

ANALYSIS OF VIETNAMESE WOMEN'S BODY SHAPE FROM ANTHROPOMETRIC DATA

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ABSTRACT

This study aims to classify and analyze the body shapes of Vietnamese women aged 18 to 50 using 3D anthropometric data. Research data was collected from 480 females across three regions: North, Central, and South. The five body types result from data analysis involving principal component analysis, K-means cluster analysis, numerical discriminant analysis, ANOVA test, and T-test comparison using SPSS software. Group 1, accounting for 15.23 %, represents the "short, thin, small-shouldered" body type with medium hip height and a bust-waist ratio higher than the hip-waist ratio. Group 2, accounting for 18.36 %, can be described as the "tall, slightly fat and large-shoulders" body type, characterized by high stature and hip height, with a bust-waist ratio smaller than the hip-waist ratio. Group 3, accounting for 35.94 %, falls under the category of the "Medium body type", with an average height stature and a fit body, and a bust-waist ratio equal to the waist-to-hip ratio. Group 4, representing 21.88 %, has a low hip height, a bust-waist ratio higher than the hip-waist ratio, and can be called the "short, fat, medium-shoulder" body type. Finally, group 5, which comprises 8.59 %, embodies the "too fat, average height, big shoulders" body type, featuring low hip height, and a bust - waist ratio higher than the hip-waist ratio. The method of body classification in this study is scientifically sound and reliable. The new research results can serve as a reference for the garment industry while contributing to the goal of building a virtual model library within 3D design software.

KEYWORDS

Analysis, classify, body shape, women, working age, Vietnamese.

INTRODUCTION

In today's rapidly evolving society, market competition has intensified, and new technologies continue to emerge, influencing various aspects of our social life. In the face of opportunities presented by the fourth Industrial Revolution and the challenges posted by the COVID-19 pandemic to the fashion industry, 3D technology has not only adapted but has also become stronger than ever before [1, 2]. As of today, 3D technology has covered all areas of society, offering growth opportunities for creativity, particularly in the fashion industry [3-5]. Additionally, 3D anthropometric data play a significant role in this ongoing development [6-8].

Furthermore, research into anthropometry serves as an important foundation for determining the precise details of costume design and body characteristics, which, in turn, profoundly influence the creation of

basic blocks [9,10]. It is essential to recognize that the human body's proportions do not follow a completely regular pattern as they evolve [11]. In fact, each geographical area has a different body shape, making body classification a significant consideration when tailoring garments to suit the specific needs and preferences of each locale, ultimately leading to cost savings, and ensuring a perfect fit during garment production [12]. According to the general laws of biology, every 10-15 years, changes in living conditions lead to alterations in size and physical strength of residents [13]. Therefore, research into shape characteristics and body classification should be regularly updated to accommodate these variations of anthropometry over time [14]. Thus, the study of 3D-supported body shape analysis remains extremely necessary in the present context, especially for women of working age [15].

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Received October 3, 2022; accepted December 4, 2023

In Vietnam, there have been many researches focused on classifying female body shape, typically [16,17]. In the study [16], author categorized Vietnamese female students into 2 distinct body shape groups: Shape 1 characterized by a small waist, wide hips, a protruding belly, warped buttocks, straight legs, and short, small thighs; and Shape 2, characterized by a larger waist, small hips, a flat stomach, low hips, slightly curved long legs, and larger thighs. Meanwhile, the study titled "Study on Terms of Adjusting the Design of Vietnamese Women's Juniors According to Body Diversity using V-Stitcher 3-Dimensional Clothing Design Software" [9] identified seven body shapes: Triangle 1, Spoon shape, Hourglass Bottom 1, Rectangle 1, Rectangle 2, Hourglass Bottom 2, Triangle 2. Moreover, another study [11] conducted in 2012 on the same topic, classified Vietnamese women's physique into three groups: Group 1 includes short and slender women with small body lengths, thin bodies, narrow shoulders, a narrow chest circumference, and a large waist; Group 2 comprised taller, obese women with prominent bellies, broad shoulders, wide hips, and smaller busts; and Group 3 includes shorter women with thick, curvier bodies, large bust, medium shoulders, and narrow hips. The proportions of the human body were also analyzed specifically in the study [18] of Bunka University - Japan. In this study, the authors mentioned the ratio of head-to-body height with a standard ratio of 7.1, hip height ratio and the relationship between width, thickness, and height of the body. However, the proportions of the Vietnamese female human body have not been published.

The research in this article focuses on classifying the body shape of Vietnamese women between the age of from 18 and 55 who are of working age. This analysis aims to discern the distinct characteristics of body shapes and proportions, contributing to the development of a virtual model library in 3D design software within the context of the Fourth Industrial Revolution.

RESEARCH CONTENT, SUBJECTS AND METHODOLOGY

Subjects

The subjects of this study consist of women between the age of 18 and 55, classified as workers, students, civil servants, residing in the two major cities of Hanoi and Ho Chi Minh City. These participants are of Kinh ethnicity, exhibit normal body shapes and overall good health, and do not have any bodily deformities. The subjects working in these two metropolitan areas represent diverse regions across Vietnam, thus ensuring that the study's measurements encompass

the entire Northern, Central, and Southern regions of the country.

