A COMPARATIVE STUDY ON FABRIC EFFICIENCIES FOR DIFFERENT HUMAN BODY SHAPES IN THE APPAREL INDUSTRY

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Abstract:
In the apparel manufacturing, fabric utilization always remains the significant apprehensions in controlling the production expenditure. Alteration in pattern shapes and marker preparation leads to the enormous utilization of fabric. The purpose of this research is to study fabric efficiency in correspondence with four different human body shapes in both genders. Two clothing styles, fitted trousers and fitted shirts, were processed conventionally in the garment manufacturing company. The comparative study of auto-marker and manual-marker making through Garment Gerber Technology (GGT) software were also accomplished. The evaluation of fabric consumptions, marker efficiency, marker loss, fabric loss, and fabric cost relevant to four different body shapes was analyzed for both women and men. The investigation carried out in this article concludes that there are differences in fabric consumptions, efficiencies, and cost-effectiveness relative to body shapes. The result revealed that the manual-marker of trousers for triangular body shape in women’s wears has the least fabric consumption (most cost-effective), whereas the shirt’s auto-marker for an oval body shape in men’s wears has the most fabric utilization (least cost-effective). The manual-virtual-marker making is efficient (significant p-value) than auto-generated-markers. Also, fabric utilization for women’s garments is cost-effective than that for men. Trousers are cost-effective compared to the shirts.

Keywords:
Fabric efficiency, body shape, marker making, apparel industry.

Introduction
The customer production orders in apparel industries are accomplished through cutting, sewing, and finishing (pressing) operations that commonly required enormous material utilization [1, 2]. To control the material utilization and wastages, human body shapes and proportions are particularly imperative, because these have a greater influence on the fabric consumptions [3]. A very minute change in pattern because of the variation in body shape creates errors in the fabric utilization, resulting in huge wastage of the fabric, production time, and cost [4]. Therefore, companies have significant apprehensions in the fabric wastage reduction through efficient resource utilization for cost-effectiveness [5]. Moreover, they often find it hard to obtain the accurate and effective framework of the fabric utilization in production orders [6]. The efficient utilization of the fabric and controlling its cost has remained the unresolved issue in the garment industries.

With the dissimilarity in human body dimensions and morphological appearances, different body shapes are discriminated into few figure types, for example, triangle, square, circle, and oval [7]. These body shape classifications play a deceive role in the fabric consumption and contribute to the issue of cost in apparel manufacturing irrespective to the conventional approach that was limited to a single standard body shape and size [8]. In 1940, Sheldon was the first who categorized the human body into three discrepancies (endomorph, mesomorph, and ectomorph) by using photographic technique and developed the sizing system for manufacturing of the garments [9]. Connell found that similar size costume cannot be anticipated to the same somatotypes because of the differences in shape [8, 10]. Therefore, body shapes are vital to clothing provision business [11].

Many studies have been accomplished by grouping the human body shapes into four classifications [8, 12-16]. Karla figured out nine classifications of women’s body shapes by using shape sorting software [17, 18]. However, her population data set only represented to five types of women’s body shapes. Likewise, Arzu obtained eight classes [19]. Contrarily, a number of studies [20-26] have been accomplished with the aim of improving material consumption. The researchers have focused mainly on cutting equipment’s and systematic procedures in the fabric saving [27-32] but none focused on the attire relationship by means of the fabric utilization and body shapes in garment
manufacturing companies. In fact, with different human body shapes, there is a lack of research analysis on the fabric consumption during marker making through technicians and auto-generated software.

Thus, the fabric consumption cost is reduced significantly through efficient fabric utilization and fabric losses control if it is related to human body shape [33]. These fabric losses include marker loss and spreading loss (end loss, width loss, splice loss, splice allowance loss, remnant loss, etc.). Fabric loss that exists inside the marker is stated as marker loss, and fabric loss that exists outside the marker is stated as spreading loss [34]. An issue of importance is to predict the fabric utilization, the fabric losses, and the fabric cost of different body shapes for the efficacy of apparel industries. The fabric is cut based on the pattern-marker [35].

A pattern-marker is a two-dimensional arrangement and connected placement of a set of convex and concave pattern pieces of the garment on a rectangular paper sheet [36]. This groundwork is highly technical, which is accomplished through experienced pattern designers. Therefore, the statisticians and mathematicians alone cannot provide ample solutions without specialized knowledge of pattern makers [37]. Marker loss is the fabric wastage that consists of those proportions (non-useable areas) of the marker that do not become the part of garment components in the rectangular sheet [38]. Fabric loss (wastage) is measured according to the marker area and the value of marker efficiency [39]. Marker efficiency (fabric efficiency) is the percentage of the total area actually used in the garment component parts [39].

The study aims to investigate the effect of four different human body shapes, both in women and men, on fabric consumption efficiencies (auto and manual) in the preparation of similar garment styles. By applying the proposed comparison framework, the apparel industries can make better decisions in the fabric utilization and cost-effectiveness. Thus, production management can be enhanced.

