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THE EFFECT OF THE DIFFERENCE IN FEMALE BODY SHAPES ON CLOTHING FITTING

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Abstract:

The aim of this study was to determine the frequency of body shapes of the studied group of women using different body shape classification methods. The objective was to investigate the fit of clothing for the average body shapes identified. Forty female participants from Slovenia, aged 20–30, were included in the analysis. Body shapes were classified using three methods: Visual assessment of body shape (VABS), female figure identification technique (FFIT), and body shape classification method (BSCM). For each classification method, ANOVA tests were performed to determine whether there were statistically significant differences in body measurements across the identified body shapes. A comparison of body shapes was carried out and also visualised by simulating 3D body shapes. The fit of clothing to body shapes was analysed with the help of virtual 3D prototyping. Four characteristic body shapes have been identified, namely triangle (pear, spoon), hourglass, rectangle and inverted triangle. The VABS method differs slightly from the other two (FFIT, BSCM), which give very similar results. When applying the FFIT and BSCM, the triangle body shape is the most representative, followed by the hourglass shape, the rectangle and the inverted triangle shape. Simulating the fit of the basic dress pattern design on 3D body shapes using the best match of dress size shows that the dress fits the hourglass shape best, while the fit for the other three shapes is inadequate. The latter indicates the need to make most of the garments for the triangle body shape and a corresponding number of garments for the hourglass and rectangle body shapes to ensure the correct fit of the garments.

Keywords:

female body shapes, body dimensions, simulation of 3D body shapes, clothing fit, virtual 3D prototyping

1. Introduction

Well-fitting garments are crucial in the fashion industry as they are important for consumer satisfaction. Therefore, they are important for the development teams, manufacturers and sellers of clothing [1]. The determination of body shapes and the clarification of their statistical characteristics are of fundamental importance for the production of high-quality and well-fitting garments [2]. For customers, the fit of a garment is the most important element for the appearance of the garment [3]. A good fit ensures not only that the garment wears well, but also that it is worn often [4]. Anthropometric measurements alone may not be sufficient to capture the full complexity of body shapes. Considering factors such as posture, shape and other personal characteristics is important to design garments that truly fit and flatter a variety of people [5]. Body shape can change over time due to factors such as ageing, lifestyle and health [6]. Accepting and appreciating our unique body shape is important for our overall well-being and self-confidence. Fashion and style choices can also accentuate different body shapes and allow individuals to highlight their favourite features [7]. Human body shape can vary greatly, and people can often be categorised according to their body proportions and the distribution of fat and muscle. The challenge in categorising female body shape is the enormous variability of female body shapes. This leads to difficulties when trying to summarise numerous body shapes in a few categories [8]. In the past, researchers have developed various methods, including the somatotyping technique, the somatometry method using calipers and shoulder angle measuring devices, the general observation method and 3D body scanning, to identify and categorise women's body shapes. These methods often aim to provide a standardised method of describing body shapes for research purposes, garment design or health assessment [9]. The concept of body shape was first introduced in the 1940s by the psychologist William Herbert Sheldon in order to analyse human temperament types with somatotype classifications. Anthropometric parameters were used to determine three somatotypes (ectomorphic, endomorphic and mesomorphic) [10]. Based on the somatotyping technique, Douty [11] developed a somatometric method for analysing body shapes in 1968. She photographed female students in front of a screen marked with a grid. These photographs were called somatographs and were used to assess posture, body mass, proportions, contours and the balance of identical body parts. The body shapes of these students were categorised into five categories using the Douty body build scale and the posture scale [11]. The Body I.D. Scale by Bonnie August (1981) contains 11 proportion designators categorised into three different groups: front view width, side view width and front view length [12]. These proportions are represented by alphabetical letters that visually correspond to the selected landmarks among the different shapes of the body forms. The scale makes it possible to combine the categories of the front view with those of the side view. The body silhouettes in the stimulus for Bonnie August's Body I.D. Scale are designed so that the corresponding alphabetical representation corresponds to the landmarks of the body shape. These

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landmarks include the shoulder points, the natural waist and the widest hip point, as mentioned in the 1997 paper by Fiore and Kimle [13]. The Body Shape Analysis Scale (BSAS©) developed by Connell et al. [8] was pivotal in providing a standard for the visual quantification of 3D scans of adult women according to the shape of the whole body as well as the individual body parts in front and side view. The BSAS© scale contains nine variants for the assessment of frontal body shapes and results from the analysis of body scans of 42 women aged between 20 and 55 years [14]. The study to develop the BSAS© scale was based on quantitative coordinate data of landmarks derived from 3D body scans in combination with expert knowledge on qualitative classification of female body shape based on nine classifications of whole-body and partial body shapes (body build, body shape, hip shape, shoulder slope, front torso shape, bust prominence, buttock shape, back curve and posture) [8,15]. Two-dimensional images of whole bodies and body parts were printed from 3D body scan files and visually classified into the synthesised categories by experts in the field. The study identified nine categories of body shapes: hourglass, bottom hourglass, top hourglass, spoon, rectangle, diamond, oval, triangle, and inverted triangle [14]. Later, algorithms were developed in a software programme to classify female bodies using the shape categories in BSAS© [14]. This method was also used to create anthropometric profiles of adult women in a study that assessed the accuracy of self-reported drawings of body size and shape compared to actual body measurements in women of reproductive age [16]. A similar approach was used in a study to create anthropometric profiles of normal and plus-size girls aged 9–14 years [17].

