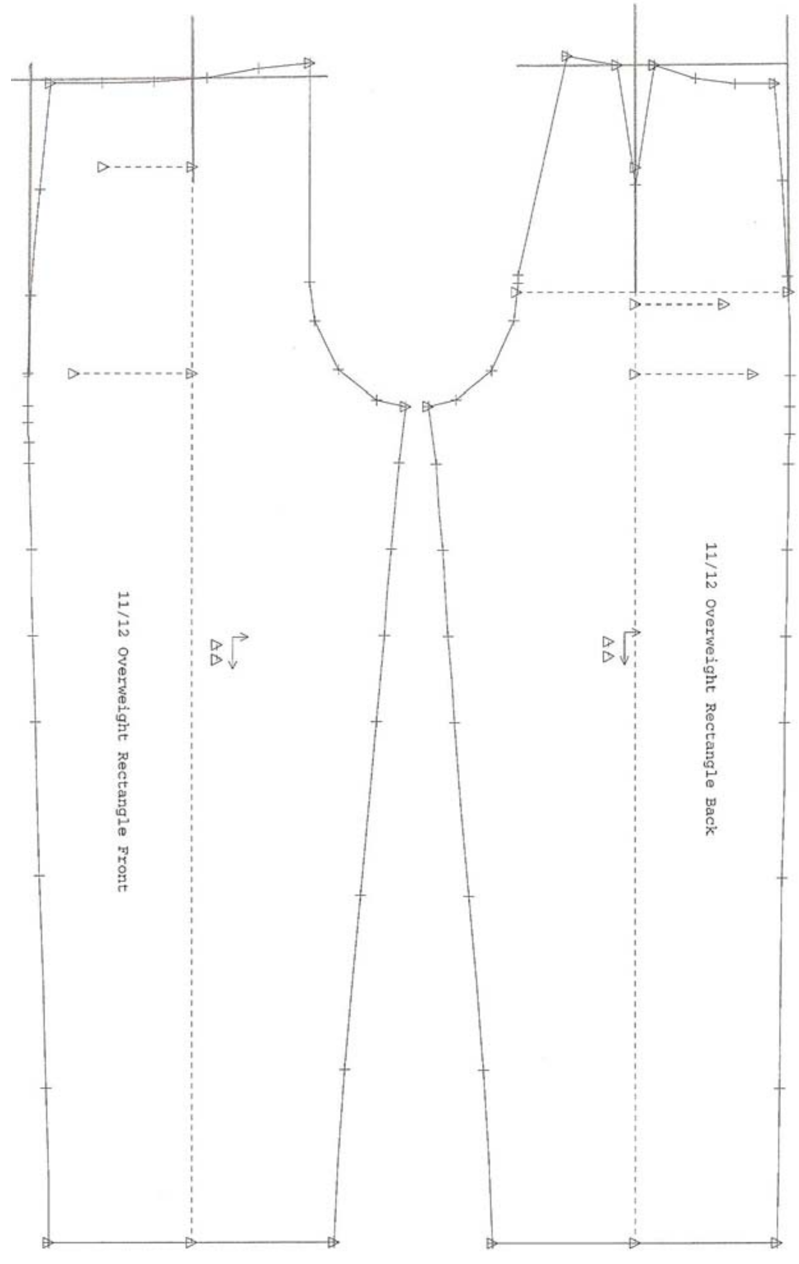

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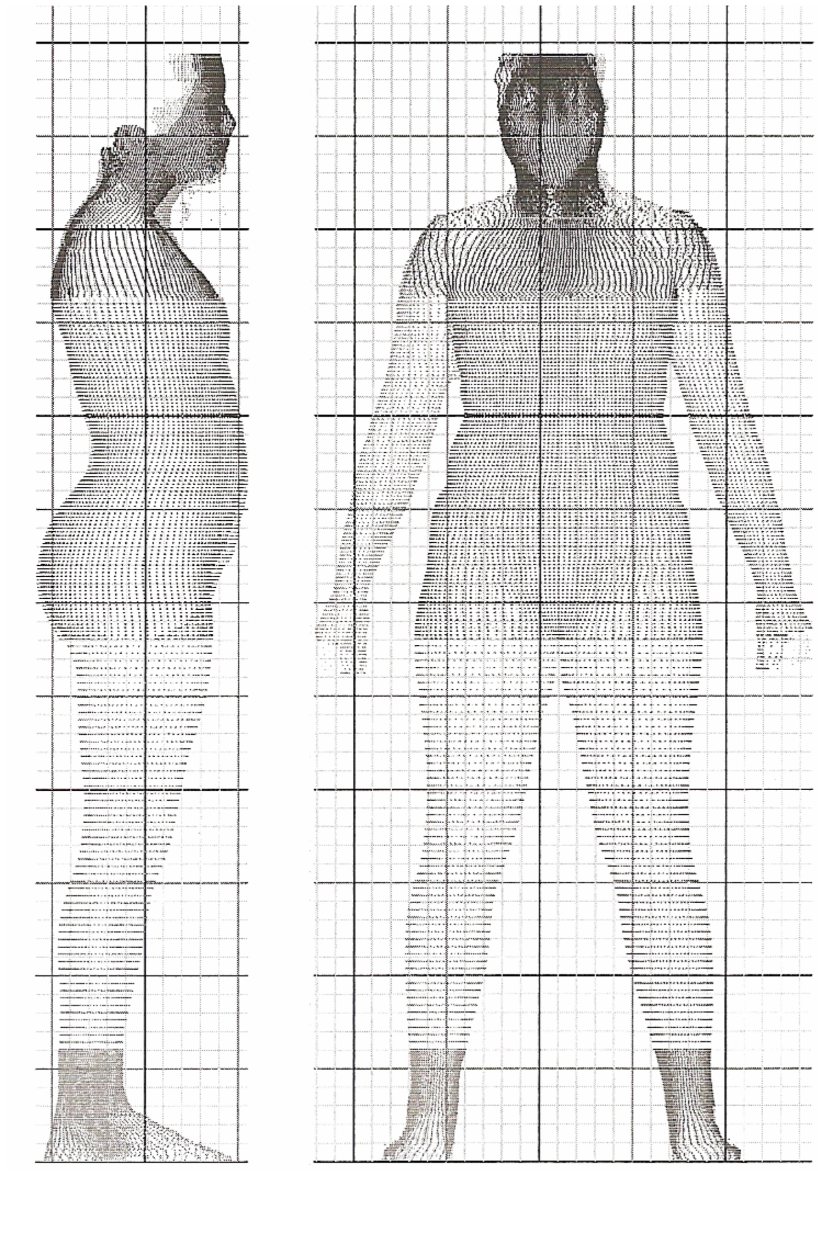

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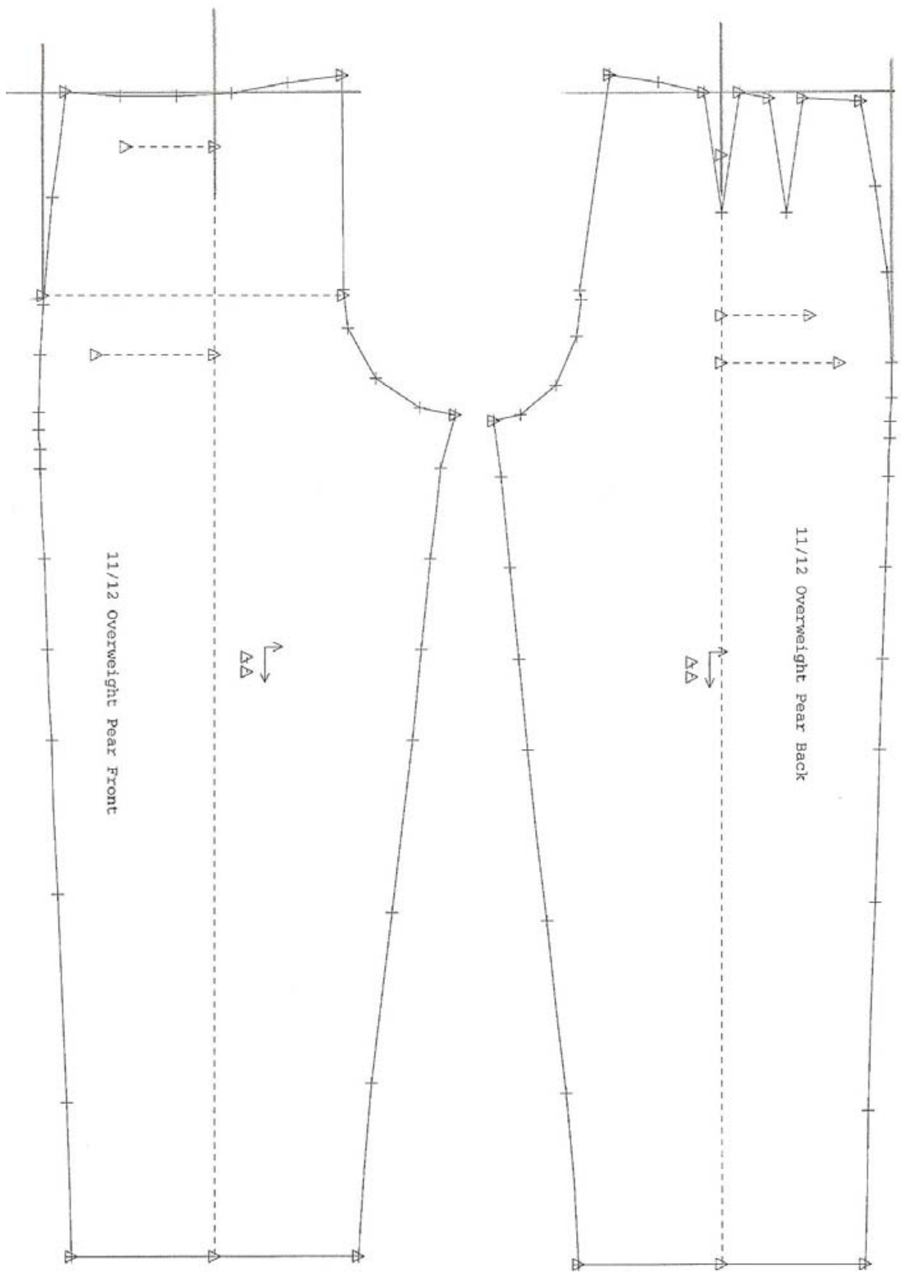