**Methodology**

**Materials and equipment**

Selected body shapes. Four different human body shapes, both in women and men, were selected for the investigation of comparison studies of the fabric utilization. For instance, Figure 1 shows the human body shapes in both genders with different body heights and Figure 2 shows the human body shapes in both genders with similar body heights (the vertical anthropometric landmarks are equal, i.e., body length, leg length, and arm length). In the literature review and learning resources, the four different body types, that is, triangle,
square/rectangle, circle, and oval, have been used widely in the world of apparel fashion and design [40].

Selected fabrics. The 100% cotton woven fabrics were selected with 2% shrinkage in warp and weft. The construction parameters of trouser fabric were $66 \times 36/10 \times 10=58$, whereas the construction parameters of shirt fabric were $100 \times 80/40 \times 40=58$.

Selected styles and equipment's used. The study was accomplished on close-fitted (following the body curves, outlining the figure) garment styles, that is, trouser and shirt, for women and men. Figure 3 has demonstrated the technical features of the selected garment styles (shirt and trouser) for these body shapes. The patterns of four different body shapes both in women and men are shown in Figures 4–7 (in Appendix). The constructed patterns include the body measurements and the additions (garment design allowances). The additions were kept equal and constant for all the constructed patterns of different shapes. The tools and equipment used in this research were pattern making kit, paper roll, pattern, and marker making software (GGT; V10.351).

**Experimental work**

The experimental work was carried out in the cutting room of an apparel manufacturing factory with constant fabric width (58 inches) in two parts, that is, the effect of body shapes on fabric consumption efficiencies with dissimilar body heights using constant bust/chest size and the effect of body shapes on fabric consumption efficiencies with similar body heights (the bust/chest and vertical landmark sizes of all the shapes were kept constant). The garment styles (shown in Figure 3) were selected for the assessment of the fabric utilization comparative to each body shape. The experiments were especially carried out in the early morning between 9 AM and 12 PM to avoid mental tiredness on the individuals and marker making experts because previous research has proved that individuals were efficient in the beginning and inefficient at the time of day's end [41-42]. The fabric cutting room temperature was kept at 23°C - 25°C.

Pattern and graded marker preparations. As the professionals in the world of fashion beauty and fitness consider triangular body shape as an ideal (highest symmetry) and best in nearly every shape of clothing and situations [43], the triangular body shape was considered as a benchmark shape in our experiments. The other three shapes, that is, circle, square, and oval were patronized in comparison to the triangular body shape.

**Human body shapes with dissimilar body heights using identical bust/chest (Part 1).**

The medium size of ideal triangle-shaped women's body measurements (shown in Table 1 in Appendix) was 36 inches (91.5 cm) bust, 26 inches (66 cm) waist and 36 inches (91.5 cm) hips, and the ideal men’s body measurements (shown in Table 2 in Appendix) was 38 inches (96.5 cm) chest, 32 inches (81.3 cm) waist, and 39 inches (99 cm) hips [44]. Relative grading skills among corresponding sizes such as extra small (XS), small (S), medium (M), large (L), and extra-large (XL) were applied as per the rule of ASTM D5585-95 standard (shown in Tables 3 and 4 in Appendix). The medium size (M), also named as “Size 12”
Figure 4. Fitted Trouser patterns of four body shapes in both genders.

Figure 5. Graded patterns of fitted trousers in both genders.
in the garment industry, is commonly used for the base size for grading [46]. The triangle-shaped women’s body drop (waist girth minus bust girth) was kept as −10 inch (25 cm) and the triangle-shaped men’s body drop (waist girth minus chest girth) was kept as −6 inch (15 cm). The size measurements for other body shapes were also originated through pattern designer from garment industry while keeping the bust/chest size constant for the four different body shapes in both genders.

The production order (4000 pieces) of fitted trousers and fitted shirts were equally distributed on the selected four different human body shapes of women and men. Size ratios (XS: S: M: L: XL: 1:1:1:1:1) were kept constant for all physique types, to explore the effects of fabric efficiencies. Thus 1000 (1050) garment pieces with ratios (XS: S: M: L: XL: 210: 210: 210: 210: 210) were generated against every body shape in both genders. The 5% garment pieces (200) were cut extra with the same ratios in each shape to accommodate the quantity order for in case of the quality rejection. Patterns of fitted trousers and fitted shirts of all shapes were drawn and cut conventionally for both genders (Figures 4–7 in Appendix) to have the optimal relationship between the body measurements (following the

Figure 6. Fitted shirt patterns of four shapes in both genders.

Figure 7. Fitted shirt graded patterns of four shapes in both genders.
body curves, outlining the figure) and the garment design measurements of close-fitted dress shirts and fitted trousers styles.

In the first part, a total of 160 patterns (each shape and five sizes) were prepared before the marker making process in both styles of women and men. The garment pieces were cut optimally in markers (lay) relative to each shape, which contained all the sizes (XS, S, M, L, XL) in an equal quantity. A lay has 105 plies and each ply contains all sizes. Thus, 525 pieces were cut in a single lay. The process was repeated twice to complete the 1050 garments. Furthermore, the pattern markers were accomplished through auto-marker and manual-marker making with the GGT software for the relative evaluation of fabric consumption and efficiencies. These steps were applied to all the shapes in both styles for women and men. Figures 8 and 9 have displayed the auto-pattern-markers and manual-pattern-markers of trouser and shirt against the given styles of women's triangular body shape. Tables 7 and 8 (in Appendix) have shown the outcomes of auto-markers and manual-markers of trousers and shirts of body shapes of both women and men.