The female figure identification technique (FFIT) is a software for the mathematical determination of female figures [18,19]. The software was developed with the goal of creating a methodology for characterising body shapes that more adequately represent the diverse shapes of the American population [18]. The main aim of the research was to use 3D data and software to categorise body shapes based on measurements, proportions and shape [18,19]. The accuracy of the FFIT was validated using a large population as a test sample with a proportion of around 90% [20]. The FFIT was used in a comparative study of the body shapes of Korean and American women based on seven body shape categories adapted to classify the shape of the subjects (hourglass, spoon, bottom hourglass, top hourglass, inverted triangle, triangle and rectangle) [21]. In this study, it was found that the largest body shape category in Korean women was a rectangle body shape (70.06%), followed by a triangle body shape (15.60%), and then followed by spoon (8.70%), bottom hourglass (4.4%), hourglass (0.5%) and inverted triangle (0.2%). Among American women, the largest body shape category was also the rectangle body shape (49.00%), followed by spoon (21.5%), hourglass (11.8%), bottom hourglass (9.4%), triangle (4.8%), top hourglass (3%) and inverted triangle (0.5%). Descriptive methods integrating simple percentiles into univariate and bivariate combinations have been used to identify a unique African female body shape [22]. These analyses were used to divide the population under study into subgroups. Data were normalised, with ranges of two standard deviations on either side of the mean [22]. The descriptive parameters for defining the five predominant shapes (hourglass, triangle, inverted triangle, apple and rectangle) to establish standards within the maximum and minimum dimensions of the drop values were determined [22]. The difference between the bust circumference (BC) and hip circumference (HC) and the difference between the BC and waist circumference (WC) were used as drop values [22]. The different body shapes in the study were determined according to the rules established by Shin and Istook [23] and Rasband and Liechty [24]. Shin and Istook [23] reported that the WC of a rectangle body shape is 23 cm smaller than the BC, while Rasband and Liechty [24] found that the WC of an hourglass body shape is more than 25 cm smaller than the HC or BC. In this study, the largest body shape category was the rectangle body shape (70%), followed by the pear (13%), hourglass (9%), inverted triangle (3.5%) and apple (4.5%) [22]. A similar approach was used in the research of Makhanya et al. [25] where body shape categories and defined parameters were determined with the adaptation from Yim Lee et al. [21] and Mastamet-Manson [22]. In the study of Makhanya et al. [25], on the differences between the body shapes of African and Caucasian women, it was found that the most common body shape in the African group was the triangle shape (58.7%), followed by the hourglass shape (27.5%) and the rectangle shape (12.8%). The least common shape was the apple shape (0.9%). In the Caucasian group, the hourglass shape (40.8%) was the most common shape, followed by triangles (33.6%) and rectangles (25.6%). There were no participants classified as inverted triangles in either ethnic group [25].

The aim of this study was to determine the frequency of body shapes of the group of women studied using different classification methods of women's body shapes and to analyse the fit of clothing for the average body shapes studied.

2. Methodology

2.1. Participants

Forty female participants between the ages of 20 and 30 from Slovenia took part in the study. The basic data of the measured persons are summarised in Table 1. The participants' body measurements, i.e. body height (BH), BC, WC, high hip circumference (HHC), and HC, were measured according to the SIST ISO 8559-1:2017 [26] standard, as well as their weight to determine body mass index (BMI). The average age of the participants was 23.32 years, their weight was 65.29 kg, and their height was 166.40 cm. On average, the group of women studied had a normal BMI (23.59).

Table 1. Basic data of female participants

	Age (years)	Weight (kg)	BH (cm)	BMI
Mean	23.32	65.29	166.40	23.59
SD	2.51	12.45	5.80	4.48
CV (%)	10.76	19.07	3.49	19.00
Min	20.00	45.00	158.00	16.90
Max	30.00	98.00	180.00	36.89

Table 2. FFIT body shape classification [21]

Body shape classification	Shape identification: Determining factors [18,19]	Shape identification: Determining factors [21]
Hourglass	A small difference between hip and bust. The difference between hips to waist and bust to waist is about the same and significant	If (bust–hips) ≤ 1* then
		If (hips–bust) < 3.6 then
		If (bust–waist) > 9 or (hips–waist) ≥ 10
Spoon	A larger circumferential difference between their hips and bust, bust-to-waist ratio is lower than the hourglass shape and hip-to-waist ratio is great	If (hips–bust) > 2 then
		If (hips–waist) ≥ 7 then
		If (high hip/waist) ≥ 1.193
Rectangle	BC and HC are relatively equal, the ratio of bust to waist and hip to waist is low, no recognisable waistline	If (hips–bust) < 3.6 and (bust–hips) < 3.6 then
		If (bust–waist) < 9 and (hips–waist) < 10
Triangle	Larger HC than BC. Ratio of hips to waist is small, with no defined waistline	If (hips – bust) ≥ 3.6 then
		If (hips – waist) < 9
Inverted triangle	Larger BC than HC. Ratio of bust to waist small, with no defined waist	If (bust–hips) ≥ 3.6 then
		If (hips–waist) < 9

*Note: Units are in inches.

Table 3. Body shape classification and defining parameters [25]

Drop values	Body shapes	Defining parameters		
		Mean (hip–bust)	**SD (hip–bust)**	**Min/Max (hip–bust)**
Hip–bust	Triangle	Mean ≤ hip – bust < Max		
	Inverted triangle	Hip – bust < 0		
Bust–waist	**Body shapes**	**Defining parameters**		
		Mean (bust – waist)	**SD (bust – waist)**	**Min/Max (bust – waist)**
	Hourglass	Mean ≤ bust – waist ≤ Max		
	Rectangular	Mean – 3 × SD < hip – bust < Mean		
	Apple	Min ≤ bust–waist ≤ −3 × SD		

2.2. Body shape classification methods

The characteristic body shapes of the studied group of women aged between 20 and 30 were determined using three methodologies. The frontal view of the participants' body shapes was observed using a visual assessment of body shape (VABS), similar to what women do at home in front of the mirror. For this purpose, the participants were photographed from the front with their arms slightly outstretched. They were dressed in a tight-fitting T-shirt and leggings. To assess the body shape

Table 4. Average body measurements of participants and appearance

	BC (cm)	WC (cm)	HC (cm)	BH (cm)	
$\bar{x}$ (cm)	90.05	73.30	99.30	166.48	
SD (cm)	8.76	8.52	8.64	5.80	
CV (%)	9.73	11.62	8.7	3.48	
Min (cm)	75.00	60.00	85.00	158.00	
Max (cm)	109.00	91.00	121.00	180.00	

Table 5. VABS and average body dimensions

Body shape/*N*	Body dimensions				
		BC	**WC**	**HC**	**BH**
 12	$\bar{x}$ (cm)	89.83	74.33	103.08	164.83
	SD (cm)	8.67	9.29	10.29	6.10
	CV (%)	9.66	12.49	9.98	3.70
	Min (cm)	80.00	62.00	89.00	158.00
	Max (cm)	107.00	91.00	121.00	178.00
 18	$\bar{x}$ (cm)	86.78	68.11	95.67	168.72
	SD (cm)	7.84	7.24	7.47	5.33
	CV (%)	9.04	10.63	7.81	3.16
	Min (cm)	75.00	60.00	85.00	160.00
	Max (cm)	109.00	90.00	116.00	180.00
 9	$\bar{x}$ (cm)	95.89	80.56	100.33	164.89
	SD (cm)	7.39	6.19	9.18	5.35
	CV (%)	7.71	7.68	9.15	3.42
	Min (cm)	83.00	70.00	87.00	159.00
	Max (cm)	105.00	88.00	110.00	175.00
 1	$\bar{x}$ (cm)	96.00	77.00	86.00	158.00
	SD (cm)	0.00	0.00	0.00	0.00
	CV (%)	0.00	0.00	0.00	0.00
	Min (cm)	96.00	77.00	86.00	158.00
	Max (cm)	96.00	77.00	86.00	158.00

independently, we extracted the shape of each person using Photoshop and drew parallel vertical lines on the image, starting from the shoulder points (acromion). In this way, we were able to assess four body shapes according to the criteria described by Connell et al. [8], namely the rectangle body shape: a balanced shoulder and hip width and a wide waist; the hourglass body shape: the shoulder and hip widths are balanced and the waist is clearly defined in relation to the shoulder and hip widths (narrow waist); the pear body shape: the hip and/or thigh width is visually wider than the shoulder width; the inverted triangle body shape: the shoulders are visually wider than the widest width at the hip or thigh.

