Yu and Kim *Fash Text* (2020) 7:35
https://doi.org/10.1186/s40691-020-00223-8

Fashion and Textiles

RESEARCH

Open Access

# Body shape classification of Korean middle-aged women using 3D anthropometry

Minji Yu[1] and Dong-Eun Kim[2*]

*Correspondence: dekim@ewha.ac.kr
[2] Associate Professor, Department of Fashion Industry, Ewha Womans University, #402-3, Human Ecology Building (Morris Hall), 52, Ewhayeodae-gil, Seodaemun-gu, Seoul 03760, South Korea
Full list of author information is available at the end of the article

**Abstract**

Most Korean apparel companies lack suitable dress forms for the different body types of middle-aged Korean women, resulting in poor clothing fit for them. As a part of an ongoing project to develop a dress form that fully reflects Korean middle-aged women's bodies, this study classified the body shapes and examined the anthropometric characteristics of women in their 40s and 50s. The 3D anthropometric data of 302 middle-aged women of normal weight ($18.5 \leq BMI < 25$) were obtained from the 6th Size Korea. Sixty-three measurements related to the construction of dress form were chosen. Based on the scores from five factors, the body shapes of Korean middle-aged women were classified into four types: Type 1 had a broader shoulder and a slightly developed upper body but a more developed lower body; Type 2 had a longer, relatively thin and flat, vertical body; Type 3 had a shorter body and smaller torso than the other types, and the lower body was more developed than the upper; Type 4 had a bulky upper body and the highest BMI, but the lower body was rather small. The nine key measurements in classifying the body shapes of Korean middle-aged women were found by discriminant analysis. The characteristics of representative body shapes obtained in this study can be useful for developing dress forms for clothing that better fits Korean middle-aged women.

**Keywords:** Body shape, 3D anthropometry, Korean middle-aged women, 3D body scanning

## Introduction

Medical advancements and well-being culture have helped middle-aged women to maintain stronger bodies and build more active lives; they take their beauty seriously and devote themselves to finding their true selves ("The Elastic Woman" 2018; Park et al. 2019). Moreover, middle-aged women have higher disposable incomes based on their stable economic power than younger women, and therefore, retailers are unwilling to bypass this huge market segment (Birtwistle and Tsim 2005). Women ages 45 to 55 spend more on clothing, footwear, and accessories, accounting for 41% of the total market (Handley 2014).

Companies designing fashion products for middle-aged women need to understand that they are passionate about clothing and want to discover their beauty and vigor through fashion, in contrast with the simple styles of the past (Felsted and Cohen 2013;

Nam and Kim 2018). Fashion brands need to be aware of the body characteristics of their target markets and offer products that fit the bodies (Yin and Annett-Hitchcock 2019). Women's bodies change with age, and women in middle age can experience problems with clothing fit (Goldsberry et al. 1996). Major physical changes that take place as women age have been recorded as shorter stature, thicker waist, prominent abdomen, and flattened buttocks (Campbell and Horne 2001).

Meanwhile, fit problems can occur during clothing production. In particular, the Korean ready-to-wear industry simply increases the sizes of young women's clothing patterns without reflecting the body shape changes and characteristics of middle-aged women, resulting in ill-fitting clothing for this population (Kang 2011). To improve garment fit, dress forms are an important tool for apparel companies to test the fit of sample garments (Yoo and Shim 2006). However, most Korean apparel companies lack suitable dress forms for the differing body types of Korean middle-aged women.

To develop garments that better fit middle-aged women, it is necessary to analyze the characteristics of their bodies as they age. Understanding the body characteristics and types of middle-age women will help to develop better-fitting clothes for them, and a number of previous authors have analyzed the body shape characteristics of this population of women (Chun and Lee 2015; Kalichman and Kobyliansky 2006; Kim 2014; Lee 2011; Shin and Nam 2015; Yoon and Suh 2009). More recently, investigators have 3D body scanners in anthropometric studies for more accurate information.

This study was a part of an ongoing project to develop a dress form for Korean middle-aged women. The purpose of the current study was to explore the body shape characteristics of Korean women in their 40s to 50s and to classify the representative body types. We used 3D measurements and body scan image data from the 6th Size Korea (2012) to address the following five research questions:

(1) What are the differences in the anthropometric data for middle-aged women in different age groups?
(2) What factors affect the body shapes of middle-aged women?
(3) What characterizes the different body types of middle-aged women?
(4) What are the key measurements that discriminate body types of middle-aged women?
(5) What is the distribution of middle-aged women's body types by age group?

## Literature review

### Body shape analysis and classification methods

Researchers have made numerous attempts to analyze and classify the human body in efforts to improve clothing fit and improve the size system. Traditional analyses used manual 2D measurement data and photographic images. With the introduction of 3D scanning technology, it became possible to obtain more detailed dimensions including items that were difficult to measure manually such as depth and angle. Three-dimensional measurement is more valid and reliable than traditional methods, and these measurements can be taken manually in addition to automatically (Xia et al. 2019). With automatic measurement, body dimensions can be obtained simultaneously with the input of 3D body scanning data using a specific program; for manual measurement, the body scan data is extracted into a mesh file that can be used in 3D CAD programs for anthropometric analysis. Previous authors revealed that 3D body measurement is sufficiently accurate with less than 1% total error in calculations of body and 3D surface (Yu et al. 2003). In short, 3D measurement is more advanced than traditional methods.

Several researchers have analyzed and classified the shapes of human bodies using 3D measurement data. For instance, Simmons et al. (2004) developed software they called Female Figure Identification Technique (FFIT) for Apparel using 3D scanned data and used the program to classify women's body shapes into nine categories: hourglass, bottom hourglass, spoon, triangle, inverted triangle, diamond, top hourglass, rectangle, and oval. Newcomb (2006) analyzed and classified the body shapes of U.S. Hispanic women using SizeUSA 3D measurement data and FFIT, and Masuda et al. (2007) used 3D measurements to create body simulations to evaluate the shape images; they extracted 6 keywords indicating full-length body images and 19 keywords related to partial images and then assessed 82 young women using the keywords. Wells et al. (2008) used 3D SizeUK and SizeUSA measurement data with indices for different body shapes to examine the size and shape differences between UK and US white adults. Vuruskan and Bulgun (2011) developed an automatic system for numerically classifying body shapes, performing 3D body scans to take measurements and delineate body silhouettes; they then input the obtained results as numeric parameters into a database to build the tool for calculating body shape. Kim and Do (2019) acquired the foot shapes of 264 elderly Korean men through body scanners and classified the shapes into 12 categories with the combination of foot length, sole type, and instep circumference in order to establish a new sizing system.

Song and Ashdown (2011) examined the lower body shapes of the US female population using 3D SizeUSA body scan data. They performed principal component and cluster analysis to develop a new classification method. Lin et al. (2004) compared the body measurements of citizens of four East Asian countries, conducting statistical analyses using 15 measurements in standing and sitting postures to illustrate the differences between the four groups. Alexander et al. (2012) analyzed plus-size women's hip shapes in the United States using SizeUSA data with Connell et al. (2006) Body Shape Assessment Scale; using the scale and the 3D data, the authors categorized the woman's hip shapes into four types: straight, low hip, mid hip, and high hip. Lee and Lee (2008) used direct and indirect measurements taken from photographs of the lateral bodies of 220 elderly women over age 60 years to classify their body types.

Size Korea is a nationwide project that entails regular surveys of anthropometric metrics in Korea's population. The data come from both traditional direct measurements of the human body and surface measurements from 3D body scanning data (Kim et al. 2017). Several researchers have used Size Korea data to examine the anthropometric characteristics of specific group. Lee et al. (2007) used FFIT to compare Size Korea and SizeUSA data and determine body shapes and body shape distributions of US and Korean women. Yi and Istook (2008) also compared the body shapes of Korean and US women using ratios and indices from Size Korea and SizeUSA data.

Lee et al. (2020) used the 3D scan data of 173 Korean abdominal obese men from the 6th Size Korea to categorize their lower body types. The authors extracted ten principal components from total measurements automatically obtained by the SNU-BM program and divided the obese men's body shapes into three types. Suh and Oh (2012) used the raw data of 515 women age 30 to 39 years from the 5th Size Korea to classify their body types and develop dress forms for the bodies of women in their 30s. Kim (2016) compared the upper body types of women in their 20s to those of women in their 30s and 40s; they used 64 items from 1675 women's measurement data from the 6th Size Korea. Sohn and Kim (2017) analyzed 29 directly measured anthropometric characteristics of 548 obese women in their 20s to 60s from the 7th Size Korea to categorize their upper bodies.

### Anthropometric characteristic of middle-aged women

Anthropometric characteristics of middle-aged women are different from those of young women; women's shapes and sizes change as they age, from various causes including aging, pregnancy, childbirth, and the menopausal transition. After young adulthood, women go through age-related changes such as the accumulation of abdominal fat and loss of skeletal muscle mass (Mclorg 2005). The onset of menopause varies, but researchers have found around 50 to be the average age, and hormonal changes during menopause can change women's bodies substantially (Loh et al. 2005; Mckinlay 1996).

Some researchers have examined the changes in body composition of Chinese women during perimenopause and found that lean muscle mass decreased and both total and abdominal fat increased in the menopausal transition (Ho et al. 2010; Sternfeld et al. 2005; Toth et al. 2000; Wich and Carnes 1995). Kim (2014) investigated the body characteristics and types of two groups of US women, young (age 26 to 35) and middle-aged (age 36 to 45 group). In the middle-aged group, there were fewer women with normal S shapes and more with obese A shapes, overweight Y shapes, and obese H shapes compared with the younger women; the younger women had slimmer, more similar body shapes, whereas the middle-aged women had larger bodies with more varied shapes. Kalichman and Kobyliansky (2006) examined the somatotypes of 738 females aged 18–90 years in Chuvashia, a republic of Russia; the researchers found that *mesomorphy* (musculoskeletal components) continued to increase until age 50 and then decreased, *ectomorphy* (longitudinal body characteristics) decreased after age 50, and *endomorphy* (relative fatness) increased after age 60 and then decreased.

In Asia, including Korea, a considerable number of researchers have investigated the body characteristics of middle-aged women using body measurements. Chun and Lee (2015) examined the upper body anthropometry of Korean women aged 40 to 69. The researchers conducted factor and cluster analysis of data from the 6th Size Korea and classified the body shapes into five types: skinny, short and stout with forward posture, composite, tall and full-bodied, and short and skinny. Shin and Nam (2015) investigated the body shapes of Korean women aged 40 to 49 in order to better reflect human body changes in a 3D virtual fitting system. The researchers used BMI to group the body shapes into three categories and conducted factor analysis using 47 body measurement items to extract seven factors as representative variables: waist circumference, waist height, knee circumference, hip circumference, biacromial breadth, neck base circumference, and chest circumference.