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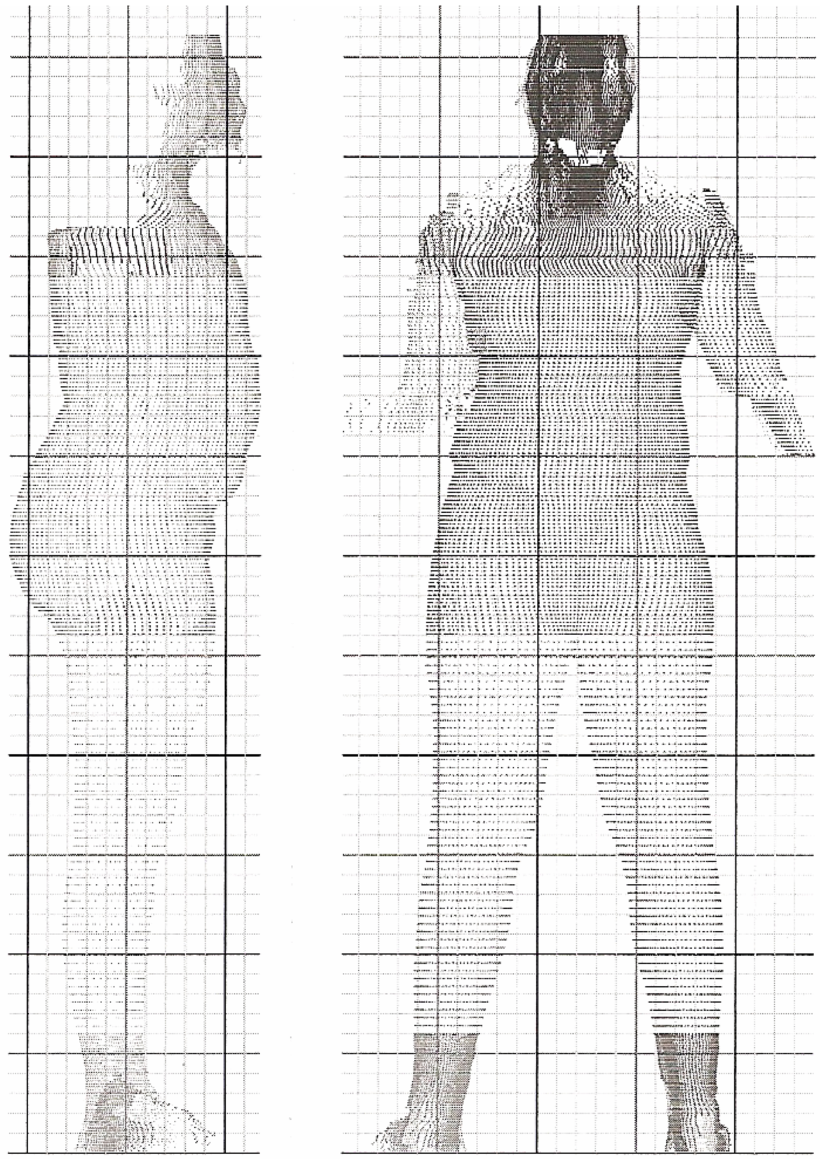

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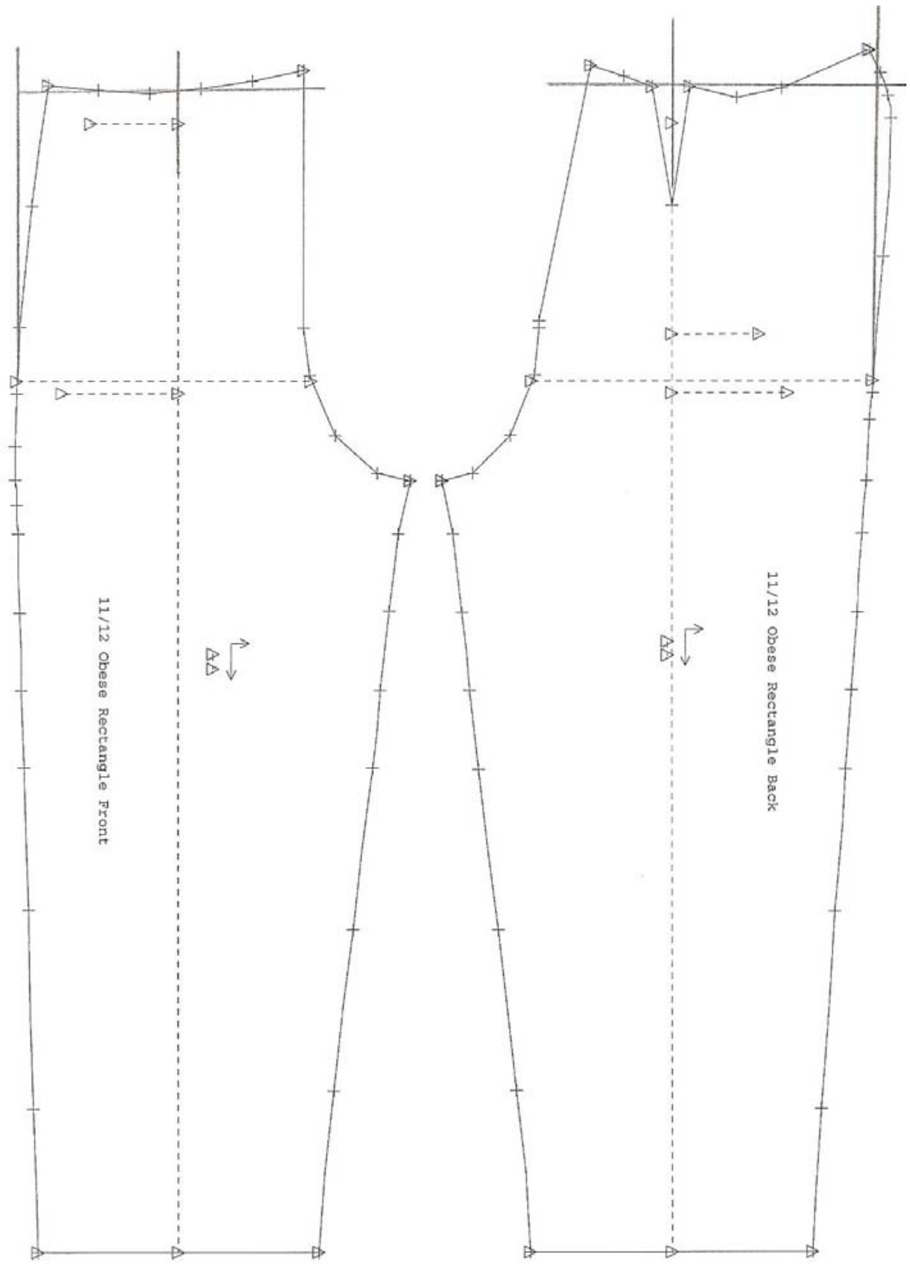

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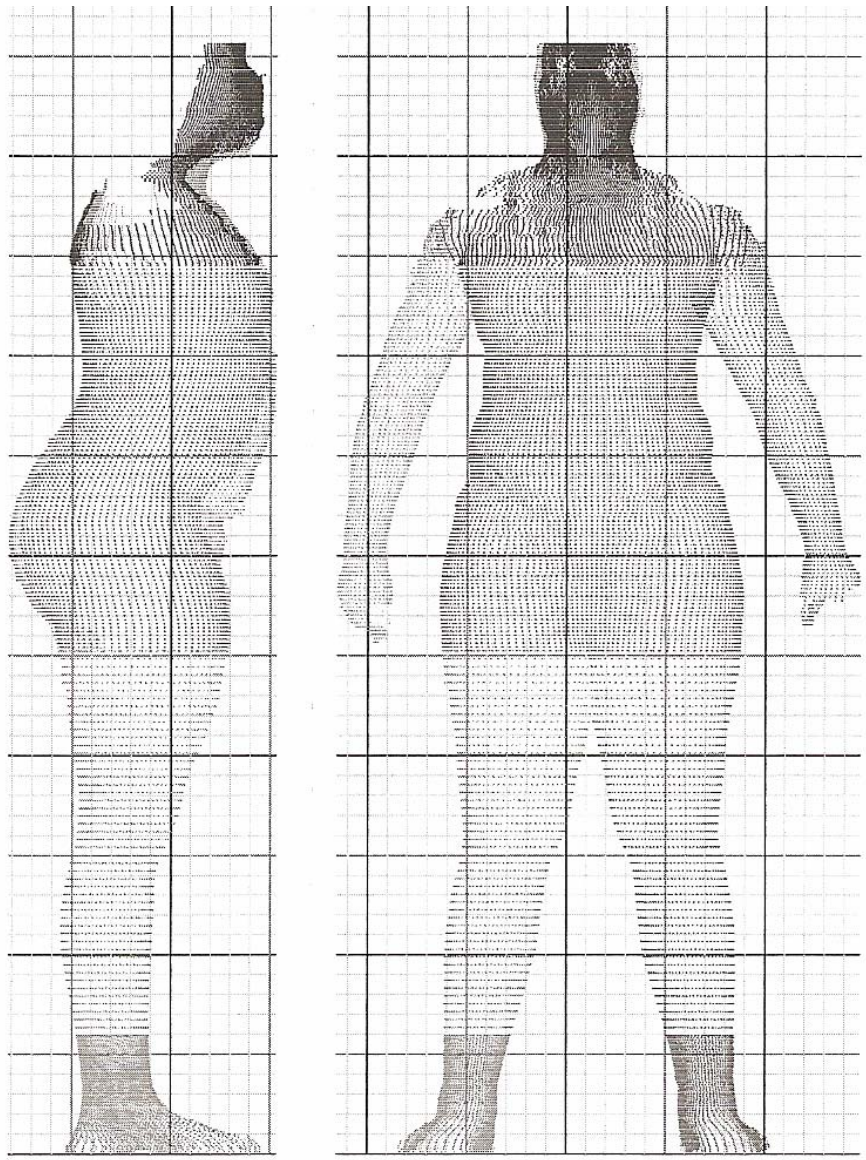