In our research, we identify five body shapes (hourglass, spoon, inverted triangle, triangle and rectangle) for the studied group of women using the FFIT methodology [18,19], the identification of which is shown in Table 2.

The third body shape classification method (BSCM) was based on the study by Makhanya et al. [25], which calculated the differences between the HC and BC measurements and the differences between the BC and WC measurements, the standard deviation, and the minimum and maximum values for the calculated differences (Table 3). The difference between HC and BC was used to first classify the triangle and inverted triangle body shapes. For the remaining body shapes, the difference between BC and WC was used to classify the hourglass, rectangle and apple body shapes.

2.2.1. Determination of body measurements

The participants' body measurements, i.e. BH, BC, WC, HHC and HC, were measured according to the SIST ISO 8559-1:2017 [26] standard. During the measurements, the participants were in the standard standing posture according to the SIST ISO 8559-1:2017 standard [26] while wearing body-fitted clothing.

2.2.2. Data analysis

Descriptive statistics were used to analyse body measurements for specific body shapes studied. For all three methodologies average values ($\bar{x}$), standard deviations (SD), coefficients of variation (CV), minimum and maximum values of the individual body shape measurements were calculated.

Table 6. VABS: ANOVA test of BC, WC and HC

VASB		ANOVA		ANOVA effect sizes[a,b]		
				95% confidence interval		
		F	*p*-value	Point estim.	Lower	Upper
BC	Between groups	2.88	0.049			
	Eta-squared			0.19	0.00	0.34
	Epsilon-squared			0.13	−0.08	0.31
	Omega-squared fixed-effect			0.12	−0.08	0.30
	Omega-squared random-effect			0.05	−0.03	0.13
WC	Between groups	5.44	0.003			
	Eta-squared			0.31	0.05	0.47
	Epsilon-squared			0.26	−0.03	0.43
	Omega-squared fixed-effect			0.25	−0.03	0.42
	Omega-squared random-effect			0.10	−0.01	0.20
HC	Between groups	2.74	0.068			
	Eta-squared			0.19	0.00	0.35
	Epsilon-squared			0.12	−0.08	0.30
	Omega-squared fixed-effect			0.12	−0.08	0.29
	Omega-squared random-effect			0.04	−0.03	0.12

Note: a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model. b. Negative but less biased estimates are retained, not rounded to zero.

2.3. Comparison of body shapes determined by different methods

Based on the calculated average body measurements for each identified body shape and the method of their determination, a comparison of the body shapes was performed using a visual representation of each body shape with a 3D body model in the OptiTex 3D software package. A generic 3D body model of the OptiTex 3D software was used, for which the body dimensions were defined based on the average body dimensions measured with each methodology. In addition, the differences in individual body measurements between the different body shapes determined by various methodologies were calculated. To determine the average differences between the circumferences of the bust, waist, and hips for each body shape, we calculated the difference between the circumference of the hips and the bust, the difference between the circumference of the hips and the waist and the difference between the circumference of the bust and the waist.

2.4. Clothing fit to body shapes

The fit of the basic pattern design of the dress to the body shapes identified by the BSCM method was conducted to determine whether the basic pattern design of the dress provides sufficient comfort for all body shapes. For this purpose, it was selected the size number for each body shape whose bust and hip measurements best matched the measured body dimensions. The basic pattern design of the women's dress was constructed according to the M. Müller & Sohn [27] construction system based on the measurement table that we mostly use in the production of clothing collections. The measurements for size 40 were BC = 95.0 cm, WC = 72.5 cm and HC = 96.0 cm, and for size 42, the measurements were BC = 99.0 cm, WC = 76.5 cm and HC = 100.0 cm. The difference in this measurement table between HC and BC is 1.0 cm, the difference between HC and WC is 23.5 cm, and the difference between BC and WC is 22.5 cm.

3. Results and discussion

3.1. Body measurements

Table 4 shows the average body measurements and the appearance of the average body of the group of women studied aged between 20 and 30.

Average body shapes obtained by using a VABS and average body measurements for the individual body shape are presented in Table 5. Four different body shapes were identified using this methodology; 12 participants have a pear body shape, 18 have an hourglass body shape, 9 have a rectangle body shape, and 1 participant has the body shape of an inverted triangle. The ANOVA in Table 6 reveals statistically significant differences between body shapes. Specifically, BC shows a p-value of 0.049 ($p < 0.05$), and WC a p-value of 0.003 ($p < 0.01$), indicating significant variation between body shapes. However, no statistically significant differences were found for

Table 7. FFIT and average body dimensions

Body shape/*N*	Body dimensions					
		BC	WC	HHC	HC	BH
 19	$\bar{x}$ (cm)	88.68	72.79	92.47	101.53	165.74
	SD (cm)	9.38	9.41	9.88	9.91	5.72
	CV (%)	10.57	12.93	10.68	9.76	3.45
	Min (cm)	75.00	62.00	80.00	89.00	159.00
	Max (cm)	109.00	91.00	114.00	121.00	180.00
 0	$\bar{x}$ (cm)	/	/	/	/	/
	SD (cm)	/	/	/	/	/
	CV (%)	/	/	/	/	/
	Min (cm)	/	/	/	/	/
	Max (cm)	/	/	/	/	/
 10	$\bar{x}$ (cm)	86.80	66.30	87.00	93.90	170.20
	SD (cm)	6.09	5.23	6.27	5.76	5.49
	CV (%)	7.01	7.89	7.21	6.14	3.23
	Min (cm)	79.00	60.00	79.00	85.00	158.00
	Max (cm)	97.00	74.00	98.00	102.00	178.00
 10	$\bar{x}$ (cm)	95.80	80.10	93.90	98.80	165.20
	SD (cm)	7.39	6.68	7.41	9.61	5.17
	CV (%)	7.71	8.34	7.89	9.64	3.13
	Min (cm)	83.00	70.00	82.00	87.00	159.00
	Max (cm)	105.00	88.00	103.00	110.00	175.00
 1	$\bar{x}$ (cm)	96.00	77.00	84.00	86.00	158.00
	SD (cm)	/	/	/	/	/
	CV (%)	/	/	/	/	/
	Min (cm)	96.00	77.00	84.00	86.00	158.00
	Max (cm)	96.00	77.00	84.00	86.00	158.00

HC. WC has the largest effect size, suggesting that body shape differences account for a substantial portion of its variability.