**Human body shapes with similar body heights using identical bust/chest (Part 2).**

In the second part, that is, bodies with similar body heights, the patterns were regenerated conventionally according to the four different shapes of both women and men while keeping the bust/chest size for all the shapes constant. Figure 2 shows the four different body shapes of both women and men with similar body heights. Tables 5 and 6 (in Appendix) have shown the body measurements of the selected four different body shapes of both women and men. All the bodies of the same gender have similar/constant vertical landmarks, that is, body height, leg length, and arm length. However, the girth measurements are not constant except bust/chest. Relative grading skills among corresponding sizes such as extra-small (XS), small (S), medium (M), large (L), and extra-large (XL) were applied again to all the body types in both genders as per the rule of ASTM D5585-95 standard. The production order was also equally distributed to all the shapes. Auto-generated markers of fitted trousers and fitted shirts were created for describing the fabric consumption efficiencies.

**Results and discussion**

To verify the dissimilarities in fabric consumption efficiencies on four different body shapes of women and men in two different styles, fitted trousers and fitted shirts, the results were observed by factors, including fabric consumption, marker efficiency, marker loss, fabric loss, and fabric cost. The factors such as fabric construction, fabric width, fabric shrinkage, number of fabric plies, and number of cut-able pieces were kept constant. The comparison study between manual-marker and auto-marker through GGT software was also analyzed in both the genders.

**Effect of body shapes on fabric consumption efficiencies with dissimilar body height (Part 1).**

Fabric consumption: Figure 10(a) demonstrates the results of fabric consumption (angle point pattern) of the fitted trousers among four different body shapes of women and men. The triangular body shape devours the less and the oval body shape consumes the most fabric relative to other body shapes in both femininities. The reason for this is the thin midriff with smallest waist girth in triangular body shape while more space is occupied by the oval body shape. The square body shape is the succeeding body after the oval body shape that consumes more fabric. Therefore, producing trousers for the triangular body shape involved less fabric consumption for the completion of order as compared to the other body shapes.

![Figure 8](http://www.autexrj.com/)  
**Figure 8.** Fitted trouser marker (auto and manual comparison) of female triangle body.

![Figure 9](http://www.autexrj.com/)  
**Figure 9.** Fitted shirt marker (auto and manual comparison) of female triangle body.
Figure 10(b) displays the results of fabric consumption (crisscross pattern) for the fitted shirt among four different body shapes of women and men. It explains that the circular body shape in comparison to other body shapes in women has consumed less fabric while the oval body shape has devoured more fabric than the other body shapes. This is due to the curvilinear midriff with small waist girth of circular body shape comparative to oval and other body shapes. Also, the bust makes less cleavage than the triangular body shape. Triangular body shape is a succeeding shape that has consumed more fabric. Figure 10(b) also indicates fabric consumption for the fitted shirts among four different body shapes in men. The angle point pattern of the results has been observed. The triangular body shape consumes the least fabric while the oval body shape consumes the most fabric. The reason is that there exist the smallest waist girth and the absence of bust cleavage in triangular body shape contrasting to women. The square body shape is the subsequent shape that devours more fabric. Therefore, producing shirts for oval body shape required more fabric for the completion of production orders as compared to the circular body shape in women and triangular body shape in men.

Figure 10 also depicts that men’s body structures devours more fabric in top wear and bottom wear garments relative to women in all body shapes because of the longer heights and broader shoulders. Furthermore, in comparison with the consumption of the fabric in shirts and trousers manufacturing, the results revealed that shirts consume more fabrics than the trousers in all the body shapes. The shirts comprised of more panels (two front, two back, and two sleeves) while the trousers involve fewer panels (two front and two backs). The more the panels, the more is the fabric consumption and working operations. Moreover, marker making operation on an auto computer system consumes more fabric comparative to the manual-marker through human expertise. The reason is the skills of the human mind that adjusts the small parts more sharply in the spaces between the placement of the panels. The small parts are easily adjustable in markers with triangular body shape markers for being their narrowest waist and more angular structure.

Marker efficiency: Figure 11 describes the marker efficiency of four different body shapes both in women and men. The marker with 90% efficiency is better than the marker with 88.5% efficiency. The increase in marker efficiency leads to decrease in the fabric loss (dependent variable). The marker efficiencies depend on the skills of the GGT software operator. It is observed that trouser-markers are more (maximum average value: 89.2%) efficient while the shirt-markers are less (maximum average value: 88.7%) efficient (both in manual- and auto-marker making). It has also been observed that the manual-markers in all the shapes and in all the styles are comparatively more efficient (significant p-value) than the...
auto-generated-markers. The working of the trousers (bottom wear) is more effectual in material utilization than the shirts (top wear). The possible reasons are the adjustments of the panels in accordance with grain lines, less number of panels, and the upper part of the body has more curviness than the lower body part.

