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## Sizing for the apparel industry using statistical analysis – a Brazilian case study

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**Abstract.** The study of the body measurements of Brazilian women used the *Kinect Body Imaging* system for 3D body scanning. The result of the study aims to meet the needs of the apparel industry for accurate measurements. Data was statistically treated using the *IBM SPSS 23* system, with 95% confidence ( $P < 0,05$ ) for the inferential analysis, with the purpose of grouping the measurements in sizes, so that a smaller number of sizes can cover a greater number of people. The sample consisted of 101 volunteers aged between 19 and 62 years. A cluster analysis was performed to identify the main body shapes of the sample. The results were divided between the top and bottom body portions; For the top portion, were used the measurements of the abdomen, waist and bust circumferences, as well as the height; For the bottom portion, were used the measurements of the hip circumference and the height. Three sizing systems were developed for the researched sample from the Abdomen-to-Height Ratio – AHR (top portion): Small (AHR < 0,52), Medium (AHR: 0,52-0,58), Large (AHR > 0,58) and from the Hip-to-Height Ratio – HHR (bottom portion): Small (HHR < 0,62), Medium (HHR: 0,62-0,68), Large (HHR > 0,68).

### 1. Introduction

The discussion about the dimensions of clothing sizes is an old question, with several countries still struggling for a consensus on the matter of the standardization of measurements. In this situation is also Brazil, for several reasons. The country still does not have a standardized sizing system. Among those reasons, are, for example, the great anthropometric variation, since the Brazilian population is a mixed race, the limited updated information on Brazilian anthropometric measurements and the few investments in technology for research.

The anthropometric researches follow the technological evolution of 3D scanning methods, as these methods allow a greater number of collected data with increased reliability and precision. Anthropometric data, when submitted to statistical analysis, generates a reliable sizing system, which can be used by the apparel industry.

The constant effort of researchers with the development of sizing systems, has as main aim, the definition of the ideal number of sizes, that can accommodate the greater percentage of the target population. These sizes, then, accurately describe the many actual sizes and shapes that can be found among the population of the sample [1]. These anthropometric surveys need to be developed individually by each country, due to the fact that body shapes differ from one continent to another.

## 2. 3D body scanning equipment

The equipment used for data collection is the *KBI-Kinect Body Imaging* system, composed of hardware and software that work for the capture of 3D images and, afterward, generate the main measurements of the dimensions of the body. The *KBI* system was developed by University of Texas and University of North Texas (USA). The system uses the Microsoft Kinects as image capture sensors.

## 3. Materials and methods

When it comes to scientific research, it is usually impossible to study the entire population of interest and, therefore, the researcher usually depends on sampling to obtain a subset of the population [2]. The results obtained by sampling can be inferred and, subsequently, applied to the entire population [3].

In order to determine the population for the study, some criteria were established, such as: only women, Brazilian nationality, over 18 years old and enrolled at University of Minho in Portugal. The total sample was composed by 101 volunteers ( $n=101$ ), aged between 19 and 62 years. Data regarding this sample was collected in the period between June and September 2016, in Portugal.

In total, 36 variables of body measurements were selected for the data analysis, however, some key variables were selected, namely: height, bust circumference, waist circumference, abdomen circumference and hip circumference. These variables are of great importance for the sizing of clothing.

A multivariate data analysis was conducted in order to reduce the number of variables and to detect the structure of the relations between them. The cluster analysis is an exploratory technique of data analysis, with the purpose of grouping objects based on their characteristics [2].

A cluster analysis was performed to identify the body dimensions of the sample. Specific descriptive analyses were developed to better present the data on each occasion. All statistical analyses were performed with the *IBM SPSS 23* system, with 95% confidence ( $P<0,05$ ) for the inferential analysis.

Initially, outliers were detected, and their probability was analysed based on the *Mahalanobis* distance [2], which resulted in the exclusion of two cases and, consequently, this analysis was performed with a reduced sample ( $n=99$ ). In this work, it was used the hierarchical clustering algorithm of complete linkage, in which the similarity of clusters is based on the maximum distance between the observations in each cluster. This method generates more compact solutions and has been considered the most appropriate for different applications [4].

## 4. Results

Three clusters were pre-established in order to obtain the sizes small (S), medium (M) and large (L), whose logic has shown excellent results in distinguishing clusters in other studies Hsu, [5]; Peña, et al. [6]. The Abdomen-to-Height Ratio – AHR as well as the Hip-to-Height Ratio – HHR were used as variables to determine the clusters of the top and bottom body portions, respectively.

