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Quantitative analysis of 3D seam shape according to easing conditions for efficient sewing using muslin

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Abstract

This study quantitatively analyzes the data of 3D seam shapes that alter according to easing conditions. By numerically approaching easing, which is only taught using traditional methods, this study suggests a method of analyzing the changes in 3D surface area, volume, and seam shape. The 3D data of the completed samples were obtained through a 3D scanner, the solid shapes were analyzed using reverse engineering, and a new program was developed. The shape, area, and volume of the data were analyzed, and the deformation rate was measured using the radius of curvature. Linear seam lines were bent because of the mechanical pushing inflicted by the garment with easing. The area increased dramatically as the ease amount increased when the seam lines were short, whereas it was relatively unaffected when seam lines were long. The radii of curvature for curved seam lines show that, for all samples, the waveform is high at the center where the seam is. The peak value did not increase for curved seams when the ease amount increased. The sum of the areas increased with a larger radius of curvature for the curved seams. It is a crucial reference for easing in garments regarding quantitative changes in seam shapes and volumes according to easing type and amount.

Keywords: 3D seam shape, Easing type, Linear seam, Curved seam, Sewing

Introduction

The garment has been part of humanity throughout history, and optimal conditions for the wearer, such as fabric, tailor, and sewing machine, have been accumulated. Understanding body shape is essential when making garments, and placing different amounts of ease according to purpose is important. Ease can generally be categorized into four types: comfort ease, which is required for essential breathing or the wearer's relaxed posture in a static stance; dynamic ease, which is used for movement; styling ease, which produces a specifically designed silhouette (Ng et al., 2008); and fabric ease, which is used with consideration of the mechanical and physical properties of fabrics with patterns (Gu et al., 2016). Appropriate ease must be set according to the garment's end use to design and produce an integrated fit.

The garment is designed on a 2D fabric and made into a 3D shape. Dart and easing are the primary techniques used to formulate shapes. Easing expresses volume and curvature by differentiating two sewing lines during the pattern-making process of traditional tailoring techniques, and it is used on lines such as the shoulder, princess, and armhole (Lee & Steen, 2014). However, in the fashion industry, the ease amount is determined by the conventional knowledge of patterning experts, and publications on pattern-making suggest consistent values without considering the dynamic properties of the fabric or pattern shape.

Easing can be complex, as it plays a crucial role in the fit and quality of the garment. However, the limitation is that it is theorized based on experience rather than a scientific approach.

Researchers strive to theoretically define a comfortable fit that is attractive and purposeful fit using scientific technology. Recently, scientific and quantitative analyses have been performed using 3D technology. Most studies have assessed ease allowance for comfortable pattern-making by analyzing the space between the garment and the body through 3D scanned data. By scanning the 3D reference body and the garments and superimposing the two, the cross-section of the area to check the ease allowance was extracted and analyzed by measuring the distance between the body and the garments (Ashdown et al., 2004; Petrova & Ashdown, 2008; Thomassey & Bruniaux, 2013; Zhang et al., 2015). Specifically, Su et al. (2015) determined the ease allowance of pants in the way above and used the data to design individual pant patterns based on the mathematical model automatically. Thomassey and Bruniaux (2013) analyzed the 3D ease allowance of a garment using the original image processing method and reverse methodology and proposed a 3D customized pattern design template. Zhang et al. (2015) analyzed the ease allowance distribution with 3D scan data centered on different angles in the bust section. They expressed that the ease allowance at a specific angle is a regression equation for a good fit. Lage and Ancutiene (2017) investigated the ease allowance distribution using virtual try-on technology. They conducted a study to confirm which factors among the material's physical properties significantly affect the virtual 3D fit. Many attempts have been made to improve the fit of clothes or design customized patterns using 3D technology and mathematical techniques.

However, in garments and textiles, easing is a technical term different from ease allowance. As mentioned earlier, easing is a 3D operation involving sewing two lines of different lengths. It is mainly used for the shoulder, bust, armhole, and waist, fundamentally affecting quality and fit (Amstrong, 2006). In other words, it is a factor that partially affects the garment's shape rather than being involved in the entire garment. Specifically, in the case of the shoulder line, two straight lines with a difference of approximately 0.7–1 cm are sewn for the volume of the shoulder blade, and two curves with a difference of approximately 1–2 cm are sewn on the breast. On the sleeves, easing is incorporated into a garment through two curved stitches with a difference of at least 2.5 cm (Zamkoff & Price, 2019). Although it is a critical factor in tailoring, it has yet to be studied scientifically and has not gained much interest. It would be meaningful to extensively analyze the role of easing in sewing and fitting garments.

Therefore, this study quantitatively analyzed the data of 3D seam shapes that alter according to easing conditions. The 3D seam shapes were divided into a straight seam line and a curved seam line to determine the change in the flat fabric state in 3D after sewing. By numerically approaching easing, which is only taught using traditional methods, this study suggests analyzing the changes in 3D surface area, volume, and seam according to easing conditions. Specifically, the research aims are as follows:

- If two straight lines of different lengths are sewn, we want to quantify the extent to which 3D is achieved and the changes in the seam line.
- When two curves of different lengths are sewn, we want to quantify the difference in the aspect of the 3D shape from that of straight-line sewing. Moreover, we will determine the difference if the curve's curvature changes during sewing.