Nam et al. (2013) examined the changes in middle-aged women's body shapes based on the measurements from the 5th and 6th Size Korea projects. Specifically, they analyzed and compared the anthropometric characteristics of women aged 35 to 64 and found that over time, middle-aged women's bodies had increased in height while decreasing in weight, BMI, width, and depth. Lee (2011) examined the characteristics of middle-aged women's lower body shapes, collecting indices of direct measurement data of 1337 women 35 to 65 years of age from the 5th National People's Physical Condition Sampling Survey in Korea. The author found that hips were wider in women in early middle-age than they were in later middle-aged women and that body shapes from waist to hip became rounder and H shaped. Lee (2014) investigated the lower body shapes of middle-aged women 40 to 59 years of age and classified the shapes into three types. Type 1 was long, slim, and rectangular with mid-length hips, Type 2 was diamond-shaped and obese with a lengthy lower body and medium-length legs, and Type 3 was trapezoidal and overweight with the longest and largest legs and hips.

Yoon and Suh (2009) examined the characteristics of middle-aged women by analyzing drop value, specifically converting the measurement data of 785 women age 40 to 59 years from the 5th Size Korea to drop values and performing cluster analysis on the data. The authors classified the women's body shapes four types: Type 1, M, had a relatively developed lower body; Type 2, X, had a balanced hourglass shape with large hips; Type 3, H, was flat and obese with large abdominal circumference, and Type 4, Y, was a large upper body with a flat shape.

## Method

### Participants

For this study, we analyzed 3D anthropometric measurement data from women aged 40 to 59 from the 6th Size Korea. We conducted this study as part of an ongoing project to make a dress form for middle-aged women in the normal range of body size. Toward that end, we eliminated the data for women who were underweight ($BMI < 18.5$), overweight ($25 \leq BMI < 30$), or obese women ($30 \leq BMI$) based on the international classification of the World Health Organization (WHO). We ultimately used the data from 302 women ($18.5 \leq BMI < 25$) in total; their age distribution is shown in Table 1.

### Items of analysis

We selected 63 measurement items related to constructing dress forms to classify the body shapes of Korean middle-aged women (Table 2): 13 related to height, 8 for length, 14 for girth, 9 for breadth, 8 for depth, 2 for weight, 4 drop values, and 3 flatness ratios.

**Table 1 Age distribution of participants**

| Age group | n | % |
|---|---|---|
| 40–44 | 77 | 25.5 |
| 45–49 | 82 | 27.2 |
| 50–54 | 81 | 26.8 |
| 55–59 | 62 | 20.5 |
| Total | 302 | 100.0 |

**Table 2 Body measurements and computational items (n = 63)**

| Category | Item | | n |
|---|---|---|---|
| Body measurement items | Height | Stature, Cervical height, Neck point height, Neck front point height, Shoulder height, Axilla height, Bust height, Underbust height, Waist height, Abdominal height, Waist height (omphalion), Hip height, Knee height | 13 |
| | Length | Shoulder length, Bishoulder length, Bust point to Bust point, Waist front length, Waist front length (omphalion), Neck point to breast point to waistline, Waist back length, Waist back length (omphalion) | 8 |
| | Girth | Neck circumference, Neck base circumference, Chest circumference, Bust circumference, Underbust circumference, Waist circumference, Abdominal circumference, Waist circumference (omphalion), Hip circumference, Thigh circumference, Knee circumference, Upper arm circumference, Elbow circumference, Wrist circumference | 14 |
| | Breadth | Neck breadth, Bishoulder breadth, Chest breadth, Bust breadth, Underbust breadth, Waist breadth, Abdominal breadth, Waist breadth (omphalion), Hip width | 9 |
| | Depth | Armscye depth, Chest depth, Bust depth, Underbust depth, Waist depth, Abdominal depth, Waist depth (omphalion), Hip Depth | 8 |
| | Angle | Inclined angle of right shoulder, Inclined angle of left shoulder | 2 |
| | Weight | BMI, Weight | 2 |
| Computational items | Drop value | Drop 1 (Bust circumference-Waist circumference), Drop 2 (Hip circumference-Waist circumference), Drop 3 (Hip circumference-Bust circumference), Drop 4 (Bust circumference-Underbust circumference) | 4 |
| | Flatness ratio | Bust flatness ratio (Bust depth/Bust breadth), Waist flatness Ratio (Waist depth/Waist breadth), Hip flatness ratio (Hip depth/Hip width) | 3 |

### Data analysis

Using SPSS 25.0 for Windows, we conducted descriptive statistics, one-way ANOVA, Duncan's and Games-Howell post hoc test, factor analysis, cluster analysis, Chi-square test, and discriminant analysis.

## Results and discussion

### Body measurements by age group

To investigate the women's body characteristic changes according to age, we divided the data into four age groups (40–44, 45–49, 50–54, and 55–59 years). We conducted one-way ANOVA and Duncan's post hoc test to compare the mean of each group and performed the Games-Howell post hoc test for some items where the assumption of homogeneity of variances was violated (Table 3).

In the height category, there were significant differences in all measurements except abdominal height and knee height. The height measurements were the largest in the age group of 40–44 years and reduced with age.

In the length category, bishoulder length and waist back length (omphalion) were the longest in the age group of 40–44 and second longest in 45–49, and similarly short in the age groups of 50–54 and 55–59 years. We found no significant differences in waist front length, waist front length (omphalion), neck point to breast point to waistline, or waist back length; these are all related to upper body length.

**Table 3 Body measurement comparison between age groups (Unit = mm)**

| Analysis item | | Mean (S.D.) | | | | | *F* |
|---|---|---|---|---|---|---|---|
| | | 40–44 (n = 77) | 45–49 (n = 82) | 50–54 (n = 81) | 55–59 (n = 62) | Total (n = 302) | |
| Height | Stature[1] | 1609.38A (54.37) | 1590.18AB (51.83) | 1573.75BC (44.30) | 1564.85C (58.01) | 1585.47 (54.31) | 10.288*** |
| | Cervical height[1] | 1360.11A (48.80) | 1342.61AB (47.00) | 1329.81B (41.77) | 1321.02B (52.83) | 1339.21 (49.31) | 9.232*** |
| | Neck point height[1] | 1341.85A (48.33) | 1323.92AB (46.50) | 1312.23B (40.59) | 1303.59B (52.11) | 1321.18 (48.54) | 9.045*** |
| | Neck Front point height[1] | 1299.70A (47.19) | 1283.98AB (45.76) | 1272.13B (39.01) | 1265.46B (51.26) | 1281.01 (47.18) | 7.840*** |
| | Shoulder height | 1294.49A (48.76) | 1276.24B (45.18) | 1265.28BC (40.30) | 1256.27C (51.52) | 1273.86 (48.10) | 9.091*** |
| | Axilla height | 1187.82A (46.86) | 1170.32B (44.23) | 1158.24BC (38.62) | 1145.67C (46.77) | 1166.48 (46.35) | 11.788*** |
| | Bust height | 1135.81A (48.19) | 1117.99B (44.03) | 1104.10BC (38.31) | 1095.46C (46.30) | 1114.18 (46.43) | 11.469*** |
| | Underbust height | 1081.46A (47.91) | 1064.36B (42.75) | 1050.02C (37.91) | 1039.50C (46.68) | 1059.77 (46.17) | 12.391*** |
| | Waist height | 963.66A (39.21) | 950.51B (35.77) | 942.32BC (32.85) | 934.28C (39.16) | 948.34 (37.97) | 8.347*** |
| | Abdominal height | 896.96 (54.34) | 884.60 (49.69) | 879.05 (47.90) | 877.22 (58.49) | 884.74 (52.64) | 2.145 |
| | Waist height (omphalion) | 920.69A (40.38) | 907.97B (37.86) | 903.61BC (34.02) | 893.87C (42.84) | 907.15 (39.54) | 5.839** |
| | Hip height | 780.70A (36.99) | 769.50AB (34.81) | 764.17B (31.47) | 758.84B (36.51) | 768.74 (35.60) | 5.155** |
| | Knee height | 414.40 (17.96) | 410.03 (16.76) | 410.13 (14.83) | 408.24 (18.63) | 410.81 (17.05) | 1.720 |
| Length | Shoulder length | 125.88 (8.55) | 124.86 (7.44) | 122.95 (8.34) | 123.38 (8.06) | 124.30 (8.15) | 2.114 |
| | Bishoulder length | 389.98A (18.19) | 385.62AB (16.69) | 379.90B (17.87) | 381.03B (16.03) | 384.26 (17.65) | 5.429** |
| | Bust point to Bust point | 177.69 (12.21) | 176.40 (13.80) | 178.25 (14.26) | 180.45 (11.46) | 178.06 (13.10) | 1.159 |
| | Waist front length | 356.98 (16.78) | 353.62 (17.87) | 353.74 (16.10) | 356.83 (20.06) | 355.17 (17.61) | 0.841 |
| | Waist front length (omphalion) | 399.51 (21.42) | 395.68 (21.91) | 391.83 (19.49) | 396.13 (22.49) | 395.72 (21.36) | 1.725 |
| | Neck point to Breast point to waistline | 425.60 (19.95) | 420.34 (18.83) | 420.05 (19.13) | 422.05 (18.46) | 421.96 (19.17) | 1.395 |
| | Waist Back length | 409.91 (19.40) | 405.26 (17.60) | 405.05 (28.99) | 402.42 (20.68) | 405.81 (22.26) | 1.404 |
| | Waist Back length (omphalion) | 452.43A (22.12) | 447.28AB (20.13) | 443.16B (28.99) | 441.76B (22.42) | 446.36 (23.97) | 2.988* |
| Girth | Neck Circumference[1] | 336.80C (14.84) | 338.34BC (17.84) | 347.01AB (26.69) | 351.06A (24.74) | 342.88 (22.09) | 7.310*** |
| | Neck Base circumference | 379.59 (14.31) | 379.13 (14.23) | 378.96 (17.43) | 382.86 (18.51) | 379.97 (16.08) | 0.864 |
| | Chest circumference | 902.42B (43.42) | 903.13B (41.31) | 918.40A (42.79) | 929.17A (38.50) | 912.39 (42.88) | 6.722*** |
| | Bust circumference | 897.65B (53.07) | 897.42B (47.08) | 920.73A (54.75) | 936.57A (43.53) | 911.77 (52.38) | 10.193*** |
| | Underbust circumference | 783.89C (42.92) | 777.61C (42.75) | 798.75B (40.33) | 817.59A (39.11) | 793.09 (43.80) | 12.814*** |
| | Waist circumference | 780.65C (55.43) | 773.34C (58.15) | 804.04B (54.21) | 839.63A (51.75) | 797.05 (60.15) | 20.085*** |

