SizeBR - The Brazilian Study on Anthropometric

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Abstract

In order to standardize and guide the clothing manufacturers in developing products to meet the textile and apparel chain, hence the construction of the gradations and modeling clothing in relation to standards bodies, Senai CETIQT, in 2006, began, still incipient, the mapping of different configurations of bodies Brazilians. Over those seven years, as the methodology was outlined and matured, the study of Senai CETIQT passed through several stages. First acquired tools for manual measurement and conducted a feasibility study with a small sample group comprised of students and staff of the institution itself. As the results were satisfactory, a new phase began with the acquisition of a body scanner and specialized services standardization of uniforms of the armed forces and auxiliaries. With the implemented methodology, it was possible a major step toward the anthropometric characteristics of the standard body of Brazilian design SizeBR. In 2010 Senai CETIQT listed the main consumption centers spread across five main regions: South, Southeast, Cento West, North and Northeast to start the first scientific study conducted by anthropometric scanning technology at the national level in order to behold the great dimensions of Brazil. Seeking greater breadth of research, the team of Innovation Management, Studies and Research through the line and Consumption Behavior of Senai CETIQT developed a questionnaire about consumption habits of Brazilians to be applied in conjunction with measurements to be obtained in these regions. For each consumption center, depending on the served population, we applied the statistical theory of sampling to define the number of Brazilians to be measured (the international standard ISO 15535:2012). So a specialized team consisting of technicians in the design, engineering, anthropology, social sciences, electronics and ergonomics was trained to go into the field and perform automatic measurements manuals and treat the images obtained by body scanners. Currently the project team SizeBR dedicated to the completion of the measurements and the statistical treatment of the data and has the forecast finalization of the national stage for males and females between 18 and 65 years and consequently Senai CETIQT. Continuing expansion SizeBR seeking to meet the other segments, Senai CETIQT is acquiring two more body scanners, one for feet and hands and another for head, in this way to meet with that segment of the field of Fashion.

Keywords: Anthropometric Survey, 3D body scanning, modeling clothing, sizing systems

1. Introduction

The Senai CETIQT is an institution of more than 60 years, is acting solely in the service of the textile and clothing chain. Through their actions and activities related to industry, plus directions, studies and research conducted in partnership with ABIT, ABDI, MDIC, MCTI, companies, plus the contributions of the agents that operate in various sectors of this segment, the anthropometric Brazilian research was one of the most relevant items requested. The research began in 2006, with the approval of SGPE-0602 for structuring the Course of Technology in Apparel Production, when it was acquired a body scanner to generate applied research and thus meet this market demand Brazilian. Through the project construction anthropometric survey, there was the beginning of it with the team structure, training, acquisition of current literature, translations, international survey of ongoing research, technologies used, physical structure among others to meet the research and technology course. After all surveys, analyzes and justifications made, the team began the process of acquiring and importing the body scanner technology of white light, in order that it could be transported more easily to the entire Brazilian territory. In parallel to the manual research and statistics guidelines to be adopted, and the team has constantly a flow through training to meet the diversity of research.

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In Brazil, the Brazilian Association of Technical Standards - ABNT is responsible for the dissemination of technical standards and standardization systems in general. Recently, more precisely in mid-2011, ABNT developed jointly with diverse stakeholders (Association of classes, educational institution, manufacturing industries and large retailers), the standard NBR16060: 2011 which defined and standardized a system of body sizes geared exclusively for making men's clothing. Throughout the year 2013 to ABNT is systematically gathering stakeholders in developing a technical standard to define a system of body size to meet the apparel for female clothing. Both technical standards that define the systems sizes of male and female bodies, were not developed from an anthropometric survey with a significant sample of the Brazilian population. The lack of standardization bodies of Brazilians causes a wide variation in the wearability of textile products from different brands and even the same brand. It is quite common to find in major retailers products of different sizes to suit one body, we can realize that there is a market practice to exchange label by companies cooking, so cater to the ego of consumers who do not accept his dummy and have consequently seek bigger clothes, but with smaller label. Thus, **The Brazilian study on anthropometric** - **SizeBR** seeks to answer the following questions: What is the body shape of the population? How many are the same way? What is the best segmentation of the population to develop a sizing system? How to relate the shape of the body with the system size? How to adjust the standard bodies in modeling clothing? What can be done so that the clothing manufacturers begin using the same system sizes? To answer these provocative questions, the Brazilian study on anthropometric - SizeBR priority in their lines of work, meet the following actions:

