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Application of Lower Body Girth Change Analysis Using 3D Body Scanning to Pants Patterns

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Abstract

Three-dimensional body data has been used in many industry fields including the apparel industry. This research used data from a study of the changes in lower body girth measurements from a 3D scan study of 25 female subjects aged 18 to 24 in four postures; a standing posture, a 120° knee bend posture, a one pace stepping posture, and a sitting posture with a 90° knee bend. We used the information on the difference between standing and seated measurements to adjust ease values for pants patterns an evaluation of the appearance, and the comfort of the pants. Waist girth in the sitting posture increased 8% compared to a standing posture and the hip girth measurement increased 7%. A basic pants pattern (pants A) with 2.4cm ease at the waist and 2.6cm ease at the hip was developed and a pants pattern (pants B) was developed using the rates of lower body girth change with a 5.7cm ease (8% change) at the waist and 7cm ease (7% change) at the hip. The appearance assessment items of pants A in a standing posture were higher than pants B. On the other hand, most appearance assessment items of pants B in a sitting posture were higher than pants A, especially the ease of pants back waistline and the appearance of the whole back. Comfort assessment items of pants B in both standing and sitting postures were higher than the comfort assessment items for pants A, especially the location of pants waistline, the ease of pants at the waistline, and the ease at the abdomen. In order to find the best level of ease for better appearance and comfort in both standing and sitting postures, 20 pants were constructed with ease values at the waist and hip in increments of 1.1cm in the range between the ease values of pants A and pants B. A fit test was conducted to compare the average appearance and comfort ratings that identified the pants with the best ease values at the waist and hip. The highest total mean was achieved in the pants with a waist ease of 4.6cm and hip ease of 4.8cm.

Key words: Lower body girth change, 3D body scanning, Pants pattern, Appearance assessment, Comfortableness assessment

I. Introduction

Three-dimensional scan data has recently been successfully used in many industries including clothing, automobile, medical science, artifact restoration, and computer animation. The use of 3D scanning body technology is especially useful for studies for the apparel industry. Use of the 3D scanner can save time and money in the collection of anthropometric data, can provide data playback and repeated measures possible and makes it feasible to measure the body in ways that are not possible using traditional anthropometry (Nam et al., 2004). It is regarded as an essential technology for the digital clothing industry of the future, and research in the application of 3D scan technology to standardization of anthropometric testing is proceeding locally and abroad (Lee et al.,

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2004). The 3D scanner is a particularly useful tool for the study of body measurement changes that occur when a person is in an active position. The clothed human body changes shapes constantly and it is important to understand body surface changes in active postures in order to make clothing patterns that do not constrict movements.

Previous research studies on body surface change in active positions using 3D body scanning are rare, Lee and Ashdown (2005) measured body surface change in active postures for the upper body using a 3D body scanner. Ashdown et al. (2004) investigated changes in measurements between seated and standing postures using 3D scanning in a limited study. Several anthropometric studies using 3D body scanning have been conducted using traditional standing and seated postures (Brunsman et al., 1997). However there is no research using 3D scan measurements to calculate lower body surface change reliably over a range of active postures until now. Lower body movements can incorporate extensive changes in body angles at the hip and knee joints.

The results of an analysis of body surface change can be an important source for development of lower garment patterns. A similar lack of studies is apparent on pattern development for the lower body. Chun et al. (2002) acquired torso body surface image data using a 3D body scanner and unfolded these 3D data as a flat surface. They then studied algorithms for the development of a method to a make basic sloper for clothing derived from this flat surface. Jeong et al. (2005) applied the 3D surface of male dummy torso to create a 2D tight basic sloper pattern using Triangle Simplification and the Runge-Kutta method. Suh (2001) also suggested a method for making man's jacket sloper using 3D body data. Most research is focused on upper garment patterns and research on development of lower garment patterns affected by lower body movements is rare. Therefore research on lower body change analysis in active positions and application of the result to lower garment patterns is needed.

The active postures selected for this research are a standing posture, a 120° knee bend posture, a one pace (body height-100cm) stepping posture, and a sitting posture with a 90° knee bend. These movements are frequent in daily life and lower body changes appear distinctly in them (Lee, 2006).

In this research, lower body girth changes were analyzed from 3D scans of American women in their twenties in four postures and were applied to pants patterns. The suitability of the patterns was evaluated. The detailed purposes of this research are as follows.

First, lower body girth measurements and rates of lower body girth change in four postures (a standing posture, a 120° knee bend posture, a one pace (body height-100cm) stepping posture, and a sitting posture with a 90° knee bend)were calculated from 3D body scans in order to analyze lower body surface change in active body positions.

Second, the rates of lower body girth change were applied in the development of the ease values for a set of basic pants patterns. The pants with the ideal level of ease were identified by judging the appearance and comfort of the pants, both from the point of view of expert fit evaluators and that of the study subjects testing the pants.

II. Methods

1. Anthropometry

1) Subjects and Anthropometry

Subjects for the study of the change in girth measurements in active positions were 25 American females, aged from 18 to 24 (average age 22.24), who wore lower garment size 8-10 (Medium, waist: 68.58-71.12cm, hip: 95.25-97.79cm) in USA size. This study was conducted in June and July in 2008. Subjects wore their own bra and panties during the scan process in order to facilitate body measuring in the active postures. Electronic anthropometry was carried out using a Human Solutions Vitus XXL whole body scanner <Fig. 1> to create the 3D image and the Innovmetric software Polyworks <Fig. 2> to measure the scans. Polyworks software provides virtual measurement tools that can be used to measure 3D scans on the computer screen in ways that correspond to traditional anthropometric tools. These virtual tools can be used to derive almost every conceivable measurement from

Fig. 1. VITUS body scanner, human solutions XXL.