The sample size was determined by the formula:

$$n = \frac{(t SD)^2}{m^2} = \frac{(1.96 \cdot 5.5)^2}{0.5^2} \approx 464.83 \quad (1)$$

where: n is the minimum sample size; probability $p = 0.95$ corresponding to standard error $t = 1.96$; m is the required accuracy of the dimensions ($m = 0.5$ cm); SD is the standard deviation of the height size of Vietnamese women ($SD = 5.5$ cm) [16, 19]. Thus, the minimum sample size is 465 (sample). However, in fact, the study measured 480 (sample) for measurement errors precautions in the study.

Body measurements: The selected body measurements are the circumference, length, width, height, and body depth dimensions which are used to set avatar parameters in CLO3D software and establish typical sizes for classifying female body types. These dimensions in CLO3D correspond to the definition of anthropometric measurements from International Standard ISO 8559-1 [20, 21]. To investigate the classification of female body shapes among individuals aged 18 to 55 in the workforce, the author employed a 3D body scanner to collect a total of 36 anthropometric measurements. These measurements include 10 circumferences, 3 lengths, 9 widths, 11 heights and 3 thickness measurements, as detailed in Table 1.

Research Methodology

480 Vietnamese women were 3D measured by F6 Smart device. The body shape analysis method employed SPSS 26.0 software in this study involved the following steps:

- Determine the statistical characteristics of the measurement.
- Determining the main components in a total of 36 measurements, we conducted factor analysis using Varimax orthogonal rotation applied to rotate the components. We assessed the suitability of variables for PCA using the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests to determine the dominant size [22, 23].
- Analysis of clustering by K-means cluster analysis and discriminant analysis. In case the final number of clusters is determined, one-way analysis of variance (ANOVA) and Scheffe - test will be performed to observe the difference in human body size for each body type because of the results. of the analytical cluster [11, 15, 22, 23, 24].
- Enter avatar size parameters in CLO3D software to display analyzed body shapes [1, 25].
- Analysis of body proportions of Vietnamese women's body groups through ANOVA results.

Table 1. Measurement used in the study.

Category	Measurement items	Number
Circumference	Neck-, Upper bust-, Bust-, Under bust-, Waist-, Abdomen-, Hip-, Thigh-, Bicep - circumference, Total rise	10
Length	HPS to apex, Center back neck to wrist, Shoulder length	3
Width	Head width, Neck width, Shoulder width, BP to BP, Across back, Across chest, Waist width, Hip width, Thigh width	9
Height	Total height, Head module, HPS to waist, Shoulder point to waist, Center back neck to waist, Center front neck to waist, Center front neck to bust, Bust to waist, Waist to hip, Hip height, Crotch height	11
Depth	Bust depth, Waist depth, Hip depth	3
Total		36

RESULTS AND DISCUSSION

Statistical analysis results

The results of the statistical analysis, including histograms with normal curve and the standard probability histogram (Normal Q-Q Plots), show that all 36 anthropometric sizes used in the study exhibit mean value that closely located near the median (Me) and dominant (Mo). At the same time, the reliability of these dimensions falls within the acceptable limits, with a Cronbach's Alpha reliability coefficient of 0.948 as shown in Table 2.

Results of the main factor analysis

After applying orthogonal rotation Varimax, the analysis showed the presence of three main components among the measurements, each with eigenvalues greater than 1 and cumulative value of 96.92%. The results in Table 3 also show that the waist circumference has the largest weight among the size factor groups at 0.990. The remaining variables after rotation have lower weight but are greater than 0.6. At the same time, the KMO and Bartlett's test results in Table 4 are 0.669, ranging from 0.5 to 1 ($0.5 < 0.669 < 1$), which assesses the appropriateness of the variables in the principal component analysis [22-24].

Factor 1 includes 22 measurements related to body volume, which including circumferences, widths and depths such as waist circumference, waist width, abdomen circumference, bust circumference, bicep circumference, neck circumference, over bust circumference, under bust circumference, waist depth, hip depth, bust depth, apex to apex, hip circumference, neck width, hip width, head width, HPS to apex, total rise, thigh circumference, across back, thigh width, chest width. The eigenvalue of the principal component 1 is 20.175, which explains 56.042% of the total variance and is the most explanatory factor among the 3 factors with Cronbach's α reliability of 0.964.

Table 2. Cronbach's Alpha reliability of anthropometric dimensions.

Reliability Statistics	
Cronbach's Alpha	N of Items
0.948	36

Factor 2 includes 12 measurements related to body height and length, which representing: center front neck to waist, center front neck to bust, shoulder point to waist, total height, HPS to waist, center back neck to waist, hip height, center back neck to wrist, crotch height, bust to waist, head module, waist to hip can be considered as representative for the length and height dimensions of the body. Specifically, the total height is 0.986, hip height is 0.964, center neck back to wrist is 0.954, crotch height is 0.947 and head module is 0.839, there is no systematic measurements factor load is less than 0.7. Principal component 2 has an eigenvalue of 13.392 which explains 37.199% of the total cumulative variance, is the second explaining factor with a Cronbach's α reliability of 0.914.