- Map the different biotypes male and female mannequins and generating tables updated measures;
- Develop a methodology for application of the results of measuring the human body, obtained from a sample survey;
- To systematize the information collected;
- Establish technical criteria for application of results;
- Structuring a methodology for building bases modeling, using the data collected;
- Create an experimental wearability laboratory;
- Develop mannequins with Brazilian standards, which will be tested in manufacturing companies, and may be used in the calibration bodyscanners;
- Develop standards for building the foundations of modeling;
- Develop standards for defining concepts of functionality and wearability;
- Provide the basis of data obtained in the project to other studies.

2. Methodology

To start the project characterization of the bodies of the population with a focus on wearability, Senai CETIQT acquired two Body Scanners White Light TC2. A team of five people was created to participate in the project of anthropometric measurements by regions of Brazil, the team consisted of an electronics technician, two physical education teachers, an expert in ergonomics and project manager. Each team member had a specific responsibility, namely: the manager was responsible for logistics system design and apply concepts of optimization and rationalization of information and material flow in the displacement of the team for the selected regions, the electronics technician by assembling and disassembling the body scanner and calibrate sensors, and monitor measurements for the case of some urgent maintenance, the physical education professionals to perform the measurements themselves and coach in ergonomics for maintaining the physical education teachers trained in the modus operandi measurements. The measurements were carried out as far as possible, according to the schedule defined in step displacement and logistics personnel. The team while receiving the volunteer in the measurement site, explained what was the project and its goals. After that the volunteer answered a socioeconomic questionnaire put the pieces of clothing suitable for measurements and headed for the body scanner to be measured.

The body measurement data were treated by the staff directly in the software of the TC2 during the treatment was verified how the cloud of points, the landmarks, and occurred the removal of spurious data. The data after treatment were deposited in a database as specified in ISO 15535.

With the bank formed, it was possible to move to the statistical analysis and validation of the bodies. In this analysis we used the technique of principal components of the multivariate statistical table to set the standards bodies. Biotypes of brazilian women were defined based on a study prepared by Lee et al., 2007 [1] and will be disclosed in later works.

The final steps of the modeling study of items of clothing, testing parts in standard and non-standard bodies and validity of modeling developed in this study have not been included because the study is still in progress, counting only with the finalized data from the Southeast.

The methodology can be seen in Figure 1 below:

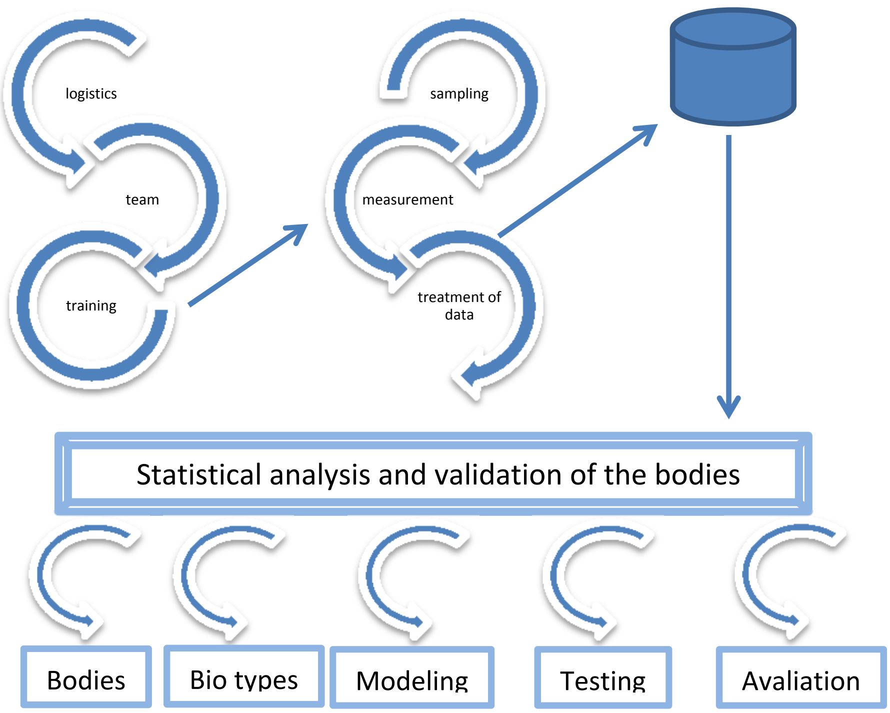

Fig 1. Methodology.