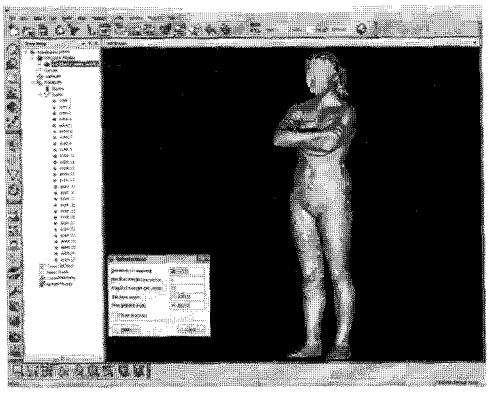


Fig. 2. Polyworks program.

the scan of the body. The actual scanning process took 12 seconds per scan, with about one minute processing time between scans. The process of measuring the scans took about 2.5 hours per scan.

2) Measuring Posture

Each subject was scanned in the standing posture <Fig. 3(a)> and three active postures; a 120 degree knee-bend posture <Fig. 3(b)>, a one-pace(body height-100cm) posture <Fig. 3(c)>, and a sitting posture with a 90 degree knee-bend (Fig. 3(d)). These positions are part of daily life and lower body changes are exhibited that affect the fit of clothing (Lee, 2006). As only lower body measurements were taken, subjects folded their arms at their chest so they would not block the cameras from the 3D scanner.

It is difficult to get a complete scan of a normal sitting posture with the Vitus XXL scanner, as the camera positions are optimized for standing postures. As a result there is often a large section of missing data the crotch and thigh area of the scanned image where one leg is shadowed from the cameras by the other leg as shown in <Fig. 4(a)>. In these cases we used a merging technique to replace missing data in the thigh by taking repeated scans of a modified posture with the focus on individual legs, and merging data using the Polyworks program from the separate scans of each leg as shown in <Fig. 4(b)>.

A goniometer was used to measure and maintain the reliability of the postures (Fig. 5(a)). Two cm diameter hemispherical dimensional landmarks provided by Human Solutions for 3D measurement were used to mark specific body landmarks as the scanner cannot capture a mark made on the skin. Twenty landmarks <Fig. 5(b)> were placed on front center point, back center point, right side point and left side point of the waist, hip, max thigh, mid thigh and knee

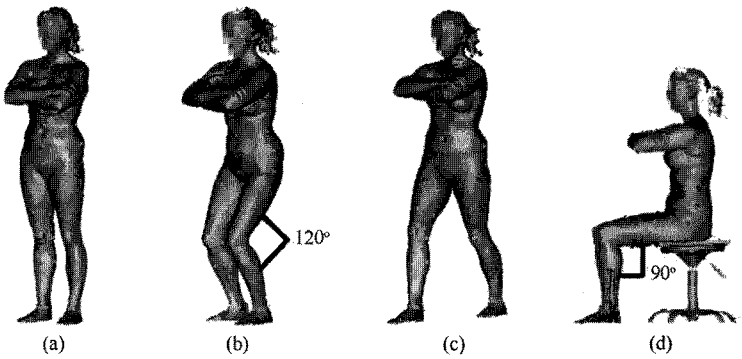


Fig. 3. Measuring posture((a) posture 1. (b) posture 2. (c) posture 3. (d) posture 4).

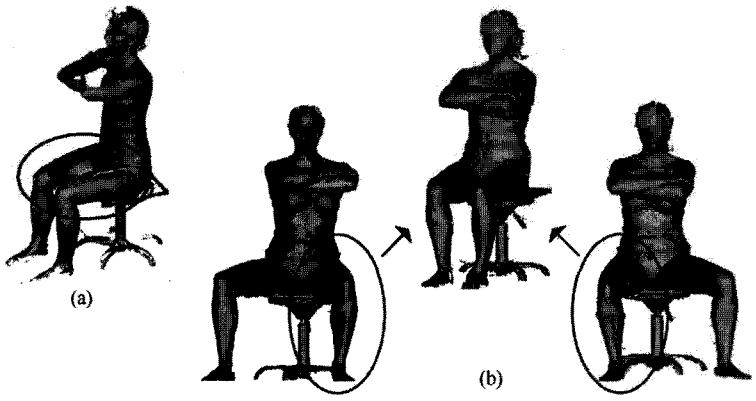


Fig. 4. Method of filling in data missing from a scan ((a) Scan showing areas of the thigh missing. (b) Multiple scans taken and portions merged to the original seated scan).

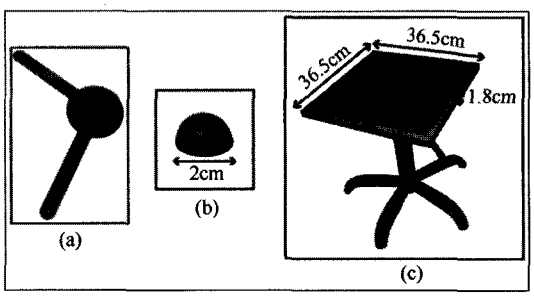


Fig. 5. Tools used in the study ((a) Goniometer. (b) Dimensional landmark. (c) Adjustable stool).

of each subject in the standing position in order to make sure that each measurement was taken from the same location for each posture. Landmark positions were identified using traditional anthropometric methods (palpating for body landmarks), marked with a pen, and then a sphere was placed precisely using special adhesive tape in the shape of the sphere. Once the first landmark was set, other landmarks at the same level were located using an anthropometer so that each girth measurement would be taken in a plane that was parallel to the floor in the standing position. The stool which was used in the sitting posture was adjustable in height, to achieve a 90-degree knee bend for each of the subjects (Fig. 5(c)).