The hourglass body shape has the smallest BC and the smallest WC but the highest BH among the analysed body shapes. On the other hand, it can be seen that the inverted triangle body shape has the lowest BH, and HC and is the smallest of all the body shapes analysed. A larger HC is typical for a pear-shaped body. The rectangle and inverted triangle body shapes have the largest BC and WC, which was to be expected.

Table 7 contains the results of the average body measurements and body shapes determined using the FFIT, in which the different body shapes of the participants were determined according to the classification given in Table 2. According to this methodology, most of the participants have a spoon-shaped body (19 participants), 10 participants have an hourglass body shape, 10 participants have a rectangle body shape, and only one participant has an inverted triangle body shape, while no participant has a triangle body shape. Compared to the VASB, quite similar results are obtained for rectangular and inverted triangular body shapes (number of body shapes and body dimensions). However, we can observe a lower number of hourglass body shapes (9) compared to the VASB method (18). The ANOVA results in Table 8 indicate statistically significant differences between the represented body shapes for BC, with a p-value of 0.029 ($p < 0.05$), and HC, with a p-value of 0.045 ($p < 0.05$). Additionally, there is a highly significant difference in WC across the body shape groups, with a p-value of 0.020 ($p < 0.05$). These findings suggest that body shape has a notable impact on these measurements. Rectangle body shape has the highest average BC, while hourglass has the lowest. Rectangle again has the highest average WC, while hourglass has the lowest. Spoon

Table 8. FFIT: ANOVA test of BC, WC and HC

FFIT		ANOVA		ANOVA effect sizes[a,b]		
				95% confidence interval		
		F	*p*-value	Point estim.	Lower	Upper
BC	Between groups	3.36	0.029			
	Eta-squared			0.22	0.00	0.39
	Epsilon-squared			0.15	−0.08	0.33
	Omega-squared fixed-effect			0.15	−0.08	0.33
	Omega-squared random-effect			0.06	−0.03	0.14
WC	Between groups	5.95	0.002			
	Eta-squared			0.33	0.06	0.49
	Epsilon-squared			0.28	−0.02	0.45
	Omega-squared fixed-effect			0.27	−0.02	0.44
	Omega-squared random-effect			0.11	−0.00	0.21
HC	Between groups	2.96	0.045			
	Eta-squared			0.20	0.00	0.36
	Epsilon-squared			0.13	−0.08	0.31
	Omega-squared fixed-effect			0.13	−0.08	0.31
	Omega-squared random-effect			0.05	−0.03	0.13

Note: a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model. b. Negative but less biased estimates are retained, not rounded to zero.

body shape has the highest average HC, while an inverted triangle has the lowest.

The FFIT also considers measurements of the HHC. It can therefore be assumed that this body dimension has a major influence on the determination of body shapes, especially the spoon body shape, which probably completely replaces the triangle body shape. We can also assume that HHC influences the determination of the hourglass body shape, as the average WC and HC decreased compared to the VASB. Thus, the hourglass body shape has the smallest BC and WC and the highest BH among the body shapes analysed. A larger HC is typical for the spoon body shape and a HHC (as expected, the rectangle body shape has a higher HHC).

The body shapes in Table 9 are the results of the third BSCM, which is based on the calculation of the differences between the HC and BC measurements and the differences between the BC and WC measurements, the standard deviation and the minimum and maximum values for the calculated differences (Table 2). According to this methodology, most participants have a triangular body shape (19 participants), 11 participants have an hourglass body shape, 8 participants have a rectangle body shape, 2 have an inverted triangle body shape, and no participant has an apple body shape. With BSCM, similar results are found as with FFIT; all 19 spoon body shapes according to FFIT are 19 triangular body shapes according to BSCM, which also have quite similar average body dimensions. Although the ANOVA for bust size was marginally non-significant (p-value = 0.062, $p > 0.05$), robust tests indicate potential differences across body shapes, with the rectangle body shape having the highest mean bust size. For WC, there is a significant difference between body shapes (p-value = 0.020, $p < 0.05$). While the ANOVA did not show significant differences in HC (p-value = 0.139, $p > 0.05$), robust tests suggest a significant difference, with the triangle body shape having the highest mean HC.

Since the number of hourglasses, rectangular and inverted triangular body shapes has already changed slightly compared to FFIT, the average body dimensions also slightly changed.

By applying all three methods, four different body shapes were determined. All methods resulted in the body shape of an hourglass, a rectangle and an inverted triangle. The different body shapes obtained with the three methods are pear-shaped (VABS, Table 5), spoon-shaped (FFIT, Table 6) and triangle-shaped (BSCM, Table 7), but all have similar average values for BC, WC and HC (Table 10), especially for the FFIT and BSCM methods. It can therefore assume that different terms are used for almost the same body shape, even though FFIT also defines a triangle body shape in addition to the spoon body shape.

3.2. Comparison of body shapes determined by different methodologies

Figure 1 shows four different women's body shapes determined using three different methods (VABS, FFIT, BSCM). The simulations of the 3D body shapes of the pear, spoon and triangle

