Metrics for Including Posture and Body-Shape Variation in Scan Databases for Apparel Practice

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https://doi.org/10.15221/24.17

Abstract

The foundations of good fit in patternmaking are identified as grain/wale, line, ease, balance and set. The interaction of these factors with themselves and the human body establishes the body-to-garment relationship understood to be 'fit'. Posture is a critical component of this relationship. Posture also impacts the balance and set of the garment, both in stationary and active poses. The skeletal joints distinguishing posture provide the understanding of the garment suspension points and direct the distribution of ease and flow of the garment from these points.

During large-scale study of scanned human body data, it is common practice to normalize subject posture and focus on subject shape. This practice has proven effective for ergonomic use cases, but problematic for apparel-related practice where the body must be understood in relationship to interaction with garment materials and design. Often, posture and shape are intrinsically related, and separation invalidates apparel use-case results. Varying degrees of head thrust, shoulder rotation, pelvic tilt, kyphosis, lordosis, and varus or valgus knee alignment all change the body-to-garment relationship. A previous posture study has identified placement, alignment, rotation, curvature, and symmetry (PARCS) as descriptors for body region relationships related to posture and pose.

In this paper, we use PARCS descriptors to consider metrics for describing the aspects of posture related to the body-to-garment relationship. These descriptors could be used to reassess vast accumulated 3D body data sets for posture-inclusive shape studies better suited to apparel practice. Recognizing where posture exists outside a baseline 'normalized' range is essential for providing good apparel fit for the population. Studies to support where skeletal posture and body shape are intrinsically intertwined will further such efforts.

Keywords: 3D body scanning, 3D body processing, apparel fit, posture, posture descriptors

1. Introduction

Factors that affect the fit of an apparel product are directly related to material choice, the body's requirements for movement and the elements of design as they relate to the human body. Different fabrics have unique properties, such as stretch, drape, thickness, and texture, directly impacting how the garment conforms to the body. For example, heavier fabrics drape differently than lighter ones, often requiring more structured designs to maintain the intended silhouette. Additionally, the texture of the fabric can influence how it interacts with the skin and other layers of clothing, potentially affecting comfort and fit [1]. The human body's need for movement is another critical factor in apparel fit. Garments must be designed to accommodate the dynamic nature of the body, allowing for a full range of motion without compromising comfort or appearance. This includes considering how the body moves in walking, sitting, or engaging in more vigorous physical activities [2]. The design elements of a garment, such as shaping devices (i.e., design features that transform flat fabric into a 3D shape that fits the body, for example, darts, seams, easing, gussets or gathers) that determine the silhouette, necklines, and hemlines, must be aligned with the human body's natural contours and proportions. These features must be proportioned to suit the wearer's body and enhance the appearance and comfort of the wearer [3].

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Good fit in apparel can be achieved through the effective interaction of the factors identified as grain/wale, line, ease, balance and set. These elements not only interact with each other but also with the individual human body, collectively establishing the body-to-garment relationship. Posture, as a key component of body shape, is critical in this relationship. The individual's positioning and relationships of their skeletal joints interact to define posture. The garment suspension points (i.e., the places where the garment naturally hangs or drapes from the body) will differ for individuals with different postures. This results in differences in the distribution of the ease and flow of the garment from these suspension points. Posture also impacts the balance and set of the garment. Balance refers to how evenly the garment hangs on the body, while set refers to how smoothly the garment lies without pulling or wrinkling. Both factors are affected by whether the body is in a stationary or active pose, indicating that posture impacts garment fit not only when standing still but also during movement. Therefore, posture is an important driver of garment fit and accounting for posture is essential for achieving a well-fitted garment that meets the needs of the individual wearer.

During large-scale study of scanned human body data, it is common practice to normalize subject posture and focus on subject shape. This practice has proven effective for ergonomic use cases. However, this practice is problematic when the data is used for apparel-related end uses where the body must be understood in relationship to interaction with garment materials and design to provide well-fitted well-designed garments. Often, posture and shape are intrinsically related, and separation invalidates apparel use-case results. A previous study on posture has introduced the concept of placement, alignment, rotation, curvature, and symmetry (PARCS) [4] as key descriptors for body region relationships related to posture and pose. These factors are important in accurately capturing how the body's posture influences apparel fit and design.

In this paper, we use PARCS descriptors to consider metrics for describing the aspects of posture related to the body-to-garment relationship. These descriptors could be used to reassess vast accumulated 3D body data sets for posture-inclusive shape studies better suited to apparel practice. Recognizing where posture exists outside a baseline 'normalized' range is essential for providing good apparel fit for the population.