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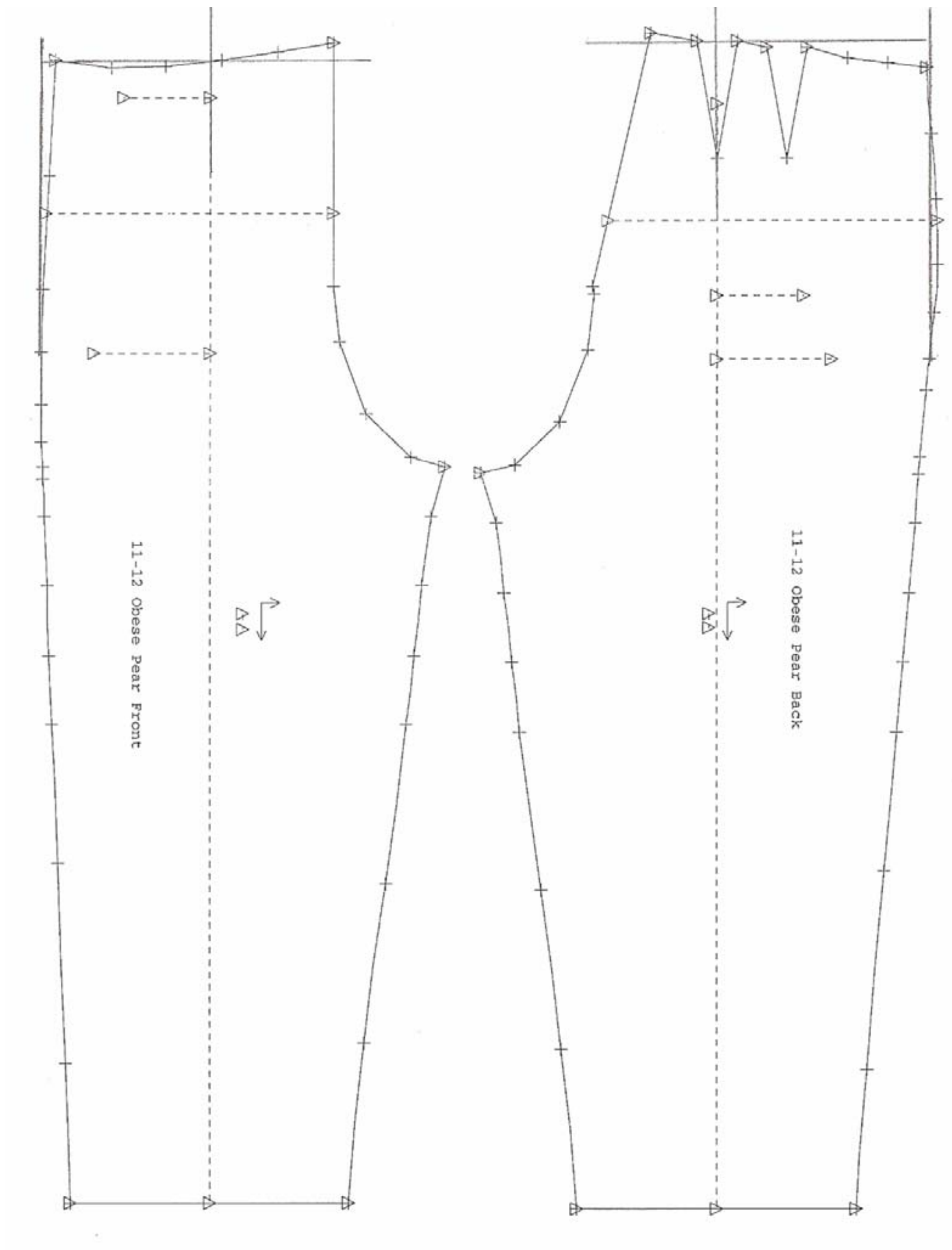

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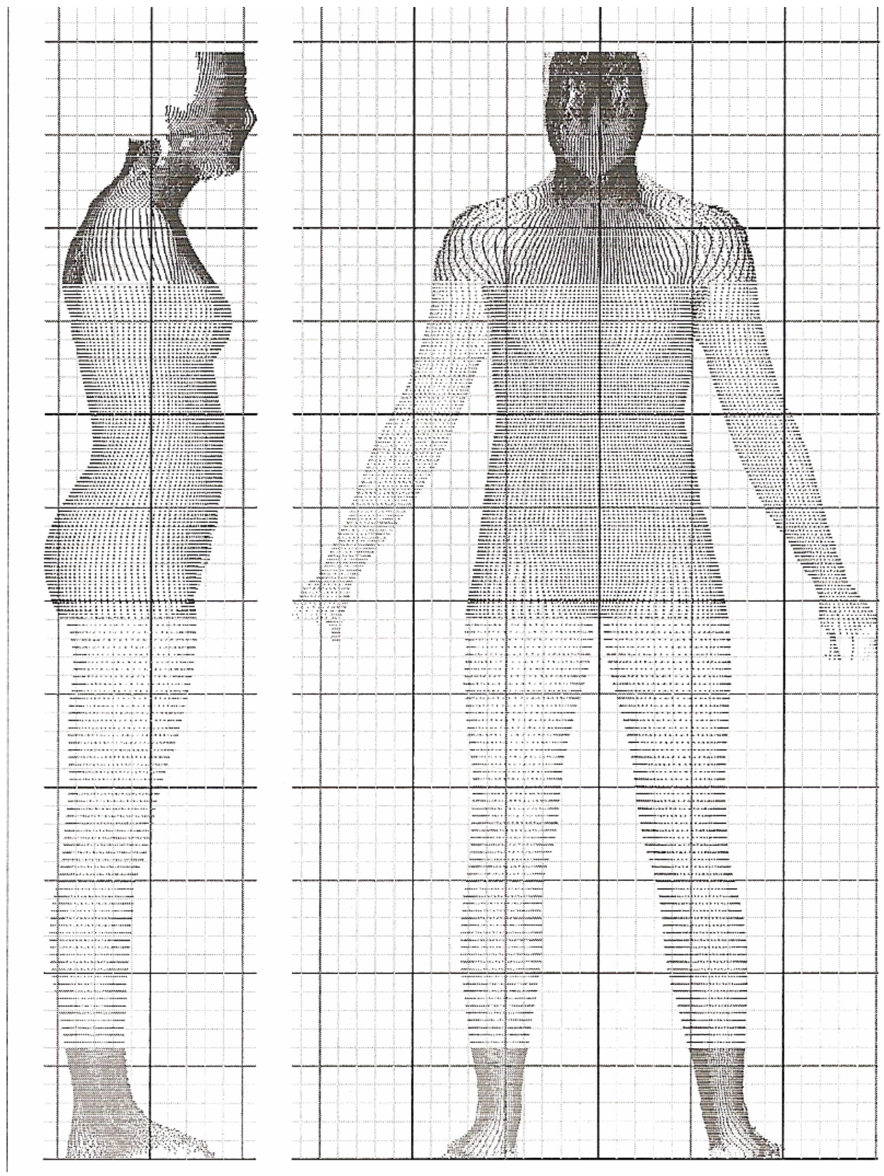

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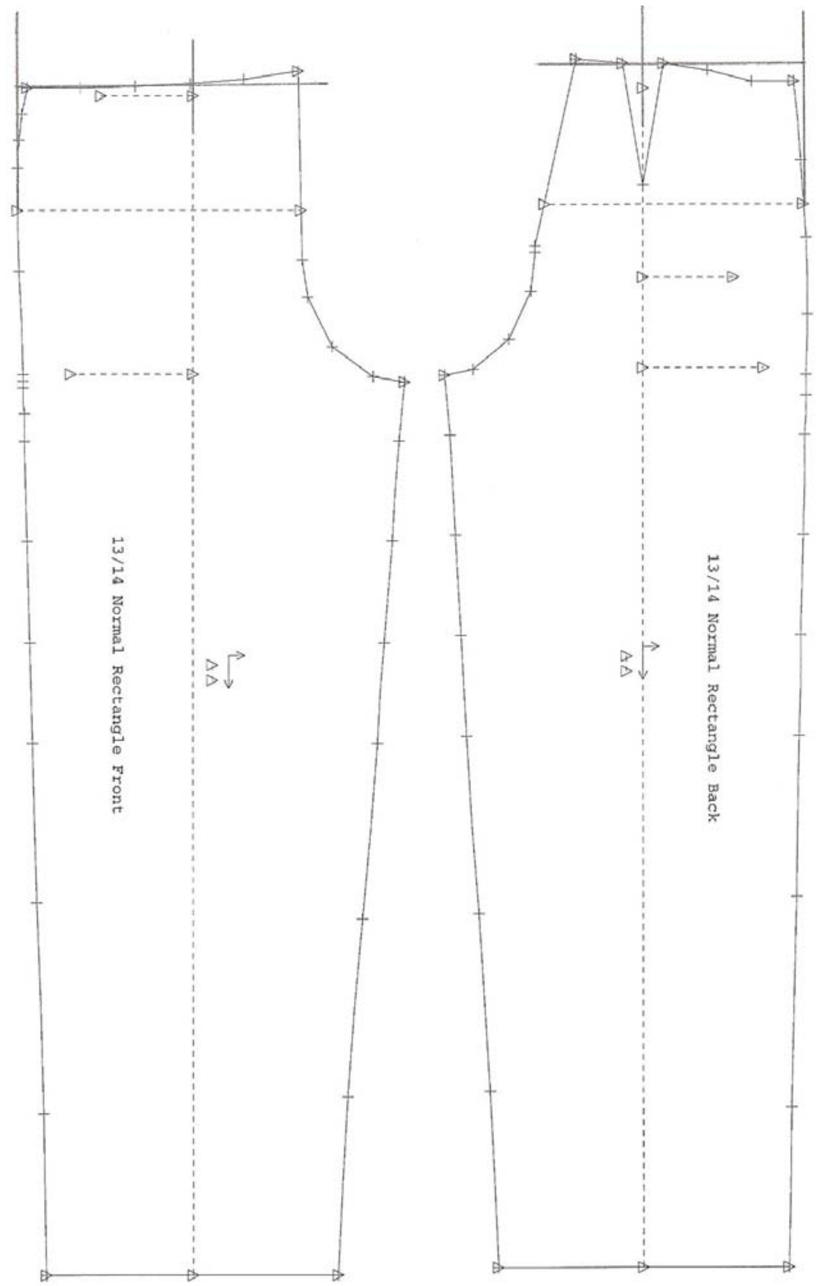