Factor 3 has the lowest eigenvalue 1.323, accounting for 3.675% of the total cumulative variance with a confidence level of 0.754, including 2 measurements: shoulder width (0.724), shoulder length (0.674). This is the main factor representing the measurement of the shoulder area of the body.

Results of cluster analysis by K-means cluster analysis

K-means cluster analysis is used in the case of expected clustering of 2-10 clusters [24]. The results of subgroup analysis using K-means cluster analysis of 10 groups can be clearly displayed as table 5. However, with the further support of Discriminant analysis could narrow the results of subgroup analysis by K-means cluster analysis and scatter plot as shown in Figure 1. It finally shows that the classification is correct with 97.3% in the case of samples classified into 5 groups, while the classifications are classified into 5 groups. 2 groups, 3 groups, 4 groups, 6 groups, 7 groups, 8 groups, 9 groups, 10 groups are 97.0%, 94.9%, 93.4%, 94.5%, 95.7%, respectively, 95.3%, 96.1% and 94.1%. Thus, classifying the samples into 5 groups appears to be the most appropriate method for achieving clear classification. These five groups will continue to be analyzed and compared by ANOVA and find out the body characteristics of each group [22 - 24].

Table 3. Main factor analysis results.

Main factor	Measurements	Factor loading	Eigen values	Cumulative %	Cronbach' α
Body volume	Waist circumference	0.990	20.175	56.042%	0.964
	Waist width	0.989			
	Abdomen circumference	0.988			
	Bust circumference	0.985			
	Bicep circumference	0.982			
	Neck circumference	0.979			
	Over bust circumference	0.977			
	Waist depth	0.976			
	Under bust circumference	0.976			
	Hip depth	0.973			
	Bust depth	0.946			
	Apex to apex	0.940			
	Hip circumference	0.924			
	Neck width	0.915			
	Hip width	0.901			
	Head width	0.898			
	HPS to apex	0.870			
	Total rise	0.841			
	Thigh circumference	0.817			
	Across back	0.806			
Thigh width	0.798				
Across chest	0.784				
Body height and length	Center front neck to waist	0.990	13.392	37.199%	0.914
	Center front neck to bust	0.988			
	Shoulder point to waist	0.988			
	Total height	0.986			
	HPS to waist	0.972			
	Center back neck to waist	0.968			
	Hip height	0.964			
	Center back neck to wrist	0.954			
	Crotch height	0.947			
	Bust to waist	0.927			
	Head module	0.839			
	Waist to hip	0.757			
	Shoulder area	Shoulder width			
Shoulder length		0.674			
Note: Rotation method: Varimax Extraction method: PCA (principal component analysis)					

Table 4. KMO and Bartlett's test results.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.669	
Bartlett's Test of Sphericity	Approx. Chi-Square	33119.171
	df	231
	Sig.	0.000

Results of ANOVA test

The mean and standard deviation of the measurements are shown in the results of F-test in ANOVA analysis and Scheffe-test for 36 body measurements are presented in Table 6.

In ANOVA analysis the results show that the significance level of $0.00 < \text{Sig} < 0.001$ shows that the cluster analysis results are more significant, and the clusters are different from each other [22, 23]. The results of testing the difference in mean values for each body type of body sizes showed interesting insights. Human Type 1, accounting for 15.23% of the sample, represents the thinnest individuals with the smallest circumference measurements, including waist circumference (64.11cm), bust circumference (80.95 cm) and hip circumference (84.33 cm). This

group also features the shortest height (151.24 cm) and a small shoulder area with shoulder width (35.34 cm) and shoulder length (10.95). Meanwhile, Human Type 5, accounting for only 8.59% of the sample, consists of fat individuals with the largest circumference measurements, bust circumference (103.36 cm), waist circumference (87.33 cm), hip circumference (105.10 cm). However, there is a large average head modulus (21.51 cm), the largest distance from waist to hip (20.95 cm) and crotch height belongs to the low group (71.74 cm); Large shoulder size with shoulder width (37.98 cm) and shoulder length (11.88 cm). Human Type 3 has the highest proportion with 35.94% of the sample, representing the symmetrical humanoid with sizes close to the size of the sample mean. Human Type 4, accounting for 21.88% of the sample, is as slightly fat