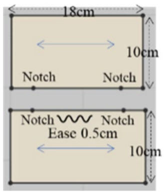
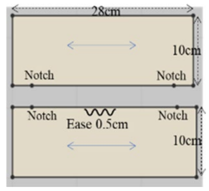
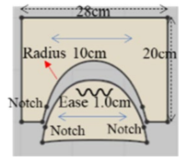
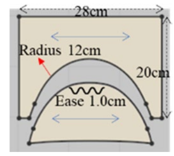
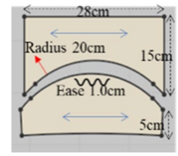
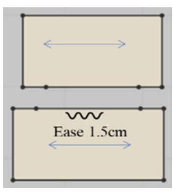
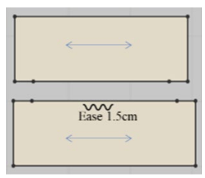
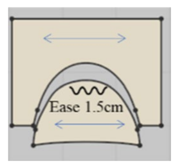
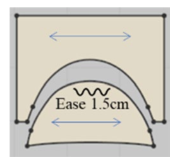
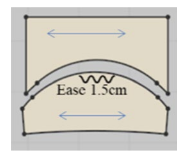
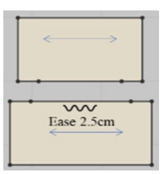
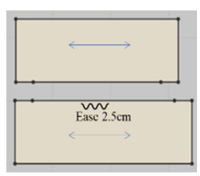
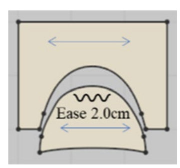
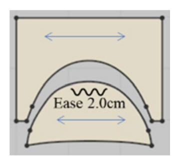
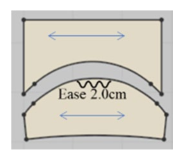
This will serve as fundamental data when scientifically specifying the relationship between 2D pattern designs and completed 3D garment shapes.

Methods

Experimental samples according to easing conditions

The types of seam lines used for easing were selected: straight and curved. The sample size was set to reflect the length of the body parts to apply to the garment. For example, according to the 8th Size Korea survey, lateral shoulder length, shoulder length, back neck point to acromion length, and back neck point to lateral shoulder length of people in their 20 s, related to the shoulder area with easing in a straight line, ranged from approximately 13 to 20 cm. In contrast, the length of the side neck point to bust point or bust point to waist level, related to the straight line pattern, ranged from approximately 26 to 30 cm. However, as the body parts that use easing in curved lines vary, from the humeral head, bust, and hip, this variation has to be considered in determining the sample size and the shape of the seam lines. Moreover, the amount of ease ranges from 0.5 to 2.5 cm according to the pattern area (Amstrong, 2006; Zamkoff & Price, 2019), gender of the wearer, and materials; the experimental samples are presented in Table 1. The short length (SL) was set to 18 cm and the long length (LL) to 28 cm for straight seam lines. A rectangular pattern with a width of 10 cm was drafted. Linear ease amounts of 0.5 cm (e0.5), 1.5 cm (e1.5), and 2.5 cm (e2.5) were respectively applied to craft six samples (SL-e0.5, SL-e1.5, SL-e2.5, LL-e0.5, LL-e1.5, and LL-e2.5). For curved lines, curved seams of 10 cm (C1), 12 cm (C2), and 20 cm (C3) radii were drafted on a rectangle of 28 cm width and 20 cm length to confirm the difference according to the radius of curvature. The amount of ease was set as 1.0 cm (e1.0), 1.5 cm (e1.5), and 2.0 cm (e2.0), totaling nine types of samples (C1-e1.0, C1-e1.5, C1-e2.0, C2-e1.0, C2-e1.5, C2-e2.0, C3-e1.0, C3-e1.5, and C3-e2.0). The fabric was muslin; a number 14-size ballpoint needle was used for sewing; the type of thread used was cotton 40 s/2; the stitch type was 301 lock (Singer sewing machine); and the stitch per inch was 10. The sewing speed was set to be maintained at 600 rpm, and the sewing tension was maintained the same. Notches were placed 3 cm from each end of the seam line. The samples' seam margin was 0.8 cm, and an expert with over 10 years of experience crafted all samples for consistency.

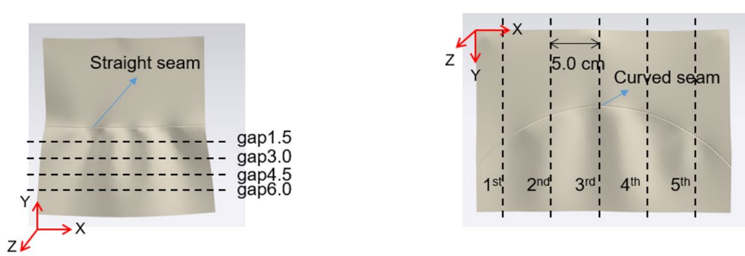
Table 1 2D patterns of experimental samples

Length of straight seam		Radius of curved seam		
18 cm (SL)	28 cm (LL)	10 cm (C1)	12 cm (C2)	20 cm (C3)
SL-e0.5	LL-e0.5	C1-e1.0	C2-e1.0	C3-e1.0
				
SL-e1.5	LL-e1.5	C1-e1.5	C2-e1.5	C3-e1.5
				
SL-e2.5	LL-e2.5	C1-e2.0	C2-e2.0	C3-e2.0
				

SL: short length; LL: long length

C1: radius 10 cm; C2: radius 12 cm; C3: radius 20 cm

e0.5: ease amount of 0.5 cm; e1.0: ease amount of 1.0 cm; e1.5: ease amount of 1.5 cm; e2.5: ease amount of 2.5 cm



(a) Measurement location of straight seam line (b) Measurement location of curved seam line