2. Foundations of Patternmaking

The foundations of good fit are driven by patternmaking techniques, which direct the end apparel product result. Metrics for assessing fit are summarized as grain/wale, ease, line, balance and set [5-8]. The priority order for these metrics depends on the garment design and the materials used. Fitted garments made from wovens may prioritize grain as it is affected by gravity; then line, ease, and balance to perfect the set of the garment. The design process for garments made from knits may prioritize negative ease values necessary when working with stretch, line, balance, and set, which are determined by the way the fabric stretches around the body with less interaction with gravity.

- ***Grain*** refers to the yarns in the fabric(s). It directs the eye, keeps the garment from twisting around the body, and can be used to create effects such as elongation or truncation when manipulated on the bias.
- ***Line*** may refer to a body feature on the human or humanoid, or a geometric feature on the apparel product: point, line, curve, seam, or the silhouette of the garment.
- ***Ease*** describes how the dimension of the garment differs from the body. Ease is the difference between the measured size of the body of human or humanoid and the measured size of the garment. Positive ease indicates the garment is larger than the human it was designed for. Negative ease indicates the garment is smaller than the body of human or humanoid. Negative ease is sometimes used to compress and modify the humans' shape. Appropriate ease is necessary for comfort and movement and also contributes to the design of the garment.
- ***Balance*** refers to the hang of the fabric in relationship with the human or humanoid.
- ***Set*** describes how the placement, alignment, rotation, curvature, and symmetry of the garment are in harmony with the placement, alignment, rotation, curvature, and symmetry of the posture of the human or humanoid.

There are many types of ease which are important in wearing, impacted by design and personal preference. Ease applications range from the overall "look" of the garment (design ease) to localized shaping of garment to body features (shaping ease) [9-11].

- Functional or Function ease: The amount of fabric required for breathing, donning, doffing, safety, movement range, wearing, and thermal considerations. This could be impacted by the fabric type used [9].
- Shaping ease: Ease used for shaping the garment in place of or assisting darts and seams.
- Styling or Design ease: Ease determines the silhouette, style or aesthetic of the garment. In addition, ease can be used to skim over the body shape of human or humanoid in certain body regions [9,10].
- Personal preference ease: The ease for garment that the consumer prefers.

3. Interaction of body with garment

The interaction of these factors with themselves and the human body establishes the body-to-garment relationship [12]. Posture, as a component of body shape, is a key element of this relationship. and therefore, an important driver of garment fit [13,14]. The skeletal joints distinguishing posture provide the garment suspension points. Every part of the garment is then affected as the garment is suspended from and moves over these points. Posture also impacts the balance and set of the garment, both in stationary and active poses [15].

During large-scale study of scanned human body data, it is common practice to normalize subject posture and focus on subject shape [16-18]. However, posture and shape are intrinsically related, and separation is not appropriate when designing or otherwise working with apparel. Varying degrees of head thrust, shoulder rotation, pelvic tilt, kyphosis, lordosis, scoliosis and varus or valgus knee alignment all change the body-to-garment relationship [19,20].

For a designer, creating well-fitting garments must include an understanding of posture, leading to questions such as:

- How does the silhouette, style or aesthetic change due to a change of posture?
- Does the line of the garment reflect the world view (i.e., how the line of the garment looks to a viewer looking at the person wearing the garment), the body, or a compromise between the two?
- Does the balance and set of the garment reflect the world view, the body, or a compromise between the two?
- As improper set on the body can result in reduced functional comfort, is the appearance of the garment more important or equally important to the functional comfort?
- Balance and set – how to maintain a symmetrical design on an asymmetrical body?

The line of the body is how the lines of the garment are aligned to the lines of the body. For most people, the lines are similar enough for the differences to be very subtle, however, if a person has scoliosis for example, these can be very different. The designer may need to understand how to design for the differences.

There is no single "correct" posture even though that is a common belief [21,22]. However, using PARCS, it is possible to describe the baseline posture used when designing a garment. Having PARCS also allows for a method to describe the differences between the baseline posture and a human's actual posture. Without identifying the specific combination of PARCS, the subtlety and nuances that are required to understand and express posture when scanning humans are not expressed. The subtlety and nuances are also required for humanoids to be properly inclusive.

The definitions for each of the elements of PARCS are as follows:

- Placement: The way in which body regions have been placed in relation to each other [Fig.1].
- Alignment: The arrangement of body regions relative to each other or to specified axes, specified planes, or specified lines [Fig.2].
- Rotation: Rotary or circular motion of body regions around a center (body or joint), an axis, or a fixed point [Fig.3].
- Curvature: The amount a curve (spinal or body region) deviates from a straight line or the amount a surface of a body region deviates from a plane [Fig.4].
- Symmetry: A property of being equivalent on opposite sides of the sagittal plane [Fig.5].

Certain combinations may be given names for common reference or to describe medical conditions.