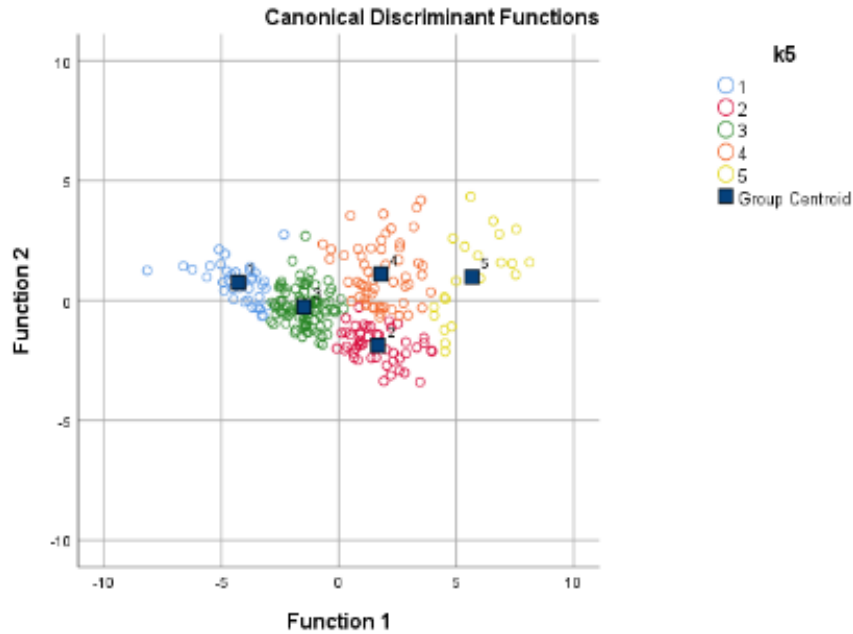


Figure 1. Scatter plot in case of analysis of 5 subgroups.

Table 5. Results of quantity and percentage of each sample.

Number of groups	Quantity and percentage of each sample									
2 group	195 40.63%					285 59.38%				
3 group	178 37.11%			139 28.91%			163 33.98%			
4 group	182 37.89%		71 14.84%		114 23.83%		113 23.44%			
5 group	73 15.23%		88 18.36%		173 35.94%		105 21.88%		41 8.59%	
6 group	26 5.47%	69 14.45%		152 32.64%		68 14.06%	86 17.97%		79 16.41%	
7 group	107 22.27%	62 12.89%		26 5.47%	58 12.11%	71 14.84%		86 17.97%	69 14.45%	
8 group	26 5.47%	94 19.53%	77 16.02%	77 16.02%	62 12.89%	69 14.45%	41 8.59%	34 7.03%		
9 group	39 8.20%	60 12.50%	60 12.50%	41 8.59%	66 13.67%	26 5.47%	34 7.03%	47 9.77%	107 22.27%	
10 group	56 11.72%	39 8.20%	84 17.58%	96 19.92%	15 3.13%	19 3.91%	45 9.38%	43 8.98%	56 11.72%	26 5.47%

person with waist circumference (79.04 cm), bust circumference (91.19 cm), hip circumference (96.73 cm). Yet, this group tends to have shorter heights with the average body height measurement (152.58 cm) and average shoulder size. Human Type 2, accounting for 18.36% of the sample, is the tall and large human body type, with the longest length measurements and larger circumferential measurements compare to the average group sizes.

Results of body proportion analysis of five body types

The simulation of body shapes is based on the measurements from each body group in Table 6. The shape of each human form is simulated in Figure 2 through CLO3D design software. Figure 3 shows a

distinct difference among the physique groups, partially in terms of body contour. When comparing height sizes, Group 5 and Group 3 show minimal difference, as do Group 4 and Group 1. However, Group 2, Group 5 and Group 4 show notable differences. In addition, clear differences can be seen among all body types when comparing body width and thickness. The results show that Group 1 represents individuals who are short, thin, and have small shoulders; Group 2 consists of taller individuals who are slightly overweight and have larger shoulders; Group 3 showcase well-proportioned figure; Group 4 includes shorter individuals who are heavier with medium-sized shoulders; Group 5 comprises individuals who are notably overweight, of average height, and possess large shoulders.


Table 6. Results of ANOVA analysis and Scheffe-test.