Fig. 1 Cross-sectional analysis locations of 3D scanned data

Measurements of 3D scanned data according to experimental samples

The 3D data of the completed samples were obtained using a 3D scanner (VIVID 910-Konica Minolta Sensing, Inc., Japan), and the solid shapes were analyzed using a reverse engineering program (Geomagic Design X-3D Systems, Inc., Korea). As seen in Fig. 1a, to measure the linear lines, cross-sectional lines 1.5 cm (gap 1.5), 3.0 cm (gap 3.0), 4.5 cm (gap 4.5), and 6.0 cm (gap 6.0) away from and parallel to the seam line according to the fabric were extracted. X and Z coordinates of each sketch line were converted into a linear graph. In this case, the point of analysis was similar to the data of 0.5 cm (gap 0.5), 1.0 cm (gap 1.0), and 1.5 cm (gap 1.5) in the preliminary experiment;

therefore, the starting point was set to 1.5 cm (gap 1.5) for the analysis of the height of the surface volume. A plane perpendicular to the seam line was extracted and analyzed for curved lines, as it was impossible to extract a parallel plane. As seen in Fig. 1b, a plane normal to the center of the seam line was generated, and planes 5.0 cm away to the left and right were generated, totaling five planes (1st, 2nd, 3rd, 4th, and 5th). Cross-sectional sketches were extracted using the Y and Z coordinates. However, group C1 had a large curvature; thus, only the 2nd, 3rd, and 4th planes were analyzed. Commercial programs could not analyze the shape, area, and volume of the obtained 3D data; therefore, a new program was developed for this study. Meanwhile, seams of linear seam group samples were deformed owing to the tension of ease after sewing, and the deformation rate was measured using the radius of curvature.

Results

Programming for analyzing 3D shape, surface area, and volume of experimental samples

Traditionally, tailors with professional know-how observe and apply easing visually, but in this study, we approached it with science and technology. Hence, a source code was developed. The programming to analyze was conducted using the Wolfram language, as shown in Table 2.

This allows 3D shapes to be analyzed according to easing types using the cross-sectional shape data obtained from programming and calculating the volume from the peak of the 2D curved graph, shape analysis, area calculation, and total area. First, the extracted (*i*, *j*) data were plotted as a curve on a Cartesian graph (list line plot). As the curve was rotated owing to the tilting of the scanner, the coordinates had to be realigned initially to obtain the linear regression function from the curve (linear model fit), and the graph was redrawn (list plot). Next, the data were rotated (transposed) by multiplying the rotation angle (arc tangent) with the rotation matrix. The rotated data were fixed

Table 2 Wolfram language description of programming

Language	Language description
List Line Plot ()	This plots a line through points {1,*y*1},{2,*y*2},…
Linear Model Fit ()	This constructs a linear model of the form β0 + β1 f1 + β2 f2 + … that fits the y_i for successive *x* values 1, 2, …
List Plot ()	This plots points {1,*y*1},{2,*y*2},… It is also known as a point plot when given a list of heights y_i and as a scatter plot when given pairs of coordinates {*xi*,*yi*}. With a set of pairs, the points are placed at the given coordinates
Arc Tan (%)	This gives the arc tangent $\tan^{-1(z)}$ of complex number *z* ArcTan (%) has branch cut discontinuities in the complex *z* plane running from $-i\infty$ to $-i$ and $+i$ to $+i\infty$
Rotation Matrix ()	This gives a matrix that rotates by θ radians in the plane spanned by *u* and *v* Angles in the rotation matrix are in radians. θ degree or θ ° specifies an angle in degrees
Transpose@ ()	This transposes the first two levels in the list
Interpolation ()	This constructs an interpolation of the function values f_i, assumed to correspond to *x* values 1, 2, …
Integrate ()	This gives the indefinite integral \[Integral]*f d x* It can evaluate integrals of rational functions. It can also evaluate integrals that involve exponential, logarithmic, trigonometric, and inverse trigonometric functions, until the result is found regarding the same set of functions
Histogram ()	This plots a histogram of values x_i

naturally using an interpolation function. Finally, the trend of the shape change was analyzed by investigating the number of peaks and width of the arc to obtain fundamental statistical values, and the volume was derived by integrating the curve (histogram) to obtain the area and totaling it (BioBrain Inc. Daejeon, Korea). The output illustration resulting from the program above is shown in Fig. 2.

Analysis of 3D shape according to easing conditions of experimental samples

The obtained 3D data, according to easing conditions, were organized by linear and curved seams, and the images are shown in Figs. 3 and 4. As seen from the image in Fig. 3, linear seams bend slightly because of the increase in the gather phenomenon when there is too much ease amount. However, curved seams protrude at ease instead of exhibiting the gather phenomenon, as seen in Fig. 4.

Sketch line data were extracted from all scanned 3D data at the analytical locations to be organized using the program developed in this study. Figure 5 is an example of an image that obtains data for the sketch line between SL-e1.5 and C1-e1.5 from the scanned 3D data.