Figure 11(a) displays the outcomes of trouser marker efficiency. The square body shape has maximum marker efficiency except for the manually fitted trousers marker in women’s wear, from all the other shapes. Triangular body shape has the least marker efficiency in all the markers except the auto-marker in women’s wear. Figure 11(b) shows the fluctuation in the results. The square body shape has the maximum marker efficiency in auto-marker while the triangular body shape has the maximum efficiency in women’s fitted shirts. In men’s fitted shirt, the pattern of auto-marker and manual-marker efficiency is different. The oval body shape is efficient in auto-marker while the circular body shape is efficient in manual-marker. Thus the fluctuation inefficiency results expose that the efficiency factor does not depend on the factors considered in the study.

Marker loss and Fabric loss: Marker wastages depend on the marker efficiencies. Figure 12 demonstrates the marker loss and the fabric loss. The more the marker is efficient, the less the marker is wasted. The bar graph of the marker losses and the fabric losses are inversely proportional to the marker efficiencies. Fabric loss is dependent on the marker. However, the fabric loss (portions of the fabric that did not become the part of the garment components) is greater than the marker loss. The reason is the width loss and the end loss including the fabric selvedge. Our results are also in accordance with the Kunz wastage results [37]. The manual-virtual-marker loss and the fabric loss have a significant difference from the auto-generated-marker and the fabric loss results.

Cost-effectiveness: Figure 13 shows the cost-effectiveness relevant to each body shape both in women and men. Figure 13(a) reveals the results of the fabric cost-effectiveness of the trousers. The triangular body shape is the most cost-effective and the oval body shape is the least cost-effective relative to other body shapes. The square body shape is the succeeding after oval body shape in both women and men. Thus, the triangular body shape requires less fabric and, hence, less cost for the completion of the same style of order as compared to the other body shapes. Figure 13(b) displays the results of the fabric cost for the fitted shirts among four different body shapes. The circular body shape comparative to other body shapes in women is the most cost-effective, whereas oval body shape is the least cost-effective. In men’s shirt, triangular body shape is the most fabric cost-effective while the oval body shape is the least cost-effective. Moreover, auto-markers are less fabric cost-effective compared to the manual-marker outcomes (significant p-value). Therefore, oval body shape...
requires more cost for the completion of the shirts orders in relation to the circular body shape in women and a triangular body shape in men.

Figure 13 also depicts that men’s body structures require more fabric and thus more cost in top and bottom wear garments relative to women in all body shapes. Furthermore, it has been observed that shirts manufacturing is costlier than the trousers in all the body shapes. Likewise, the auto-marker-making operation is expensive to the one that is operated through human skills and expertise. The t-test proves that the marker efficiency conducted through skilled workforce yields better results, that is, significant p-value (Tables 7 and 8 in Appendix). It has also been verified in previous research that saving of two million dollars per year can be achieved through 0.1% improvement in marker (fabric) efficiency by a trousers manufacturing company [46]. Thus the companies can make more profit while scrutiny the material consumptions in more depth.

**Effect of body shapes on fabric efficiencies when they are similar in body heights (part 2).**

Figure 14 reveals the results of marker efficiency and the fabric utilization for the four different body shapes in women and men with similar vertical landmarks and constant bust/chest. The figure shows that shirts consume more fabrics than the trousers in all the shapes. The marker efficiency of the trousers is greater than the shirts in both the genders. In women’s trouser marker efficiency, the circular body shape is the most efficient while the oval body shape is the least efficient.

![Figure 14. Marker efficiency and fabric utilization in both women’s and men’s with similar body heights.](image)

The triangular body shape in trousers manufacturing, both in women and men, has least fabric utilization, while in shirts manufacturing, circular body shape has the least fabric utilization. Oval body shape in both the trousers and the shirts consume more fabric among all the shapes in women and men. The triangular bodies have a narrower waist, and the weight of the bodies lies at thigh area in comparison to other shapes; therefore, it is more effective in trousers making. The oval body shape has extreme shoulder slop and the body weight lies at the midriff to make waist girth bigger; therefore, it consumes more fabric in both the trousers and the shirts. The circular body shape has the narrowest waist similar to the triangular body shape but body weight lies mostly at hips, shoulders are sloppy instead of the straight across shoulders similar to that in triangular body shape; thus the circular body shape supports less consumption of the fabric. The shirts manufacturing involve more fabric panels (two front and back sleeves, two fronts, two back, two collars, plackets, etc.), while the trousers includes fewer fabric panels (two front and back leg panels, waistband, zipper fly, etc.). These factors effect the trousers to have an efficient working.

**Recommendations for product manufacturers**

This study has revealed only one operation (marker-making) with two styles (the trousers and the shirt) for four different human body shapes both in women and men. This first step is introductory for researchers and apparel manufactures to make the apparels and garment production assembly lines more cost-effective. For more strengthening the knowledge, there is a need to explore a number of different production orders, which would be highly expensive. The same experimental analysis could be conducted in more garment industries to benchmark the approaches, techniques, and production management capabilities.