**Table 3 (continued)**

| Analysis item | | Mean (S.D.) | | | | | *F* |
|---|---|---|---|---|---|---|---|
| | | 40–44 (n=77) | 45–49 (n=82) | 50–54 (n=81) | 55–59 (n=62) | Total (n=302) | |
| | Abdominal circumference | 857.12B (64.05) | 846.77B (58.19) | 866.97B (61.65) | 891.17A (59.99) | 863.94 (62.72) | 6.666*** |
| | Waist circumference (omphalion) | 825.10BC (53.30) | 816.11C (52.66) | 834.94B (51.53) | 861.90A (48.96) | 832.85 (54.05) | 9.979*** |
| | Hip circumference | 933.70 (40.56) | 921.89 (37.18) | 922.01 (39.29) | 923.55 (34.64) | 925.28 (38.28) | 1.707 |
| | Thigh circumference | 548.02A (30.26) | 538.24B (28.72) | 538.63B (25.11) | 534.84B (31.01) | 540.14 (28.97) | 2.835* |
| | Knee circumference | 357.44A (18.37) | 352.53AB (14.65) | 351.45B (15.13) | 350.45B (17.41) | 353.07 (16.50) | 2.656* |
| | Upper Arm circumference | 309.73 (20.54) | 305.99 (19.04) | 306.21 (18.69) | 310.63 (19.24) | 307.96 (19.39) | 1.110 |
| | Elbow circumference | 235.80B (12.34) | 234.85B (11.15) | 236.45B (12.21) | 242.41A (11.58) | 237.07 (12.10) | 5.548** |
| | Wrist circumference[1] | 160.54C (7.61) | 161.47BC (7.83) | 164.72AB (8.47) | 167.44A (9.75) | 163.33 (8.74) | 9.894*** |
| Width | Neck breadth | 121.79 (5.32) | 120.77 (5.99) | 120.39 (5.71) | 119.70 (5.82) | 120.71 (5.73) | 1.649 |
| | Bishoulder breadth | 350.69A (14.90) | 348.50AB (12.44) | 343.84B (14.57) | 344.63B (12.72) | 347.01 (13.96) | 4.216** |
| | Chest breadth | 315.18AB (15.20) | 314.38B (13.89) | 319.53A (14.32) | 319.35A (13.95) | 316.99 (14.48) | 2.720 |
| | Bust breadth | 295.30B (15.19) | 295.50B (13.84) | 299.82AB (15.14) | 301.96A (15.03) | 297.94 (14.98) | 3.527* |
| | Underbust breadth | 275.09BC (13.74) | 272.91C (13.83) | 277.97AB (13.15) | 281.20A (13.69) | 276.53 (13.87) | 4.974** |
| | Waist breadth | 279.79BC (18.76) | 276.41C (18.06) | 285.10B (16.51) | 294.98A (16.15) | 283.42 (18.62) | 14.807*** |
| | Abdominal breadth | 306.59 (24.61) | 303.35 (20.46) | 307.39 (23.11) | 312.98 (21.73) | 307.24 (22.68) | 2.175 |
| | Waist breadth (omphalion) | 296.74B (18.48) | 292.61B (16.59) | 297.09B (16.57) | 303.01A (15.75) | 297.00 (17.21) | 4.452** |
| | Hip Width | 341.72 (16.06) | 338.11 (12.83) | 336.98 (14.33) | 337.38 (14.37) | 338.58 (14.47) | 1.724 |
| Depth | Armscye depth | 114.95B (10.06) | 114.08B (10.39) | 117.27AB (10.47) | 119.01A (9.54) | 116.17 (10.28) | 3.462* |
| | Chest depth | 209.50C (14.43) | 211.02C (14.12) | 216.33B (13.42) | 224.44A (13.98) | 214.81 (14.98) | 15.823*** |
| | Bust depth | 232.93C (18.55) | 233.46C (16.61) | 241.63B (18.95) | 249.59A (15.74) | 238.83 (18.69) | 13.823*** |
| | Underbust depth | 207.95C (16.24) | 208.85C (16.62) | 216.94B (15.70) | 226.18A (15.74) | 214.35 (17.49) | 19.097*** |
| | Waist depth | 204.78C (18.85) | 204.93C (20.03) | 215.62B (19.49) | 227.80A (18.75) | 212.45 (21.25) | 21.937*** |
| | Abdominal depth | 225.85C (18.43) | 223.61C (18.96) | 233.42B (18.62) | 243.77A (18.73) | 230.95 (20.07) | 16.326*** |
| | Waist depth (omphalion) | 211.86C (16.94) | 211.76C (18.21) | 218.79B (18.88) | 230.62A (17.60) | 217.54 (19.29) | 16.503*** |
| | Hip depth | 233.29 (13.44) | 231.26 (14.55) | 234.69 (15.44) | 237.11 (13.87) | 233.90 (14.47) | 2.079 |

**Table 3 (continued)**

| Analysis item | | Mean (S.D.) | | | | | F |
|---|---|---|---|---|---|---|---|
| | | 40–44 (n = 77) | 45–49 (n = 82) | 50–54 (n = 81) | 55–59 (n = 62) | Total (n = 302) | |
| Angle | Inclined angle of right shoulder | 22.81 (3.58) | 23.29 (3.35) | 23.01 (3.08) | 23.26 (2.96) | 23.09 (3.25) | 0.371 |
| | Inclined angle of left shoulder | 23.90 (3.90) | 23.67 (3.17) | 24.22 (3.23) | 23.96 (3.11) | 23.93 (3.36) | 0.368 |
| Weight | Weight (kg) | 55.86 (5.28) | 54.11 (4.91) | 54.54 (4.99) | 55.18 (5.01) | 54.89 (5.07) | 1.796 |
| | BMI | 21.83BC (1.77) | 21.67C (1.79) | 22.25AB (1.59) | 22.78A (1.50) | 22.10 (1.72) | 6.057** |
| Drop value | Drop 1 (Bust circumference-Waist circumference)[1] | 117.00A (39.63) | 124.08A (33.10) | 116.69A (37.89) | 96.94B (28.22) | 114.72 (36.41) | 7.352*** |
| | Drop 2 (Hip circumference-Waist circumference) | 153.05A (43.28) | 148.55A (42.20) | 117.98B (44.55) | 83.92C (41.82) | 128.23 (50.37) | 38.060*** |
| | Drop 3 (Hip circumference-Bust circumference) | 36.05A (46.52) | 24.47A (41.21) | 1.29B (47.70) | -13.02B (41.90) | 13.51 (48.08) | 17.595*** |
| | Drop 4 (Bust circumference-Underbust circumference) | 113.77 (27.54) | 119.81 (25.82) | 121.98 (29.42) | 118.99 (20.70) | 118.68 (26.40) | 1.368 |
| Flatness ratio. | Bust flatness ratio (Bust depth/Bust breadth) | 0.79C (0.05) | 0.79BC (0.05) | 0.81B (0.05) | 0.83A (0.05) | 0.80 (0.05) | 9.088*** |
| | Waist flatness ratio (Waist depth/Waist breadth) | 0.73C (0.05) | 0.74C (0.04) | 0.76B (0.04) | 0.77A (0.04) | 0.75 (0.05) | 11.158*** |
| | Hip flatness ratio (Hip depth/Hip width) | 0.68B (0.04) | 0.68B (0.04) | 0.70AB (0.05) | 0.70A (0.05) | 0.69 (0.04) | 3.708* |

Alphabet is the result of post hoc tests (Duncan's test, [1] Games-Howell test) (A > B > C)

*$p < .05$, **$p < .01$, ***$p < .001$

In the girth category, most items showed a tendency to increase with age, being the largest in the age group of 55–59 years. The lower body circumference measurements such as thigh and knee circumference were the largest in the age group 40–44 years, while the other three groups showed similar levels. Thus, the upper body mass generally increased by the 50s, while the lower body became thinner with age. There were no significant differences in hip circumference by age group.

In the width category, bishoulder breadth was the largest in the age group of 40–44 years and the other groups were similarly small. For many items (chest breadth, bust breadth, underbust breadth, waist breadth, and omphalion), the measurements were larger in women in their 50s than in those in their 40s; that is, the women developed greater upper body mass with age. Neck breadth, abdominal breadth, and hip width did not differ significantly by age.

In the depth category, all items except hip depth showed significant differences between age groups. Chest depth, bust depth, underbust depth, waist depth, abdominal depth, and waist depth (omphalion) were largest in the 55–59 age group, followed by ages 50–54, and the same measurements were similarly small in the 40–44 and 45–49 age groups. In short, body thickness increased with age. Although abdominal breadth was not significantly different between the age groups, abdominal depth increased significantly; that is, the women's bodies thickened laterally as they aged.

In the shoulder angle category, the measurements were similar in all age groups. The weight was similar across age groups as well. Although we selected participants in the normal range for BMI, BMI did increase with age because the women's height decreased as they aged.

We found significant differences in all drop values except Drop 4 (Bust circumference-Underbust circumference): The results indicated that bra cup size tended to stay the same even as women aged. Drop 1 (Bust circumference-Waist circumference) was significantly lower in the age group of 55–59 years. Although both bust and waist circumference increased with age, greater increases occurred in waist circumference, which influenced Drop 4. As we interpreted these results, women in their late 50s have voluminous upper bodies with particularly large waists. Drop 2 (Hip circumference-Waist circumference) was the highest in the age group 40–44 and reduced notably with age, which could be interpreted that women in their early 40s have defined waist shapes relative to the hip. Drop 3 (Hip circumference-Bust circumference) tended to gradually decline from the 40s to 50s; women in their 50s had larger bust circumferences but hip circumferences stayed similar to those in women in their 40s.

All flat ratios (bust [Bust depth/Bust breadth], waist [Waist depth/Waist breadth], and hip [Hip depth/Hip width] flatness) increased with age. Because a large flat ratio indicates a laterally thick body, we considered that breast, waist, and hip volume increased in women's 50s, especially laterally.

Summarizing the anthropometric changes of middle-aged women by age group, the vertical bodies of the middle-aged women tended to shorten from the 40s to the 50s. The circumference, width, and thickness of the upper body were similar in the 40–44 and 45–49 age groups but increased in the early 50s, tending to be largest in the late 50s. In contrast, items related to lower body mass were larger in the 40s and tended to be smaller in the 50s. These results suggest that the changes in body mass of middle-aged women occurred at the transition from the 40s to 50s.