								<i>Unit: cm</i>
Main factor	Measurements	Mean (SD)						F
		Group 1 (n=73) 15.23% <SD>	Group 2 (n=88) 18.36% <SD>	Group 3 (n=173) 35.94% <SD>	Group 4 (n=105) 21.88% <SD>	Group 5 (n=41) 8.59% <SD>	Total (n=480) 100% <SD>	
Body volume: circumference, width and depth measurements	Waist circumference	64.11 A <2.90>	75.03 C <3.33>	69.39 B <2.64>	79.04 D <2.67>	87.33 E <3.82>	73.27 <7.19>	319.454***
	Waist width	22.86 A <0.91>	26.65 C <0.97>	24.62 B <0.68>	27.30 D <0.80>	29.92 E <0.99>	25.77 <2.14>	364.716***
	Abdomen circumference	79.12 A <2.79>	92.49 C <3.39>	85.77 B <2.48>	94.73 D <2.97>	104.21 E <3.88>	89.54 <7.51>	350.164***
	Bust circumference	80.95 A <2.77>	91.35 C <3.47>	85.89 B <2.74>	95.19 D <2.67>	103.36 E <3.91>	89.67 <7.00>	286.725***
	Bicep circumference	23.67 A <1.03>	27.85 C <1.28>	25.78 B <1.00>	28.99 D <1.13>	32.15 E <1.51>	27.09 <2.61>	272.294***
	Neck circumference	30.58 A <0.59>	33.42 C <0.66>	31.86 B <0.48>	33.63 C <0.62>	35.69 D <0.81>	32.67 <1.53>	361.142***
	Over bust circumference	80.03 A <2.08>	90.69 C <2.27>	85.29 B <1.43>	94.19 C <1.96>	101.94 D <2.49>	89.01 <5.08>	381.575***
	Waist depth	16.60 A <0.88>	19.65 C <1.04>	18.13 B <0.93>	21.09 D <0.89>	23.55 E <1.32>	19.29 <2.20>	261.032***
	Under bust circumference	68.54 A <2.85>	77.92 C <3.39>	73.12 B <2.77>	83.38 D <3.10>	91.76 E <4.85>	77.15 <7.37>	276.616***
	Hip depth	20.48 A <0.87>	24.37 C <1.05>	22.43 B <0.83>	24.97 C <0.97>	27.74 D <1.22>	23.50 <2.20>	280.268***
	Bust depth	21.13 A <0.95>	23.81 C <1.18>	22.53 B <1.11>	25.62 D <1.03>	27.99 E <1.57>	23.70 <2.27>	195.128***
	Apex to apex	15.42 A <0.50>	17.54 C <0.54>	16.35 B <0.36>	17.52 C <0.49>	18.92 D <0.54>	16.90 <1.08>	283.884***
	Hip circumference	84.33 A <2.53>	97.20 C <3.27>	90.68 B <2.49>	96.73 C <3.06>	105.10 D <3.89>	93.47 <6.37>	241.518***
	Neck width	9.92 A <0.21>	10.87 D <0.19>	10.32 B <0.13>	10.71 C <0.20>	11.32 E <0.20>	10.53 <0.43>	313.553***
	Hip width	30.51 A <0.84>	34.83 C <1.06>	32.63 B <0.82>	34.44 C <0.99>	37.06 D <1.30>	3.49 <2.04>	226.376***
	Head width	14.17 A <0.13>	14.86 D <0.14>	14.47 B <0.10>	14.72 C <0.15>	15.17 E <0.15>	14.61 <0.30>	316.647***
	HPS to apex	22.79 A <0.50>	25.44 D <0.58>	24.02 B <0.48>	24.92 C <0.60>	26.59 E <0.55>	24.51 <1.18>	244.884***
	Total rise	70.46 A <1.60>	78.43 D <1.88>	74.16 B <1.65>	76.49 C <2.01>	81.75 E <2.12>	75.54 <3.59>	188.262***
	Thigh circumference	49.85 A <1.24>	56.57 C <1.65>	53.18 B <1.38>	55.40 C <1.59>	59.41 D <2.05>	54.32 <2.68>	133.829***
	Across back	29.61 A <0.72>	32.26 D <0.54>	30.67 B <0.50>	31.48 C <0.67>	33.03 E <0.55>	31.18 <1.16>	183.730***
Thigh width	15.96 A <0.50>	18.14 C <0.67>	17.04 B <0.57>	17.74 C <0.65>	19.03 D <0.86>	17.40 <1.05>	117.473***	
Across chest	29.40 A <0.86>	32.33 D <0.65>	30.56 B <0.62>	31.44 C <0.80>	33.13 E <0.65>	31.12 <1.30>	152.401***	
Body height and length measurements	Center front neck to waist	30.49 A <0.76>	32.68 C <0.82>	31.36 B <0.88>	30.47 A <0.80>	31.39 B <0.75>	31.28 <1.13>	56.817***
	Center front neck to bust	17.94 A <0.53>	19.55 C <0.56>	18.60 B <0.60>	18.06 A <0.54>	18.71 B <0.48>	18.56 <0.78>	60.115***
	Shoulder point to waist	23.99 A <0.64>	25.97 C <0.67>	24.78 B <0.73>	24.12 A <0.67>	24.99 B <0.64>	24.75 <0.96>	61.776***
	Total height	151.24 A <4.29>	164.68 C <4.39>	156.73 B <4.97>	152.58 A <4.19>	157.95 B <3.88>	156.55 <6.34>	63.065***
	HPS to waist	31.80 A <0.74>	34.28 C <0.79>	32.81 B <0.84>	32.17 A <0.80>	33.31 B <0.70>	32.83 <1.14>	66.540***
	Center back neck to waist	32.36 A <0.75>	34.75 C <0.81>	33.35 B <0.86>	32.66 A <0.79>	33.75 B <0.71>	33.34 <1.13>	61.147***
	Hip height	76.71 A <3.05>	84.75 C <3.05>	79.93 B <3.57>	76.58 A <2.87>	79.24 B <2.78>	79.53 <4.27>	51.477***
	Center back neck to wrist	67.81 A <2.20>	74.87 D <2.17>	70.63 B <2.37>	69.26 B <2.01>	72.25 C <1.72>	70.82 <3.13>	68.552***
	Crotch height	70.64 A <2.96>	77.59 C <2.97>	73.34 B <3.48>	69.74 A <2.77>	71.74 A <2.77>	72.79 <4.09>	47.539***
	Bust to waist	12.55 A <0.26>	13.13 D <0.28>	12.76 C <0.30>	12.41 A <0.30>	12.68 B <0.29>	12.71 <0.37>	43.134***