This study suggests the apparel firms that are producing garments for women and men to make their strategies better for the different markets. The production companies that are involved in trousers manufacturing of women and men are generating more profits as compared to the shirts manufacturers for the reason of the fabric utilization and involvement of the fewer production operations. In addition, if the manufacturers execute the operations through skilled workforce, they could generate more profits while minimizing the material (fabric) wastages.

**Conclusion**

The objective of this research was to study the fabric efficiencies in correspondence with four different human body shapes, that is, oval, circle, square, and triangle, in the apparel industry. Two order styles, the fitted trousers and the fitted shirts, were selected and transformed on to four different body shapes of women and men. A comparative analysis of auto-generated-marker and skilled operative marker through GGT software was also anticipated. The study reveals that many variations exist in the fabric consumption in accordance with different body shapes in both women and men. The most efficient shape in women’s shirt is the circle shape with an average fabric consumption of 95.05 cm and that in men’s shirt is the triangle shape with an average fabric consumption of 101.31 cm. While the least efficient shape in both women’s and men’s shirts is an oval body shape with an average fabric consumption of 105.53 and 114.23 cm, respectively. Similarly, in women’s and men’s trousers, the most efficient shape is triangular body, with an average fabric consumption of 80.25 and 80.33 cm, respectively. While the least efficient shape in both women’s and men’s trousers is
an oval body with an average fabric consumption of 87.91 and 89.54 cm, respectively. Therefore, the shape in women (circle) and in men (triangle) in shirt manufacturing and shape (triangle) in trousers manufacturing in both gender devour a lesser amount of the fabric than the other human body shapes. Henceforth, they are less expensive in production orders. Moreover, an oval shape body devours more fabric in the shirts and the trousers than the other body shapes in both genders. Thus it is the most expensive. Also, manual-marker making operatives of GGT software is found efficient (0.90%) than the auto-generated-marker making (0.85%). In the second part, when the bodies have the same height, the triangular body shape in the trousers and the circular body shape in the shirts consume less fabric in both the genders. Thus these are least expensive.

The overall result reveals that the triangular body shape is most effective in the trousers manufacturing and the circular body shape is effective in the shirts manufacturing in both the genders. Manual-markers at GGT software through an expert has the highest efficiency (significant p-value) comparing to the auto-generated-markers. However, the manual-virtual-marker is comparatively a time-consuming operation than the auto-generated-marker. Women’s garment orders are cost-effective than men’s garments because of the fabric utilization. The trousers consume less fabric; therefore, they are cost-effective while the shirts are expensive.

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### Appendix

**Table 1.** Size measurements of ideal women for the four different body shapes with dissimilar body heights.

| Sr. No | Description          | Triangle (ideal body) | Circle    | Oval     | Square/Rectangle |
|--------|----------------------|-----------------------|-----------|----------|------------------|
|        |                      | Most curvaceous       | More curvaceous | Curvaceous | Less curvaceous |
|        |                      | (highly curviest)     | (curvier)  | (curvy)  | (less curvy)     |
| 1      | Bust girth           | 36 inches (91.5 cm)   | 36 inches (91.5 cm) | 36 inches (91.5 cm) | 36 inches (91.5 cm) |
| 2      | Waist girth          | 26 inches (66 cm)     | 30 inches (76 cm)   | 32 inches (81 cm)   | 34 inches (86 cm)   |
| 3      | Hips girth           | 36 inches (91.5 cm)   | 38 inches (97 cm)   | 37 inches (94 cm)   | 35 inches (89 cm)   |
| 4      | Shoulder span        | 16 inches (41 cm)     | 16.5 inches (42 cm) | 16 inches (41 cm)   | 17 inches (43 cm)   |
| 5      | Leg length (crotch to ankle) | 26 inches (66 cm) | 24 inches (61 cm)   | 27 inches (69 cm)   | 25 inches (64 cm)   |
| 6      | Thigh girth          | 21 inches (53 cm)     | 22 inches (56 cm)   | 23 inches (58 cm)   | 21 inches (53 cm)   |
| 7      | Calf girth           | 9 inches (23 cm)      | 11 inches (28 cm)   | 12 inches (30.5 cm) | 10 inches (25 cm)   |
| 8      | Arm length           | 29 inches (74 cm)     | 27 inches (69 cm)   | 30 inches (76 cm)   | 28 inches (71 cm)   |
| 9      | Armscye (armhole)    | 15 inches (38 cm)     | 15.5 inches (39 cm) | 16 inches (41 cm)   | 14 inches (36 cm)   |
| 10     | Neck girth           | 13.5 inches (34 cm)   | 14.5 inches (37 cm) | 14 inches (35.5 cm) | 13.5 inches (34 cm) |
| 11     | Wrist girth          | 6.15 inches (16 cm)   | 6.0 inches (15 cm)  | 6.45 inches (17 cm) | 6.30 inches (16 cm) |
| 12     | Shoulder slope (degree) | 20 70                | 26 64             | 23 67             | 18 72             |
| 13     | Body height          | 67 inches (170 cm)    | 62 inches (157.5 cm) | 68 inches (173 cm) | 64 inches (162.5 cm) |