## Body shape classification

### *Factor analysis*

We conducted factor analysis to identify factors affecting middle-aged women's body type classification and to obtain factor scores for cluster analysis. We used 56 items related to constructing dress forms (Table 4) in factor analysis. We excluded seven computational items, four drop values and three flatness ratios, from the factor analysis because KMO and Bartlett's test showed that these variables might not have been suitable for detecting structure. The results revealed five factors accounting for the middle-aged women's body measurements (reliability from .793 to .985). Factor 1 (Upper body mass and weight) accounted for 29.479% of the total variance (Eigenvalue = 16.508). Factor 1 was explained with 26 items related to the horizontal size of the upper body and weight: bust circumference, chest circumference, underbust circumference, waist circumference, waist depth, underbust depth, waist circumference (omphalion), bust depth, waist breadth, waist depth (omphalion), BMI, underbust breadth, chest depth, bust breadth, waist breadth (omphalion), chest breadth, abdominal depth, armscye

**Table 4 Factor analysis of body measurements**

| Factor | Item | Factor loading | Eigenvalue | % of variance | Cumulative % | α |
|---|---|---|---|---|---|---|
| Factor 1. Upper body mass and weight | Bust circumference | .929 | 16.508 | 29.479 | 29.479 | .954 |
| | Chest circumference | .924 | | | | |
| | Underbust circumference | .921 | | | | |
| | Waist circumference | .901 | | | | |
| | Waist depth | .883 | | | | |
| | Underbust depth | .866 | | | | |
| | Waist circumference (omphalion) | .853 | | | | |
| | Bust depth | .846 | | | | |
| | Waist breadth | .842 | | | | |
| | Waist depth (omphalion) | .838 | | | | |
| | BMI | .800 | | | | |
| | Underbust breadth | .783 | | | | |
| | Chest depth | .772 | | | | |
| | Bust breadth | .768 | | | | |
| | Waist breadth (omphalion) | .761 | | | | |
| | Chest breadth | .756 | | | | |
| | Abdominal depth | .692 | | | | |
| | Armscye depth | .691 | | | | |
| | Hip depth | .670 | | | | |
| | Weight | .667 | | | | |
| | Bust point to Bust point | .651 | | | | |
| | Neck circumference | .603 | | | | |
| | Elbow circumference | .580 | | | | |
| | Upper arm circumference | .550 | | | | |
| | Neck base circumference | .533 | | | | |
| | Wrist circumference | .503 | | | | |
| Factor 2. Body length | Waist height | .968 | 13.815 | 24.670 | 54.149 | .985 |
| | Axilla height | .965 | | | | |
| | Shoulder height | .965 | | | | |
| | Neck Point height | .957 | | | | |
| | Cervical height | .951 | | | | |
| | Bust height | .948 | | | | |
| | Waist height (omphalion) | .948 | | | | |
| | Underbust height | .947 | | | | |
| | Neck front point height | .946 | | | | |
| | Stature | .942 | | | | |
| | Hip height | .923 | | | | |
| | Knee height | .909 | | | | |
| | Abdominal height | .652 | | | | |

**Table 4 (continued)**

| Factor | Item | Factor loading | Eigenvalue | % of variance | Cumulative % | α |
|---|---|---|---|---|---|---|
| Factor 3. Lower body mass | Abdominal breadth | .765 | 4.873 | 8.701 | 62.850 | .829 |
| | Abdominal circumference | .724 | | | | |
| | Hip circumference | .689 | | | | |
| | Hip width | .642 | | | | |
| | Thigh circumference | .596 | | | | |
| | Knee circumference | .580 | | | | |
| Factor 4. Upper body length | Waist front length (omphalion) | .770 | 3.373 | 6.022 | 68.872 | .892 |
| | Waist front length | .762 | | | | |
| | Neck point to breast point to waistline | .706 | | | | |
| | Waist back length (omphalion) | .595 | | | | |
| | Waist back length | .507 | | | | |
| Factor 5. Shoulder breadth and angle | Bishoulder length | .821 | 3.293 | 5.881 | 74.753 | .793 |
| | Bishoulder breadth | .696 | | | | |
| | Shoulder length | .679 | | | | |
| | Inclined angle of left shoulder | .560 | | | | |
| | Neck breadth | .557 | | | | |
| | Inclined angle of right shoulder | .557 | | | | |

depth, hip depth, weight, bust point to bust point, neck circumference, elbow circumference, upper arm circumference, neck base circumference, and wrist circumference.

Factor 2 (Body length) accounted for 24.670% of the total variance (Eigenvalue = 13.815). Factor 2 was explained with 13 items related to torso vertical length: waist height, axilla height, shoulder height, neck point height, cervical height, bust height, waist height (omphalion), underbust height, neck front point height, stature, hip height, knee height, and abdominal height.

Factor 3 (Lower body mass) accounted for 8.701% of the total variance (Eigenvalue = 4.873). Factor 3 was explained with 6 items related to circumference and width of the lower body: abdominal breadth, abdominal circumference, hip circumference, hip width, thigh circumference, and knee circumference.

Factor 4 (Upper body length) accounted for 6.022% of the total variance (Eigenvalue = 3.373). Factor 4 was explained with 5 items related to the length of the upper body: waist front length (omphalion), waist front length, neck point to breast point to waistline, waist back length (omphalion), and waist back length.

Factor 5 (Shoulder breadth and angle) accounted for 5.881% of the total variance (Eigenvalue = 3.293). Factor 5 was explained with 6 items related to the length of shoulder and shoulder slope: bishoulder length, bishoulder breadth, shoulder length, inclined angle of left shoulder, neck breadth, and inclined angle of right shoulder.

#### *Cluster analysis*

We used the factor scores from factor analysis for a K-means cluster analysis to classify body shape. After reviewing the results by changing the number of clusters from three to five, we determined that four clusters were optimal for classifying the body shapes of the middle-aged women and explaining the differences between clusters. In contrast, with three clusters, the body differences between each type were less clear and the number of women was biased to one group, and with five clusters, one cluster contained a very small number of women, making them inappropriate for body shape classification. In four clusters, the number of women were evenly distributed between the four body types: Type 1, 26.16% of women (n = 79); Type 2, 24.83% (n = 75); Type 3, 25.83% (n = 78); and Type 4, 23.18% (n = 70). We performed one-way ANOVA with Duncan's and Games-Howell post hoc tests to compare the mean factor scores (Table 5) and the means for the 56 body measurements for each of the four body types (Table 6). ANOVA showed significant differences between types in all measurements. The results of multiple comparisons between types through Duncan's test and Games-Howell test were as follows.

Most of the measurement items in Factor 1 (Upper body mass and weight) were largest in Type 4, followed by Types 1, 2, and 3. As we noted earlier, for this study, we only selected women who were in the normal BMI range ($18.5 \leq \text{BMI} < 25$) international WHO classification standards. However, if we were basing our study on the obesity and overweight classification in the WHO Western Pacific Region and Korean Society for the Study of Obesity, under which BMI over 23 is overweight, Types 2 and 3 would be classified as a normal weight while Types 1 and 4 would be overweight. BMI in Type 4 was the largest at 23.06. The mean weight across all middle-aged women was 54.9 kg, and individually, the means were as follows: Type 1, 57.5 kg; Type 4, 56.6 kg, Type 2, 55.9 kg; and Type 3, 49.7 kg.

Type 4 had the largest bust and waist circumferences, while Type 3's were the smallest; the means in Type 1 were similar to those for the full group of women. In addition, mean upper arm circumference, elbow circumference, waist breadth (omphalion), and neck base circumference, was the largest in Type 1, followed by Types 4, 2, and Type 3. Briefly, then, upper bodies were larger for Type 4, and Type 4 had the highest fat percentage. Type 1 also had large upper bodies, although they were smaller than those of the women in the Type 4 group. Type 3 had the smallest upper body mass.

**Table 5 Comparison of factor scores between body types (n = 302)**

| Factor | Body type | | | | |
|---|---|---|---|---|---|
| | Type 1 (n = 79) | Type 2 (n = 75) | Type 3 (n = 78) | Type 4 (n = 70) | *F* |
| 1. Upper body mass and weight | 0.102B | − 0.162C | − 0.783D | 0.930A | 58.136*** |
| 2. Body length | − 0.136B | 1.098A | − 0.757C | − 0.180B | 84.928*** |
| 3. Lower body mass | 0.935A | − 0.030B | − 0.170B | − 0.834C | 65.830*** |
| 4. Upper body length[1] | − 0.139B | − 0.335B | − 0.025B | 0.544A | 11.274*** |
| 5. Shoulder breadth and angle | 0.762A | − 0.509C | − 0.429C | 0.163B | 36.900*** |

Alphabet is the result of post hoc test (Duncan's test, [1] Games-Howell test). (A > B>C > D)

***$p < .001$

**Table 6 Measurement comparison by factors according to body types (Unit = mm)**

| Factor | Item | Mean (S.D.) | | | | | F |
|---|---|---|---|---|---|---|---|
| | | Type 1 (n = 79) | Type 2 (n = 75) | Type 3 (n = 78) | Type 4 (n = 70) | Total (n = 302) | |
| Factor 1. Upper body mass and weight | Bust circumference | 915.42B (41.24) | 900.58C (43.19) | 874.08D (44.25) | 961.64A (39.74) | 911.77 (52.38) | 55.301*** |
| | Chest Circumference | 922.89B (30.76) | 903.50C (39.31) | 877.42D (36.26) | 949.04A (29.49) | 912.39 (42.88) | 58.007*** |
| | Underbust circumference | 797.77B (38.70) | 788.83B (35.82) | 761.16C (35.47) | 827.95A (38.26) | 793.09 (43.80) | 40.670*** |
| | Waist circumference | 814.08B (49.16) | 789.83C (52.15) | 754.19D (54.98) | 833.32A (54.42) | 797.05 (60.15) | 31.498*** |
| | Waist depth | 216.64B (18.60) | 208.11C (17.87) | 199.15D (19.29) | 227.22A (18.95) | 212.45 (21.25) | 30.431*** |
| | Underbust depth | 215.93B (16.15) | 209.12C (14.28) | 204.68C (14.55) | 228.94A (15.18) | 214.35 (17.49) | 35.900*** |
| | Waist Circumference (omphalion) | 852.44A (42.47) | 829.17B (47.95) | 790.53C (47.92) | 861.84A (48.45) | 832.85 (54.05) | 35.148*** |
| | Bust depth | 240.63B (15.61) | 232.80C (15.53) | 228.17C (16.17) | 255.13A (16.05) | 238.83 (18.69) | 40.437*** |
| | Waist breadth | 289.66A (14.39) | 282.63B (16.92) | 269.56C (17.35) | 292.66A (16.94) | 283.42 (18.62) | 29.776*** |
| | Waist depth (omphalion) | 221.91B (16.43) | 213.43C (15.24) | 205.00D (17.46) | 231.01A (18.08) | 217.54 (19.29) | 32.691*** |
| | BMI | 23.03A (1.34) | 21.17B (1.38) | 21.18B (1.57) | 23.06A (1.49) | 22.10 (1.72) | 41.969*** |
| | Underbust breadth | 278.88B (12.45) | 277.10B (12.38) | 266.02C (11.02) | 284.96A (12.66) | 276.53 (13.87) | 31.864*** |
| | Chest depth | 216.00B (13.39) | 209.71C (12.80) | 206.89C (12.54) | 227.76A (12.43) | 214.81 (14.98) | 37.990*** |
| | Bust breadth | 299.19B (11.07) | 298.47B (13.09) | 286.46C (12.66) | 308.74A (14.41) | 297.94 (14.98) | 37.774*** |
| | Waist breadth (omphalion) | 304.25A (13.55) | 298.28B (16.00) | 282.51C (14.56) | 303.60A (15.17) | 297.00 (17.21) | 35.958*** |
| | Chest breadth | 319.72B (10.67) | 317.95B (13.37) | 304.98C (12.16) | 326.25A (13.03) | 316.99 (14.48) | 39.348*** |
| | Abdominal depth | 240.01A (18.25) | 228.28B (17.06) | 220.77C (21.24) | 234.94A (18.15) | 230.95 (20.07) | 15.337*** |
| | Armscye depth[1] | 121.43A (7.48) | 110.87B (9.89) | 111.31B (9.71) | 121.33A (8.48) | 116.17 (10.28) | 33.348*** |
| | Hip depth | 239.41A (12.73) | 231.71B (12.13) | 224.37C (14.58) | 240.65A (12.07) | 233.90 (14.47) | 25.903*** |
| | Weight (kg) | 57.54A (4.27) | 55.89B (4.06) | 49.69C (3.61) | 56.64AB (4.04) | 54.89 (5.07) | 61.327*** |
| | Bust point to Bust point | 177.85B (12.19) | 176.59B (10.31) | 170.48C (11.20) | 188.31A (12.34) | 178.06 (13.10) | 30.078*** |
| | Neck circumference | 348.38AB (19.78) | 342.00B (23.95) | 329.15C (14.02) | 352.93A (22.39) | 342.88 (22.09) | 19.613*** |
| | Elbow circumference | 244.20A (11.91) | 233.79B (10.03) | 229.30C (9.72) | 241.21A (10.48) | 237.07 (12.10) | 31.948*** |
| | Upper arm circumference | 318.53A (16.33) | 300.20B (18.77) | 298.02B (17.05) | 315.40A (16.61) | 307.96 (19.39) | 28.039*** |
| | Neck base circumference | 386.29A (14.80) | 380.94B (14.08) | 368.77C (12.84) | 384.28AB (16.61) | 379.97 (16.08) | 22.391*** |
| | Wrist circumference | 165.81A (8.95) | 164.24A (7.35) | 157.31B (6.92) | 166.28A (8.57) | 163.33 (8.74) | 20.839*** |