2.1. Sampling

Initially by having no body measurements of the sample population, it was decided to conduct a sampling as described in Thompson 2012 [3]. The sample size was calculated for the main regions of Brazil, ranked matches by major cities due to its position consumption. A search on the basis of the Brazilian Geographical and Statistical Institute - IBGE was performed to determine the population of Brazil, of both sexes, aged between 18 and 59 years in these cities. Table 1 shows the data obtained in the calculations IBGE and initial sampling.

Table 1. Sampling Search SizeBR.

REGIONS	LOCAL SEARCH	POSITION IN RANKING CONSUMER		Nº TOTAL OF ADULT POPULATION (18-59)			SAMPLE SEARCH					
				FONT: IBGE			M	F	M	F	M	F
		NATIONAL	STATE	MEN	WOMEN	TOTAL	1%		1,5%		2%	
SOUTHEAST	São Paulo - SP	1	1	3.606.889	3.971.840	7.578.729	732	1023	326	454	183	256
	Rio de Janeiro - RJ	2	1	1.971.817	2.171.420	4.143.237	400	559	178	248	100	140
	Belo Horizonte - MG	4	1	766.695	859.314	1.626.009	156	221	69	98	39	55
SOUTH	Curitiba - PR	5	1	576.150	627.708	1.203.858	640	888	284	394	160	222
	Porto Alegre - RS	7	1	439.529	493.657	933.186	488	698	217	310	122	175
	Florianólpolis - SC	27	1	144.328	153.084	297.412	160	217	71	96	40	54
NORTHEAST	Salvador - BA	6	1	873.315	1.001.894	1.875.209	529	739	235	328	132	185
	Fortaleza - CE	8	1	773.567	887.161	1.660.728	469	655	208	291	117	164
	Recife - PE	10	1	479.558	554.500	1.034.058	291	409	129	182	73	102
MIDWEST	Brasília - DF	3	1	835.539	928.515	1.764.054	850	1192	378	529	213	298
	Goiânia - GO	9	1	430.896	475.782	906.678	438	611	195	271	110	153
NORTH	Manaus - AM	11	1	575.109	609.862	1.184.971	729	993	324	441	182	248
	Palmas - TO	24	1	65.780	68.254	134.034	83	111	37	49	20	28
	Belém - PA	13	1	441.712	496.981	938.693	560	809	249	360	140	202
						TOTAL BY GENDER	6.525	9.125	2.900	4.051	1.611	2.282
							TOTAL	15.650	6.951		3.893	

The Brazilian study on anthropometric- SizeBR - was initiated in southeastern Brazil. This region was chosen due to its proximity to Senai CETIQT, allowing rapid movements of the Body Scanner and study staff, namely the region permitted an easy logistics implementation.

After some measurements in the cities of Rio de Janeiro, Sao Paulo and Belo Horizonte the initial sampling established was recalculated to meet the established standard ISO 15535.

With the measurements it was possible to calculate the coefficient of variation - CV - the main measures to characterize the body of the Brazilian.

According to ISO 15535, it is necessary to calculate the minimum number of samples (via a small sample basis as before) that presents value of the variable with the highest coefficient of variation for this variable will request a higher number of samples, which will supply all the data involved in this kind of research.

The number of sample being measured takes into account a 95% confidence on the measurement error determined by the investigator using the following equation:

$$N = \left(\frac{1.96\ \ CV}{a}\right)^2 \ .\ 1.534^2$$

Being:
N = number of samples required;
1.96 = critical value of z, representing 95% confidence;
CV = coefficient of variation is determined by the following equation:

$$CV = \frac{SD}{\bar{x}} .100$$

Being:
SD = standard deviation;
$\bar{x}$ = Average
a = the relative error to what you want

With these parameters we can calculate the necessary quantity to be measured to an error of 1%, 1.5% and 2%, by measuring the whole body as shown in table 2. In that table it can be seen that for both genders as they showed higher coefficient of variation was waist circumference, and therefore the variable that defines the sampling minimum required to represent, with a prescribed error and 95% confidence, the Brazilian population. Thus, the sampling table by region was corrected to the value pointed to 1260 males and 1662 females for an error rate of 1%, see Table 3.