**Table 2.** Size measurements of ideal men for the four different body shapes with dissimilar body heights.

| Sr. No | Description          | Triangle (ideal body) | Circle    | Oval     | Square/rectangle |
|--------|----------------------|-----------------------|-----------|----------|------------------|
|        |                      | Most curvaceous       | More curvaceous | Curvaceous | Less curvaceous |
|        |                      | (highly curviest)     | (curvier)  | (curvy)  | (less curvy)     |
| 1      | Chest girth          | 38 inches (96.5 cm)   | 38 inches (96.5 cm) | 38 inches (96.5 cm) | 38 inches (96.5 cm) |
| 2      | Waist girth          | 32 inches (81 cm)     | 34 inches (86 cm)   | 33 inches (84 cm)   | 36 inches (91.5 cm) |
| 3      | Hips girth           | 39 inches (99 cm)     | 38 inches (96.5 cm) | 40 inches (102 cm)  | 39 inches (99 cm)   |
| 4      | Shoulder span        | 18 inches (46 cm)     | 17 inches (43 cm)   | 19 inches (48 cm)   | 18 inches (46 cm)   |
| 5      | Leg length (crotch to ankle) | 32 inches (81 cm) | 31 inches (79 cm)   | 33 inches (84 cm)   | 32 inches (81 cm)   |
| 6      | Thigh girth          | 23 inches (58 cm)     | 22 inches (56 cm)   | 24 inches (61 cm)   | 23 inches (58 cm)   |
| 7      | Calf girth           | 15 inches (38 cm)     | 14.5 inches (37 cm) | 15.5 inches (39.5 cm) | 15 inches (38 cm)   |
| 8      | Arm length           | 29 inches (74 cm)     | 28 inches (71 cm)   | 30 inches (76 cm)   | 29 inches (74 cm)   |
| 9      | Armscye (armhole)    | 18 inches (46 cm)     | 17 inches (43 cm)   | 19 inches (48 cm)   | 18 inches (46 cm)   |
| 10     | Neck girth           | 15 inches (38 cm)     | 14.5 inches (37 cm) | 15.5 inches (39.5 cm) | 15 inches (38 cm)   |
| 11     | Wrist girth          | 7.17 inches (18 cm)   | 7.0 inches (18 cm)  | 7.45 inches (19 cm) | 7.30 inches (19 cm) |
| 12     | Shoulder slope (degree) | 20 70                | 26 64             | 23 67             | 18 72             |
| 13     | Body height          | 70 inches (178 cm)    | 66 inches (168 cm)  | 72 inch (183 cm)    | 68 inch (173 cm)    |
### Table 3. Size chart of an ideal women’s body shape (triangle)

| Sr. No | Description     | Extra-small (XS) | Small (S) | Medium (M) | Large (L) | Extra-large (XL) |
|--------|-----------------|------------------|-----------|------------|-----------|-----------------|
|        | Sizes 2–20      | 2–4              | 6–8       | 10–12      | 14–16     | 18–20           |
| 1      | Bust girth      | 30 inches (76 cm) | 32 inches (81 cm) | 36 inches (91.5 cm) | 40 inches (102 cm) | 42 inches (107 cm) |
| 2      | Waist girth     | 20 inches (51 cm) | 22 inches (56 cm) | 26 inches (66 cm) | 30 inches (76 cm) | 32 inches (81 cm) |
| 3      | Hips girth      | 30 inches (76 cm) | 32 inches (81 cm) | 36 inches (91.5 cm) | 40 inches (102 cm) | 42 inches (107 cm) |
| 4      | Shoulder span   | 14.5 inches (37 cm) | 15 inches (38 cm) | 16 inches (41 cm) | 17 inches (43 cm) | 17.5 inches (44.5 cm) |
| 5      | Inseam length   | 23 inches (58.5 cm) | 24 inches (61 cm) | 26 inches (66 cm) | 28 inches (71 cm) | 29 inches (74 cm) |
| 6      | Thigh girth     | 18 inches (46 cm) | 19 inches (48 cm) | 21 inches (53 cm) | 23 inches (58.5 cm) | 24 inches (61 cm) |
| 7      | Calf girth      | 7.5 inches (19 cm) | 8 inches (20 cm) | 9 inches (23 cm) | 10 inches (25.5 cm) | 10.5 inches (27 cm) |
| 8      | Arm length      | 26 inches (66 cm) | 27 inches (69 cm) | 29 inches (74 cm) | 31 inches (79 cm) | 32 inches (81 cm) |
| 9      | Armhole         | 13.5 inches (34 cm) | 14 inches (36 cm) | 15 inches (38 cm) | 16 inches (41 cm) | 16.5 inches (42 cm) |
| 10     | Neck girth      | 10.5 inches (27 cm) | 11.5 inches (29 cm) | 13.5 inches (34 cm) | 15.5 inches (39.5 cm) | 16.5 inches (42 cm) |
| 11     | Wrist girth     | 5.90 inches (15 cm) | 6.0 inches (15 cm) | 6.15 inches (16 cm) | 6.35 inches (16 cm) | 6.5 inches (17 cm) |
| 12     | Body height     | 62 inches (157.5 cm) | 64.5 inches (164 cm) | 67 inches (170 cm) | 69.5 inches (176.5 cm) | 72 inches (183 cm) |