**Table 6 (continued)**

| Factor | Item | Mean (S.D.) | | | | | *F* |
|---|---|---|---|---|---|---|---|
| | | Type 1 (n = 79) | Type 2 (n = 75) | Type 3 (n = 78) | Type 4 (n = 70) | Total (n = 302) | |
| Factor 2. Body length | Waist height | 949.05B (30.51) | 986.96A (26.18) | 919.46D (25.70) | 938.33C (33.16) | 948.34 (37.97) | 73.098*** |
| | Axilla height | 1163.64B (35.02) | 1213.32A (36.25) | 1132.87C (32.51) | 1156.95B (40.42) | 1166.48 (46.35) | 66.642*** |
| | Shoulder height | 1271.96B (37.24) | 1321.77A (36.18) | 1237.32C (32.64) | 1265.37B (42.99) | 1273.86 (48.10) | 67.467*** |
| | Neck point height | 1323.88B (38.03) | 1366.22A (37.03) | 1282.27C (33.89) | 1313.25B (43.63) | 1321.18 (48.54) | 62.972*** |
| | Cervical height | 1342.27B (39.04) | 1383.97A (37.38) | 1299.89C (34.97) | 1331.59B (45.01) | 1339.21 (49.31) | 60.019*** |
| | Bust height | 1109.64B (36.05) | 1160.67A (35.16) | 1082.01C (34.22) | 1105.35B (40.98) | 1114.18 (46.43) | 62.229*** |
| | Waist height (omphalion) | 908.17B (31.20) | 947.39A (26.30) | 879.12D (28.45) | 894.12C (35.41) | 907.15 (39.54) | 70.083*** |
| | Underbust height | 1056.22B (36.34) | 1106.31A (35.24) | 1029.91C (34.11) | 1047.19B (40.48) | 1059.77 (46.17) | 60.974*** |
| | Neck front point height | 1281.53B (37.42) | 1324.40A (37.09) | 1243.98C (33.14) | 1275.18B (42.35) | 1281.01 (47.18) | 59.356*** |
| | Stature | 1588.58B (43.17) | 1634.93A (42.79) | 1542.75C (38.32) | 1576.57B (48.42) | 1585.47 (54.31) | 59.378*** |
| | Hip height | 765.04B (27.52) | 803.03A (25.62) | 740.44C (25.24) | 767.71B (32.54) | 768.74 (35.60) | 65.639*** |
| | Knee height | 409.67B (14.06) | 427.29A (12.78) | 397.76C (11.64) | 408.96B (15.03) | 410.81 (17.05) | 63.101*** |
| | Abdominal height[1] | 865.65B (38.57) | 911.77A (40.24) | 847.45C (40.91) | 918.89A (53.27) | 884.74 (52.64) | 48.487*** |
| Factor 3. Lower body mass | Abdominal breadth | 322.71A (18.91) | 310.79B (18.74) | 298.00C (20.89) | 296.26C (21.64) | 307.24 (22.68) | 28.982*** |
| | Abdominal circumference | 904.35A (51.19) | 867.15B (53.79) | 833.59C (62.05) | 848.72C (60.36) | 863.94 (62.72) | 22.391*** |
| | Hip circumference | 953.61A (30.88) | 928.84B (35.84) | 895.54C (33.53) | 922.62B (27.28) | 925.28 (38.28) | 43.252*** |
| | Hip width | 348.56A (12.46) | 342.96B (13.46) | 328.51D (11.67) | 333.83C (10.95) | 338.58 (14.47) | 42.145*** |
| | Thigh circumference | 560.20A (25.10) | 536.28B (26.11) | 523.82C (26.16) | 539.84B (25.97) | 540.14 (28.97) | 26.831*** |
| | Knee circumference | 362.71A (16.96) | 354.83B (14.62) | 342.42C (14.25) | 352.16B (12.97) | 353.07 (16.50) | 24.990*** |
| Factor 4. Upper body length | Waist front length (omphalion)[1] | 393.61BC (17.97) | 396.93B (24.18) | 385.75C (20.11) | 407.91A (16.66) | 395.72 (21.36) | 15.585*** |
| | Waist front length[1] | 353.34B (14.63) | 357.92AB (19.24) | 346.00C (16.14) | 364.51A (15.07) | 355.17 (17.61) | 16.801*** |
| | Neck point to breast point to waistline[1] | 420.09B (15.16) | 425.03AB (21.02) | 411.64C (16.56) | 432.26A (17.90) | 421.96 (19.17) | 17.704*** |
| | Waist back length (omphalion) | 451.39A (25.56) | 449.15A (20.30) | 433.85B (22.43) | 451.62A (22.85) | 446.36 (23.97) | 10.641*** |
| | Waist Back length | 411.02A (27.83) | 410.11A (17.45) | 394.15B (19.11) | 408.30A (18.46) | 405.81 (22.26) | 10.762*** |

**Table 6 (continued)**

| Factor | Item | Mean (S.D.) | | | | | *F* |
|---|---|---|---|---|---|---|---|
| | | Type 1 (n = 79) | Type 2 (n = 75) | Type 3 (n = 78) | Type 4 (n = 70) | Total (n = 302) | |
| Factor 5. Shoulder breadth and angle | Bishoulder length | 393.49A (15.81) | 384.49B (15.61) | 370.67C (13.74) | 388.72AB (16.68) | 384.26 (17.65) | 31.406*** |
| | Bishoulder breadth | 353.03A (11.85) | 350.16A (12.58) | 335.60B (11.32) | 349.58A (13.12) | 347.01 (13.96) | 31.801*** |
| | Shoulder length | 127.25A (7.59) | 125.22A (7.83) | 119.39B (6.59) | 125.46A (8.42) | 124.30 (8.15) | 15.686*** |
| | Inclined angle of left shoulder | 25.63A (2.85) | 22.51C (3.33) | 23.52BC (3.01) | 23.99B (3.52) | 23.93 (3.36) | 12.951*** |
| | Neck Breadth | 123.58A (5.16) | 120.76B (5.56) | 116.92C (4.56) | 121.63B (5.51) | 120.71 (5.73) | 22.506*** |
| | Inclined angle of right shoulder | 24.77A (2.50) | 21.48C (3.06) | 22.74B (3.39) | 23.29B (3.16) | 23.09 (3.25) | 15.492*** |

Alphabet is the result of post hoc test (Duncan's test, [1] Games-Howell test). (A > B > C > D)

***$p < .001$

For most items in Factor 2 (Body length), Type 2 was the longest, followed by Types 1 and 4, and Type 3 was the shortest. The mean stature of the women as a group was 158.5 cm, which Type 1 and 4 were close to. Type 2 was the tallest body type with a mean stature of 163.5 cm, while Type 3 was the shortest at a mean of 154.3 cm. For waist height, Type 2 was the longest and Type 3 was the shortest, and for abdominal height, the longest were Types 4 and 2, followed by Type 1 and then Type 3. Overall, the women with body Type 2 had longer body characteristics and the women of Type 3 were shorter.

Among the items in Factor 3 (Lower body mass), for abdominal circumference and abdominal breadth Type 1 was the largest, followed by Type 2, and Types 3 and 4 were similarly the smallest. The mean hip circumference for the women as a group was 92.5 cm, with Types 2 and 4 close to this mean; Type 1 was significantly larger than the other body types, and Type 3 was the smallest. For hip width, thigh circumference, and knee circumference, Type 1 was also the largest, followed by Types 2, 4, and 3. That is, Type 4 had smaller lower body mass but the largest BMI and upper body mass; Type 1 had the largest lower body mass and the second largest upper body mass. Type 3 had small upper and lower bodies.

In Factor 4 (Upper body length), Type 4 had the largest values for all items except waist back length. Type 4's mean waist front length (omphalion) was 40.8 cm, the longest, while Type 3 had the shortest mean waist front was 38.6 cm. For waist back length, Types 1, 2, and 4 had similar means, while Type 3's was the smallest. Overall, Type 2 had long bodies but comparatively short upper bodies, and Type 4 had longer upper bodies than lower. We considered that Type 3 had shorter upper bodies than the other types because that type had the shortest overall body length.