3) Measuring Items

Fourteen basic dimensions <Table 1>, <Fig. 6> of the lower body were measured in the standing posture, and five girth dimensions (waist girth, hip girth, max thigh girth, mid thigh girth and knee girth) of the lower body that are important in the fit of lower garments were measured in the three active postures using virtual measurement of the 3D scans.

The measurements were not automatically derived, but were measured using the Innovmetric software Polyworks. First the landmark points were generated and labeled by visually choosing the top center point of each landmark hemisphere and projecting this point down to the surface of the body by transposing it the known height of the marker. Then the landmark bump was removed from the scan and the resulting void filled so that the dimension of the marker would not distort the measurement. Finally virtual measuring tools were used to measure the scan.

4) Data Analysis

Data analysis was completed using SPSS. Mean values and standard deviation of each dimension were calculated.

Table 1. Measuring items

	Items
Height	1. Body height 2. Waist height 3. Hip height 4. Crotch height 5. Knee height
Girth	6. Waist girth 7. Hip girth 8. Total crotch girth 9. Max thigh girth 10. Mid thigh girth 11. Knee girth
Length	12. Hip length 13. Crotch length
	14. Weight

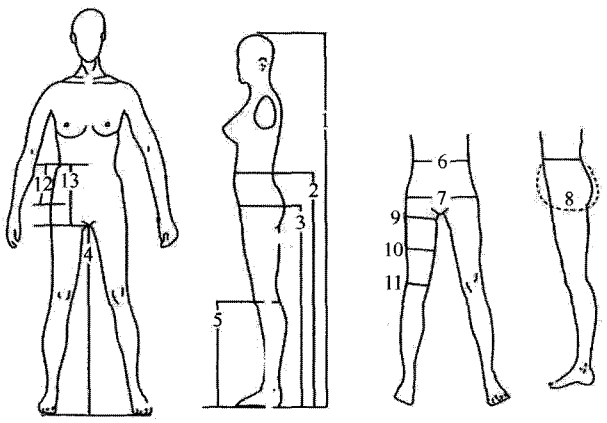


Fig. 6. Measuring items.

2. Analysis of Lower Body Girth Change in four Different Postures Using 3D Scan Measurement

3D scan measurement was conducted for the four different postures of the subjects. Data on the lower body girth (waist girth, hip girth, max thigh girth, mid thigh girth and knee girth) change measurement values and the rates of lower body girth change among the different postures were calculated.

3. Application Lower Body Girth Changes Analysis in Four Postures to Pants Pattern and Evaluation of Suitability of the Pattern

1) Making Pants Applied Ease Based on the Rates of Lower Body Girth Change in Four Postures

Ease values for the girth in the pants pattern were decided based on rates of lower body girth change from the 3D scan study. As an initial step two pair of pants were made, one with ease values from 『Pattern-making for fashion design』 (Armstrong, 2006) <Fig. 7> (pants A) and a second pair made with ease values derived from the change in girth measurements between the standing and seated body positions form the 3D body scan study.

2) Fit Test of Pants A and B

Fit tests of the two pants were conducted on subjects order to compare the appearance and comfort in

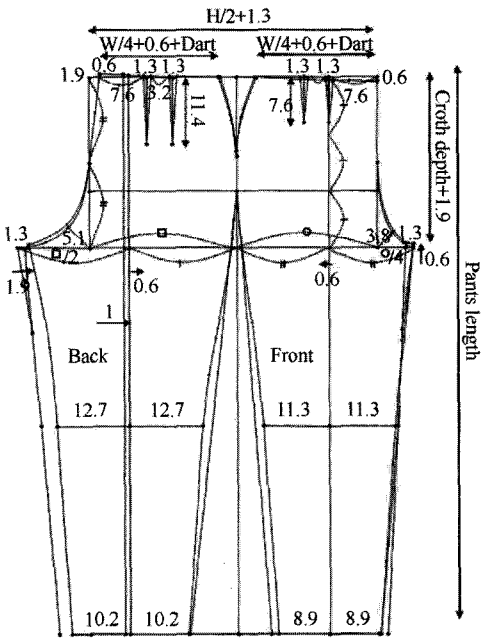


Fig. 7. Basic pants pattern.
from Armstrong. (2006). p. 552-556.

November, 2008. Subjects for the fit test were 3 American females, aged from 18 to 24, who wore lower garment size 8-10 (Medium, waist: 68.58-71.12cm, hip: 95.25-97.79cm) in USA sizes. The material of the pants was 100% cotton.

The assessment group included 3 expert judges in clothing construction, who assessed the appearance of the pants and the 3 subjects wearing the pants who assessed the fit and comfort of the pants after wear-

Table 2. Expert assessment items

	Items
Front	1. Is the location of pants waist-line correct for this style?
	2. Is the ease of pants at the waist-line appropriate?
	3. Is the ease at the abdomen appropriate?
	4. Is the ease at the crotch appropriate?
	5. Does the abdomen area look good, without stress folds?
	6. Is the ease at the thigh appropriate?
	7. Is the ease at the knee appropriate?
	8. Is the width of the hem appropriate?
	9. Judge the appearance of the whole front.
Back	10. Is the location of pants waist-line correct for this style?
	11. Is the ease of pants at the waist-line appropriate?
	12. Is the ease at the hip appropriate?
	13. Is the ease at the crotch appropriate?
	14. Does buttock area look good, without stress folds?
	15. Is the ease at the thigh appropriate?
	16. Is the ease at the knee appropriate?
	17. Is the width of the hem appropriate?
	18. Judge the appearance of the whole back.
Side	19. Judge the appearance of the whole side.
	20. Judge the appearance of the overall of the pants?