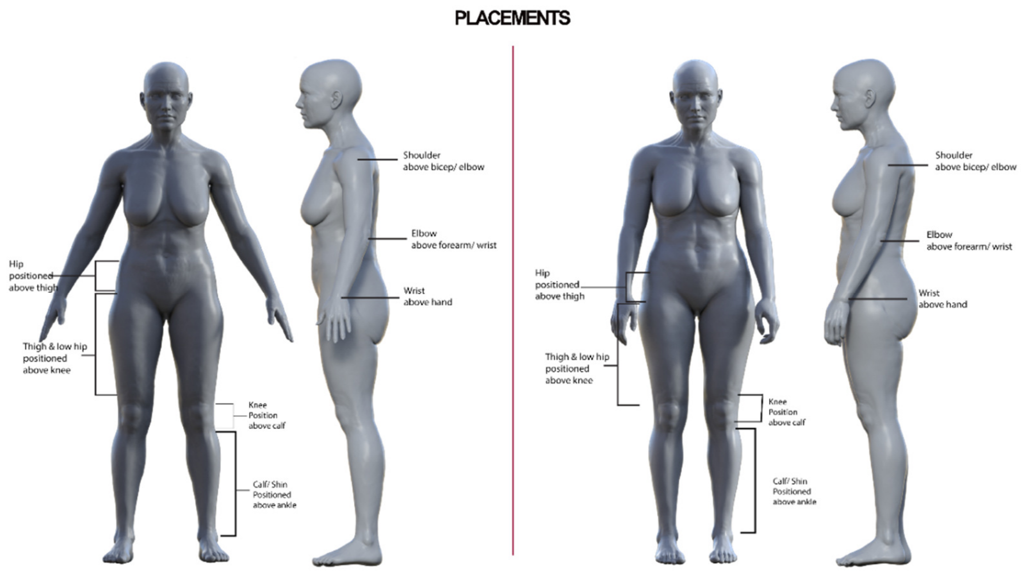

Fig.1. Placement.
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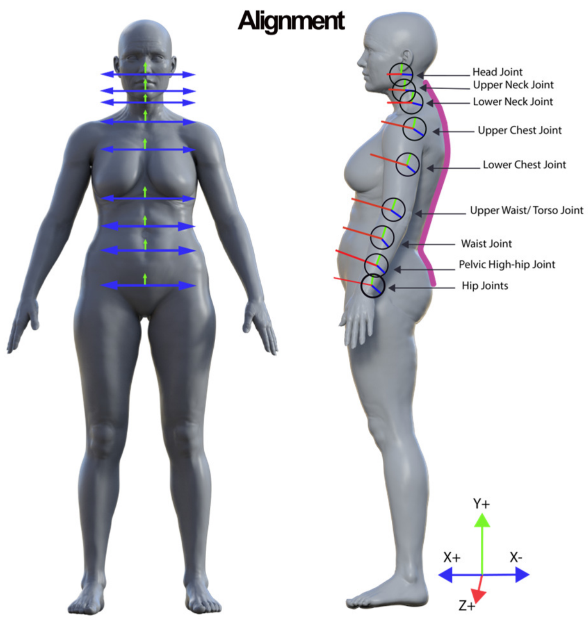

Fig.2. Alignment
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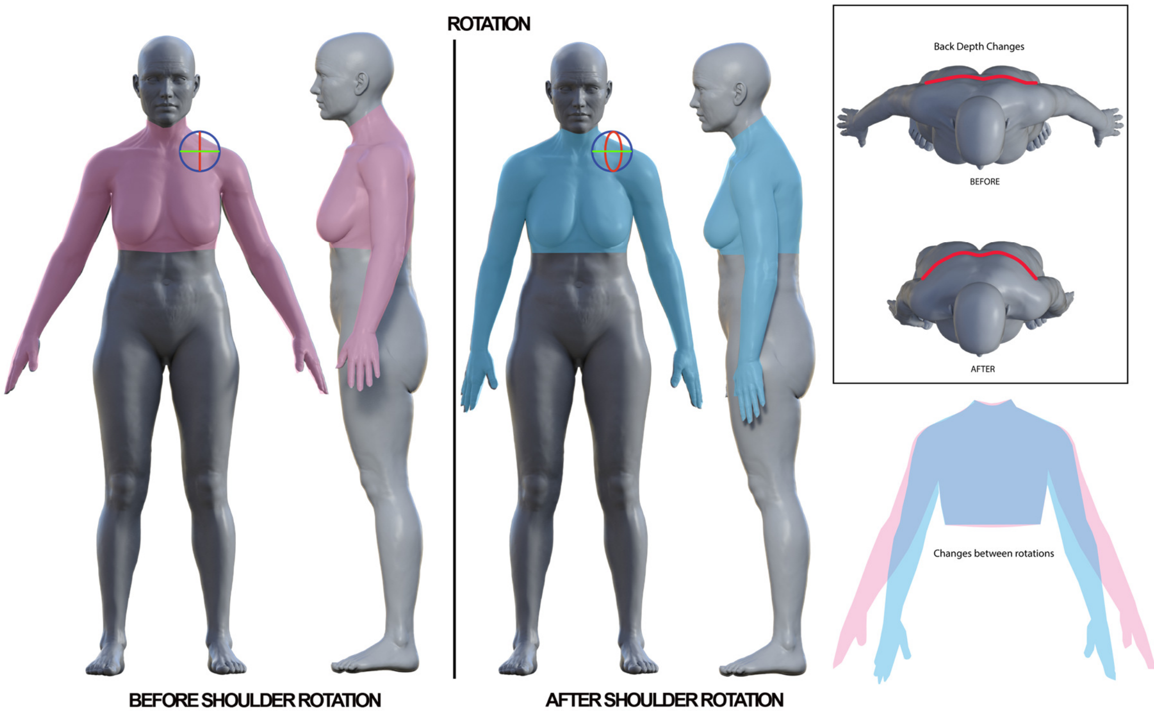