Among the items in Factor 5 (Shoulder breadth and angle), the overall mean bishoulder length was 38.4 cm, Type 1's was the longest at 39.3 cm, and Type 3's was the shortest at 37.1 cm. For bishoulder breadth, shoulder length, and neck breadth, Type 1 was

**Table 7 Drop value and flatness ratio comparison according to body types**

| Item | | Body type<br>Mean (S.D.)<br>Type 1 (n = 79) | Type 2 (n = 75) | Type 3 (n = 78) | Type 4 (n = 70) | Total (n = 302) | *F* |
|---|---|---|---|---|---|---|---|
| Drop Value | Drop 1 (Bust circumference-Waist circumference) | 101.34C (36.93) | 110.76BC (35.75) | 119.89AB (31.64) | 128.32A (36.24) | 114.72 (36.41) | 8.175*** |
| | Drop 2 (Hip circumference-Waist circumference) | 139.53A (46.14) | 139.01A (47.25) | 141.35A (43.19) | 89.30bB (46.68) | 128.23 (50.37) | 21.977*** |
| | Drop 3 (Hip circumference-Bust circumference) | 38.19A (39.71) | 28.26AB (40.99) | 21.46B (36.19) | -39.02C (35.12) | 13.51 (48.08) | 60.184*** |
| | Drop 4 (Bust circumference-under-bust circumference) | 117.65B (25.15) | 111.76B (24.58) | 112.92B (26.37) | 133.68A (24.15) | 118.68 (26.40) | 11.647*** |
| Flatness ratio. | Bust flatness ratio (Bust depth/Bust breadth) | 0.80B (0.05) | 0.78C (0.05) | 0.80B (0.05) | 0.83A (0.05) | 0.80 (0.05) | 11.658*** |
| | Waist flatness ratio (Waist depth/Waist breadth) | 0.75B (0.04) | 0.74B (0.04) | 0.74B (0.04) | 0.78A (0.04) | 0.75 (0.05) | 12.830*** |
| | Hip flatness ratio (Hip depth/Hip width) | 0.69B (0.04) | 0.68B (0.04) | 0.68B (0.05) | 0.72A (0.04) | 0.69 (0.04) | 17.279*** |

Alphabet is the result of Duncan's post hoc test (A > B > C)

***$p < .001$

the largest, followed by Types 2 and 4, and Type 3 was the smallest. For both right and left shoulder angle, Type 1 was the largest, followed by Types 4, 3, and 2. Type 1 had a wide and slightly sloping shoulder, and Type 3 had the narrowest shoulder.

We also conducted one-way ANOVA and Duncan's post hoc test using four drops and three flatness ratios to identify the body shapes of middle-aged women. For all drop values and flatness ratios, the result showed significant differences between the four types (Table 7). Because Type 1 had the highest mean for Drop 3 (Hip circumference-Bust circumference) and the lowest for Drop 1 (Bust circumference-Waist circumference), Type 1 had the most developed lower body mass. Considering that Type 1 had the second-largest bust circumference, Type 1 also had more developed body mass on the waist than at the bust. For the flatness ratios, Type 1 had a smaller hip flatness ratio (Hip Depth/Hip Breadth) than that of Type 4, indicating that Type 1 had a wider, flatter hip than Type 4 considering that Type 1 had the largest hip circumference.

Type 2 had the smallest Drop 4 (Bust circumference-Underbust circumference), reflecting a small bust cup. All of Type 2's flat ratios were the lowest, reflecting relatively flat busts, waists, and hips. Type 3 had the largest Drop 2 (Hip circumference-Waist circumference), indicating a slightly more developed lower body even though Type 3 was small overall. In addition, given that Type 3 had one of the larger Drop 1 (Bust circumference-Waist circumference) values even with comparatively small bust circumference and the smallest waist circumference, Type 3 presented with a narrow waist. All of Type 3's flat ratios were in the middle of the four groups' values.

For Type 4, Drop 1 (Bust circumference-Waist circumference) and Drop 4 (Bust circumference-Underbust circumference) were the largest among all body types, reflecting a large breast. In contrast, Type 4 had the smallest Drop 2 (Hip circumference-Waist circumference) and Drop 3 (Hip circumference-Bust circumference), reflecting smaller lower than upper body mass. Type 4 had the largest flat ratios of the four groups, which appeared to indicate the most voluminous lateral breast, waist, and hip areas despite the smaller lower than upper body masses.

Comparing all four body types, Type 1 had broad shoulders and slightly developed upper body areas such as the chest and arms but more developed lower bodies such as in the belly and hip areas; however, Type 1 had flatter hips even with the more developed lower bodies. Type 2 had a relatively high shoulder slope, with long overall body length and height, in particular with longer legs than upper bodies; Type 2 was also a relatively slim figure with flat busts, waists, and hips. Type 3 had a narrow shoulder and short overall vertical length, including upper torso, and smaller upper and lower bodies than the other types; in particular, Type 3 had a thinner waist and a slightly more developed lower than upper body. Type 4 had the largest upper body mass, with the greatest fat ratio, and a relatively small lower body. Also, the body length of Type 4 also had a mid-level body length but with a long upper and relatively short lower body. In addition, the breast, waist, and hip areas were thickest by breadth, especially at the bust. Examples of the body-scanned images from Size Korea data for each body type and their major measurements are shown in Table 8. These women were judged as the best examples of the four body types among participants because their overall measurements were most similar to the means for each type including BMI, drop values, length, girth, breadth, and depth from chest to hip. We thus interpreted that these women well reflected the characteristics of each body type.

### *Discriminant analysis*

We performed a discriminant analysis to find the key measurements that can be used to classify the body types of middle-aged women and to develop a method for this classification. We extracted nine measurements as the key variables for best distinguishing the four groups that the cluster analysis identified: waist height, abdominal height, bishoulder length, waist front length (omphalion), bust circumference, hip circumference, abdominal breadth, inclined angle of right shoulder, and BMI. The stature and waist circumference, which are generally considered key factors body type determination, were not included. However, stature can be reflected in the vertical length of the torso, such as waist and abdomen height. The bust, abdomen, and hips appeared to better distinguish the women's body types than did the waist.

We found a total of three DFs (degrees of freedom). In Table 9, the first row, "1 through 3," shows the statistical significance of the model that combined DF 1, DF 2, and DF 3; the model with all DFs had a consequential role in predicting group membership: Wilks' Lambda = 0.109, $x^2$ (27) = 653.30, $p<.001$. The model with both DF 2 and DF 3 predicted group classification significantly: Wilks' Lambda = 0.265, $x^2$ (16) = 390.90, $p<.001$. The model with DF 3 alone importantly predicted group classification: Wilks' Lambda = 0.529, $x^2$ (7) = 187.688, $p<.001$. Table 10 presents the proportions of explained variance for DF 1, DF 2, and DF 3: DF 1 predicted 43.3% of the variance, followed by DF 2 for 29.9% and DF 3 for 26.8% of the variance. Therefore, it was clear that all DFs should be combined to explain 100% of the variance.

**Table 8 Examples of 3D scanned images and measurements according to four body types (Unit = mm)**

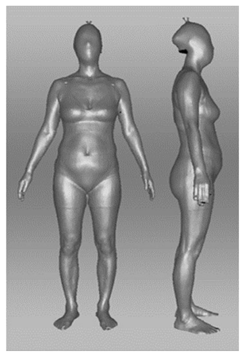
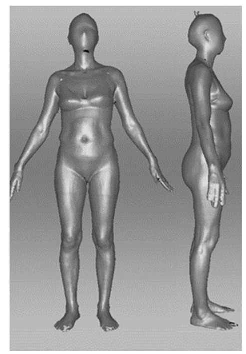
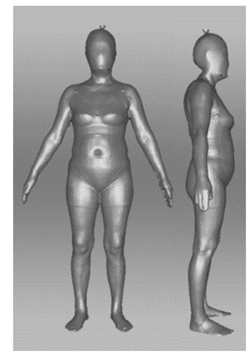
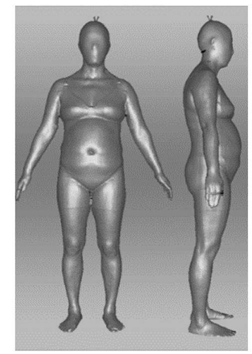
| | Type 1 | Type 2 | Type 3 | Type 4 |
|---|---|---|---|---|
| 3D image |  |  |  |  |
| BMI | 22.2 | 20.6 | 20.6 | 23.9 |
| Stature | 1602 | 1635 | 1484 | 1584 |
| Weight (kg) | 55.9 | 54.5 | 44.8 | 60.0 |
| Bust circumference | 917 | 877 | 879 | 1005 |
| Waist circumference | 782 | 759 | 765 | 883 |
| Hip circumference | 966 | 914 | 882 | 940 |

**Table 9 Wilks' Lambda**

| Test of functions | Wilks' Lambda | Ch-square | Df | Sig. |
|---|---|---|---|---|
| 1 through 3 | 0.109 | 653.299 | 27 | 0.000 |
| 2 through 3 | 0.265 | 390.904 | 16 | 0.000 |
| 3 | 0.529 | 187.688 | 7 | 0.000 |

The standardized canonical discriminant function coefficients showed that the independent variables used to construct the DFs had unique contributions to the discriminant functions (Table 11); the standardized coefficients for each variable were significant. For instance, for DF 1, bust circumference was the important predictor with a coefficient of 0.775, followed by abdominal height (0.592) and waist front length (0.414). For DF 2, bishoulder length was the significant predictor with a coefficient of 0.646, followed by BMI (0.600) and hip circumference (0.494). For DF 3, waist height was the crucial predictor with a coefficient of 0.718, followed by abdominal height (0.534) and abdominal breadth (0.468). The coefficients of these canonical variables were effective for calculating a canonical variable score for each case.

Table 12 reflects that we used the classification function coefficients from Fisher's linear discriminant to assign each case to a group. Each column contains estimated coefficients for classifying function for each group, so that with a person's key measurements, it is possible to predict that person's body type. By multiplying each coefficient by the value of the corresponding variable and summing the products and constant, we could classify each case into a group based on the scores; specifically, the person belongs to the group with the highest scores in the calculation. The estimates of the classification function for groups were as follows:

$$\begin{aligned}\text{DF 1} = {} & (a \times 1.024) + (b \times 0.111) + (c \times 1.058) + (d \times 0.167) \\ & + (e \times 0.060) + (f \times 0.006) + (g \times -0.189) \\ & + (h \times 2.704) + (i \times 19.988) + (-1100.383)\end{aligned}$$

$$\begin{aligned}\text{DF 2} = {} & (a \times 1.086) + (b \times 0.127) + (c \times 0.956) \\ & + (d \times 0.165) + (e \times 0.083) + (f \times -0.037) \\ & + (g \times 0.195) + (h \times 2.298) + (i \times 19.153) + (-1089.714)\end{aligned}$$

$$\begin{aligned}\text{DF 3} = {} & (a \times 1.013) + (b \times 0.098) + (c \times 0.956) \\ & + (d \times 0.189) + (e \times 0.081) + (f \times -0.018) \\ & + (g \times 0.132) + (h \times 2.483) + (i \times 18.770) + (-996.340)\end{aligned}$$

$$\begin{aligned}\text{DF 4} = {} & (a \times 0.987) + (b \times 0.153) + (c \times 1.021) \\ & + (d \times 0.232) + (e \times 0.128) + (f \times -0.055) \\ & + (g \times 0.141) + (h \times 2.582) + (i \times 19.492) + (-1091.934)\end{aligned}$$