ing them. The 3 expert judges were academic experts in apparel fit with an average of 6 years of experience in fit analysis. The expert appearance assessment consisted of 20 items, 9 front items, 9 back items, 1 side item and 1 whole body item. These items are shown in <Table 2>. The assessment by the subjects consisted of 9 items on fit and comfort, and are shown in <Table 3>. Assessments were conducted in standing and seated postures separately. The scale for all assessments was a 5-point likert scale, ranging from 5 (very good) to 1 (very bad). Assessment data analysis was completed using SPSS. Mean values and standard deviation of each item were calculated and a comparison of the two pants was made by t-test.

Table 3. Subject assessment items

1. Is the waistline of the pants at the right level?
2. Do the pants fit at the waistline?
3. Do the pants fit at the belly?
4. Do the pants fit at the hips and buttocks?
5. Do the pants fit at the crotch?
6. Do the pants fit at the thigh?
7. Do the pants fit at the knee?
8. Overall, how comfortable are the pants?
9. Overall, how flattering do the pants look?

3) Test of Intermediate Values to Discover Ideal Ease Values for Appearance, Fit, and Comfort In Both Standing and Sitting Postures

In order to discover the optimal ease for both appearance and comfort in both standing and sitting postures, we also constructed a set of 20 pair of pants with incremental waist and hip ease (1.1cm increments) ranging between the pants pattern with standard ease values and the pants pattern with ease values based on lower body girth change, and conducted a fit test of each pair of pants for appearance and comfort assessment. We then compared the results to identify the ease values that best combined comfort and appearance. Three new subjects were recruited for this stage of the study. The assessment method for the fit tests of the 20 pair of pants were same as those conducted for pants A and B.

III. Results

1. Descriptive Statistics of Body Measurements for the 3D Scan Study

Twenty-five American females, ages from 18 to 24 (average age 22.24), who wore lower garment size 8-10 (Medium) in USA Misses size, were scanned using the 3D scanner and their body measurements were taken. As indicated in <Table 4>, the average body height and weight of the subjects were 164.57cm, and 61.48kg respectively. Average waist and hip girth measurements were 72.42cm and 98.74cm.

Table 4. Descriptive statistics from 3D scanning anthropometric measurements (subjects in standing posture)

(units: cm, kg)

Items	Mean	S.D.	Max.	Min.
1. Body height	164.57	5.49	178.00	156.33
2. Waist height	104.05	3.73	111.97	96.75
3. Hip height	83.83	3.15	91.58	78.90
4. Crotch height	74.74	3.55	82.09	69.05
5. Knee height	44.79	1.86	47.92	41.14
6. Waist girth	72.42	2.66	80.13	68.45
7. Hip girth	98.74	3.38	107.99	92.78
8. Total crotch girth	75.79	4.00	83.64	70.47
9. Max thigh girth	59.51	2.61	64.83	55.90
10. Mid thigh girth	47.41	2.78	51.85	43.18
11. Knee girth	36.71	1.50	39.86	33.22
12. Hip Length	21.10	1.85	25.78	17.34
13. Crotch Length	30.29	1.97	36.46	26.47
14. Weight	61.48	3.94	70.40	53.90
15. Age	22.24	1.67	25.00	20.00

2. Making Pants A (Standard Ease) and Pants B (Ease Derived from 3D Scan Study)

Before deciding the ease values in pants pattern based on the rates of lower body girth change in four active postures, pilot 3D scans were made of subjects wearing pants with standard ease values <Fig. 7> in each of the postures. Landmarks were adhered to the pants in the standing position corresponding to the body landmarks. From these scans it was observed that the location of base lines at the waist, hip, and knee of the pants did not align with body surface base lines at these locations when subjects with pants assumed the active positions. For example, when subjects with pants took a sitting posture and the pants were pulled by body movements, the line defined by the landmarks shifted over the body to a new location (Fig. 8).

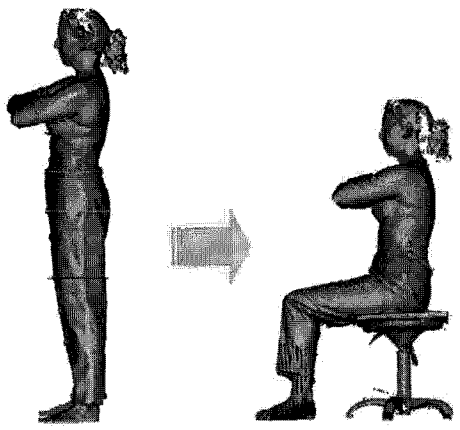


Fig. 8. Shift in base lines with body movement.

Therefore, it is necessary to discover where the pant girth lines shift in relation to the body surface when subjects are in active positions, as these are the locations that will determine the amount of ease needed to fit well. To discover this, subjects donned pants and assumed the standing position, and landmarks were attached to the pants at the girth lines (waist, hip, max thigh, mid thigh, and knee, at the front, back, and sides for each location) The subjects were then scanned in each of the active positions and the shifted locations of the pants landmarks identifying the girth lines were identified. These marks were then transferred to a 3D scan of the same subject in the same active positions but without pants. Using the Polyworks measuring tool the dimensions of the body where the girth lines were located were obtained. These measurements establish the appropriate dimensions for pants girth dimensions at the body areas to which the pants shift in the active positions.