Table 2. Sampling and errors associated.

Sampling error of the measured variables														
Nº	**measured variables**	**Average**		**Standard Deviation**		**CV**		**Error of 1%**		**Error of 1.5%**		**Error of 2%**	
		M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
409	**Waist Circumference**	**91.5**	**84.8**	**10.8**	**11.5**	**11.8**	**13.6**	**1260**	**1662**	**560**	**739**	**315**	**416**
407	Thorax circumference	103.0	96.3	9.3	10.4	9.0	10.8	740	1059	329	471	185	265
416	Circumference of Hips	99.9	101.8	7.5	9.5	7.5	9.3	508	782	226	348	127	196
002	stature	174.4	162.0	6.9	6.4	3.9	4.0	141	144	63	64	36	36
106	Height of the crotch	77.4	73.5	4.7	5.1	6.1	6.9	338	431	150	192	85	108
117	Height Waist Pelvis	29.1	24.6	2.3	3.2	7.9	13.0	557	1539	247	684	139	385
301	Length Front View	40.6	38.7	4.1	3.4	10.2	8.8	944	703	420	313	236	176
302	Length Rear View	48.3	43.0	4.0	3.1	8.3	7.2	628	472	279	210	157	118
113	Height Waist Solo	104.7	98.0	5.9	5.1	5.7	5.2	292	249	130	111	73	63
124	Height Knee Dir.	48.4	44.3	2.9	3.0	5.9	6.9	315	426	140	190	79	107
419	Thigh circumference Dir	58.8	59.8	5.4	7.0	9.2	11.7	758	1234	337	549	190	309
300	Cervical Solo Length	169.0	156.7	7.1	6.5	4.2	4.1	162	154	72	69	41	39
104	Height Shoulder Dir	141.3	130.7	6.6	5.9	4.7	4.5	196	187	87	83	49	47
303	Front Shoulder Length Cross Dir	48.8	44.7	3.8	3.1	7.7	7.0	538	439	239	195	135	110
304	Posterior Length Shoulder Cross Dir	48.9	43.2	3.3	2.8	6.8	6.4	420	373	187	166	105	94
423	Calf circumference Dir	37.6	36.2	3.1	3.6	8.2	10.0	608	897	270	399	152	225

Table 3. Sampling and errors associated with region of Brazil.

<table>
<tr><th rowspan="3">REGIONS</th><th rowspan="3">LOCAL SEARCH</th><th colspan="2" rowspan="2">POSITION IN RANKING CONSUMER</th><th colspan="6">RESEARCH SAMPLE</th></tr>
<tr><th>M</th><th>F</th><th>M</th><th>F</th><th>M</th><th>F</th></tr>
<tr><th>NATIONAL</th><th>STATE</th><th colspan="2">1%</th><th colspan="2">1.5%</th><th colspan="2">2%</th></tr>
<tr><td rowspan="3">SOUTHEAST</td><td>São Paulo - SP</td><td>1</td><td>1</td><td rowspan="3">1260</td><td rowspan="3">1662</td><td rowspan="3">560</td><td rowspan="3">739</td><td rowspan="3">315</td><td rowspan="3">416</td></tr>
<tr><td>Rio de Janeiro - RJ</td><td>2</td><td>1</td></tr>
<tr><td>Belo Horizonte - MG</td><td>4</td><td>1</td></tr>
<tr><td rowspan="3">SOUTH</td><td>Curitiba - PR</td><td>5</td><td>1</td><td rowspan="3">1260</td><td rowspan="3">1662</td><td rowspan="3">560</td><td rowspan="3">739</td><td rowspan="3">315</td><td rowspan="3">416</td></tr>
<tr><td>Porto Alegre - RS</td><td>7</td><td>1</td></tr>
<tr><td>Florianólpolis - SC</td><td>27</td><td>1</td></tr>
<tr><td rowspan="3">NORTHEST</td><td>Salvador - BA</td><td>6</td><td>1</td><td rowspan="3">1260</td><td rowspan="3">1662</td><td rowspan="3">560</td><td rowspan="3">739</td><td rowspan="3">315</td><td rowspan="3">416</td></tr>
<tr><td>Fortaleza - CE</td><td>8</td><td>1</td></tr>
<tr><td>Recife - PE</td><td>10</td><td>1</td></tr>
<tr><td rowspan="2">MIDWEST</td><td>Brasília - DF</td><td>3</td><td>1</td><td rowspan="2">1260</td><td rowspan="2">1662</td><td rowspan="2">560</td><td rowspan="2">739</td><td rowspan="2">315</td><td rowspan="2">416</td></tr>
<tr><td>Goiânia - GO</td><td>9</td><td>1</td></tr>
<tr><td rowspan="3">NORTH</td><td>Manaus - AM</td><td>11</td><td>1</td><td rowspan="3">1260</td><td rowspan="3">1662</td><td rowspan="3">560</td><td rowspan="3">739</td><td rowspan="3">315</td><td rowspan="3">416</td></tr>
<tr><td>Palmas - TO</td><td>24</td><td>1</td></tr>
<tr><td>Belém - PA</td><td>13</td><td>1</td></tr>
<tr><td></td><td></td><td></td><td></td><td>6300</td><td>8310</td><td>2800</td><td>3690</td><td>1575</td><td>2080</td></tr>
<tr><td></td><td></td><td></td><td>TOTAL</td><td colspan="2">14610</td><td colspan="2">6490</td><td colspan="2">3655</td></tr>
</table>