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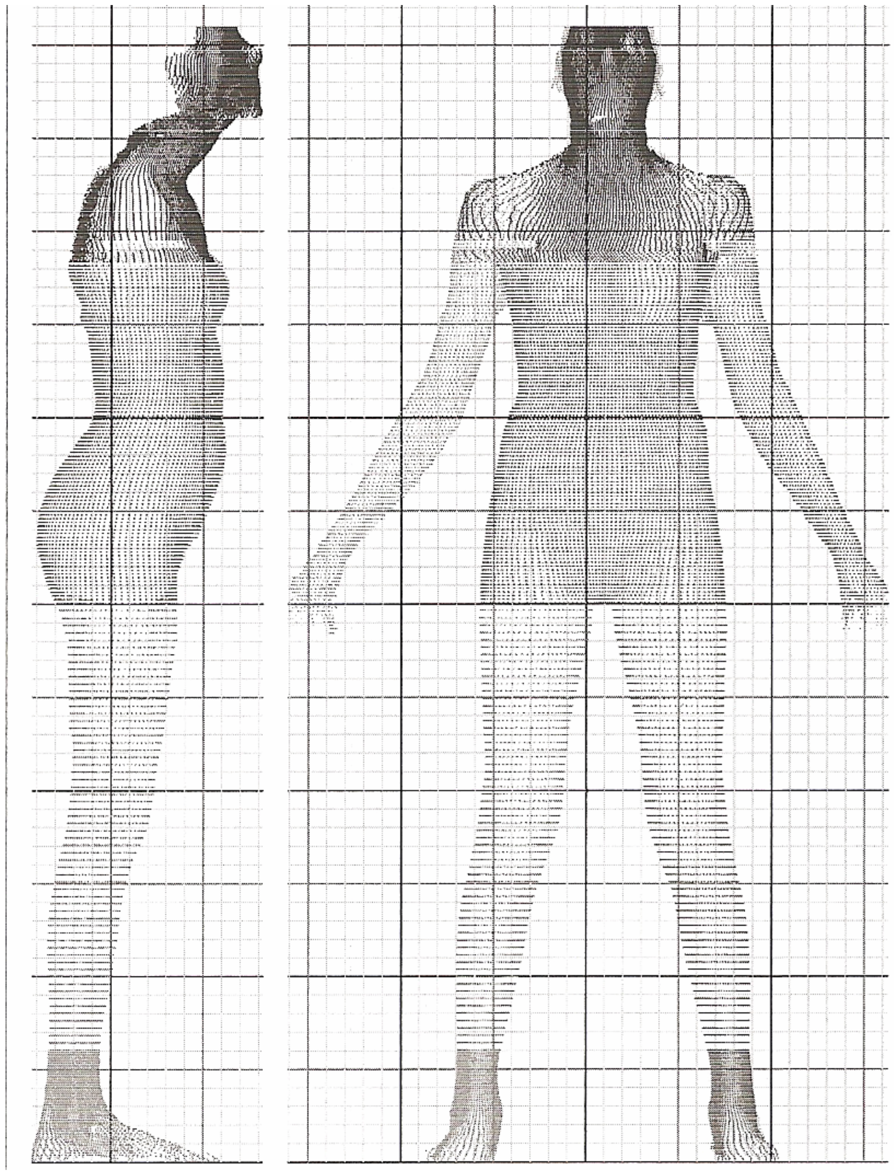

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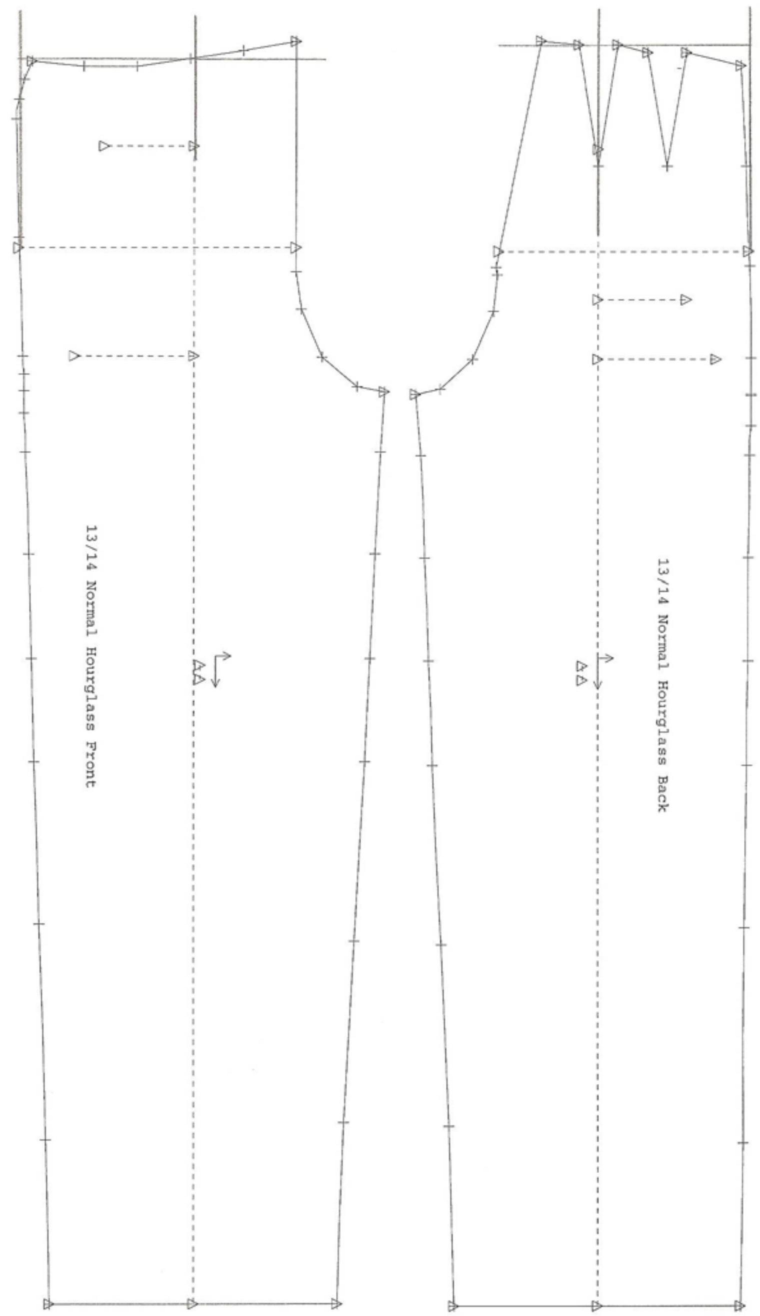

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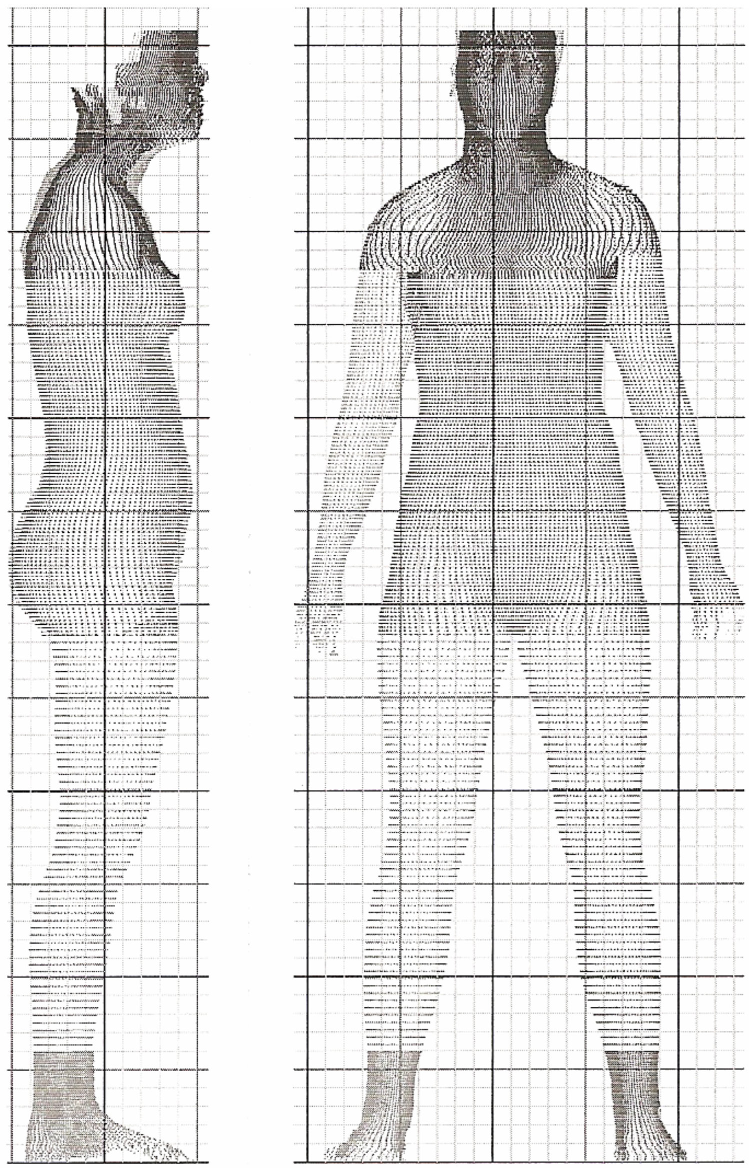