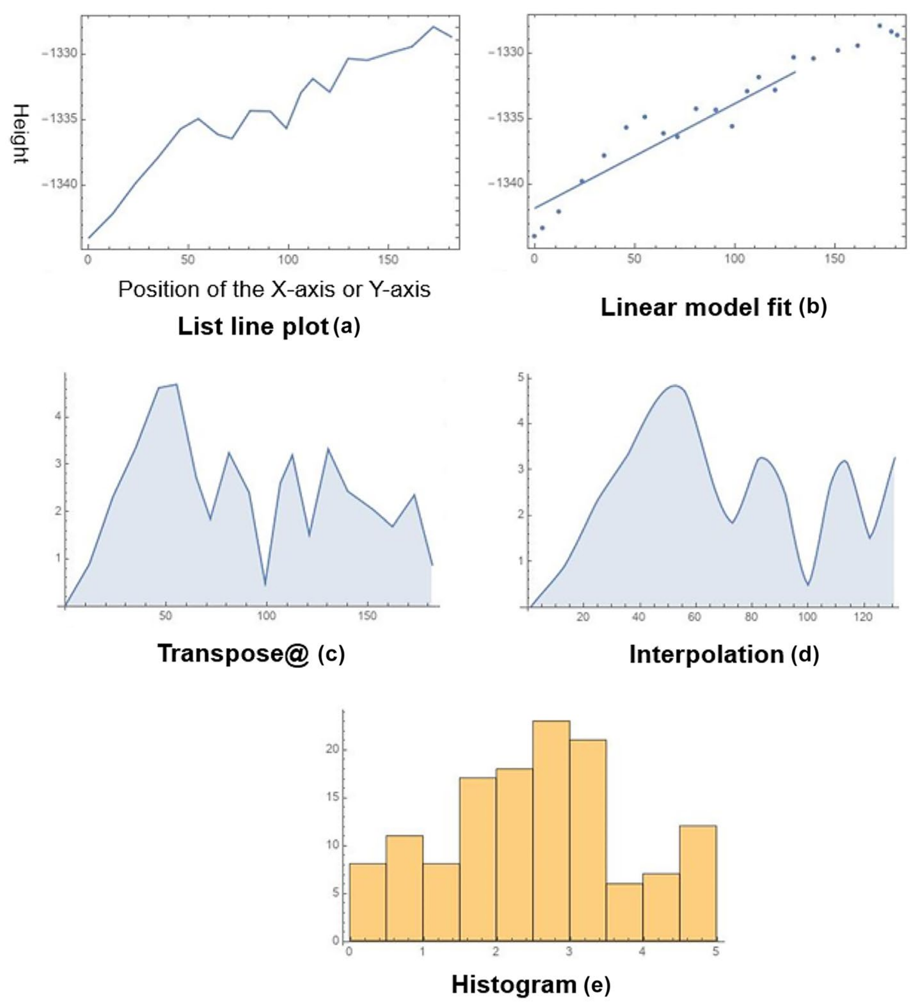


Fig. 2 Output images for each language

Fig. 3. 3D images of linear seams according to easing conditions

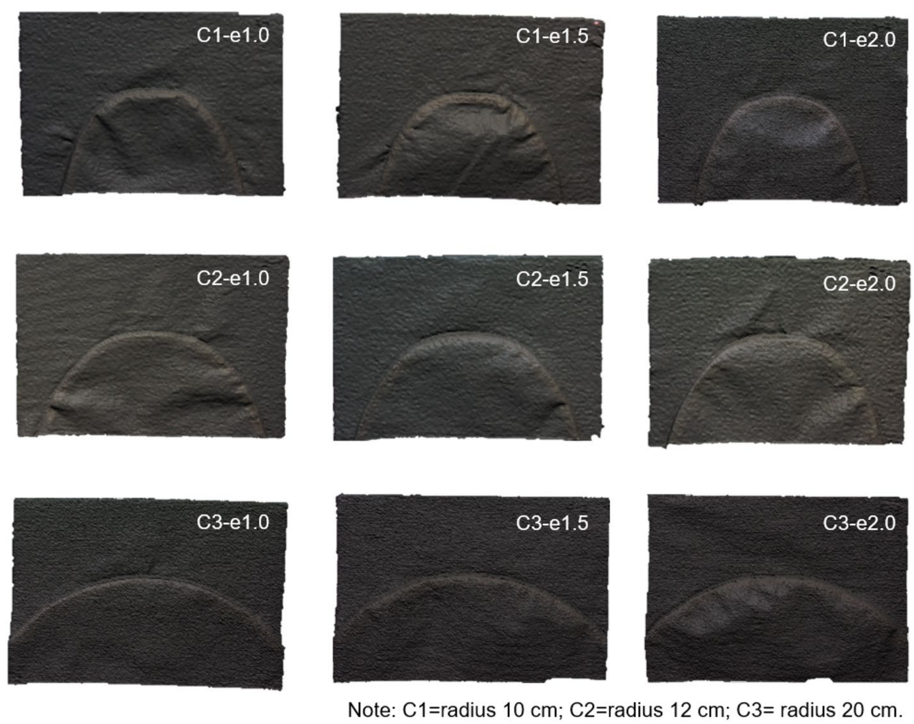


Fig. 4. 3D images of curved seams according to easing conditions

The graphic results according to the analytical locations of the SL linear seam (gap 1.5, gap 3.0, gap 4.5, and gap 6.0) are illustrated in Fig. 6, showing that the number of peaks and their heights increased as the amount of ease increased. However, when the lines are long (LL), as in the case of Fig. 7, the waveforms do not change significantly because the ease amount is relatively less than the 28 cm length of LL, dispersing the ease more than the SL sample. SL formulated more volume than LL owing to its high wave height, excluding gap 6.0. When the SL seam was 18 cm, near the sewn seam, the ease was 0.5 cm, 1.5 cm, and 2.5 cm; the height was approximately 0.5 cm, 1.0 cm, and 1.5 cm, respectively. When moving away from the sewing line, the height increased by

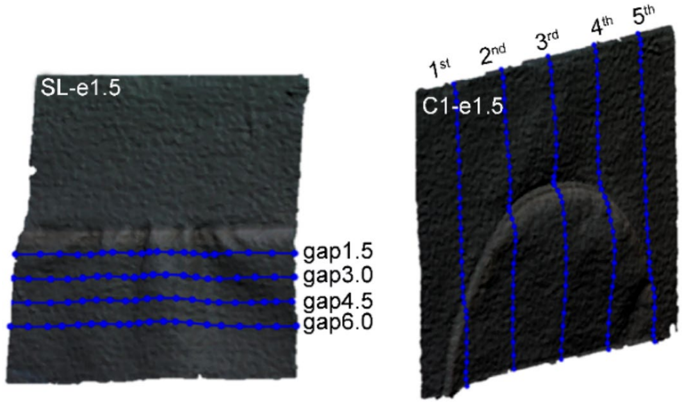


Fig. 5 Image of sketch lines obtained from 3D data between linear and curved seams