To evaluate the accuracy of the DFs when classifying middle-aged women into one of the four body types, we compared the original results of membership by cluster analysis and the group membership results predicted by the DFs (Table 13). Overall,

**Table 10 Eigenvalues of functions**

| Function | Eigenvalue | % of variance | Cumulative % | Canonical correlation |
|---|---|---|---|---|
| 1 | 1.438 | 43.3 | 43.3 | 0.768 |
| 2 | 0.994 | 29.9 | 73.2 | 0.706 |
| 3 | 0.891 | 26.8 | 100.0 | 0.687 |

**Table 11 Standardized canonical discriminant function coefficients**

| Variable | Function | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| a. Waist height | −.622 | −.312 | .718 |
| b. Abdominal height | .592 | −.120 | .534 |
| c. Bishoulder length | .203 | .646 | .073 |
| d. Waist front length (omphalion) | .414 | −.104 | −.141 |
| e. Bust circumference | .775 | −.456 | .086 |
| f. Hip circumference | −.402 | .494 | −.245 |
| g. Abdominal breadth | −.241 | .199 | .468 |
| h. Inclined angle of right shoulder | .125 | .403 | −.169 |
| i. BMI | .112 | .600 | .272 |

**Table 12 Classification function coefficients of Fisher's linear discriminant**

| Variable | Function | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| a. Waist height | 1.024 | 1.086 | 1.013 | .987 |
| b. Abdominal height | .111 | .127 | .098 | .153 |
| c. Bishoulder length | 1.058 | .956 | .956 | 1.021 |
| d. Waist front length (omphalion) | .167 | .165 | .189 | .232 |
| e. Bust circumference | .060 | .083 | .081 | .128 |
| f. Hip circumference | .006 | −.037 | −.018 | −.055 |
| g. Abdominal breadth | .189 | .195 | .132 | .141 |
| h. Inclined angle of right shoulder | 2.704 | 2.298 | 2.483 | 2.582 |
| i. BMI | 19.988 | 19.153 | 18.770 | 19.492 |
| Constant | −1100.383 | −1089.714 | −996.340 | −1091.934 |

the DFs correctly classified 87.4% of participants, which we considered sufficiently accurate to predict body type.

### *Distribution of body types by age*

We used Chi-square statistics to examine the relationships between the two age groups (40s and 50s) and four body types (Table 14), and there were significant differences among the age groups ($\chi^2 = 10.460^*$, $p < .05$). By type, women in their 40s were distributed in the order of Type 1, Type 2, Type 3, and Type 4; the women in their 50s were distributed in the order of Types 4, 3, 2, and 1.

**Table 13 Classification result**

| | | | Predicted group membership | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | |
| Original group membership | Count | 1 | 71 | 3 | 4 | 1 | 79 |
| | | 2 | 3 | 65 | 4 | 3 | 75 |
| | | 3 | 4 | 4 | 66 | 4 | 78 |
| | | 4 | 4 | 1 | 3 | 62 | 70 |
| | % | 1 | 89.9 | 3.8 | 5.1 | 1.3 | 100.0 |
| | | 2 | 4.0 | 86.7 | 5.3 | 4.0 | 100.0 |
| | | 3 | 5.1 | 5.1 | 84.6 | 5.1 | 100.0 |
| | | 4 | 5.7 | 1.4 | 4.3 | 88.6 | 100.0 |

Overall 87.4% of the originally grouped cases were correctly classified

**Table 14 Relationships between body types and age groups n(col. %)**

| Body type | Age group | | Total | Ch-square |
|---|---|---|---|---|
| | 40s | 50s | | |
| Type 1 | 49 (30.8) | 30 (21.0) | 79 (26.2) | 10.460* |
| Type 2 | 45 (28.3) | 30 (21.0) | 75 (24.8) | |
| Type 3 | 38 (23.9) | 40 (28.0) | 78 (25.8) | |
| Type 4 | 27 (17.0) | 43 (30.1) | 70 (23.2) | |
| Total | 159 (100.0) | 143 (100.0) | 302 (100.0) | |

* $p<.05$

Type 1, with a larger lower body than the upper body, had a higher percentage of women in their 40s (30.8%, n = 49) than women in their 50s (21.0%, n = 30). Type 2 had long, thin bodies, and by age, 28.3% (n = 45) of the women were in their 40s and 21.0% (n = 30) were in their 50s. Type 3, which had short bodies with small body mass, comprised 23.9% (n = 38) women in their 40s and 28.0% (n = 40) women in their 50s. In Type 4, with significantly larger upper than lower bodies, there was a larger percentage of women in their 50s than in their 40s (30.1%, n = 43 vs. 17.0%, n = 27). By these results, women in their 40s had balanced upper and lower bodies and their lower bodies tended to be developed, whereas women in their 50s had voluminous upper bodies and flat lower body bodies. These findings corresponded with the earlier results of analyzing the anthropometric characteristics according to age group (Table 3): Lower body mass in the hip and thigh were larger in women in their 40 s, and upper body mass increased significantly with age.

## Conclusion

In this study, we investigated the anthropometric characteristics of middle-aged women and classified the representative body types using the three-dimensional measurement data from the 6th Size Korea. We performed more complete research using more accurate 3D measurement data than the data from the traditional methods and included items such as depth and angle, which are difficult to obtain in 2D measurement. In addition to presenting measurement information and the results of statistical analysis, we presented 3D scanned images of participants who had the closest distances from their cluster centers to more clearly show the body shape differences across types. Whereas previous researchers who classified body shapes (Kim 2014; Masuda et al. 2007; Olds et al. 2013; Viktor et al. 2006) performed only factor and cluster analysis, we added discriminant analysis to this study to identify key variables that distinguish the body types of middle-aged women.

Five factors accounted for the middle-aged women's body measurements; each factor clearly represented a grouping of measurement items that together composed the women's different body shapes: Factor 1, Upper body mass and weight; Factor 2 Body length; Factor 3, Lower body mass; Factor 4, Upper body length; Factor 5, Shoulder breadth and angle.

Cluster analysis revealed four body types among middle-aged women aged 40 to 59. Although four clusters might not have sufficiently accounted for the overall variance, they were more detailed and less biased than were fewer clusters; dividing the characteristics into more clusters resulted in a very small percentage of the population that was not suitable for use in the analysis. Type 1 had a broader shoulder and a slightly developed upper body, such as chest and upper arm, but more developed lower bodies. Type 2 had a longer vertical bodies that were relatively thin and flat. Type 3 had shorter shoulders and bodies with smaller upper and lower bodies and more developed lower bodies than upper. Type 4 had the largest upper bodies and the highest BMI, bulky chests, comparatively small lower bodies, and longer upper bodies. By age group distribution, there were more women in their 40s distributed in Types 1 and 2 and more in their 50s in Types 3 and 4.

The discriminant analysis revealed that 9 out of 56 variables were key measurements for distinguishing the body types of middle-aged women: waist height, abdominal height, bishoulder length, waist front length (omphalion), bust circumference, hip circumference, abdominal breadth, inclined angle of right shoulder, and BMI. These key measurements are significant for the apparel industry because they can be utilized for providing customized garment fit based on the characteristics of the target group. Discriminant analysis identified three DFs, with 87.4% accuracy of the predicted results for group membership compared with the original results by cluster analysis; we considered that the classification by computation of all DFs had high accuracy.

For this study, we explored the anthropometric characteristics of middle-aged women according to age group using simply descriptive statistics and ANOVA; these results were consistent with the cluster distribution by age group after cluster analysis. Our study results showed that middle-aged female body types could be classified and that there were significant differences according to each type and age group. The representative body shape and size characteristics we obtained in this study can serve as basic data for developing dress forms that represent the bodies of middle-aged women.

Although middle-aged women's consumption power related to their increasing self-expression and social participation are not negligible in the apparel industry, there has been a lack of research to date on the anthropometric characteristics of this population.

The significance of this study is that we focused on middle-aged women whereas previous researchers have studied either young adults only or entire age groups (Alexander et al. 2012; Song and Ashdown 2011; Wells et al. 2008). In addition, we developed a deeper method by combining the cluster and discriminant analysis; the discriminant analysis identified the relative importance of each variable in the cluster analysis. In contrast with previous researchers who only studied women's lower or upper bodies, we analyzed a number of torso-related measurements to give more complete descriptions of the middle-aged women's body shapes.

For this study, we only used women of the normal weight range, and we did not consider plus size or underweight women. The normal weight range accounts for the largest proportion of middle-aged women, and as such these results are not affected by extreme values; this increases the possibility that our results will be utilized to improve fit in the apparel industry and best suited for representing a wide range of body characteristics. However, future research on the body characteristics of plus-size and overweight women, who compose a relatively large proportion of the population of middle-aged women, would be meaningful for further improving garment fit for this group of women.

With this study, we focused on analyzing 3D and direct measurement data of middle-aged women age 40–59 and presented 3D image examples of each body type. In subsequent studies, it is necessary to examine detailed body shape characteristics such as bust angle that cannot be analyzed from the existing measurement data. Also, it would be meaningful to investigate the changes in the dimensions between dynamic and static postures using 3D scanned data from representative body types.

**Acknowledgements**
Not applicable.

**Authors' contributions**
MY analyzed the data, discussed the results, proposed the conclusion of this study, and drafted the manuscript. DK guided the design of the study and finalized the manuscript. Both authors read and approved the final manuscript.

**Funding**
This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea government (MSIT) (No. NRF-2018R1C1B5031230).

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

**Competing interests**
The authors declare that they have no competing interests.

**Author details**
[1] Graduate Student, Department of Fashion Industry, Ewha Womans University, #402-3, Human Ecology Building (Morris Hall), 52, Ewhayeodae-gil, Seodaemun-gu, Seoul 03760, South Korea. [2] Associate Professor, Department of Fashion Industry, Ewha Womans University, #402-3, Human Ecology Building (Morris Hall), 52, Ewhayeodae-gil, Seodaemun-gu, Seoul 03760, South Korea.

Received: 23 April 2020 Accepted: 17 August 2020
Published online: 15 November 2020

**References**
Alexander, M., Pisut, G. R., & Ivanescu, A. (2012). Investigating women's plus-size body measurements and hip shape variation based on SizeUSA data. *International Journal of Fashion Design, Technology and Education, 5*(1), 3–12. https://doi.org/10.1080/17543266.2011.589083.

Birtwistle, G., & Tsim, C. (2005). Consumer purchasing behaviour: an investigation of the UK mature women's clothing market. *Journal of Consumer Behaviour, 4*(6), 453–464. https://doi.org/10.1002/cb.31.

Campbell, L. D., & Horne, L. (2001). Trousers developed from the ASTM D5586 and the Canada Standard Sizing for women's apparel. *Clothing and Textiles Research Journal, 19*(4), 185–193. https://doi.org/10.1177/0887302X0101900404.

Chun, J. S., & Lee, S. Y. (2015). The upper body type classification of middle-aged and elderly Korean women. *The Research Journal of the Costume Culture, 23*(3), 512–522. https://doi.org/10.7741/rjcc.2015.23.3.512.