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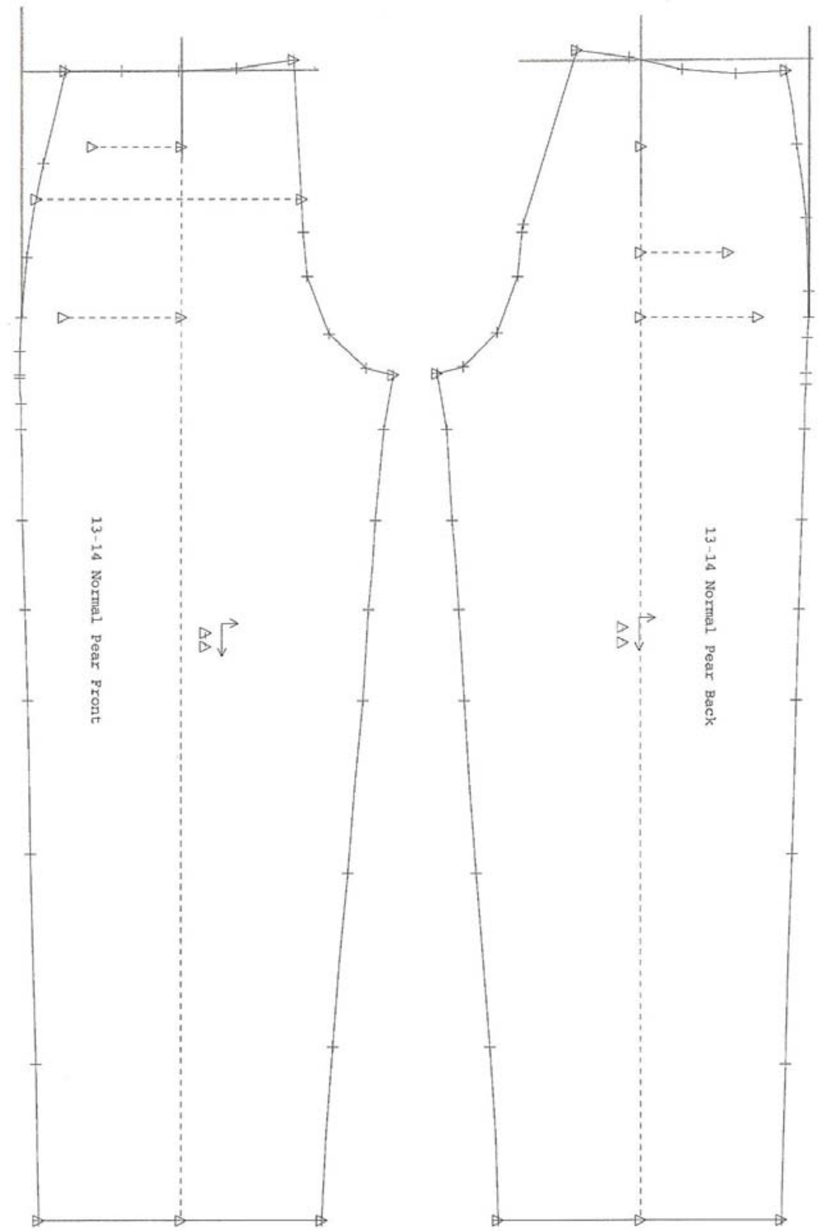

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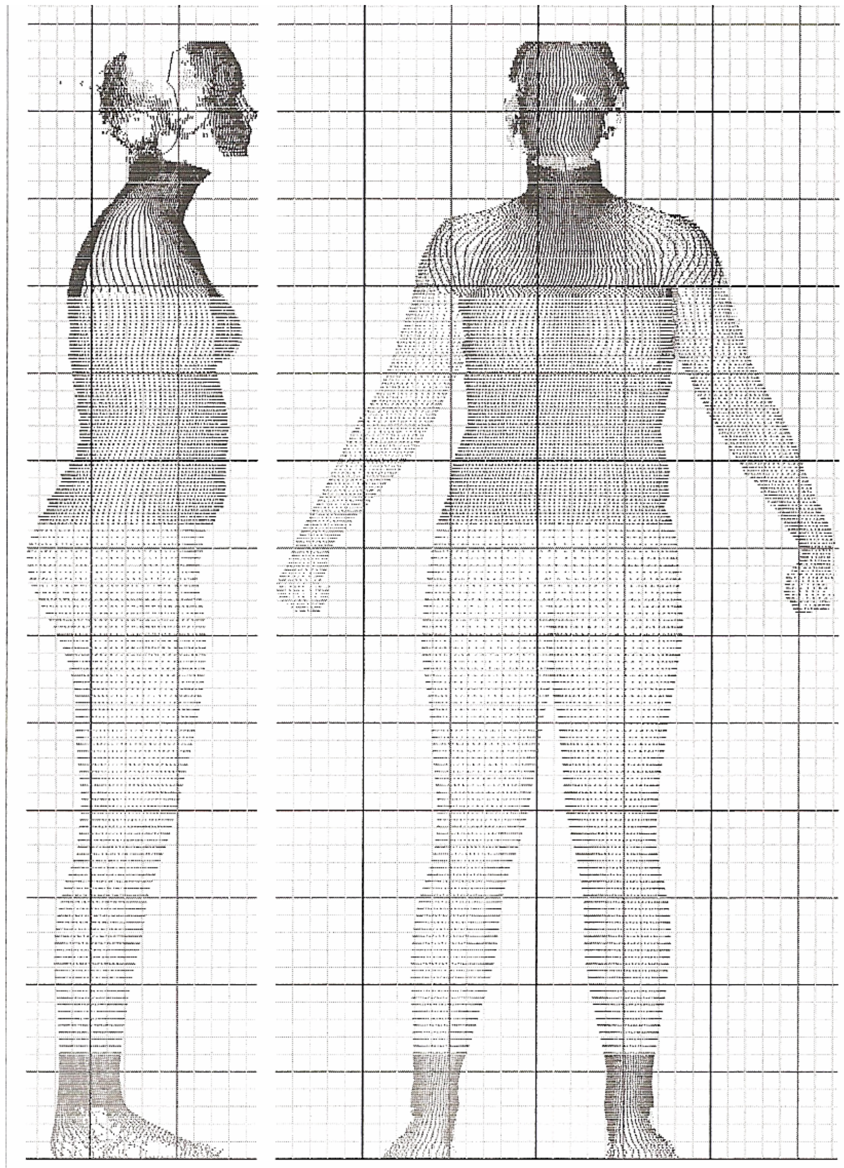

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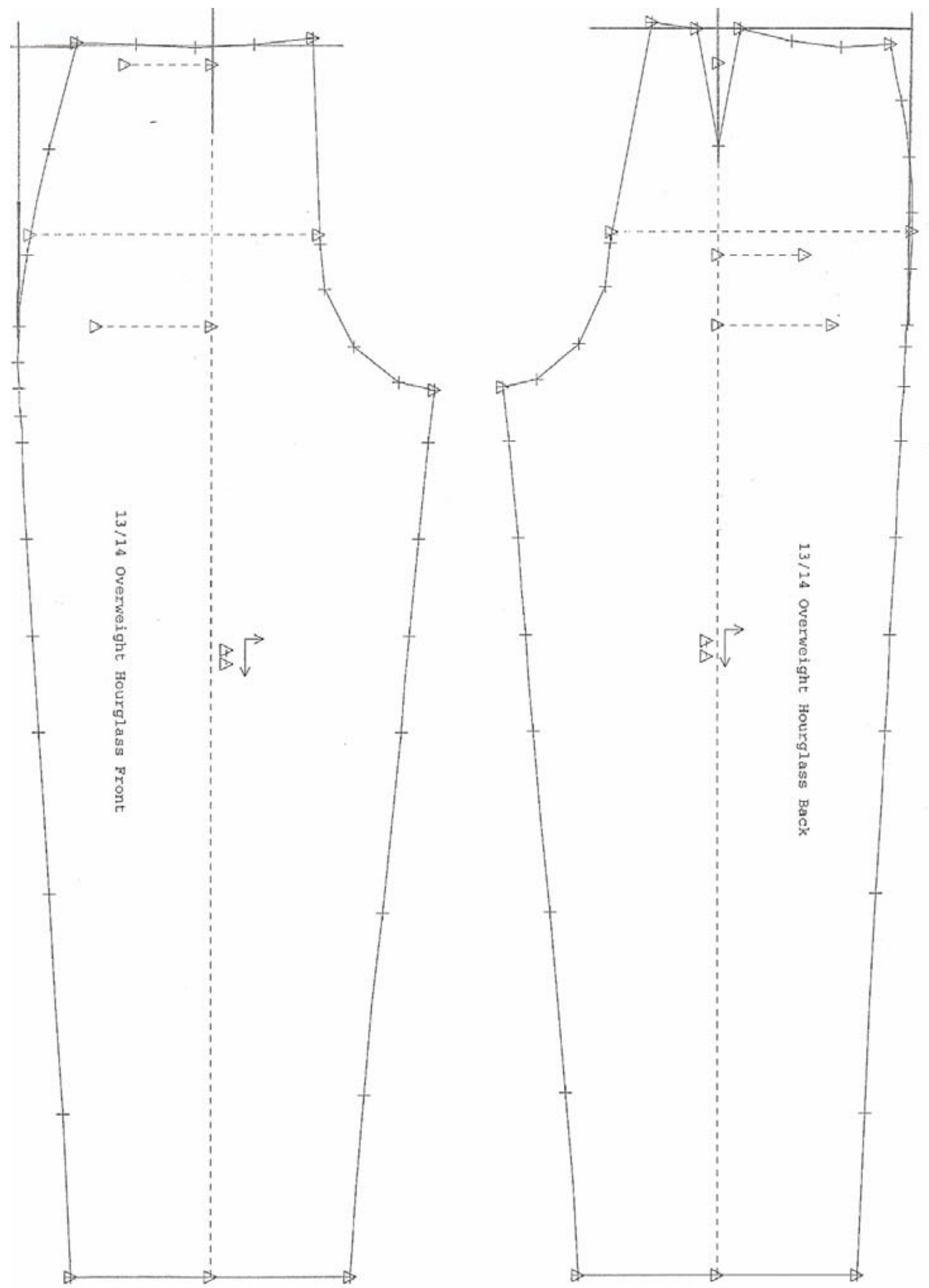