As shown in <Table 5>, girth measurements in posture 3 (the one-pace posture) showed greater variation than posture 2 (the 120 degree knee-bend posture) compared to the standing posture. Girth measurements in posture 4 (the sitting posture) showed the greatest change from the standing posture. The waist girth in the sitting posture increased about 8% comparing to the standing posture, the hip girth measurement increased about 7%, the max thigh girth increased about 2%, the mid thigh girth increased about 9.6% and the knee girth increased about 17%. In order to make pants that allow free movement of the lower body, these rates of lower body girth change were applied to ease of basic pants pattern shown in <Fig. 7>.

First a basic pants pattern (pants A) with 2.4cm ease at the waist and 2.6cm ease at the hip were constructed, using an average waist girth of 72.42cm, and an average hip girth of 98.74cm from 25 study subjects. The pants were based on the pants drafting pattern from Patternmaking for Fashion Design by Joseph-Armstrong. A second pants pattern (pants B) was drafted with 5.7cm ease (8% change rate) at the waist and 7cm ease (7% change rate) at the hip line. We made pants A and pants B, and evaluated the fit, appearance and comfort of each of them. The rates of body surface change of max thigh girth, mid thigh girth and knee girth were not applied in the drafting process because we intended to focus on the critical areas of ease at the waist and hip. The ease values at the max thigh girth, mid thigh girth and knee girth were those specified for the basic pants pattern. These values were generally quite large, as they are based on conventions of style ease, which in these locations are greater than the fit ease required.

3. Result of Verification of Pants Suitability by Wearing Test

<Table 6> shows the average body measurements of 3 subjects for the wearing test.

<Table 7>-<Table 8> show the averaged results of the appearance assessments from the fit tests in standing and sitting postures by the expert fit judges and <Table 9>-<Table 10> show the averaged results of fit and comfort assessments in standing and sitting posture by the subjects themselves. All ratings are averages of scores from the 5 point scale, with higher numbers more positive.

Most expert appearance assessment items for pants A were higher than pants B in the standing posture. The ease at the pants front waist (2.11) and at the back crotch (2.67) of pants B were rated especially low and were significantly different from pants A (Table 7). This means the ease applied to pants B

Table 5. Dimensional change values (cm) and rates of active postures (girths) (standard of standing posture)

Items	Posture	Change values (posture 2, 3, 4-1)	Changing rate (%)
Waist girth	2	2.91	3.70
	3	2.04	2.60
	4	6.31	8.03
Hip girth	2	-0.54	-0.55
	3	1.00	1.01
	4	6.95	7.04
Max thigh girth	2	-0.04	-0.07
	3	0.06	0.10
	4	1.21	2.03
Mid thigh girth	2	2.92	6.16
	3	3.35	7.06
	4	4.55	9.59
Knee girth	2	2.93	7.98
	3	3.03	8.25
	4	6.40	17.43

Table 6. Body measurements of 3 subjects for the wearing test (subjects in standing posture, from 3D scanning anthropometric measurements)
(units: cm, kg)

Items	Mean	S.D.
1. Body height	164.00	2.75
2. Waist height	102.74	1.48
3. Hip height	83.21	2.40
4. Crotch height	71.90	2.62
5. Knee height	43.25	1.22
6. Waist girth	71.08	0.98
7. Hip girth	97.00	2.04
8. Total crotch girth	78.94	6.59
9. Max thigh girth	59.05	4.45
10. Mid thigh girth	45.98	3.96
11. Knee girth	36.14	0.80
12. Hip length	20.44	3.51
13. Crotch length	31.95	4.13
14. Weight	60.67	4.20
15. Age	21.00	1.00

based on the rate of body surface change in a sitting posture are not appropriate values for a standing posture. On the other hand, most expert appearance assessment items for pants B were higher than pants A for the sitting posture <Table 8>, especially the ease of pants back waist (3.89) and the appearance of the whole back (3.56).

In the subjects' assessment of fit and comfort of pants B, the location of pants waist (4.33), the ease at the pants waist (3.67), the ease at the abdomen (3.67), and the overall comfort (3.33) were rated better than pants A in the standing posture (Table 9). Most of the subjects' assessment items for pants B were also higher than pants A for the fit and comfort assessment in the sitting posture (Table 10). So overall the assessed fit and comfort of pants B with ease based on girth changing rates in a sitting posture turned out to be better than pants A.

As mentioned above, pants B was assessed worse

Table 7. Comparison of the appearance between pants A and B by experts (standing posture, 5 point scale)

Items		Pants A		Pants B		t-value
		Mean	S.D.	Mean	S.D.	
Front	1. The location of pants waist-line	3.89	0.333	3.67	0.707	0.853
	2. The ease of pants waist-line	3.78	0.833	2.11	0.782	4.376***
	3. The ease of abdomen part	3.11	1.167	2.44	1.014	1.294
	4. The ease of crotch part	2.89	0.928	2.44	1.014	0.970
	5. The abdomen part without stress folds	3.33	0.866	2.56	1.014	1.750
	6. The ease of thigh part	3.33	1.000	3.33	0.866	0.000
	7. The ease of knee part	3.67	0.707	3.67	0.707	0.000
	8. The width of hem	3.67	0.707	3.78	0.667	-0.343
	9. The appearance of the whole front	3.56	1.130	2.67	1.118	1.677
Back	10. The location of pants waist-line	3.67	0.707	3.00	1.118	1.512
	11. The ease of pants waist-line	3.78	0.667	3.89	0.333	-0.447
	12. The ease of hip part	3.44	0.882	3.11	0.928	0.781
	13. The ease of crotch part	3.44	0.882	2.67	0.500	2.302*
	14. Buttock area without stress folds	3.33	0.866	2.67	0.707	1.789
	15. The ease of thigh part	3.22	0.972	3.00	0.866	0.512
	16. The ease of knee part	3.44	0.882	3.67	0.500	-0.658
	17. The width of hem	3.89	0.333	3.33	0.866	1.796
	18. The appearance of the whole back	3.33	0.866	2.78	0.833	1.387
Side	19. The appearance of the whole side	3.33	0.866	3.22	0.972	0.256
	20. The appearance of the overall fit	3.50	1.378	2.67	1.211	1.112
Mean		3.48		3.03		