As a way to validate the clustering solution, a validity of criteria was established from an analysis of variance (ANOVA), with the post hoc Tukey's HSD test. In this way, the differences between the clusters for key variables were statistically tested in the top body portion (bust, abdomen and waist circumferences) and in the bottom body portion (hip circumference), as proposed by Hair Jr, et al. [2], since they are very important measurements for the design and manufacture of clothing. All the variables of this analysis met the assumption of homogeneity of the variances (Levene's Test,  $P>0,05$ ). The average and the percentiles 5 (P5) and 95 (P95) were used to represent the clusters.

In order to better represent the clusters in the sample analysed, the variables of height, abdomen circumference and hip circumference were used in the calculation of the indices for the top (AHR) and bottom body portions (HHR).

Singly, these variables did not present autocorrelation and, therefore, were combined in indices of easy calculation. This proposal differs from previous investigations that use height as the primary dimension of control and the bust and/or hip circumferences as secondary dimensions [7], [8].

The partitioning technique has grouped the data into three groups, which are significantly different between them. The three body types in the sample were the small (S), medium (M) and large (L) sizes, as shown in Table 1. A complementary ANOVA showed significant differences between all pairs of clusters ( $F_{2, 96} > 4,8$ ;  $P < 0,05$ ) for the AHR and HHR and for important body measurements of the top body portion (circumferences of the abdomen, waist and bust) and bottom body portion (hip), but not for height, where some pairs of clusters were similar.

**Table 1.** Variables in the clusters for the top and bottom body portions (n = 99)

Variables	Cluster 1	Cluster 2	Cluster 3
<i>TOP</i>			
Size of grouping	n=24	n=39	n=36
Sizes	Large	Medium	Small
AHR*	0,62 (0,58-0,68)	0,55 (0,52-0,58)	0,50 (0,45-0,52)
Height	162,4 (150,7-170,8)	162,2 (153,0-170,0)	165,7 (156,7-178,0)
Abdomen girth *	100,5 (91,8-114,0)	88,8 (82,9-96,1)	82,2 (72,0-89,6)
Waist girth *	88,2 (77,8-100,0)	78,4 (69,6-86,0)	70,4 (61,9-80,5)
Bust girth *	106,0 (94,9-122,0)	98,0 (89,2-110,6)	90,2 (78,8-99,7)
<i>BOTTOM</i>			
Size of grouping	n=10	n=52	n=37
Sizes	Large	Medium	Small
HHR*	0,72 (0,69-0,79)	0,65 (0,62-0,68)	0,59 (0,55-0,62)
Height	163,0 (150,0-170,0)	161,7 (151,0-171,0)	166,3 (157,9-178,0)
Hip girth *	117,7 (114,5-132,5)	105,1 (97,3-114,1)	98,0 (89,4-104,3)

Values reported by mean and percentiles ( $P_5$ - $P_{95}$ ). \* Significant difference between all paired comparisons ( $P < 0,05$ )

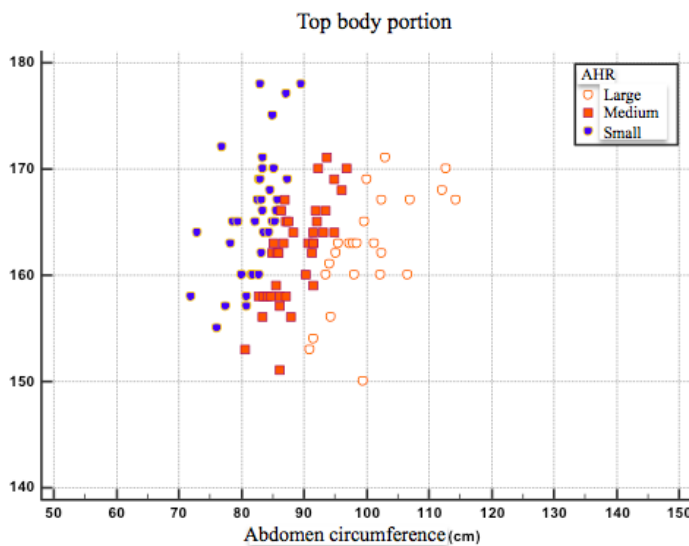
#### 4.1 Results of the top body portion

For the top body portion, the largest proportion was allocated in cluster 2 (n=39), corresponding to the size M. The second largest distribution was that of cluster 3 (n=36), which is the size S. The last cluster (n=24) represented the size L.