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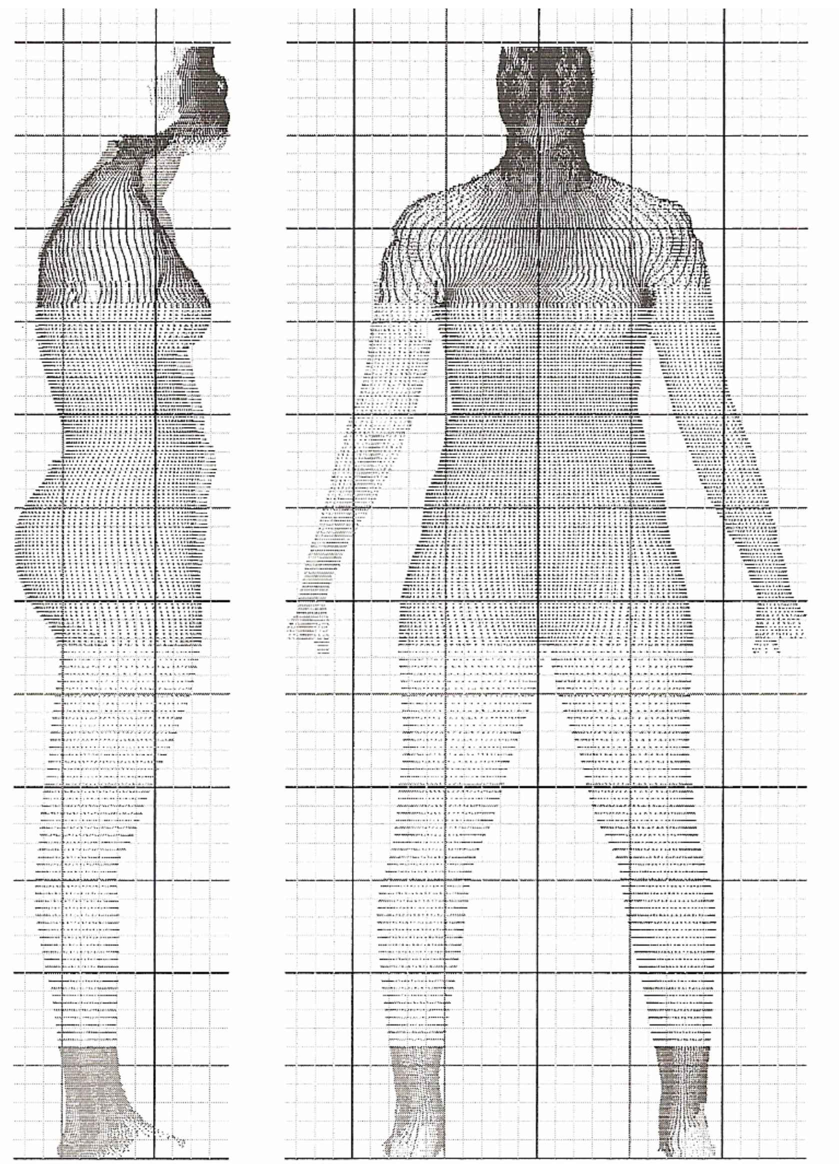

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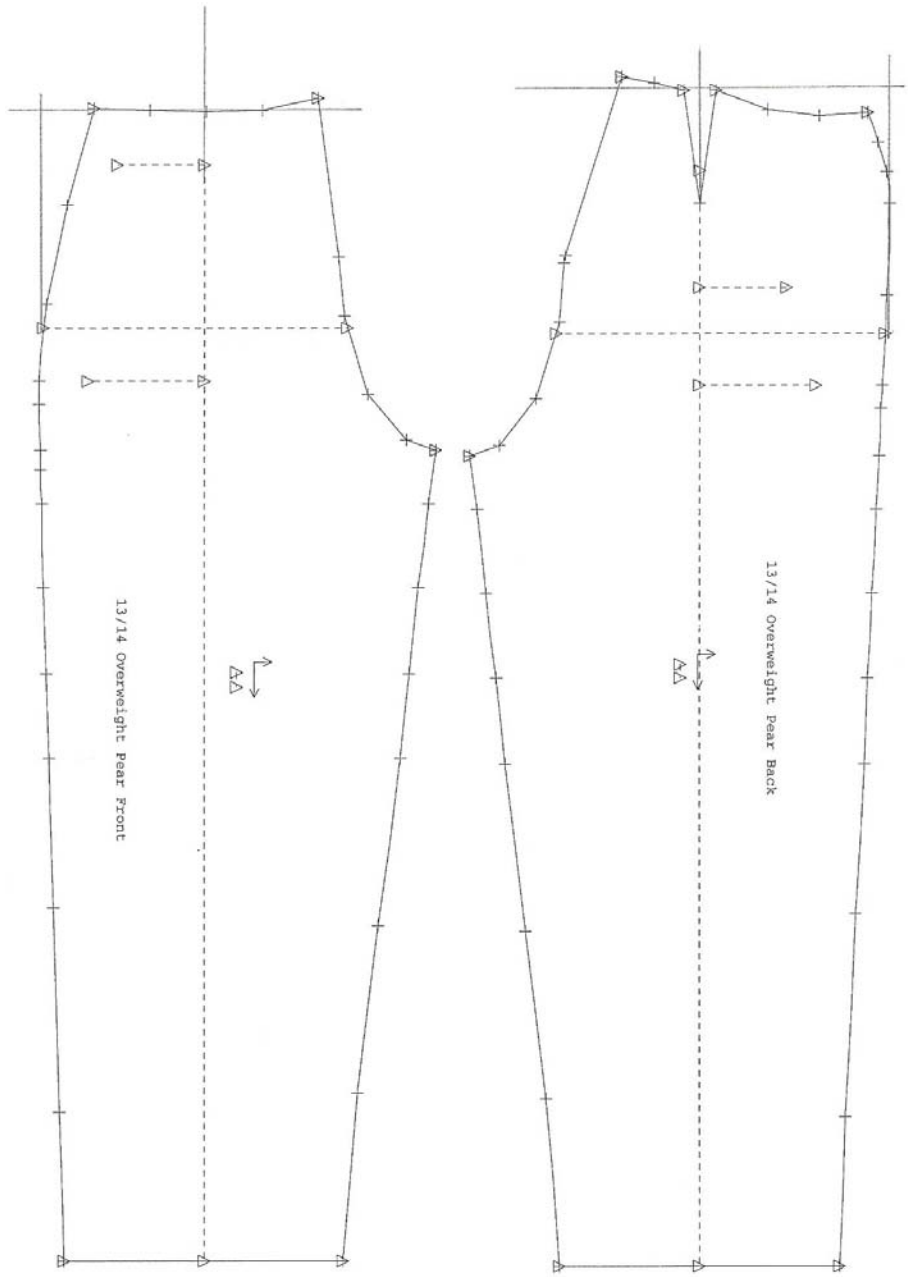