*$p \leq .05$, ***$p \leq .001$
Pants A: basic pants
Pants B: pants applied proper ease values of waist girth and hip girth from the rate of body surface change

Table 8. Comparison of the appearance between pants A and B by experts (sitting posture, 5 point scale)

Items		Pants A		Pants B		t-value
		Mean	S.D.	Mean	S.D.	
Front	1. The location of pants waist-line	3.67	0.707	3.89	0.782	-0.632
	2. The ease of pants waist-line	2.11	0.782	2.67	0.866	-1.429
	3. The ease of abdomen part	2.44	1.014	2.78	1.202	-0.636
	4. The ease of crotch part	2.44	1.014	3.00	0.866	-1.250
	5. The abdomen part without stress folds	2.56	1.014	2.11	0.782	1.042
	6. The ease of thigh part	3.33	0.866	3.44	0.882	-0.270
	7. The ease of knee part	3.67	0.707	3.78	0.667	-0.343
	8. The width of hem	3.78	0.667	3.89	0.333	-0.447
	9. The appearance of the whole front	2.67	1.118	3.11	0.928	-0.918
Back	10. The location of pants waist-line	2.67	1.118	3.00	0.866	0.707
	11. The ease of pants waist-line	3.22	0.333	3.89	0.833	2.228*
	12. The ease of hip part	0.11	0.928	3.33	0.866	-0.525
	13. The ease of crotch part	2.67	0.500	3.00	0.707	-1.155
	14. Buttock area without stress folds	2.67	0.707	3.00	0.866	-0.894
	15. The ease of thigh part	3.00	0.866	3.44	0.726	-1.180
	16. The ease of knee part	3.67	0.500	3.56	0.527	0.459
	17. The width of hem	3.33	0.866	3.56	0.726	-0.590
	18. The appearance of the whole back	2.78	0.833	3.56	0.527	-2.366*
Side	19. The appearance of the whole side	3.22	0.972	3.67	0.707	-1.109
	20. The appearance of the overall fit	2.67	1.211	3.67	0.516	-1.861
Mean		2.95		3.32		

*$p \leq .05$
Pants A: basic pants
Pants B: pants applied proper ease values of waist girth and hip girth from the rate of body surface change

Table 9. Comparison of the comfortableness between pants A and B by subjects (standing posture, 5 point scale)

Items	Pants A		Pants B		t-value
	Mean	S.D.	Mean	S.D.	
1. The location of pants waist-line	3.00	1.000	4.33	0.577	-2.000
2. The ease of pants waist-line	3.33	0.577	3.67	1.528	-0.354
3. The ease of belly part	3.33	0.577	3.67	1.528	-0.354
4. The ease of hip part	3.67	1.528	3.33	0.577	1.414
5. The ease of crotch part	3.67	2.309	2.33	1.528	0.834
6. The ease of thigh part	4.00	1.000	3.83	0.577	1.000
7. The ease of knee part	4.33	0.577	4.33	0.577	0.000
8. The whole comfortableness	3.00	1.000	3.33	0.577	-0.500
9. How flattering the pants look	1.67	0.577	2.00	1.000	-0.500
Mean	3.33		3.42		

Pants A: basic pants
Pants B: pants applied proper ease values of waist girth and hip girth from the rate of body surface change

in appearance (expert judges) in the standing posture, but better in appearance (expert judges) and fit and comfort (subjects) in the sitting posture. Even though optimal results for both standing and seated postures are not achieved with either pants A or pants B, it is clear that there is value in the use of ease values

Table 10. Comparison of the comfortableness between pants A and B by subjects (sitting posture, 5 point scale)

Items	Pants A		Pants B		t-value
	Mean	S.D.	Mean	S.D.	
1. The location of pants waist-line	3.00	1.000	4.33	0.577	-2.000
2. The ease of pants waist-line	3.00	1.000	3.67	1.528	-0.632
3. The ease of belly part	2.33	0.577	3.67	1.528	-1.414
4. The ease of hip part	2.67	0.577	4.33	0.577	3.536*
5. The ease of crotch part	2.33	1.732	4.00	1.528	1.250
6. The ease of thigh part	3.73	0.577	3.33	0.577	2.121
7. The ease of knee part	4.00	1.000	3.67	1.528	0.316
8. The whole comfortableness	2.33	0.577	3.00	1.000	-1.000
9. How flattering the pants look	1.67	0.577	2.00	1.000	-0.500
Mean	2.78		3.56		

*$p \leq .05$
Pants A: basic pants
Pants B: pants applied proper ease values of waist girth and hip girth from the rate of body surface change

derived from the rates of lower body girth change to pants patterns in this research. The primary posture for fit assessment in the clothing construction field is a standing posture, and all clothing patterns are generally designed to exhibit the ideal appearance in a standing posture. Therefore further research is needed in order to make clothing that is appropriate for appearance, fit, and comfort for a variety of active body positions.