The clusters 1 and 2 presented similarities regarding height ( $P > 0,05$ ), but were distinguished in the measurements of the abdomen, waist and bust circumferences ( $P < 0,05$ ).

Cluster 3 (S) was composed of taller women, however, with smaller measurements concerning the abdomen, waist and bust circumferences than the other clusters ( $P < 0,05$ ).

A scatter graph displaying the relationship between the height and the abdomen circumference is shown in Figure 1. The graphs were developed in the MedCalc 16.8.4 (MedCalc Software bvba, Belgium).



**Figure 1.** Scatter graph of the relationship between the height and the abdomen circumference of the Brazilian women (n=99), derived from the clustering based on the Abdomen-to-Height Ratio (AHR).

*4.2 Results of the bottom body portion*

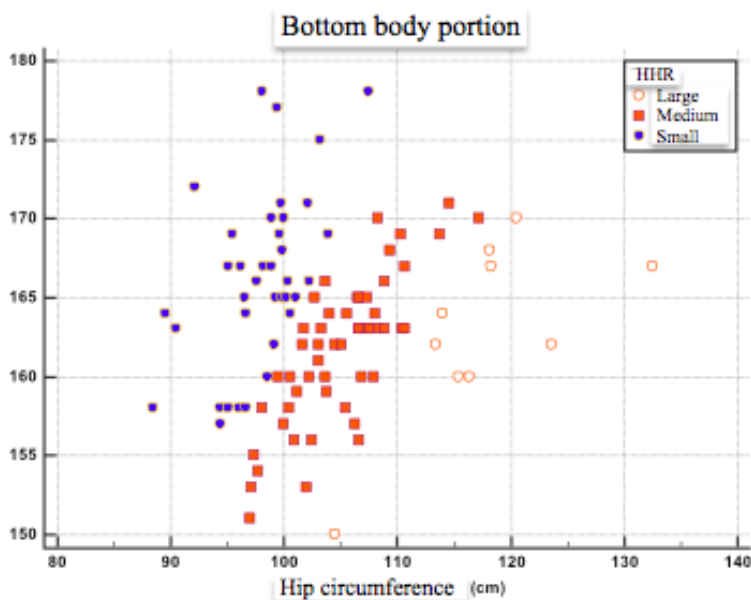
The results shown in table 1, for the bottom body portion, show that the majority of women (n=52) formed cluster 2, of size M.

The second largest cluster was 3 (n=37), corresponding to size S, and, finally, the third was cluster 1 (n=10), representing size L.

In the same way as with the results obtained for the top body portion, clusters 1 and 2 presented a similar height ( $P>0,05$ ), but differed in the measurement of the hip circumference ( $P<0,05$ ).

Cluster 3 (S) was composed of taller women, however, with smaller measurements concerning the hip circumference than the other clusters

A scatter graph displaying the relationship between the height and the hip circumference is shown in Figure 2.



**Figure 2.** Scatter graph of the relationship between the height and the hip circumference of the Brazilian women (n=99), derived from the clustering based on the Hip-to-Height Ratio (HHR).

Based on the cluster analysis and being the differences confirmed through ANOVA, the following profiles were proposed, based on the AHR and HHR, for the top and bottom body portions: sizes S, M, L, as shown on Table 2.

**Table 2.** Classification profile of the body types of the Brazilian students (n = 99).

Sizes	Top			Bottom
Small	Abdomen < 89,6	AHR < 0,52 Waist < 80,5	Bust < 99,7	HHR < 0,62 Hip < 104,3
Medium	82,9 < Abdomen < 96,1	0,52 < AHR > 0,58 69,6 < Waist < 86,0	89,2 < Bust < 110,6	0,62 < HHR > 0,68 97,3 < Hip < 114,1
Large	Abdomen > 91,8	AHR > 0,58 Waist > 77,8	Bust > 94,9	HHR > 0,68 Hip > 114,1

## 5. Discussion

The study presented results for the sizing of clothing divided into three categories, namely, small, medium and large. Usually, the industry uses more clothing sizes with the objective of serving all its customers, however, in this specific case, since the sample was reduced (n=99), if more divisions of size were made, the sample in each would be very small, impairing, consequently, the final result.

The three body types in the sample, the sizes S, M and L, present the possible values of the bust, waist and abdomen circumferences for each of the sizes, being that the values may overlap, especially in intermediate measurements.

Since it is a case study involving Brazilian women living in Portugal, it cannot be stated that the result is representative for the entire population of women living in Brazil. Future studies with a larger sample of Brazilian women can use the same methodology to obtain results that are representative of the population.

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