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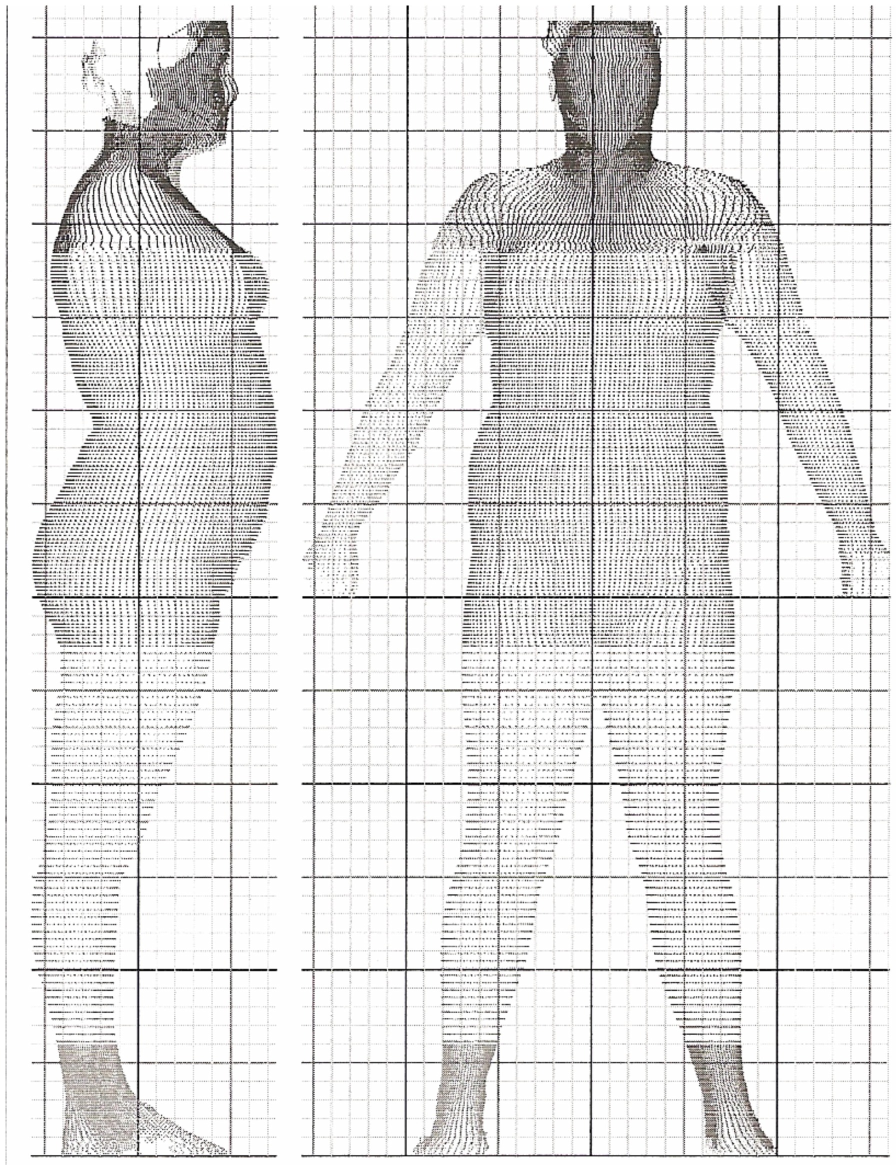

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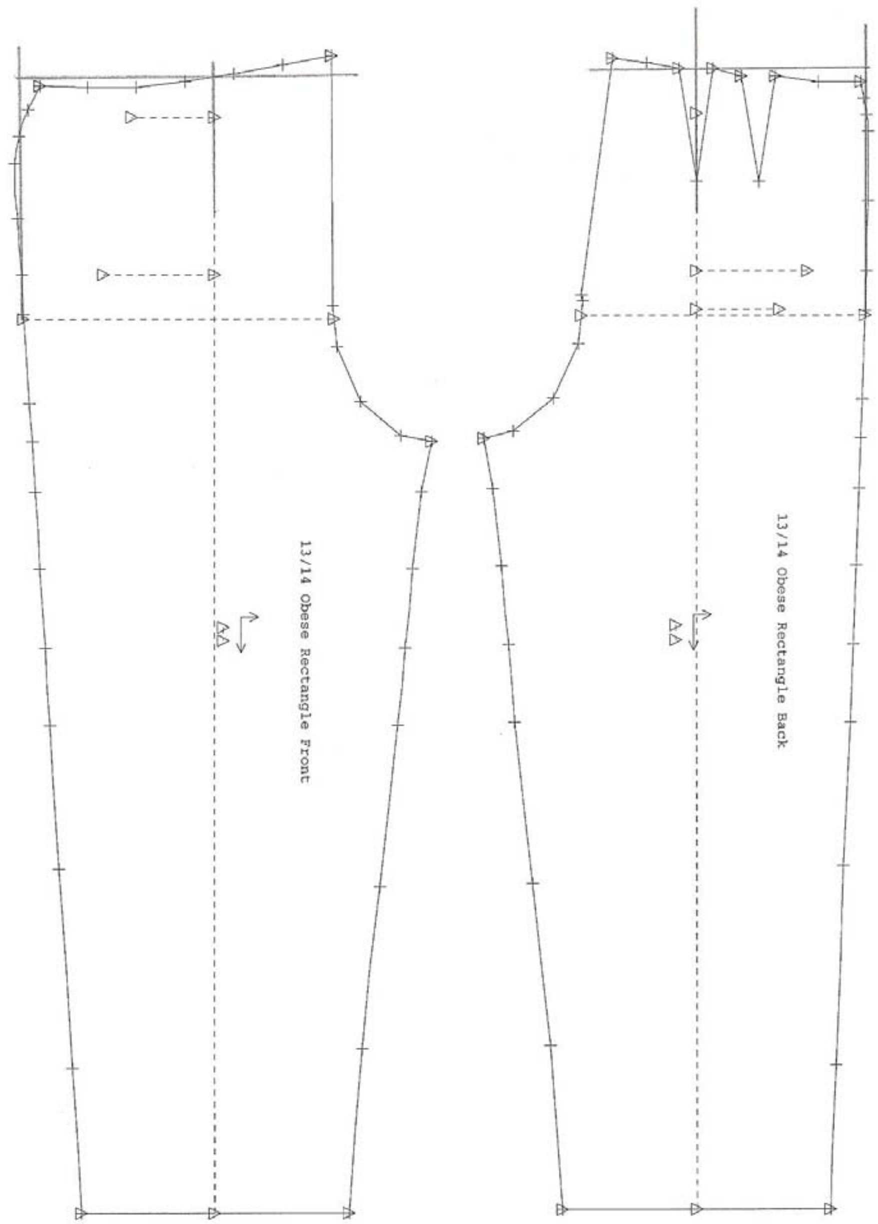

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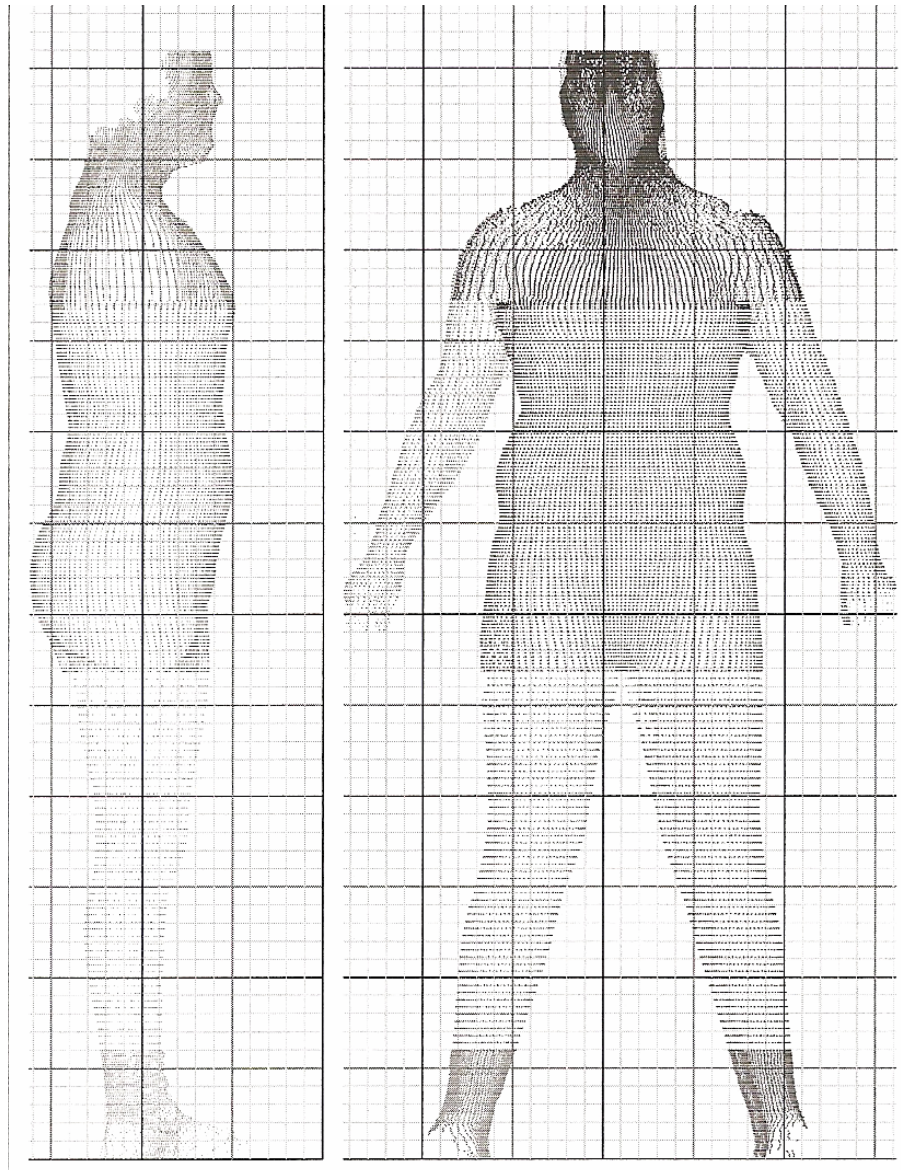