Fig.3. Rotation
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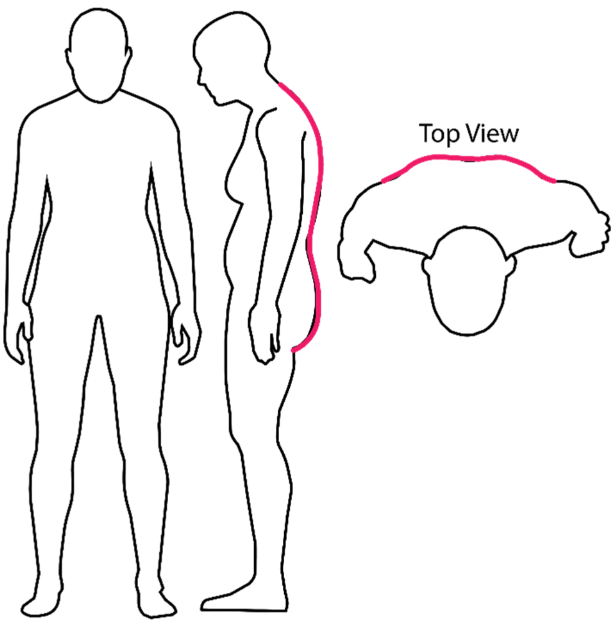

Fig.4. Curvature

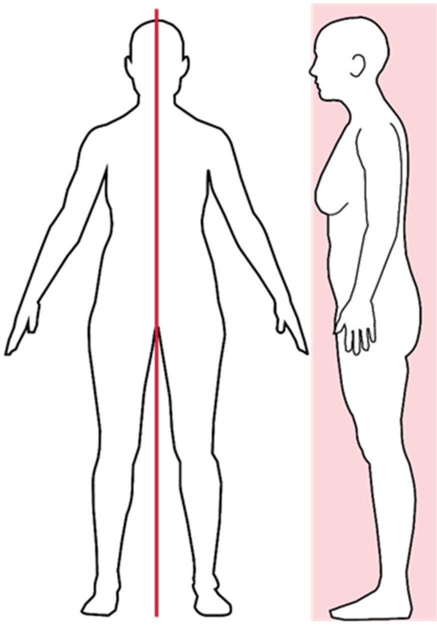

Fig.5. Symmetry

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5. PARCS and Design

Now, it is possible to link the PARCS to the garment design mnemonic (i.e., the key factors in designing well-fitted garments: grain/wale, line, ease, balance, and set), creating a comprehensive approach to understanding how posture and body shape influence clothing design and fit.

- Placement: Impacts the location of lines, location of fabric grain versus the body shape of human or humanoid, location of shaping devices placement of balance and set of the garment versus the body shape of human or humanoid.
- Alignment: Understanding the orientation of lines, orientation of fabric grain versus the body, orientation of shaping devices, balance and set of garment in relationship to the balance and set required for the human or humanoid can make the garment fit more naturally on the body.
- Curvature: Impacts the shaping requirements and placement of lines. The curvature of the human or humanoid impacts "how" the fabric drapes on the body. The amount and location of muscular tissue and the amount and location of adipose tissue impact the curvature of the body along with the curvature of the spinal column. curvature for shaping requirements and placement of the shaping devices. Curvature for balance and set of the garment is also a factor in relation to the balance and set of the body shape of human or humanoid
- Rotation: shoulder and hip rotation impacts lines and grain interaction, shoulder and hip rotation impacts shaping devices, and balance and set interaction.
- Symmetry: Impacts whether or not the lines in the same location and orientation on both sides of the body, the grain of the fabric reacts the same way on both sides of the body and the shaping devices in the same location and orientation on both sides of human or humanoid.