Connell, L. J., Ulrich, P. V., Brannon, E. L., Alexander, M., & Presley, A. B. (2006). Body shape assessment scale: *Instrument development for analyzing female figures*. *Clothing and Textiles Research Journal, 24*(2), 80–95. https://doi.org/10.1177/0887302X0602400203.

Felsted, A., & Cohen, N. (2013). Fashion: A mature market. *Financial Times.* Retrieved from https://www.ft.com/content/78098abe-67d9-11e3-a905-00144feabdc0.

Goldsberry, E., Shim, S., & Reich, N. (1996). Women 55 years and older: Part II. Overall satisfaction and dissatisfaction with the fit of ready-to-wear. *Clothing and Textiles Research Journal, 14*(2), 121–132. https://doi.org/10.1177/0887302X9601400203.

Handley, L. (2014). How women aged over 50 shop for fashion. *Marketing Week.* Retrieved from https://www.marketingweek.com/2014/02/10/how-women-aged-over-50-shop-for-fashion/.

Ho, S. C., Wu, S., Chan, S. G., & Sham, A. (2010). Menopausal transition and changes of body composition: a prospective study in Chinese perimenopausal women. *International Journal of Obesity, 34*(8), 1265. https://doi.org/10.1038/ijo.2010.33.

Kalichman, L., & Kobyliansky, E. (2006). Sex-and age-related variations of the somatotype in a Chuvasha population. *Homo, 57*(2), 151–162. https://doi.org/10.1016/j.jchb.2006.01.002.

Kang, J. S. (2011). *A study on gal ot dress pattern: in the case of their 50's (Unpublished master's thesis)*. Jeju-do: Jeju National University.

Kim, D. E. (2014). Analysis of body characteristics of the US women aged from 26 to 45 using 3D body scan data. *International Journal of Human Ecology, 15*(2), 13–21. https://doi.org/10.6115/ijhe.2014.15.2.13.

Kim, Y. K. (2016). A comparison of upper body sizes and body types of women in their 20s and 30s–40s: identifying problems generated by preferences of women in their 30s and 40s for young casual brands. *Journal of the Korea Fashion & Costume Design Association, 18*(2), 15–33.

Kim, N., & Do, W. (2019). Developing elderly men's footwear sizing system based on their foot shapes. *Fashion and Textiles, 6*(1), 1–18. https://doi.org/10.1186/s40691-019-0184-2.

Kim, J. Y., You, J. W., & Kim, M. S. (2017). South Korean anthropometric data and survey methodology: 'Size Korea'project. *Ergonomics, 60*(11), 1586–1596. https://doi.org/10.1080/00140139.2017.1329940.

Korean Agency for Technology & Standards. (2012). *The national anthropometric survey of Korea 2012*. Seoul: KATS.

Lee, K. H. (2011). An analysis of the physical characteristics of the middle aged woman's lower body somatotype based on the body index. *Journal of Korean Traditional Costume, 14*(3), 33–49.

Lee, J. J. (2014). Classification of lower body shape of middle-aged women (aged 40 to 59). *Journal of the Korea Fashion & Costume Design Association, 16*(4), 27–36.

Lee, J. Y., Istook, C. L., Nam, Y. J., & Park, S. M. (2007). Comparison of body shape between USA and Korean women. *International Journal of Clothing Science and Technology, 19*(5), 374–391. https://doi.org/10.1108/09556220710819555.

Lee, K. S., Song, H. K., & Kim, S. (2020). Categorization of lower body shapes of abdominal obese men using a script-based 3D body measurement software. *Fashion and Textiles, 7*(1), 1–16. https://doi.org/10.1186/s40691-019-0199-8.

Lee, Y. K., & Lee, J. Y. (2008). Classification of lateral body type for elderly women: Focused on lateral posture and obesity. *Journal of the Korean Society of Fashion Design, 8*(2), 1–22.

Lin, Y. C., Wang, M. J. J., & Wang, E. M. (2004). The comparisons of anthropometric characteristics among four peoples in East Asia. *Applied Ergonomics, 35*(2), 173–178. https://doi.org/10.1016/j.apergo.2004.01.004.

Loh, F. H., Khin, L. W., Saw, S. M., Lee, J. J., & Gu, K. (2005). The age of menopause and the menopause transition in a multiracial population: a nation-wide Singapore study. *Maturitas, 52*(3–4), 169–180. https://doi.org/10.1016/j.maturitas.2004.11.004.

Masuda, T., Nishi, M., Nanao, H., & Okabe, H. (2007). Classification of three-dimensional body shape based on the extraction of body shape image words for young women. *Sen'i Gakkaishi, 63*(2), 23–32. https://doi.org/10.2115/fiber.63.23.

Mckinlay, S. M. (1996). The normal menopause transition: an overview. *Maturitas, 23*(2), 137–145. https://doi.org/10.1016/0378-5122(95)00985-x.

Mclorg, P. A. (2005). Anthropometric patterns in middle-aged and older rural Yucatec Maya women. *Annals of Human Biology, 32*(4), 487–497. https://doi.org/10.1080/03014460500129337.

Nam, Y. R., Choi, H. S., & Lee, J. H. (2013). A study on the middle-aged women's body type changes for clothing construction-focused on the 5th and 6th Size Korea's anthropometric data. *Fashion & Textile Research Journal, 15*(4), 583–595.

Nam, Y. R., & Kim, D. E. (2018). Middle-aged Women's Jacket Fit and Design Preference according to Down-aging Consumption. *Journal of the Korean Society of Clothing and Textiles, 42*(4), 657–670. https://doi.org/10.5850/JKSCT.2018.42.4.657.

Newcomb, E. A. (2006). *Body shape analysis of Hispanic women in the United States (Unpublished Master's Thesis)*. Raleigh: North Carolina State University.

Olds, T., Daniell, N., Petkov, J., & Stewart, A. D. (2013). Somatotyping using 3D anthropometry: a cluster analysis. *Journal of Sports Sciences, 31*(9), 936–944. https://doi.org/10.1080/02640414.2012.759660.

Park, S., Hong, K., Choi, Y., Lee, J. S., & Lee, Y. (2019). Suggestion of yoga wear prototype design for women over 50s based on market survey. *Journal of the Korean Society of Clothing and Textiles, 43*(2), 243–254. https://doi.org/10.5850/JKSCT.2019.43.2.243.

Shin, J. Y. A., & Nam, Y. J. (2015). A study on body shape for 3D virtual body shape transformation: Focusing on the women with age of forties. *Fashion & Textile Research Journal, 17*(2), 265–277. https://doi.org/10.5805/SFTI.2015.17.2.265.

Simmons, K., Istook, C. L., & Devarajan, P. (2004). Female figure identification technique (FFIT) for apparel. Part II: development of shape sorting software. *Journal of Textile and Apparel, Technology and Management, 4*(1), 1–16.

Sohn, J. M., & Kim, D. E. (2017). A study on the torso body size and body shape classification of obese adult women. *The Research Journal of the Costume Culture, 25*(5), 561–576. https://doi.org/10.29049/rjcc.2017.25.5.561.

Song, H. K., & Ashdown, S. P. (2011). Categorization of lower body shapes for adult females based on multiple view analysis. *Textile Research Journal, 81*(9), 914–931. https://doi.org/10.1177/0040517510392448.

Sternfeld, B., Bhat, A. K., Wang, H., Sharp, T., Charles, P., & Quesenberry, J. R. (2005). Menopause, physical activity, and body composition/fat distribution in midlife women. *Medicine and Science in Sports and Exercise, 37*(7), 1195–1202. https://doi.org/10.1249/01.mss.0000170083.41186.b1.

Suh, D., & Oh, S. Y. (2012). Development of bodice dress forms by body types for women in thirties applying 3D body scan data. *The Journal of the Korea Contents Association, 12*(9), 136–145. https://doi.org/10.5392/JKCA.2012.12.09.136.

The Elastic Woman. (2018). *Samsungdesign.net*. Retrieved from http://www.samsungdesign.net/Lifestyle/Report/Content.asp?an=40449&keyword=%C1%DF%B3%E2.

Toth, M. J., Tchernof, A., Sites, C. K., & Poehlman, E. T. (2000). Effect of menopausal status on body composition and abdominal fat distribution. *International Journal of Obesity, 24*(2), 226–231.

Viktor, H. L., Paquet, E., & Guo, H. (2006). Measuring to Fit: Virtual tailoring through cluster analysis and classification. In J. Fürnkranz, T. Scheffer, & M. Spiliopoulou (Eds.), *European Conference on Principles of Data Mining and Knowledge Discovery. Paper presented at Knowledge Discovery in Databases: PKDD 2006, Italy* (pp. 395–406). Berlin: Springer. https://doi.org/10.1007/11871637_38.

Vuruskan, A., & Bulgun, E. (2011). Identification of female body shapes based on numerical evaluations. *International Journal of Clothing Science and Technology, 23*(1), 46–60. https://doi.org/10.1108/09556221111096732.

Wells, J. C. K., Cole, T. J., Bruner, D., & Treleaven, P. (2008). Body shape in American and British adults: Between-country and inter-ethnic comparisons. *International Journal of Obesity, 32*(1), 152–159. https://doi.org/10.1038/sj.ijo.0803685.

Wich, B. K., & Carnes, M. (1995). Menopause and the aging female reproductive system. *Endocrinology and Metabolism Clinics of North America, 24*(2), 273–295.

Xia, S., Guo, S., Li, J., & Istook, C. (2019). Comparison of different body measurement techniques: 3D stationary scanner, 3D handheld scanner, and tape measurement. *The Journal of The Textile Institute, 110*(8), 1103–1113. https://doi.org/10.1080/00405000.2018.1541437.

Yi, K. H., & Istook, C. (2008). Comparison of 3D scanned anthropometric data between Korean and American adults by using ratios and indices. *Journal of the Korean Society of Clothing and Textiles, 32*(6), 959–967. https://doi.org/10.5850/JKSCT.2008.32.6.959.

Yin, L., & Annett-Hitchcock, K. (2019). Comparison of body measurements between Chinese and U.S. females. *The Journal of The Textile Institute, 110*(12), 1716–1724. https://doi.org/10.1080/00405000.2019.1617531.

Yoo, H., & Shim, B. J. (2006). The development of men's dress form for pattern making. *Journal of Fashion Business, 10*(5), 159–179.

Yoon, J. W., & Suh, M. A. (2009). Characteristics of somatotype classified by the drop value of middle-aged women. *The Research Journal of the Costume Culture, 17*(6), 939–946.

Yu, C. Y., Lo, Y. H., & Chiou, W. K. (2003). The 3D scanner for measuring body surface area: a simplified calculation in the Chinese adult. *Applied Ergonomics, 34*(3), 273–278. https://doi.org/10.1016/S0003-6870(03)00007-3.

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.