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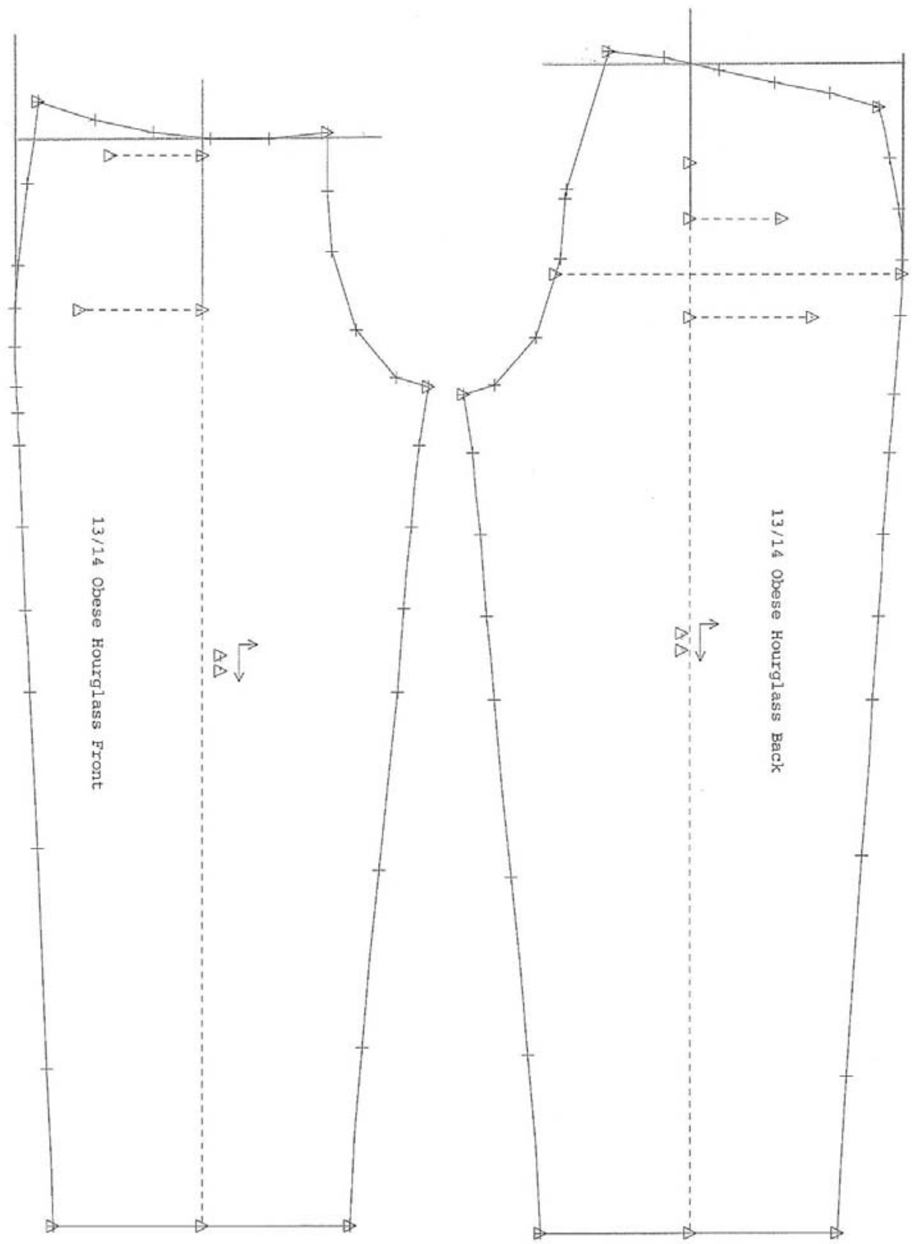

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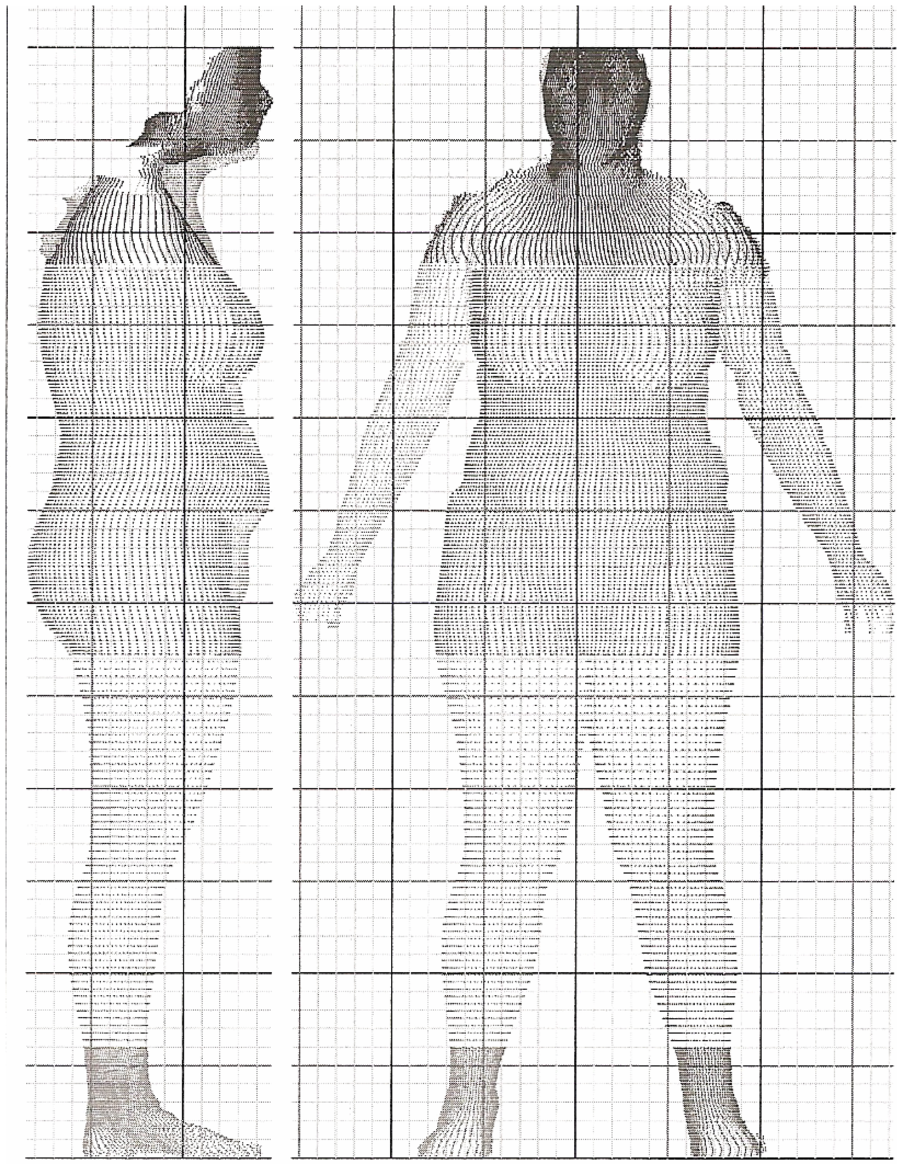

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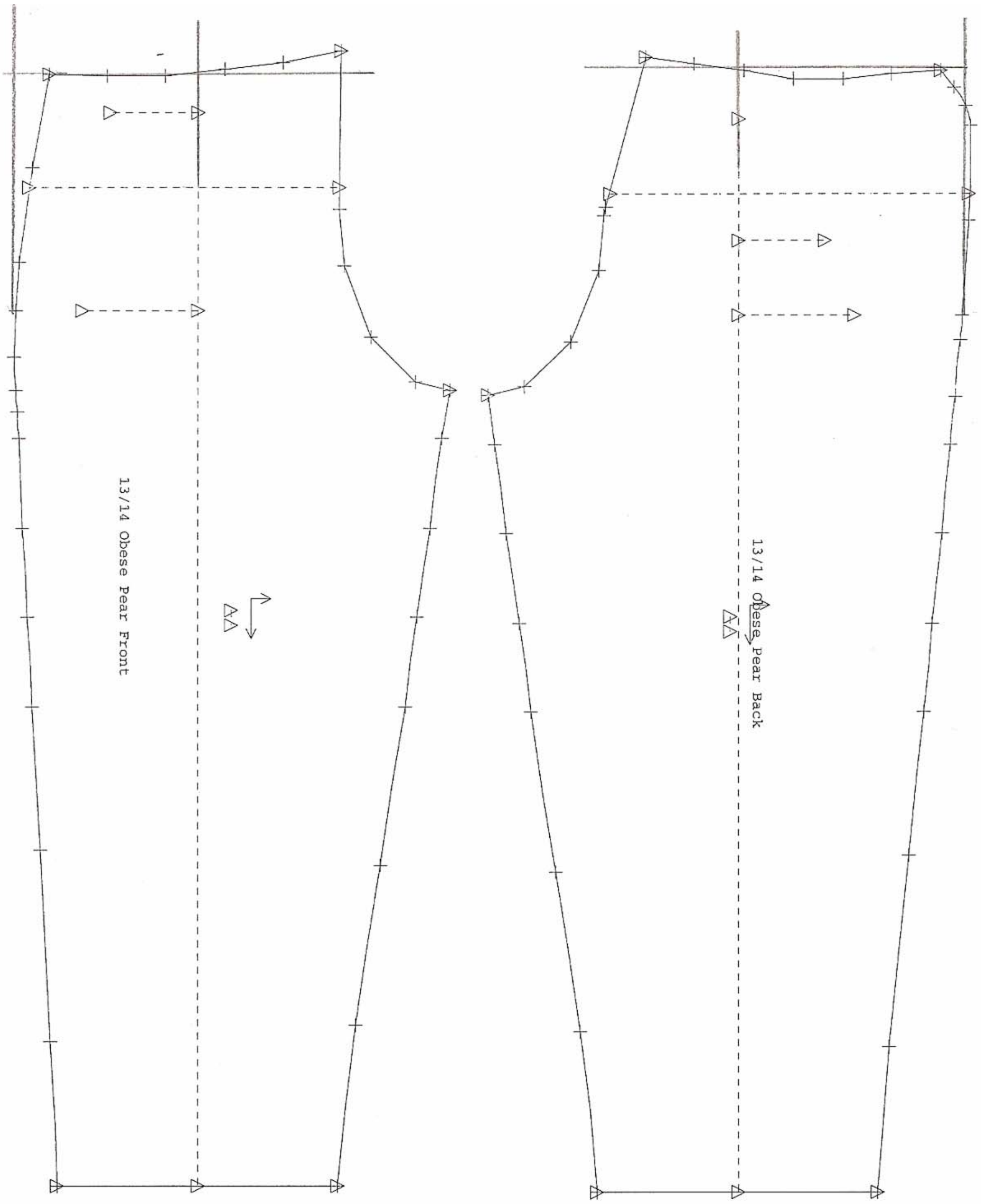

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