### Table 4. Size chart of an ideal men’s body shape (triangle)

| Sr. No | Description               | Extra-small (XS) | Small (S) | Medium (M) | Large (L) | Extra-large (XL) |
|--------|---------------------------|------------------|-----------|------------|-----------|-----------------|
|        | Sizes 2–20                | 2–4              | 6–8       | 10–12      | 14–16     | 18–20           |
| 1      | Chest girth               | 32 inches (81 cm) | 34 inches (86.5 cm) | 38 inches (96.5 cm) | 42 inches (107 cm) | 44 inches (112 cm) |
| 2      | Waist girth               | 26 inches (66 cm) | 28 inches (71 cm) | 32 inches (81 cm) | 36 inches (91.5 cm) | 38 inches (96.5 cm) |
| 3      | Hips girth                | 33 inches (84 cm) | 35 inches (89 cm) | 39 inches (99 cm) | 43 inches (109 cm) | 45 inches (114 cm) |
| 4      | Shoulder span             | 16.5 inches (42 cm) | 17 inches (43 cm) | 18 inches (46 cm) | 18 inches (46 cm) | 18.5 inches (47 cm) |
| 5      | Leg length (crotch to ankle) | 29 inches (74 cm) | 30 inches (76 cm) | 32 inches (81 cm) | 32 inches (81 cm) | 33 inches (84 cm) |
| 6      | Thigh girth               | 20 inches (51 cm) | 21 inches (53 cm) | 23 inches (58 cm) | 25 inches (63.5 cm) | 26 inches (66 cm) |
| 7      | Calf girth                | 12 inches (30.5 cm) | 13 inches (33 cm) | 15 inches (38 cm) | 17 inches (43 cm) | 18 inches (46 cm) |
| 8      | Arm length                | 26 inches (66 cm) | 27 inches (69 cm) | 29 inch (74 cm) | 31 inches (79 cm) | 32 inches (81 cm) |
| 9      | Armhole                   | 16.5 inches (42 cm) | 17 inches (43 cm) | 18 inches (46 cm) | 19 inches (48 cm) | 19.5 inches (50 cm) |
| 10     | Neck girth                | 13.5 inches (34 cm) | 14 inches (36 cm) | 15 inches (38 cm) | 16 inches (41 cm) | 16.5 inches (42 cm) |
| 11     | Wrist girth               | 6.85 inches (17 cm) | 7.0 inches (18 cm) | 7.17 inches (18 cm) | 7.30 inches (19 cm) | 7.45 inches (19 cm) |
| 12     | Body height               | 64 inches (163 cm) | 67 inches (170 cm) | 70 inches (178 cm) | 72 inches (183 cm) | 73 inches (185.5 cm) |
Table 5. Size measurements of ideal women for the four different body shapes with similar body heights and bust.

| Sr. No | Description       | Triangle (ideal body) | Circle | Oval | Square/rectangle |
|--------|-------------------|-----------------------|--------|------|------------------|
|        |                   | Most curvaceous (highly curviest) | More curvaceous (curvier) | Curvaceous (curvy) | Less curvaceous (less curvy) |
| 1      | Bust girth        | 36 inches (91.5 cm)   | 36 inches (91.5 cm)   | 36 inches (91.5 cm) | 36 inches (91.5 cm) |
| 2      | Waist girth       | 26 inches (66 cm)     | 30 inches (76 cm)     | 32 inches (81 cm)  | 34 inches (86 cm)  |
| 3      | Hips girth        | 36 inches (91.5 cm)   | 38 inches (97 cm)     | 37 inches (94 cm)  | 35 inches (89 cm)  |
| 4      | Shoulder span     | 16 inches (41 cm)     | 16.5 inches (42 cm)   | 16 inches (41 cm)  | 17 inches (43 cm)  |
| 5      | Leg length (crotch to ankle) | 26 inches (66 cm) | 26 inches (66 cm) | 26 inches (66 cm) | 26 inches (66 cm) |
| 6      | Thigh girth       | 21 inches (53 cm)     | 22 inches (56 cm)     | 23 inches (58 cm)  | 21 inches (53 cm)  |
| 7      | Calf girth        | 9 inches (23 cm)      | 11 inches (28 cm)     | 12 inches (30.5 cm) | 10 inches (25 cm)  |
| 8      | Arm length        | 29 inches (74 cm)     | 29 inches (74 cm)     | 29 inches (74 cm)  | 29 inches (74 cm)  |
| 9      | Armscye (armhole) | 15 inches (38 cm)     | 15.5 inches (39 cm)   | 16 inches (41 cm)  | 14 inches (36 cm)  |
| 10     | Neck girth        | 13.5 inches (34 cm)   | 14.5 inches (37 cm)   | 14 inches (35.5 cm) | 13.5 inches (34 cm) |
| 11     | Wrist girth       | 6.15 inches (16 cm)   | 6.0 inches (15 cm)    | 6.45 inches (17 cm) | 6.30 inches (16 cm) |
| 12     | Shoulder slope (degree) | 20 70               | 26 64               | 23 67             | 18 72             |
| 13     | Body height       | 67 inches (170 cm)    | 67 inches (170 cm)    | 67 inches (170 cm) | 67 inches (170 cm) |