Table 9. BSCM and average body dimensions

Body shape/*N*	Body dimensions				
		BC	**WC**	**HC**	**BH**
 19	$\bar{x}$ (cm)	87.37	71.53	100.37	165.79
	SD (cm)	7.95	8.33	9.09	4.79
	CV (%)	9.10	11.65	9.06	2.89
	Min (cm)	75.00	61.00	89.00	160.00
	Max (cm)	107.00	91.00	121.00	175.00
 11	$\bar{x}$ (cm)	90.27	69.55	96.00	169.64
	SD (cm)	8.75	9.10	8.66	6.65
	CV (%)	9.70	13.09	9.02	3.92
	Min (cm)	81.00	60.00	85.00	158.00
	Max (cm)	109.00	90.00	116.00	180.00
 8	$\bar{x}$ (cm)	96.88	81.50	95.75	164.50
	SD (cm)	8.167	7.35	7.81	5.45
	CV (%)	8.43	9.02	8.16	3.31
	Min (cm)	83.00	70.00	82.00	159.00
	Max (cm)	105.00	88.00	103.00	175.00
 2	$\bar{x}$ (cm)	94.50	77.00	87.00	163.50
	SD (cm)	2.12	0	1.41	7.78
	CV (%)	2.24	0	1.63	4.76
	Min (cm)	93.00	77.00	86.00	158.00
	Max (cm)	96.00	77.00	88.00	169.00
 0	$\bar{x}$ (cm)	/	/	/	/
	SD (cm)	/	/	/	/
	CV (%)	/	/	/	/
	Min (cm)	/	/	/	/
	Max (cm)	/	/	/	/

look very similar. In all cases, the width of the hips is visually wider than that of the bust. In the body shape of the spoon, we can also notice the shaped high hips, which reflects the measured body dimension of the HHC using the FFIT method. The difference between hips and bust is about 13.00 cm (VABS = 13.25 cm, FFIT = 12.85 cm and BSCM = 13.00 cm). Figure 2 shows that the values for BC, WC and HC and the relationships between them are similar for all three methods, which confirms that different methods use different names for the same body shape. These body shapes are also the most represented among the participants studied. According to the VABS, 30% of participants have a pear body shape, according to the FFIT 47.5% have a spoon body shape and according to the BSCM 47.5% have a triangle body shape. Participants with these body shapes were on average about 165.00 cm tall, namely 164.83 cm according to the VABS, 165.74 cm according to the FFIT and 165.22 cm according to the BSCM.

About 45% of participants have hourglass body shape according to the VABS, and according to the FFIT, 25% of participants have an hourglass body shape and according to the BSCM, 27.5% of participants have this type of body shape (Figure 1). 3D body models created for the hourglass body shape have a balanced bust and hip width and a defined, quite narrow waist (Figure 1). Figure 2 also shows significantly smaller average values for WC in relation to BC and HC. Participants with an hourglass body shape were also the tallest on average (VDBS = 168.72 cm, FFIT = 170.20 cm and BSCM = 169.64 cm). In this research, the hourglass body shape is the second most represented body shape.

The rectangle 3D body shape shows a balanced bust and hip width and almost no waist definition (Figure 1). This body shape is representative of 22.5% of participants using the VABS method, 25% of participants using the FITT method and 20%

Table 10. VABS: BSCM test of BC, WC and HC

BSCM		ANOVA		ANOVA effect sizes[a,b]		
				95% confidence interval		
		F	*p*-value	Point estim.	Lower	Upper
BC	Between groups	2.68	0.62			
	Eta-squared			0.18	0.00	0.35
	Epsilon-squared			0.11	−0.08	0.29
	Omega-squared fixed-effect			0.11	−0.08	0.29
	Omega-squared random-effect			0.04	−0.03	0.12
WC	Between groups	3.71	0.020			
	Eta-squared			0.24	0.04	0.40
	Epsilon-squared			0.17	−0.08	0.35
	Omega-squared fixed-effect			0.17	−0.08	0.35
	Omega-squared random-effect			0.06	−0.02	0.15
HC	Between groups	1.945	0.139			
	Eta-squared			0.14	0.00	0.30
	Epsilon-squared			0.06	−0.08	0.24
	Omega-squared fixed-effect			0.07	−0.08	0.24
	Omega-squared random-effect			0.02	−0.03	0.93

Note: a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model. b. Negative but less biased estimates are retained, not rounded to zero.

of participants using the BSCM method. Figure 2 shows that the average values for WC are lower than the BC and HC.

The simulations of the 3D body shape of the inverted triangle show a larger BC than HC, while the waist is undefined (Figure 1). The comparison of the average body measurements of the body shapes determined by VABS, FFIT and BSCM clearly shows that the body measurements are almost the same (Figure 2). It should be noted that only one participant had this body shape according to the VABS and FITT method and two participants had the inverted triangle body shape according to the BSCM method.

Figure 2 shows that the average body measurements determined using the VABS, FFIT and BSCM methods are quite similar. The differences between the average body measurements are very small (Table 11). The largest difference in BC for the pear/spoon/triangle body shape was found between the VABS and BSCM methods, namely 2.46 cm, while the difference between the BSCM and FFIT methods was −1.31 cm. For the hourglass body shape, the largest difference in BC was found between the VABS and BSCM methods (3.49 cm), while the difference between the VABS and FFIT methods was only 0.02 cm. For the rectangle body shape, the differences in BC were very small, ranging from −0.99 cm for the VABS and BSCM methods to 0.99 cm for the BSCM and FFIT methods. For the inverted triangle body shape, the largest difference in BC was 1.50 cm between the VABS and BSCM and BSCM and FFIT methods.

The largest difference in WC for the pear/spoon/triangle body shape was found between the VABS and BSCM methods (2.80 cm), while the difference between the BSCM and FFIT methods was −1.21 cm. For the hourglass body shape, the largest difference in WC was found between the BSCM and FFIT methods (3.25 cm). The largest difference in WC between the BSCM and FFIT methods for the rectangle body shape was 1.39 cm. There was no difference in WC between the methods for the inverted triangle body shape.

For the pear/spoon/triangle body shape, it was found that the largest difference in HC was between the VABS and BSCM methods (2.71 cm), while the difference between the BSCM and FFIT methods was −1.16 cm. For the hourglass body shape, the largest difference in HC was found between the BSCM and FFIT methods (2.10 cm). The largest difference in HC between the BSCM and FFIT methods for the rectangle body shape was 1.39 cm. The difference between the methods for HC for the inverted triangle body shape was between −1.00 for the VABS and BSCM methods and 1.00 cm for the BSCM and FFIT methods.