	Head module	20.64 A <0.23>	21.58 C <0.25>	21.04 B <0.24>	21.01 B <0.25>	21.51 C <0.22>	21.11 <0.39>	100.083***
	Waist to hip	19.21 A <0.45>	20.92 C <0.46>	19.94 B <0.47>	19.94 B <0.52>	20.95 C <0.49>	20.10 <0.74>	
Shoulder area measurements	Shoulder width	35.34 A <0.78>	37.98 C <0.57>	36.36 B <0.62>	36.61 B <0.76>	37.98 C <0.59>	36.70 <1.10>	109.388***
	Shoulder length	10.95 A <0.27>	11.83 C <0.21>	11.30 B <0.22>	11.42 B <0.26>	11.88 C <0.19>	11.42 <0.38>	

*** p < 0.001

The alphabet is the result of a Post - hoc test (Scheffe test) (with A< B< C<D<E).

 : Size with the highest mean


 : Size with the lowest mean



Figure 2. Simulation of 5 types of women through CLO3D software.

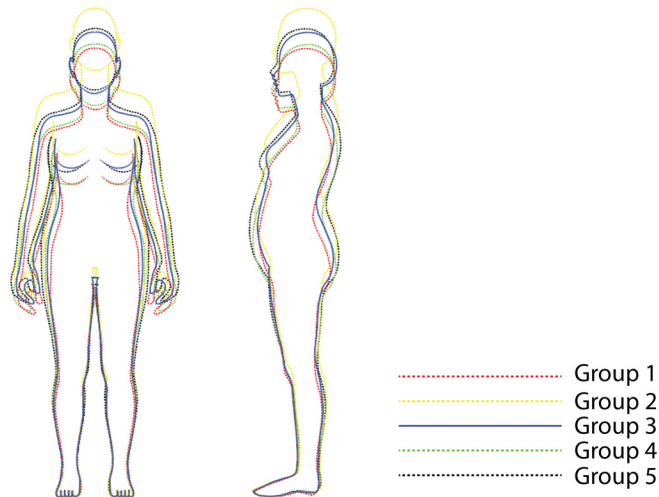


Figure 3. Compare the differences between body shapes.

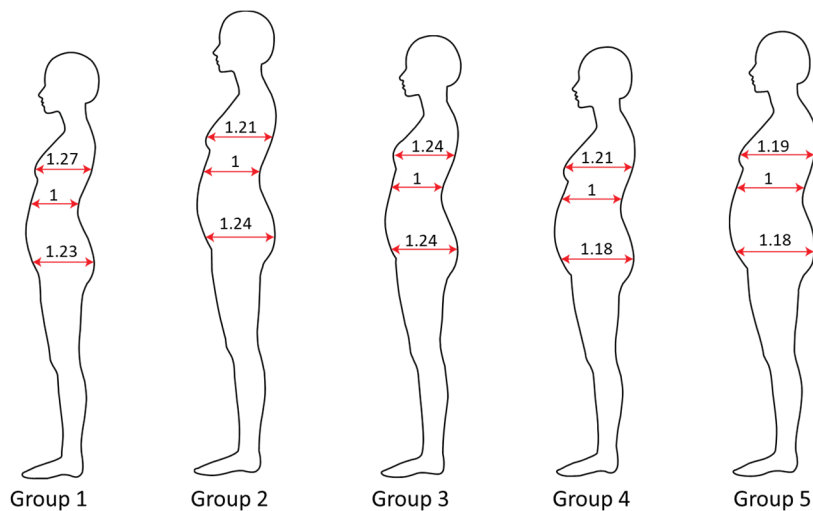


Figure 4. Body thickness ratio of 5 body shapes.