Table 6. Size measurements of ideal men for the four different body shapes with similar body heights and chest.

| Sr. No | Description       | Triangle (ideal body) | Circle | Oval | Square/rectangle |
|--------|-------------------|-----------------------|--------|------|------------------|
|        |                   | Most curvaceous (highly curviest) | More curvaceous (curvier) | Curvaceous (curvy) | Less curvaceous (less curvy) |
| 1      | Chest girth       | 38 inches (96.5 cm)   | 38 inches (96.5 cm)   | 38 inches (96.5 cm) | 38 inches (96.5 cm) |
| 2      | Waist girth       | 32 inches (81 cm)     | 34 inches (86 cm)     | 33 inches (84 cm)  | 36 inches (91.5 cm) |
| 3      | Hips girth        | 39 inches (99 cm)     | 38 inches (96.5 cm)   | 40 inches (102 cm) | 39 inches (99 cm)  |
| 4      | Shoulder span     | 18 inches (46 cm)     | 17 inches (43 cm)     | 19 inches (48 cm)  | 18 inches (46 cm)  |
| 5      | Inseam length     | 32 inches (81 cm)     | 32 inches (81 cm)     | 32 inches (81 cm)  | 32 inches (81 cm)  |
| 6      | Thigh girth       | 23 inches (58 cm)     | 22 inches (56 cm)     | 24 inches (61 cm)  | 23 inches (58 cm)  |
| 7      | Calf girth        | 15 inches (38 cm)     | 14.5 inches (37 cm)   | 15.5 inches (39.5 cm) | 15 inches (38 cm)  |
| 8      | Sleeve length     | 29 inches (74 cm)     | 29 inches (74 cm)     | 29 inches (74 cm)  | 29 inches (74 cm)  |
| 9      | Armscye (armhole) | 18 inches (46 cm)     | 17 inches (43 cm)     | 19 inches (48 cm)  | 18 inches (46 cm)  |
| 10     | Neck girth        | 15 inches (38 cm)     | 14.5 inches (37 cm)   | 15.5 inches (39.5 cm) | 15 inches (38 cm)  |
| 11     | Wrist girth       | 7.17 inches (18 cm)   | 7.0 inches (18 cm)    | 7.45 inches (19 cm) | 7.30 inches (19 cm) |
| 12     | Shoulder slope (degree) | 20 70               | 26 64               | 23 67             | 18 72             |
| 13     | Body height       | 70 inches (178 cm)    | 70 inches (178 cm)    | 70 inches (178 cm) | 70 inches (178 cm) |
Table 7. t-Test statistics for the differences between two marker making systems in trouser.

| Sr. No | Body shapes | Fabric consumption per piece (cm) | Marker efficiency (%) | Marker wastage/loss (%) | Fabric wastage/loss (%) |
|--------|-------------|----------------------------------|------------------------|-------------------------|-------------------------|
|        |             | Auto Manual | Auto Manual | Auto Manual | Auto Manual | Auto Manual | Auto Manual |
|        |             | A M         | A M         | 100-A       | 100-M       | 100-A       | 100-M       |
| 1      | Triangle    | 81.29 80.25 | 87.46 88.6* | 12.54 11.4* | 15.4 14.3* |
| 2      | Circle      | 82.43 81.3  | 87.43 88.65* | 12.57 11.35* | 15.42 14.25* |
| 3      | Oval        | 88.85 87.81 | 87.79 88.73* | 12.21 11.27* | 15.04 14.13* |
| 4      | Square      | 83.49 82.77 | 87.92 88.68* | 12.08 11.32* | 14.94 14.21* |
| Average|             | 84.015 83.0325 | 87.65 88.665 | 12.35 11.34 | 15.2 14.23 |

*Significant (p-value = 0.00) at significance level α = 0.05.

Table 8. t-Test statistics for the differences between two marker making systems in shirt.

| Sr. No | Body shapes | Fabric consumption per piece (cm) | Marker efficiency (%) | Marker wastage/loss (%) | Fabric wastage/loss (%) |
|--------|-------------|----------------------------------|------------------------|-------------------------|-------------------------|
|        |             | Auto Manual | Auto Manual | Auto Manual | Auto Manual | Auto Manual | Auto Manual |
|        |             | A M         | A M         | 100-A       | 100-M       | 100-A       | 100-M       |
| 1      | Triangle    | 81.33 80.33 | 87.42 88.51* | 12.58 11.49* | 15.44 14.39* |
| 2      | Circle      | 82.1 81.46  | 88.09 88.78* | 11.91 11.22* | 14.79 14.12* |
| 3      | Oval        | 90.36 89.54 | 88.06 89* | 11.94 11* | 14.77 13.99* |
| 4      | Square      | 86.6 85.78  | 88.34 89.19* | 11.66 10.81* | 14.52 13.7* |
| Average|             | 85.0975 84.2775 | 87.9775 88.87 | 12.0225 11.13 | 14.88 14.05 |

*Significant (p-value = 0.00) at significance level α = 0.05.