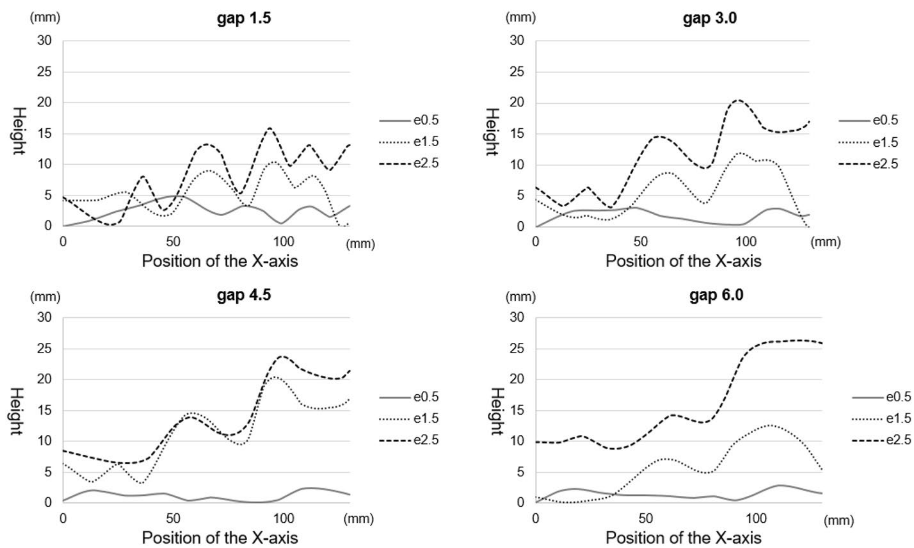


Fig. 6 X, Z data for each location according to amount of ease for short length linear seam

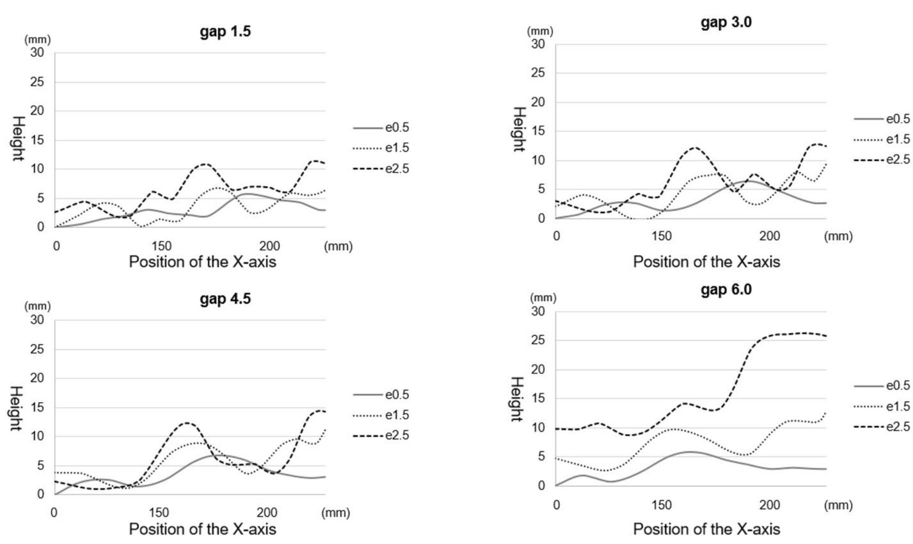


Fig. 7 X, Z data for each location according to amount of ease for long length linear seam

more than 2.0 cm when the easing was 2.5 cm. When the LL seam was 28 cm near the sewn seam, and the ease was 0.5 cm and 1.5 cm, the height was approximately 0.5 cm, and when it was 2.5 cm, the height was 1.0 cm. When it moved away from the sewing line, the height was similar to that when the straight line was 18 cm. Generally, all samples from the SL and LL groups displayed fewer peaks and waves of wider amplitude further from the seam line, and this was prominently visible at a location of 3.0 cm away from the seam.

Therefore, the amount of ease must be controlled according to the length of the line to compensate for the body's curvature. For example, if a garment is created with SL-e2.5 on a body with a shoulder length of 18 cm and a curved height of the shoulder of less than 15 mm, the curved height will be 20 mm, which is too much ease for the length of the line, probably making the wearer's shoulder seem bulging. An excessive amount of ease is not critical when one wants to express exaggerated volume for a design purpose. Setting a proper amount of ease for the designed line is crucial to get a good fitting. Thus, applying a different technique is wiser, such as darts or tucks, rather than easing, to utilize volume as a design detail.

Additionally, the linear seam lines bent because of the mechanical pushing inflicted by the cloth with ease. The measured radii of curvature for the seam are shown in Fig. 8; they tended to decrease as the ease increased owing to more bending. For SL, the radius of curvature was 166.4 cm at e0.5 but decreased to 33.6 cm at e2.5. For LL, it was 192.5 cm at e0.5 but decreased to 73.8 cm at e2.5. The radius of curvature of the SL tended to be smaller. A reliable regression equation of 0.99 and 0.91 and R^2 values could be derived, and information from this equation can be applied when enhancing the fitting of body curvature by deliberately bending the composition line of the garment in areas such as the yoke or shoulder line.