Four characteristic body shapes were identified in the women between the ages of 20 and 30, namely the body shapes triangle (pear, spoon), hourglass, rectangle and inverted triangle. The VABS differs slightly from the other two methods (FFIT and BSCM), which show very similar results. The reason for this is that the VABS is only done from the front, while the other methods determine body shape based on body

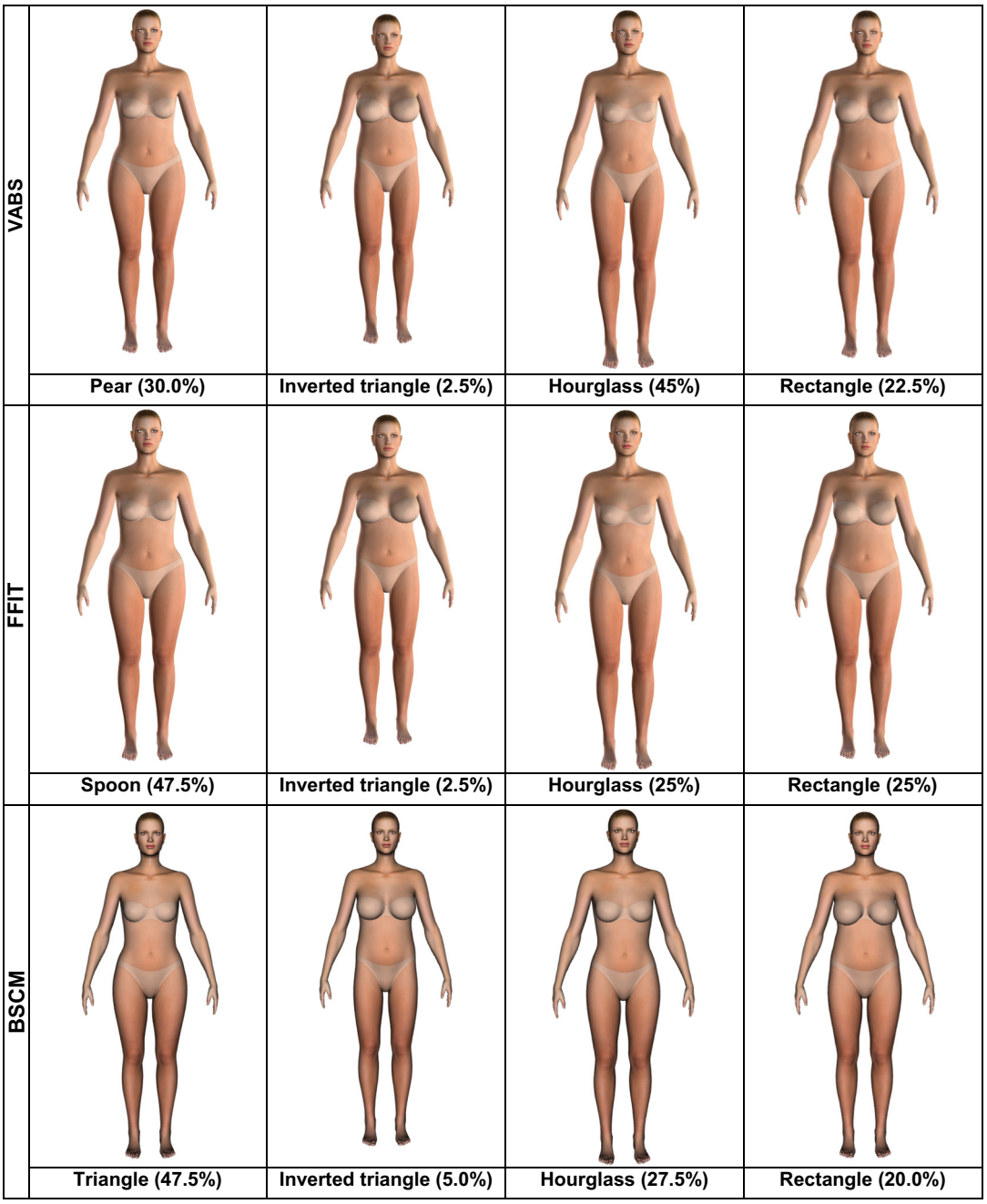


Figure 1. Simulations of average 3D body shapes determined by VABS, FFIT and BSCM methods.

circumferences. Therefore, in studies in which a single person visually assesses their own body shape, we have to include one of the two methods discussed in parallel to the assessment. In this study using the FFIT and BSCM methods, it was found that on average the triangle body shape (47.5%) is the most representative, followed by the hourglass body shape (25.0–27.5%), the rectangle body shape (25.0–20.0%) and the inverted triangle body shape (2.5–5.0%). On the basis of this part of the study, it can be assumed that it is necessary to make most of the garments for the triangle body shape and a corresponding number of garments for the hourglass and rectangle body shapes in order to ensure the correct fit of the garments for the women's body shapes studied.

The average differences between HC and BC, the average differences between HC and WC, and the average differences between BC and WC were calculated for the FFIT and BSCA methods (Table 12). For an average pear/spoon/triangle body shape, it is typical that the difference between the average HC and the BC is 12.85 cm for FFIT and 13.00 cm for BSCM, the difference between the average HC and the WC is 28.74 cm for FFIT and 28.84 cm for BSCM, and the difference between the average BC and the WC is 15.89 cm for FFIT and 15.84 cm for BSCM. For an average hourglass body shape, it is typical that the difference between the average HC and the BC is 7.10 cm for FFIT and 5.73 cm for BSCM, the difference between the average HC and the WC is 27.60 cm for FFIT and 26.45 cm