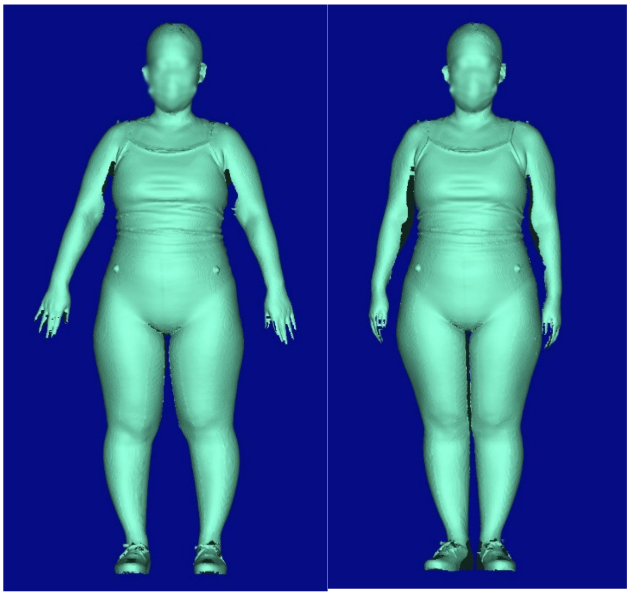
6. Reassess data sets

In this paper, we use PARCS descriptors to consider metrics for describing the aspects of posture related to the body-to-garment relationship. These descriptors could be used to reassess vast accumulated 3D body data sets for posture-inclusive shape studies better suited to apparel practice. Recognizing where posture exists outside a baseline 'normalized' range is essential for providing good apparel fit for the population. Studies that support the idea that skeletal posture and body shape are intrinsically intertwined [23,13] will further such efforts.

7. Proposed scanning in clothing poses

We propose scanning for clothing be done in poses suitable for the purpose. These poses can be called clothing poses or C-poses in contrast to A-, T-, and I-poses. These poses assume a natural pose that the subject is comfortable maintaining. The heels should be aligned, and limbs aligned in the coronal plane to the extent possible. If prosthetics are generally worn, subjects should wear them while posing. Examples include breast(s) and limb(s) as well as other items such as colostomy bags and medical devices. If a cane is consistently used, subjects should be scanned with one that is invisible to the scanner, or that can be automatically removed from the scan. They should stand if able. If a chair must be used, then it should have no arms and be invisible to the scanner, or it can be automatically removed from the scan.

ISO 20685-1-2018: section A.2.4 identifies poses as standing position A and standing position B. Standing position A is commonly called the A-pose, and standing position B is commonly called the I-pose [24]. One aspect of these poses is the subject is standing erect (standing up straight), the arms are at the side of the body, and the feet are at prescribed locations. Examples of these are poses are shown in Figure 6. These scans have not been "cleaned". The person should have hands closer to the body in I-pose, but this was her interpretation of the standing position B.



(a) (b)

Fig.6. (a) A-pose and (b) I-pose examples (Cornell Fashion & Body Tech Lab)

C-pose#1: Standing in a natural posture. Subjects stand as they normally do. Weight as equally balanced between the feet as comfortable. They shift weight between the left and right legs to relax the hips to the usual orientation. The knees are not locked. If possible, feet and heels aligned. Toes pointed in comfortable orientation. Shoulders relaxed, not braced or lifted; arms relaxed at the side of the torso, palms in comfortable orientation, fingers as desired. Head and neck are in a relaxed, comfortable position. Eyes are looking in the direction of the head. Examples of the scans shown in Figures 7, 8, and 9 have not been "cleaned". In a "natural" pose, the placement of the feet is about shoulder width apart; the shoulders are relaxed as the hands are hanging freely [Fig.7]. The location of the hands will impact the shoulders and the back. The purpose of this pose is to understand the subject's usual standing position. This is very different for some people than in a very instructed pose.

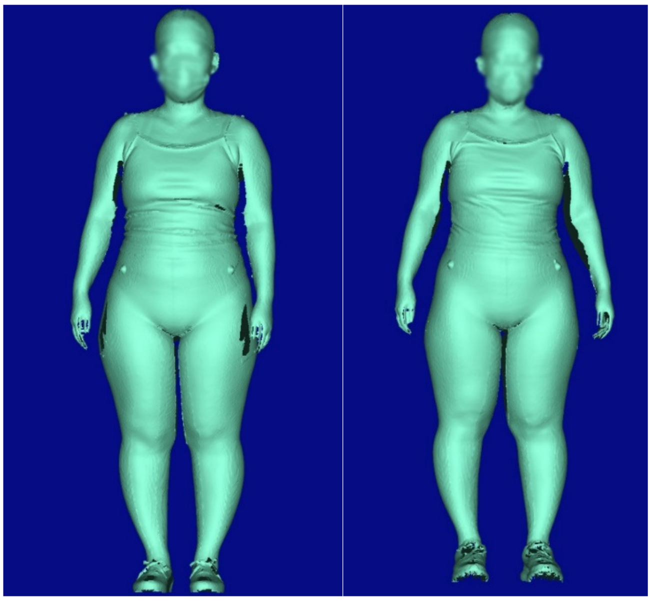


Fig.7. C-pose #1, two different interpretations of standing, natural pose (Cornell Fashion & Body Tech Lab)