The curved seam lines C1, C2, and C3 data are shown in Fig. 9. The waveform was high at the center of the seam for all samples. For curved seams, the peak value did not increase with the amount of ease because the analytic location was perpendicular to the curved seam. Group C3, which had a relatively higher radius of curvature, tended to have higher peaks. Moreover, a 3D of approximately 1.0 cm was created regardless of the

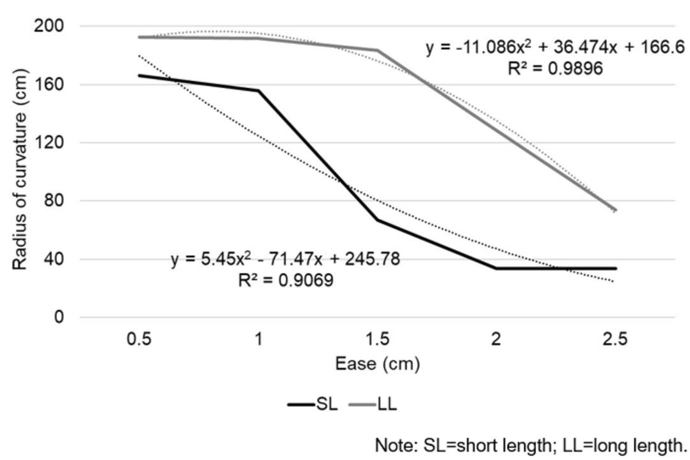


Fig. 8 Radius of curvature of the linear seam

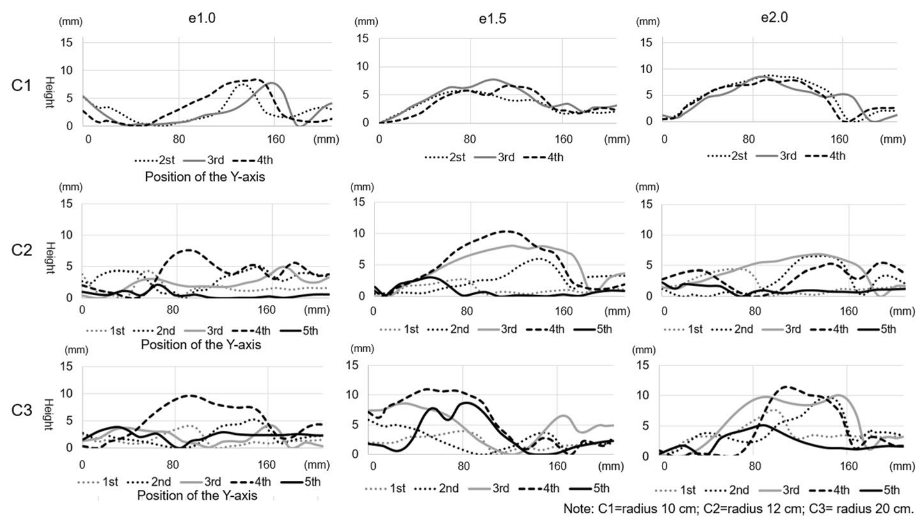


Fig. 9 Y, Z data of each analytical location for C1, C2, C3 according to amount of ease for the curved seam

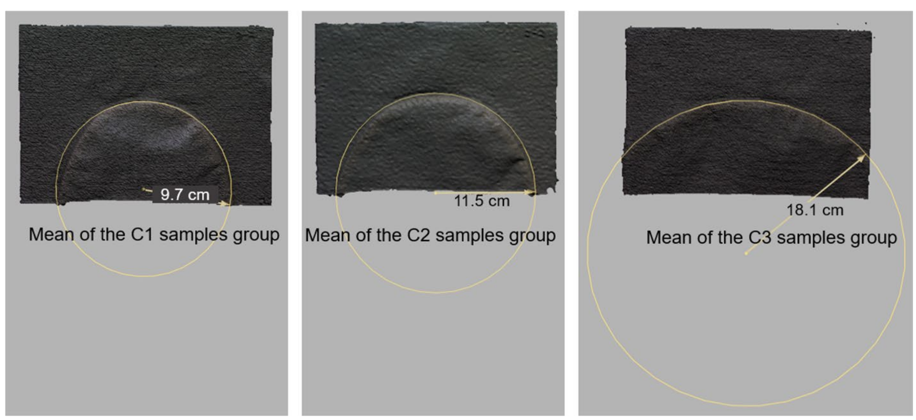


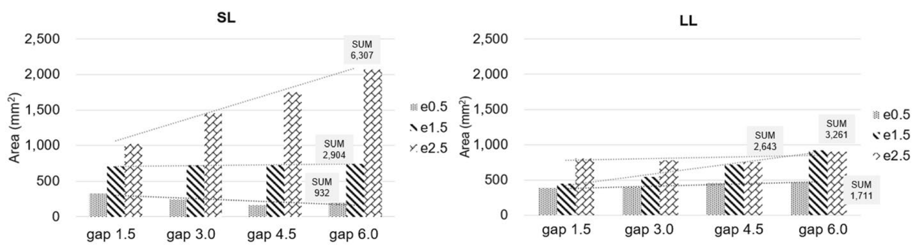
Fig. 10 Radius of curvature on 3D images for the curved seam samples

curvature (C1, 10 cm; C2, 12 cm; C3, 20 cm) and the amount of ease. Most set-in sleeves have extra room in the sleeve cap to easily allow for upper arm appearance and comfort (Fung et al., 2021). Suppose the above-curved seam is applied to the sleeve pattern. In that case, this result can be used by appropriately adopting, predicting, and transforming the ease allowance suitable for the bicep line determined by the sleeve cap's height according to the garment's purpose.

In the 2D pattern, the radius of curvature was 10 cm for C1, 12 cm for C2, and 20 cm for C3. However, in 3D, it was 9.7 cm for C1, 11.5 cm for C2, and 18.1 cm for C3, showing a slightly smaller trend (Fig. 10). That is, the curve has become slightly convex.