4. Results of Wearing Test by Collating in the Ease Range of between the Basic Pants Pattern and the Rates of Lower Body Girth Change

In order to discover the optimal ease for both appearance and comfort in both standing and sitting postures, we then constructed a set of 20 pair of pants with incremental waist and hip ease (1.1cm increments) ranging between the pants pattern with standard ease values (waist ease: 2.4cm, hip ease: 2.6cm) and the pants pattern with ease values based on lower body girth change (waist ease: 5.7cm, hip ease: 7cm), and conducted a fit test of these pants for expert appearance and subject fit and comfort assessment. We then compared the results to identify the pants with the ease values that best combined appearance and comfort. Three new subjects were recruited for this stage of the study. The assessment method for the fit tests of the 20 pair of pants were same as those conducted for pants A and B. We then compared the averages for each pair of pants to discover which pair of pants were rated the highest overall (Table 11).

As the result of the appearance assessment in a standing posture, the average rating for the pants with waist ease of 2.4cm, and hip ease of 2.6cm was the highest among the 20 pants, at a rating of 3.48. Average scores tended to be lower as waist ease and hip ease increased. Appearance was also assessed lower for pants with larger differences between waist ease and hip ease.

As the result of the appearance assessment in a sitting posture, the average rating for the pants with waist ease of 5.7cm, and hip ease of 7cm was the highest among the 20 pants, at a rating of 3.32. Average scores tended to be lower as waist ease and hip ease decreased.

As the result of the fit and comfort assessment in a standing posture, the average ratings for the 20 pair of pants ranged between 3.33 and 3.45. no special tendencies were observed.

As the result of the fit and comfort in a sitting posture, the average rating for the pants with waist ease 5.7cm and hip ease of 7cm was the highest among the 20 pants, at a rating of 3.56. The pants with waist ease of 2.4cm, and hip ease of 2.6cm) were ranked lowest at 2.78. Average scores tended to be lower as waist ease and hip ease decreased.

Highest total mean (appearance, fit, and comfort)

Table 11. Comparison of all average scores of the appearance, fit, and comfort among all 20 pants

Waist ease / Hip ease	2.4cm		3.5cm		4.6cm		5.7cm	
	Stand	Sit	Stand	Sit	Stand	Sit	Stand	Sit
2.6cm	A: 3.48	A: 2.95	A: 3.34	A: 2.95	A: 2.95	A: 3.05	A: 2.75	A: 3.05
	C: 3.33	C: 2.78	C: 3.33	C: 2.98	C: 3.35	C: 3.00	C: 3.35	C: 3.07
	Total mean: 3.14		Total mean: 3.15		Total mean: 3.09		Total mean: 3.06	
3.7cm	A: 3.35	A: 2.99	A: 3.27	A: 2.99	A: 3.15	A: 3.08	A: 2.89	A: 3.08
	C: 3.35	C: 2.98	C: 3.35	C: 3.00	C: 3.33	C: 3.17	C: 3.35	C: 3.25
	Total mean: 3.17		Total mean: 3.15		Total mean: 3.18		Total mean: 3.14	
4.8cm	A: 3.32	A: 3.05	A: 3.33	A: 3.11	A: 3.30	A: 3.25	A: 3.10	A: 3.25
	C: 3.42	C: 3.00	C: 3.45	C: 3.23	C: 3.45	C: 3.35	C: 3.42	C: 3.25
	Total mean: 3.20		Total mean: 3.28		Total mean: 3.34		Total mean: 3.26	
5.9cm	A: 2.98	A: 3.09	A: 3.14	A: 3.19	A: 3.12	A: 3.30	A: 3.07	A: 3.28
	C: 3.42	C: 3.07	C: 3.43	C: 3.30	C: 3.43	C: 3.35	C: 3.33	C: 3.48
	Total mean: 3.14		Total mean: 3.27		Total mean: 3.30		Total mean: 3.29	
7cm	A: 2.75	A: 3.09	A: 2.96	A: 3.15	A: 3.05	A: 3.28	A: 3.03	A: 3.32
	C: 3.33	C: 3.17	C: 3.38	C: 3.30	C: 3.40	C: 3.48	C: 3.42	C: 3.56
	Total mean: 3.09		Total mean: 3.20		Total mean: 3.30		Total mean: 3.33	

Stand: in a standing posture, Sit: In a sitting posture
A: Appearance assessment average, C: Comfort and fit assessment average

was 3.34, for the pants with waist ease of 4.6cm, and hip ease of 4.8cm among all of the 20 pairs of pants. <Table 12>-<Table 13> show the detailed results of the appearance and comfort assessments for the pants with waist ease of 4.6cm and hip ease of 4.8cm. For the experts' appearance assessment, the front waist line location rating was 3.69 and the back waist ease rating was 3.58 for the standing posture and 3.79 (front) and 3.77 (back) for the sitting posture. For the subjects' fit and comfort assessment, the waist line location rating was 4.00 and the waist ease rating was 3.71 for the standing posture, and the waist line location rating was 3.92. The hip ease rating was 3.82 in a sitting posture. The appearance of the pants with waist ease of 4.6cm and hip ease of 4.8cm was shown in <Fig. 9>.

IV. Conclusions

Recently three-dimensional body data has been used successfully in many industries including the clothing industry. However previous research on lower body analysis using 3D body scanning and its application to patterns is rare. In this research, lower body girth changes were obtained from measurement of 3D scans of study subjects in four postures; a standing posture, a 120° knee bend posture, a one pace stepping posture, and a sitting posture with a 90° knee bend. Ease values were calculated from these data, and were applied to pants patterns. The results are as follows.