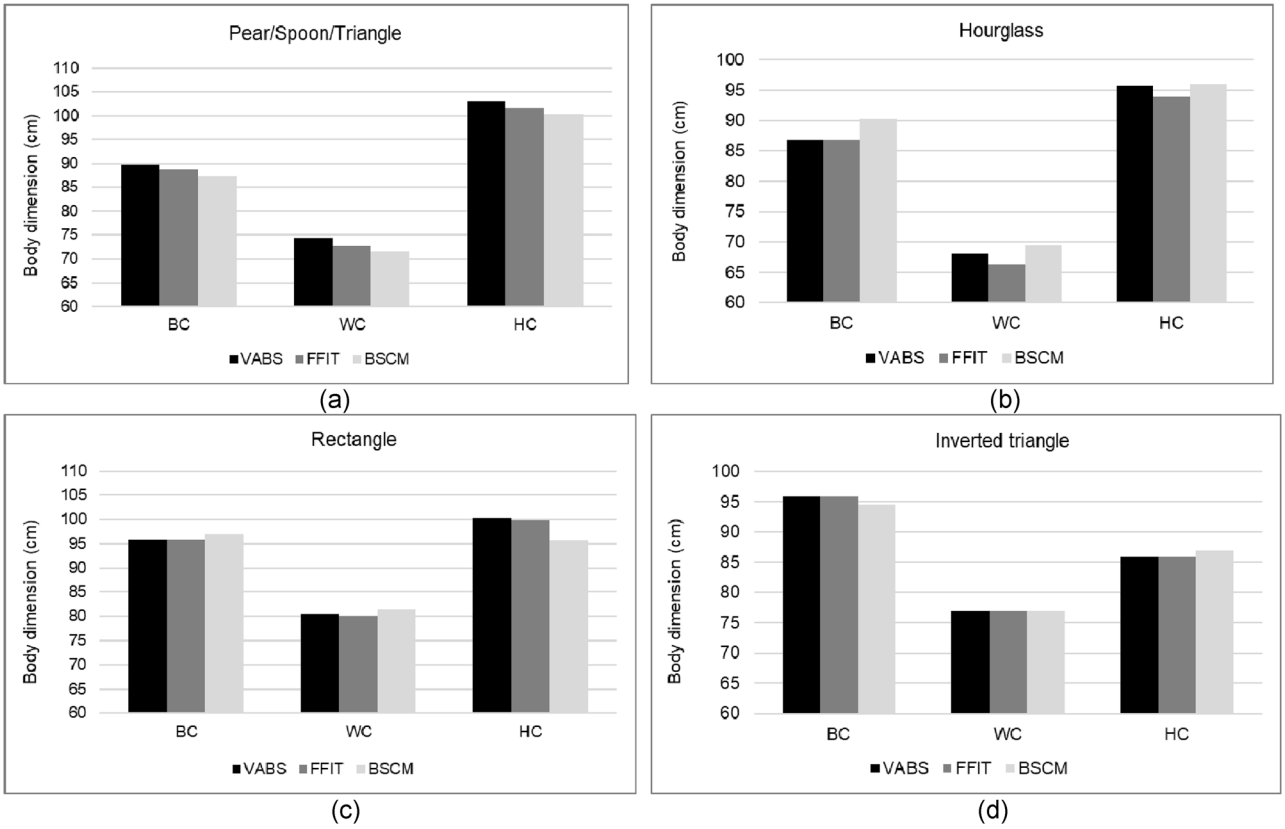


Figure 2. Comparison of average body dimensions of body shapes determined by VABS, FFIT and BSCM methods: (a) Pear/Spoon/Triangle, (b) Hourglass, (c) Rectangle, (d) Inverted triangle.

for BSCM, and the difference between the average BC and the WC is 20.50 cm for FFIT and 20.72 cm for BSCM. For an average rectangle body shape, it is typical that the difference between the average HC and the BC is smallest and amounts to 3.89 cm for FFIT and −1.13 cm for BSCM, the difference between the average HC and the WC is 19.67 cm for FFIT and 14.25 cm for BSCM, and the difference between the average BC and the WC is 15.78 cm for FFIT and 15.38 cm for BSCM. For an average inverted triangle body shape the difference between the average HC and the BC is −10.00 cm for FFIT and −7.50 cm for BSCM, the difference between the average HC and the WC is 9.00 cm for FFIT and 10.00 cm for BSCM, and the difference between the average BC and the WC is 19.00 cm for FFIT and 17.50 cm for BSCM.

It was found that the differences between the circumferences considered for the FFIT and BSAS methods are quite similar, indicating the equivalence of using both methods to determine women's body shapes. Based on this study, it can be concluded that both methods can be applied to a larger number of participants in future studies on female body shapes of different age groups. The results of research on the differences between body circumferences can be used to create measurement charts for the needs of constructing garment pattern designs for different female body shapes. This can ensure an appropriate fit of garments for the body shapes of the group of women studied.

3.3. Clothing fit to average body shapes researched

The fit of the woman's dress to the body shapes determined using the BSCM method is shown in Figure 3. The dress size was used whose BC and HC best matched the measured body measurements. The frontal and side views of simulated dresses clearly show that used measurements for the construction of a dress basic pattern pieces enable the best fit to the hourglass body shape, i.e. fit around the bust, waist, hips and contour of the back and buttocks. The latter is also reflected in the lowest tension of the fabric in the dress, i.e. in the least red-coloured areas. The highest tension (red) in a dress for the hourglass body shape can only be observed at the bust point, which is normal due to the end of the sewn bust darts. The dress fit well to the contour of the back and buttocks, which can be seen in the side view. As the HC matches the circumference of the dress at the hips, we can see less tension in the fabric around the buttocks (yellow). Tension in the bust area can also be observed for the dress fit to a triangle body shape. However, as the dress is much larger than the average BC, its fit is poorer, which is particularly noticeable at the back (side view) when the dress does not follow the contours of the back. The high tension of the dress can be seen in the hip area, as the average HC of a triangular body shape is 0.4 cm larger than the dress pattern design. Simulating the fit of the dress on an inverted triangle 3D body shape shows high tension around the bust, in the back area and also around the waist, while

Table 11. Differences between average body measurements

Pear/spoon/triangle			Hourglass			Rectangle			Inverted triangle		
VABS – FFIT	VABS – BSCM	BSCM – FFIT	VABS – FFIT	VABS – BSCM	BSCM – FFIT	VABS – FFIT	VABS – BSCM	BSCM – FFIT	VABS – FFIT	VABS – BSCM	BSCM – FFIT
BC (cm)											
1.15	2.46	−1.31	0.02	3.49	3.47	0.00	−0.99	0.99	0.00	1.50	1.50
WC (cm)											
1.54	2.80	−1.26	1.81	1.44	3.25	0.45	−0.94	1.39	0.00	0.00	0.00
HC (cm)											
1.55	2.71	−1.16	1.77	0.33	2.10	0.55	4.58	1.39	0.00	−1.00	1.00

the dress fits quite loosely around the hips due to the typically small HC. The tension in the bust, back and the entire stomach and buttocks area can be observed when looking at the fit of the dress for the rectangle 3D body shape.

This part of the investigation shows that the fit of the dress and thus the supposedly good wearing comfort depends on the body measurement tables used by the clothing manufacturer. The measurement tables typically vary from manufacturer to manufacturer, who usually only provide body measurements for a single, average body shape (hourglass body shape). The latter can be seen more than clearly in Figure 3. The identified fit of dresses for different body shapes suggests that each body shape requires a garment pattern design whose construction measurements correspond to the body shapes of the women most represented in the target markets of garment manufacturers. Therefore, future research will focus on investigating the appearance of female body shapes for different age groups in a larger number of research participants.