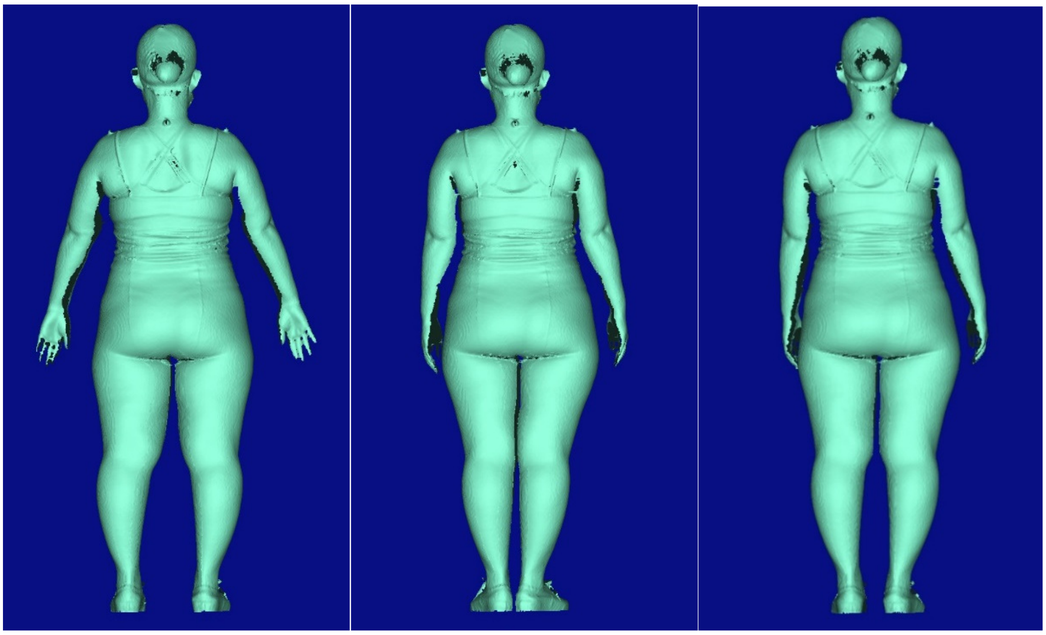


Fig.8 Comparison of back between A, I and C-pose #1 poses (Cornell Fashion & Body Tech Lab)

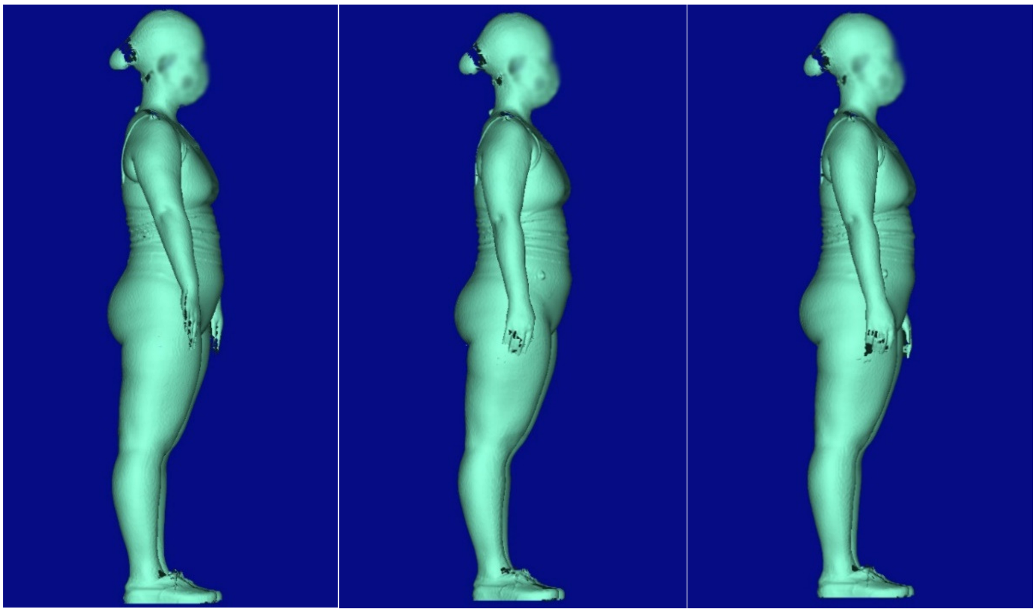


Fig.9 Comparison of side between A, I and C-pose#1 poses (Cornell Fashion & Body Tech Lab)

C-pose #2-1: Standing in a natural posture, with hips and legs as well as head and neck, the same as for C-pose #1. Arms bent, 60 degrees, shoulders relaxed and forward as if holding a steering wheel, upper arms to torso angle up to 60 degrees, elbow angle at 90 degrees, forearm parallel to the floor, wrists straight, hands palms down, fingers spread apart, and wrists shoulder-width apart.