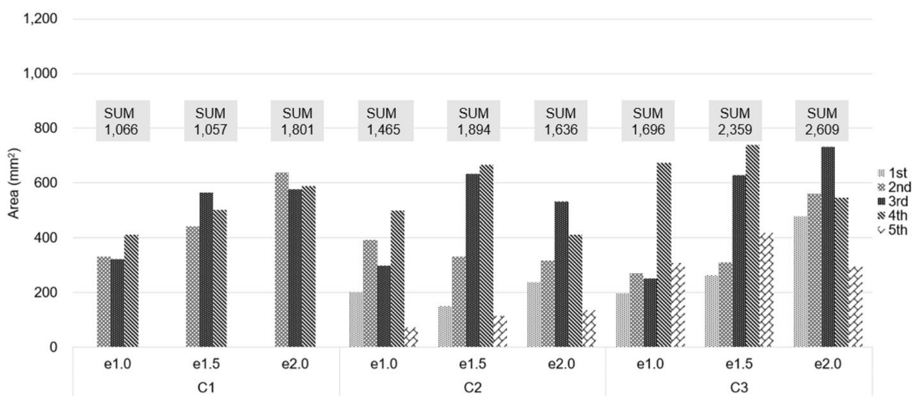
Analysis of 3D volume according to easing conditions of experimental samples

The 3D volume was derived from the sample data by calculating the sum of all cross-sectional areas at each analytical location. First, when the seam lines were short (SL), the area increased dramatically as the amount of ease increased. However, the area was



Note: SL=short length; LL=long length.

Fig. 11 Cross-sectional area according to amount of ease and analytical area for linear seam samples



Note: C1=radius 10 cm; C2=radius 12 cm; C3= radius 20 cm.

Fig. 12 Cross-sectional area according to amount of ease and analytical area for samples with curved seam

relatively unaffected by easing when the seam lines were long (LL), as seen in Fig. 11. The total area of the SL seam was 932 mm^2, 2904 mm^2, and 6907 mm^2 when the ease was 0.5 cm, 1.5 cm, and 2.5 cm, and areas of the LL seam were 1711 mm^2, 2643 mm^2, and 3261 mm^2, respectively. When plenty of ease was used on the short seam line, the volume increased as a large amount of ease was resolved within the limited length of the seam line.

Regarding the highest amount of ease (2.5 cm), SL must disperse within the range of 12 cm, whereas LL must do so within the range of 22 cm, leading to almost twice the difference. Generally, the convexity of the scapula is covered by 1.5 cm of ease on 13–20 cm of seam length along the shoulder line; thus, the SL-e2.5 sample in this experiment has much ease compared to its seam length. Meanwhile, the volume increased as the amount of ease increased for SL, and the distance from the seam increased to a gap of 6.0. However, 2.5 cm of ease did not affect LL as much as SL. Therefore, volume must be controlled appropriately by easing according to purpose and garment area, as linear easing is affected by the length of the seam line and the amount of ease.

The results of the cross-sectional area analysis of the curved seams are shown in Fig. 12. When the radius of curvature was 10 cm, the total area was 1066 mm^2, 1057 mm^2, and 1081 mm^2 when the ease was 1.0 cm, 1.5 cm, and 2.0 cm, respectively. When the radius of curvature was 12 cm, and the ease was 1.0 cm, 1.5 cm, and 2.0 cm, it was 1465 mm^2, 1894 mm^2, and 1636 mm^2, respectively. When the radius of curvature was 20 cm, and the ease was 1.0 cm, 1.5 cm, and 2.0 cm, it was 1696 mm^2, 2359 mm^2, and

2609 mm^2, respectively. The sum of the areas increased with a larger radius of curvature for the curved seams. Therefore, it was found that the volume is formulated and distributed around the third location (precisely in the middle of the curved seam line), corresponding to the central cross-section of the curved seam. This trend agrees with how volume is formulated around the top of the armhole's curve, even when the garment is made to distribute the gathering with ease evenly.

Discussion

The human body is complex in that two curved surfaces are continuously connected to form a 3D shape. In order to produce the garment that perfectly fits this 3D shape, the former traditional empirical knowledge is reflected in each production step. However, the production guidelines according to these steps are not documented separately and depend on experts' knowledge in each field. In particular, no work manual provides accurate information in the sewing field because garments are made by moving the sewing machine in order and assembling while transferring in search of countries with cheap labor. Therefore, creating a manual containing numerical information is necessary for the sewer to work accordingly.

As existing commercial programs are used in various fields, it took much work to focus on the study's aim and analyze it, so it was newly programmed. Moreover, in apparel, programming has mainly been used in made-to-measure garments (Harwood et al., 2020; Turner, 1994; Yunchu & Weiyuan, 2007). Therefore, this study developed an analysis program to systematize the production guidelines using scientific data, focusing on patterns and sewing. According to the easing condition, the waveforms of fabric gathering that occur at specific intervals according to the seam were measured along with the generated area and the total volume.

In addition, to match the research results with the human body shape, we discussed using CLO (CLO Virtual Fashion LLC., Korea). This 3D virtual garment program has been used in the garment industry recently. The radius of curvature passing through the three points and the height of the shoulder blades were measured using the average data of females and males in their 20 s, provided by the 6th Size Korea survey, and compared with the study results. As shown in Fig. 13, male shoulder blades (radius of curvature: 18.2 cm) were more convex than females (radius of curvature: 22.9), and the height was about 1.1 cm for females and about 1.6 cm for males. In this study, in the case of a linear seam, SL had a height of 0.5, 1.0, and 1.5 cm when the ease was 0.5, 1.5, and 2.5 cm, respectively, so an ease of 1.5 cm was suitable for females' shoulder blades, and an ease of 2.5 cm was suitable for males' shoulder blades. Contrastingly, when the ease of LL was 0.5, 1.5, and 2.5 cm, the height was 0.5, 0.5, and 1.0 cm, respectively, so an ease of 2.5 cm could cover the convexity of females' shoulder blades. Of course, since the seam length is long, it may be challenging to apply if it fits the design.