Lower body girth changes were calculated from body scans of 25 females aged from 18 to 24 of a medium size. Of the three active body positions, girth measurements in a sitting posture changed the most compared to a standing posture. The waist girth in the sitting posture increased about 8% comparing to a sitting posture, the hip girth measurement increased about 7%. In order to make pants that accommodate movements of the lower body, these girth changing rates were used to calculate ease for pants patterns.

For the first test two basic pants patterns were created, pants A with 2.4cm ease at the waist and 2.6cm ease at the hip (standard ease), and pants B, with 5.7cm ease (8% change rate) at the waist and 7cm ease (7% change rate) at the hip. We made pants A

Table 12. Result of the appearance assessment of pants (waist ease 4.6cm, hip ease 4.8cm)

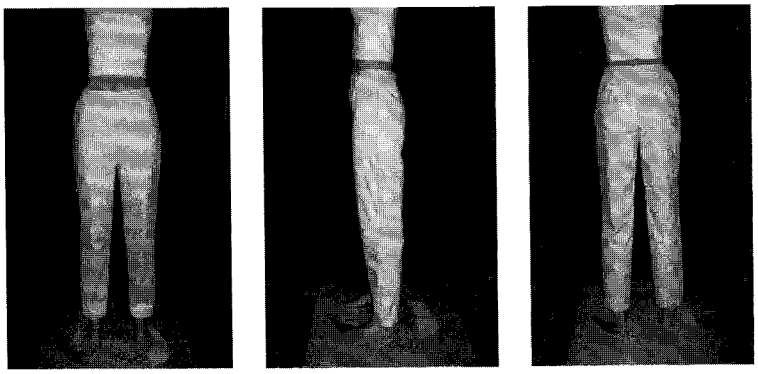
	Items	Standing		Sitting	
		Mean	S.D.	Mean	S.D.
Front	1. The location of pants waist-line	3.69	0.312	3.79	0.667
	2. The ease of pants waist-line	3.58	0.814	2.55	0.782
	3. The ease of abdomen part	2.91	1.227	2.67	1.004
	4. The ease of crotch part	2.79	0.858	2.98	0.904
	5. The abdomen part without stress folds	3.03	0.866	2.00	1.004
	6. The ease of thigh part	3.23	0.990	3.43	0.146
	7. The ease of knee part	3.57	0.697	3.78	0.697
	8. The width of hem	3.67	0.707	3.89	0.667
	9. The appearance of the whole front	3.26	1.000	3.01	1.118
Back	10. The location of pants waist-line	3.47	0.707	2.89	1.008
	11. The ease of pants waist-line	3.58	0.667	3.77	0.341
	12. The ease of hip part	3.14	0.712	3.23	0.928
	13. The ease of crotch part	3.34	0.622	2.99	0.500
	14. Buttock area without stress folds	3.03	0.856	2.99	0.778
	15. The ease of thigh part	3.12	0.972	3.43	0.843
	16. The ease of knee part	3.44	0.872	3.56	0.550
	17. The width of hem	3.89	0.393	3.56	0.416
	18. The appearance of the whole back	3.03	0.846	3.45	0.523
Side	19. The appearance of the whole side	3.03	0.866	3.56	0.782
	20. The appearance of the overall fit	3.20	1.188	3.56	1.321
Mean		3.30		3.25	

Table 13. Result of the comfort assessment of pants (waist ease 4.6cm, hip ease 4.8cm)

Items	Standing		Sitting	
	Mean	S.D.	Mean	S.D.
1. The location of pants waist-line	4.00	0.990	3.92	0.577
2. The ease of pants waist-line	3.71	1.000	3.36	0.828
3. The ease of belly part	3.69	0.587	3.39	0.428
4. The ease of hip part	3.35	0.544	3.82	0.677
5. The ease of crotch part	2.35	0.622	3.99	0.828
6. The ease of thigh part	3.85	0.577	3.30	0.477
7. The ease of knee part	4.33	0.990	3.67	0.628
8. The whole comfortableness	3.37	0.587	2.69	0.900
9. How flattering the pants look	2.41	0.587	2.00	0.900
Mean	3.45		3.35	

and pants B, and evaluated the fit, appearance and comfort of each, in both standing and sitting position of subjects wearing the pants in fit tests. Results were that most assessment items for pants A were higher than pants B in appearance assessment for the standing posture. On the other hand, most assessment items of pants B turned out to be higher than pants A in appearance assessment for the sitting posture. Fit and comfort assessment items of pants B, overall were better than pants A for both standing and sitting postures.

In order to find out the most effective ease values for both better appearance and comfort, standing and sitting, we made 20 pants with incremental values of waist ease and hip ease at 1.1cm intervals in the



Front Side Back

Fig. 9. Appearance of the pants with waist ease of 4.6cm and hip ease of 4.8cm.

range between the basic pants pattern (waist ease: 2.4cm, hip ease: 2.6cm) and the ease calculated from the rates of lower body girth change (waist ease: 5.7cm, hip ease: 7cm). We conducted a wearing test of these pants for appearance and comfort assessment, and compared the average ratings to identify the pants with the best appearance, fit and comfort in both positions. The highest total ranking (3.34) was given to pants with waist ease of 4.6cm and hip ease of 4.8cm.

In this research, we calculated ease values based on surface body measurement change in active positions, and tested the pants ease at the waist and hip for a range of ease values to identify values that provided the best appearance and comfort in active postures. This study adds to our understanding of the optimal fit of clothing made from woven materials for active body positions. There is value in the use of ease values derived from the rates of lower body girth change to pants patterns. The primary posture for fit assessment in the clothing construction field is a standing posture, and clothing patterns are generally designed to exhibit the ideal appearance in a standing posture. Research is needed to make clothing with good appearance, fit, and comfort for a variety of active body positions.

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