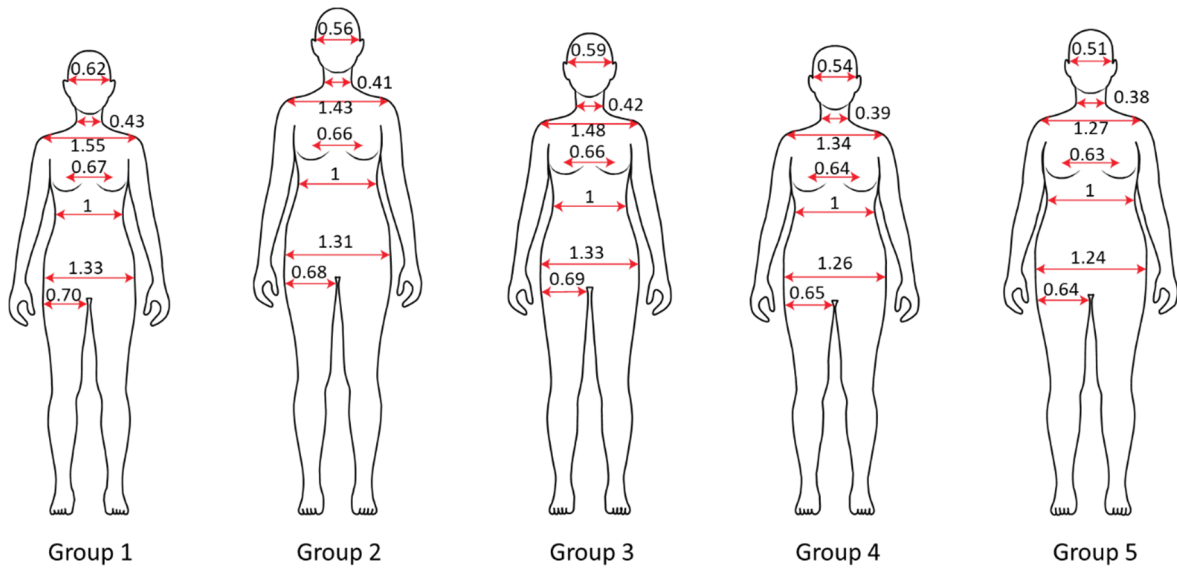


Figure 5. Body width ratio of 5 body types.

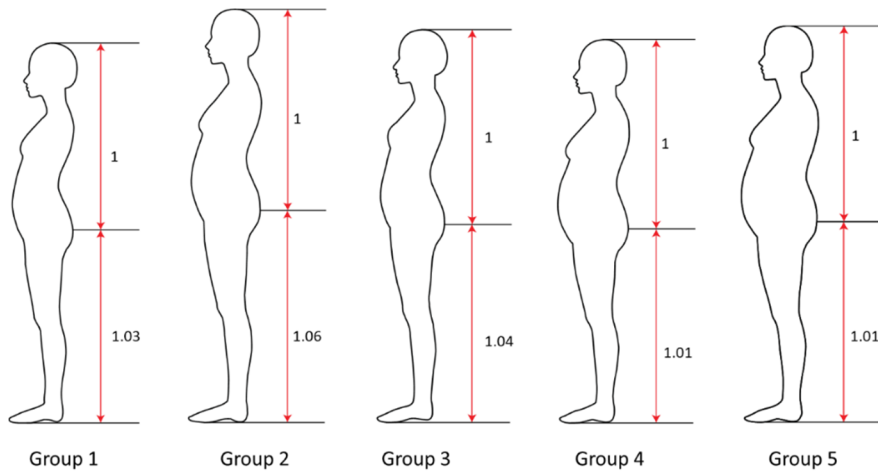


Figure 6. Hip height ratio of 5 body types.

In addition, the proportions of each body type are shown in Figures 4, 5, 6, 7, 8, 9, 10, 11, 12.

The body thickness ratio among the 5 body shape groups is shown in Figure 4. The results show that Group 3 is the body group with the bust - waist ratio equal to the hip waist ratio, indicating a symmetrical body shape. Conversely, Groups 1, 4 and 5 all display a larger bust - waist ratio than hip - waist ratio, while Group 2 showed a smaller bust waist ratio than the hip waist ratio.

Figure 5 shows the body width ratio among five body types. When compares to Group 3, which is the average group for width-to-waist sizes ratios, Group 2, 4 and 5 all have a smaller width-to-waist ratio. This explains more clearly that body groups 2, 4, 5 represent slightly fat, fat and over-fat bodies, respectively. The other group, Group 1, has a larger of width-to-waist ratio than Group 3, especially, the hip size has the same ratio as Group 3. This is the body group representing the thin group.

The ratio of hip height to the height from the top of the head to the hip of the five body shapes is shown in

Figure 6. Looking at the figure and the results of the ratio calculation, Group 2 has the highest hip height ratio at 1.06, representing a body type with higher hip position. In contrast, Group 4 and Group 5 have the lowest hip height ratios of 1.01, representing body types with sagging hips. The remaining groups, Group 1 and Group 3 have an average hip height ratio of 1.04 compared to the height from the top of the head to the hip.

Figures 7, 8, 9, 10, 11 analyze the height ratio measurement to the size of the body height for five body groups. From the analysis results, Groups 2 and 3 have the same ratio of height to standing height dimensions, while Groups 1, 4 and 5 have differences. Specifically:

- Group 1 matches Groups 2 and 3 in proportions for bust height, hip height, and crotch height but has a larger head modulus size ratio. Other measurements show smaller proportions than Groups 2 and 3.
- Group 4 has smaller proportions than groups 2 and 3, except for the head modulus, which matches Groups 1 and 5.