C-pose #2-2: Standing in a natural posture, with hips and legs as well as head and neck, the same as for C-pose #1. Arms bent, 90 degrees, shoulders relaxed and forward as if holding a steering wheel, upper arms to torso angle up to 90 degrees, elbow angle at 90 degrees, forearm parallel to the floor, wrists straight, hands palms down, fingers spread apart, and wrists shoulder-width apart. The purpose of this pose is to understand the stretch of the back and shoulders when performing the everyday task of stretching while limiting the amount of hidden area for the scanner. Different angles for the arms were tried to see which would be better to see the shoulder and back differences [Fig. 10 and Fig.11].

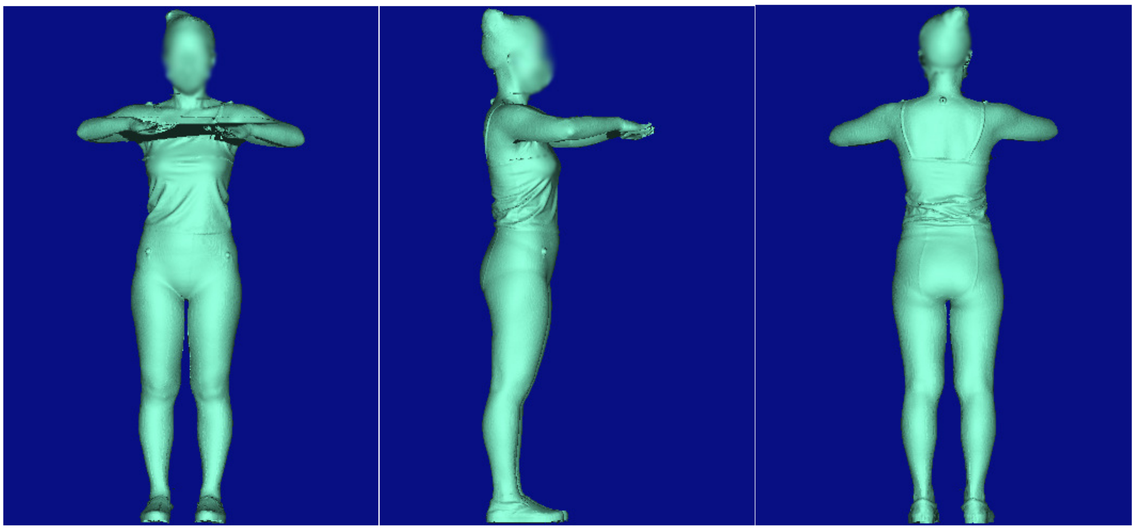


Fig.10 C-pose #2-1, stretching, hands closer (Cornell Fashion & Body Tech Lab)

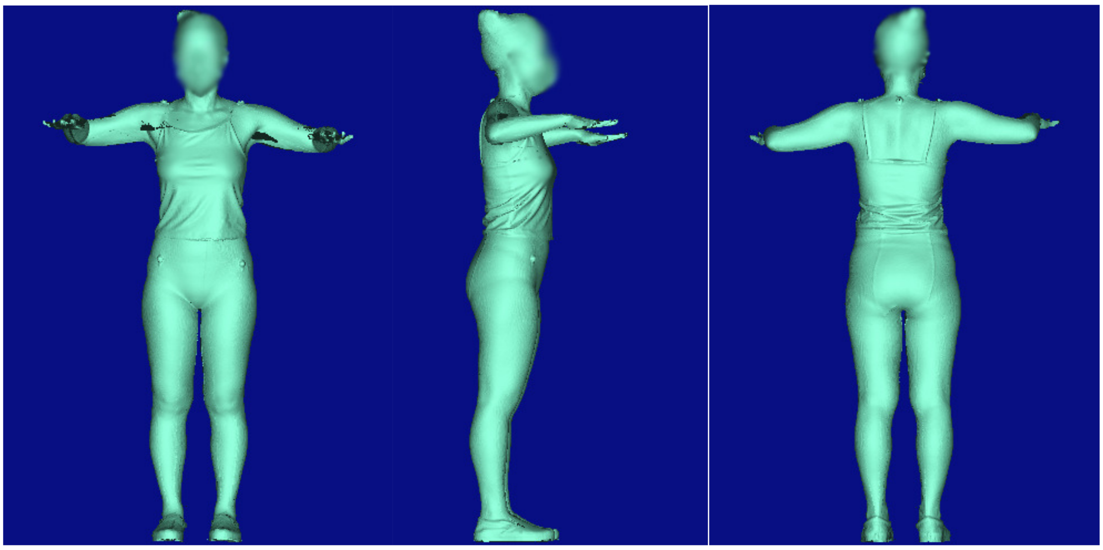


Fig.11 C-pose #2-2, stretching (Cornell Fashion & Body Tech Lab)