4. Conclusions

Forty Slovenian women between the ages of 20 and 30 were analysed using three classification methods, the VABS, the FFIT and the BSCM. A comparison was made of the body shapes determined using different methods, which are also represented by the simulation of 3D body shapes, and the fit of the dress to body shapes was examined using virtual 3D prototyping. When analysing the body shapes, four different body shapes were identified: Triangle (pear, spoon), hourglass, rectangle and inverted triangle. All three methods used in this study provided similar results. The VABS, in which the body shapes were assessed visually from the front, differs slightly from the other two methods, which show very similar results (FFIT and BSCM) and determines the body shapes based on the body circumference. In this research, it was found that by using the FFIT and BSCM methods, the triangle body shape (47.5%) was the most representative, followed by the hourglass body shape (25.0–27.5%), rectangle body shape (20.0–25.0%) and the inverted triangle body shape (2.5–5.0%). Comparison between different studies, using similar methods to determine female body shape, showed a higher prevalence of triangle/pear/spoon body shapes among Slovenian women like African women [22], but distinct from Korean and American women [21], where the rectangle shape was dominant. Among American women, the spoon body shape appears at 21.5%, while the pear shape is less common (4.8%). The hourglass shape is significantly more represented in Caucasian women (40.80%) and African women (27.50%) [22,25]. For American women, it appears moderately with 11.8% (plus 9.4% bottom hourglass). In our study, the hourglass shape represents 25% of Slovenian women (FFIT) and 27.5% (BSCM), making it the second most represented shape. The rectangle shape is the most common in Korean women (70.06%) and also has a high prevalence in American women (49%). Among Slovenian women, the rectangle shape ranges from 20% (BSCM) to 25% (FFIT). African and Caucasian women show less representation of the rectangle shape compared to Koreans and Americans [21,22,25]. The

Table 12. Difference between circumferences

Body shape	Pear/spoon/triangle		Hourglass		Rectangle		Inverted triangle	
	FFIT	BSCM	FFIT	BSCM	FFIT	BSCM	FFIT	BSCM
HC–BC (cm)	12.85	13.00	7.10	5.73	3.89	−1.13	−10.00	−7.50
HC–WC (cm)	28.74	28.84	27.60	26.45	19.67	14.25	9.00	10.00
BC–WC (cm)	15.89	15.84	20.50	20.72	15.78	15.38	19.00	17.50

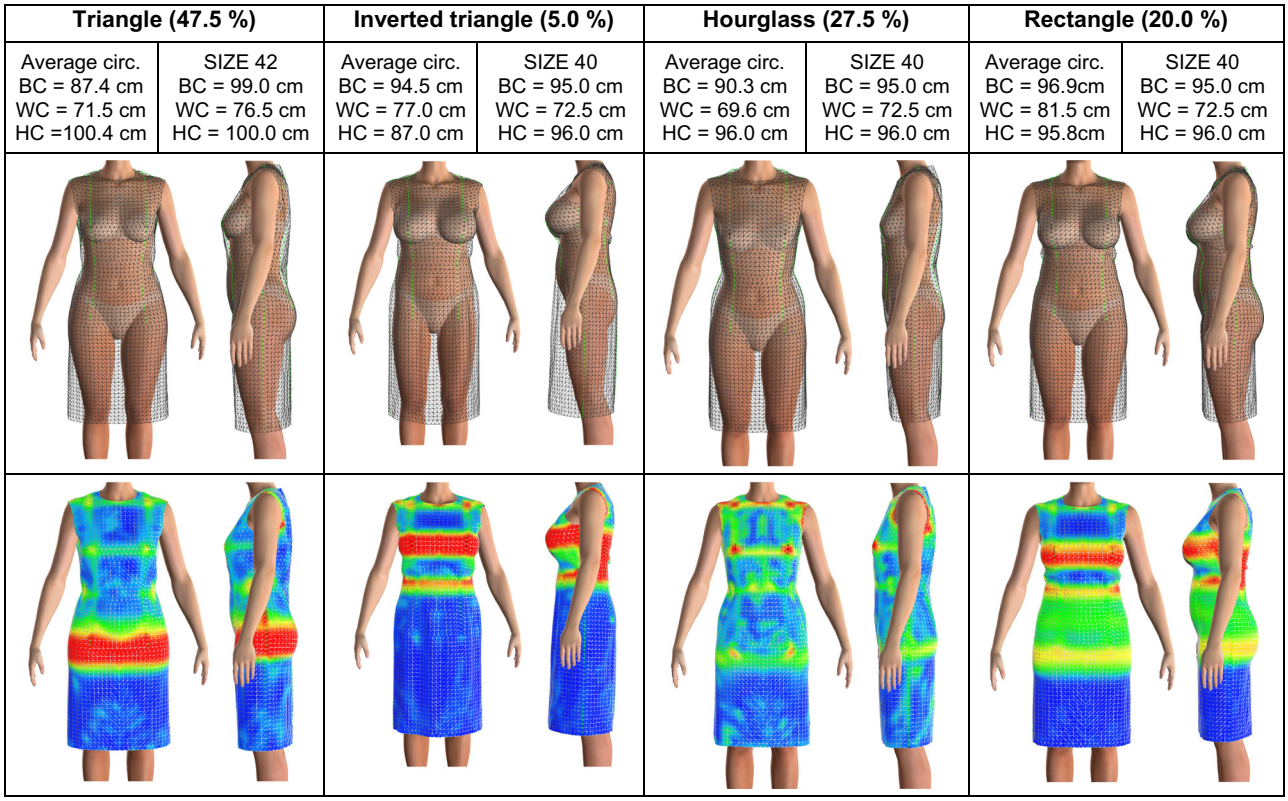


Figure 3. Simulation of the women's dresses fit to 3D body shapes determined using the BSCM method.

inverted triangle is the least common shape across studies. In American and Korean women, it represents a very small proportion (0.2–0.5%). In our study, it accounts for 2.5–5% of Slovenian women, with slightly higher representation using the BSCM method. The study also highlights that garments are often designed based on the hourglass figure, yet the triangle/pear/spoon shape is the most represented body type. Based on these results, it can be assumed that it is necessary to make the majority of garments for the triangle body shape and a corresponding number of garments for the hourglass and rectangle body shapes in order to ensure the correct fit of the garments for the women's body shapes studied. Comparison of the average differences between HC, BC and WC for different body shapes and methods showed that the differences were quite similar for the FFIT and BSAS methods. This indicates that both methods are equivalent for determining women's body shapes. Therefore, the BSCM method will be used in future studies on female body shapes of different age groups and a larger number of participants.

The results of the study on the differences between body circumferences can be used to create measurement tables for the needs of garment pattern construction for the most typical female body shapes (triangular, hourglass and rectangular), ensuring an appropriate fit of garments for the body shapes of the studied group of women.

The simulation of the fit of women's dresses on 3D body shapes, determined using the BSCM method, shows the best fit of the dress on an hourglass body shape and a poor fit of a dress on a triangle body shape, which is the most represented in the analysed group of women. The presented fit of dresses on the analysed body shapes strongly suggests that each body shape requires a dress pattern design whose construction measurements correspond to the body shapes of the women most represented in the target markets of the clothing manufacturers. Therefore, future research will focus on investigating the appearance of female body shapes for different age groups in a larger number of research participants.

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Ethical approval: The conducted research is not related to either human or animal use.

Data availability statement: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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