In summary, a straight line, providing ease of approximately 8–9% of the seam length, produced a smooth fit and volume for females' shoulder lines, and an ease of about 5% produced a smooth fit and volume for males' shoulder lines. In other words, the curvature rate and length are different for males and females, even for the same body parts; therefore, they should be set differently for the pattern design while making garments. It was confirmed that applying an amount of ease that changes in response to body

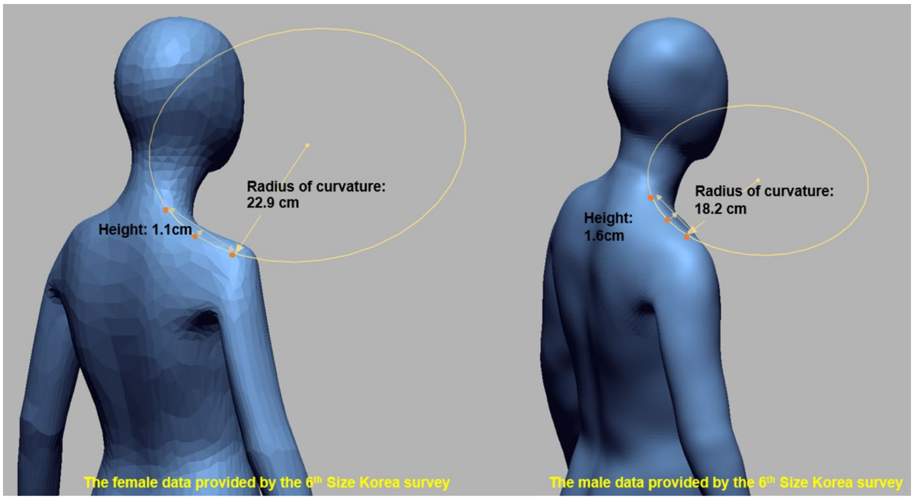


Fig. 13 The radius of curvature and height of the shoulder blades of the female and male data provided by the 6th Size Korea Survey

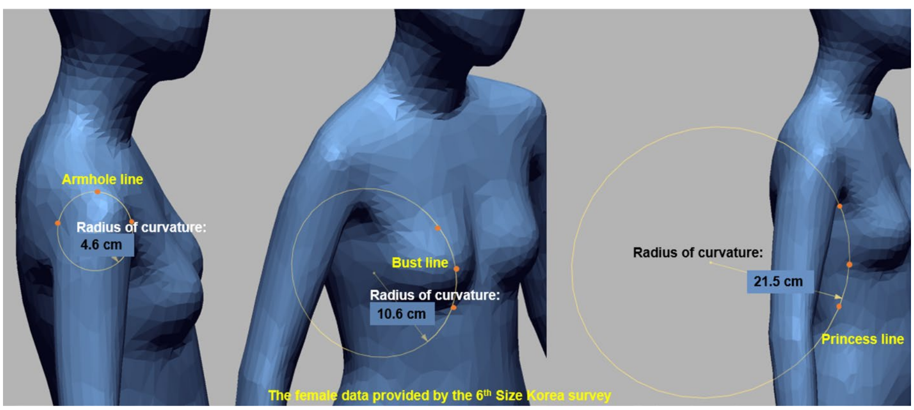


Fig. 14 The radius of curvature of various parts of the female data provided by the 6th Size Korea survey

curvature and length, rather than an absolute constant amount, is more beneficial to get a good fit. This finding is consistent with Petrova and Susan (2012), who pointed out that although ease should reflect different sizes for comfort and fit, the same constant value is still applied for all sizes. In addition, the bending of linear seams owing to ease was established using a regression equation (SS: $y = 5.45x^2 - 71.47x + 245.78$, $R^2 = 0.9896$; LL: $-11.086x^2 + 36.474x + 166.6$, $R^2 = 0.9069$).

In the case of a curved seam, as it becomes slightly convex after sewing, these figures should be considered in the 2D pattern, and as the radius of curvature becomes small, a higher volume is formed around the center. As shown in Fig. 14, in the case of a female, the seams of various curves (armhole, bust, princess line) are made on the garments. It will be possible to predict the relationship between the 3D shape of the 2D pattern if the research method is used to calculate the exact amount of ease in these areas. Petrova and Ashdown (2008) mentioned that their size and shape should determine the amount of ease for pants, but they described ease simply as the percentage difference between the wearer's body dimensions. In this study, we demonstrated the amount of ease quantitatively and visually through a cross-sectional analysis of easing shape in 3D space and provided a solution for the 3D shape to be implemented by simulation digitally. Daelenmans et al. (2016) also attempted to take a numerical approach to study the behavior of woven fabrics by conducting a finite elements simulation using micro-CT data. However, the microdata had limitations when applied to the garment. In this regard, using 3D data in the current study is a step forward in garment research.

Conclusions

This study serves as a cornerstone by quantitatively analyzing the degree of 3D by sewing using a scientific approach to overcome the limitations of tailoring techniques. Curves were plotted using coordinates obtained from cross-sectional data scanned in 3D at specific locations to investigate the ease of distribution, and integration was performed to confirm the numerical trends. Predicting the shape of the seam using this regression expression can be crucial in pattern design for an ideal fit for a pattern maker. Moreover, the proposed topic is the first attempt to change the method of providing numerical information and visual images, which has been conveyed only verbally with the know-how of long experience in the fashion industry. It should be noted that this study is limited because it cannot be compared with and differentiated from other works because there are no similar studies as of the time of writing. Furthermore, a database could be continuously constructed for appropriate use in the fashion industry by collecting necessary data on 3D shapes according to a combination of variables, such as fabric, tailor, and stitch type.

Abbreviations

SL	Short length
LL	Long length
C1	Radius 10 cm
C2	Radius 12 cm
C3	Radius 20 cm
e0.5	Ease amount of 0.5 cm
e1.0	Ease amount of 1.0 cm
e1.5	Ease amount of 1.5 cm
e2.5	Ease amount of 2.5 cm

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Authors' contributions
YL proposed the research idea and HL and SP carried out the research. HL and SP were mainly responsible for data analysis and the experiment along with writing the manuscript, and YL was involved in the edition of the manuscript as well as data analysis and the experiments. All of the authors read and approved the final version of the manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

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Not applicable.

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The authors declare that they have no competing interests.

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