C-pose #3: Sitting in natural posture comfortably. Subjects comfortably balance weight between the feet. For support, they use a device that the scanner will not pick up. In this example, shown in Figure 12, an acrylic seat was used. If someone may not be able to do a standing pose, this may be the pose that is possible for their base pose. For a person who can stand, a sitting pose is helpful to understand, for example, the impact on the hip measurements, the changes to the curve of the back, and the shortening of the hip to rib distance while sitting. It should be noted that we are in the process of testing these poses. Improved specifications for scanning attire are required for more accurate body measurements

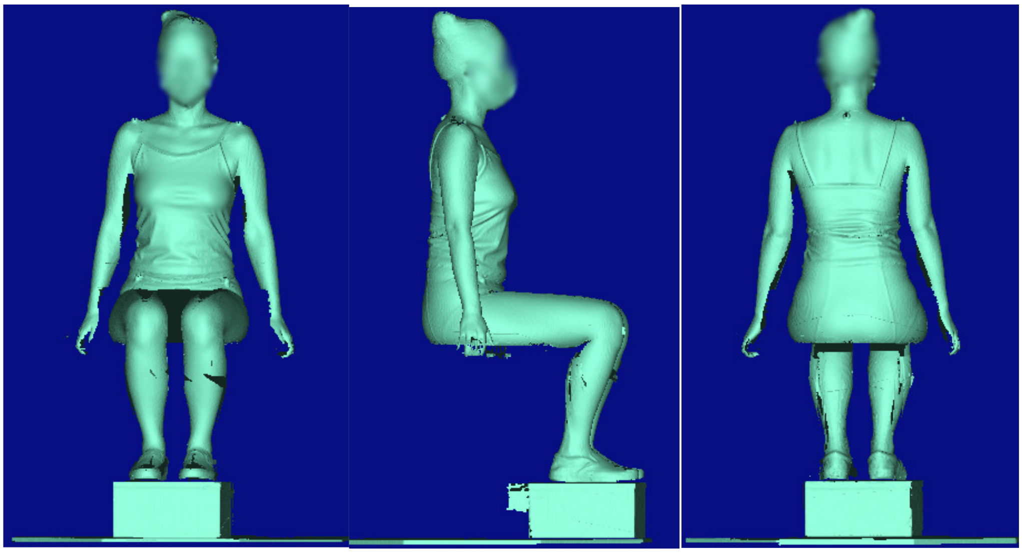


Fig.12 C-pose #2, sitting pose (Cornell Fashion & Body Tech Lab)

8. Conclusion

By linking the PARCS framework to the garment design mnemonic, designers can better understand how posture and body shape interact with clothing. This approach allows for creating garments that fit well and enhance the wearer's comfort, movement, and overall appearance. It bridges the gap between the science of human anatomy and the art and science of fashion design, resulting in more thoughtfully designed and better-fitting clothing. Using descriptors that allow one to describe posture opens up the ability to fabricate well-fitting garments for everyone. Introducing individual posture in algorithms to create patterns for automated custom fit will improve the performance of these ventures.

Recognizing where posture exists outside a baseline 'normalized' range is essential for providing good apparel fit for the population. A focus on the relationships between posture and clothing fit factors can also lead to investigating issues in new and effective ways. For example, Does personal preference ease change if the ease of the garment is placed in the proper locations to the body of the human? Does the amount of ease required for functional ease decrease if in the proper location of the body of the human? If a person has never experienced garment fit when properly aligned with their posture, will they initially find such a garment feels unfamiliar and therefore uncomfortable? What are the limits of body asymmetry beyond which a symmetrical garment will not be satisfactory?

The body regions identified for pattern body regions will be different than the body regions identified in this paper. However, the thought process concerning the body regions can be expanded to include pattern body regions. Substantial study has identified pattern techniques for corrective pattern adaptations during fitting sessions [5]. Toward inclusion of posture in pattern drafting theory, further should consider the relationship between set, line, balance, ease, grain and posture. Pattern theory establishes a body-to-pattern mapping process to correlate body regions to pattern blocks. The effects of posture on the dimensions of these body regions require further study [20].

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