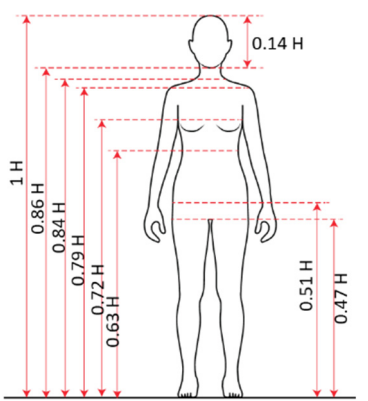


Figure 7. Ratio of height dimensions of group 1

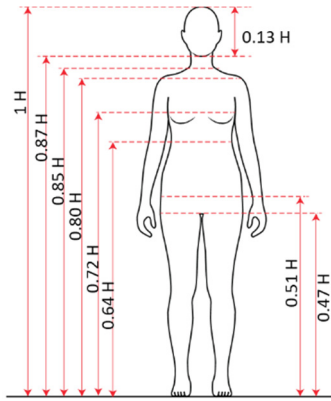


Figure 8. Ratio of height dimensions of group 2

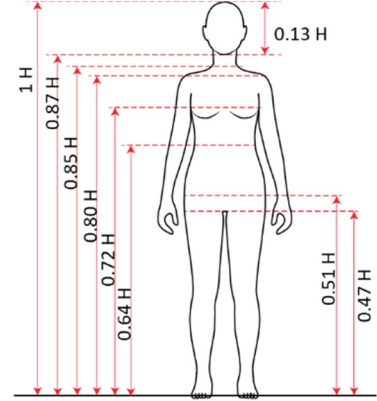


Figure 9. Ratio of height dimensions of group 3

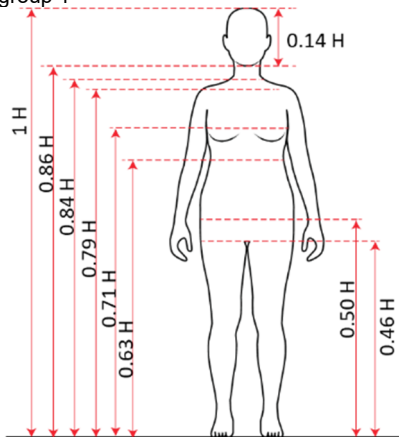


Figure 10. Ratio of height dimensions of group 4

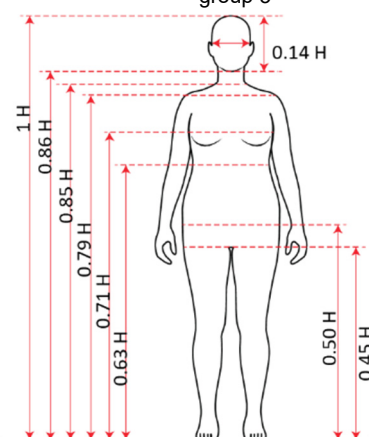


Figure 11. Ratio of height dimensions of group 5

- Group 5 has a first modulus ratio greater than Groups 2 and 3, similar to Groups 1 and 4, with neck height proportions matching Groups 2 and 3. Other measurements show smaller proportions than Groups 2 and 3.

- In addition, Groups 1, 4 and 5 share equal proportions for chin height, shoulder height, waist height and head modulus.

CONCLUSION

This study collected 36 anthropometric measurements from a sample of 480 Vietnamese women residing in major cities, representing three regions of North, Central, and South. The analysis results, including statistical characteristics, principal component analysis, K-means cluster analysis, discriminant analysis, ANOVA analysis and Scheffé-test showed the existence of five female body types: "short and thin with small shoulder" accounting for 15.23 %; "tall with slightly fat and large shoulders" accounting for 18.36 %; "Medium body type", with an average accounting for height stature and a fit body, and a bust-waist ratio equal to the waist-to-hip ratio, accounting for 35.94 %; "short with fat and medium-large shoulder" accounting for 21.88 %; and "too fat with average height, big shoulders" accounting for 8.59 %. The analysis of body thickness ratio of five body shapes showed results that: Group 3 had a

bust-waist ratio equal to the hip-waist ratio; Groups 1, 4 and 5 had a bust-waist larger than the hip-waist ratio; Group 2 exhibited a bust-waist ratio smaller than the hip-waist ratio. The analysis of body width ratio showed that: Group 2, 4 and 5 had a smaller width to waist ratio than Group 3. Group 1 had a width to waist ratio larger than Group 3, especially the hip size has the same ratio as Group 3. The results of analyzing the ratio of hip height to the height from the top of the head to the hips of the five body shapes showed that: Group 2 had the highest hip height ratio (1.06), representing a body types with a high hip position; Group 4, 5 had the lowest hip height ratio (1.01), representing the body type with sagging hip; Group 1 and 3 had an average hip height ratio of 1.04 compared to the body. The results of analysis of height dimensions ratio to body height for five body groups show that Groups 2 and 3 have the same height dimensions ratio to body height, the remaining Groups 1, 4 and 5 have significant differences in these ratios.

The research results can serve as a reference for the garment industry while contributing to the goal of building a virtual model library within 3D design software and mass-customization.

Acknowledgement: This research was supported by the Hanoi University of Science and Technology (HUST) under project number T2018-PC-048.

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