The current landscape of the measurements with the body scanner is shown in Table 4. It can be observed that the sampling on the southeast region is well below the stipulated percentage error of 1% for both sexes and that measures of other regions of Brazil are still incipient issues for local logistics. The Senai CETIQT intend to finalize the measurements of other regions of Brazil in 2014.

Table 4. Current frame.

Southest		North		Midwest		Northest		Brasil	
M	F	M	F	M	F	M	F	M	F
2413	3809	112	207	10	41	63	286	2598	4343

2.2. Statistical Techniques

The Multivariate Statistics consists of a set of statistical methods that apply in cases where several variables are measured simultaneously in each sample element (Mingoti. 2005 [2]).

One application is to explore the multivariable statistical data variability seeking a significant reduction in variables under study such that it does not compromise the overall variability of the data. In this study we used the exploratory techniques of data variability known as factor analysis and principal component analysis.

The factor analysis aims to describe the relationship between a large number ***p*** of variables in terms of a reduced number ***m*** of variables or factors unobservable. These unobservable variables and uncorrelated with each other represent a significant percentage of the variability of the original data and are related to the original variables through a linear model.

When the original variables replaced by their common factors must be interpreted through their numerical values called scores.

The number of factors ***m < p*** common that best represents the variability of the original data is defined according to criteria of interpretation of these factors and the variability structure of the linear model between the factors and the original variables standardized.

The Principal Component Analysis seeks to explain the structure of variance and covariance of a vector composed of p-random variables by constructing linear combinations of maximum variance uncorrelated called principal components. The Principal Component Analysis (PCA) allows a reduction in the number of variables making the phenomenon under study is represented simply without significant loss of information. In many cases this information can be combined in only two or three main components making interpretations easier as well as its graphical visualization.

The database is composed of 115 anthropometric measures of the body. To check the statistical methodology were selected initially by technician of Senai CETIQT 41 measures considered most significant for modeling clothing.

The first stage of the development of grid sizes was to validate the database. This stage is the cleaning of spurious data detection of typos or data transfer and disposal of individuals with missing data. This stage is very labor intensive because it depends on the concentration and the operator display and without it results may be compromised due to the failure in the database.

The second phase consisted of multivariate analysis itself. For this phase a program in MATLAB (Matrix Laboratory) is designed to perform statistical calculations and provide technical support to the analysis of modeling. The processing of the data by relying on interactive adjustments depending on the specific knowledge of anthropometry technicians and experts in statistics is not fully automated which requires time to run the program several times.

The program runs in two main routines. The first aims to eliminate variables with low correlation small communality (variance of the common factor given as a proportion of the total variance) and high variability attributed to random error. This routine makes the variance explained by the principal components closer to the total variance of data.

The second routine is based on principal component analysis in weighted variables and the individuals measured. The weights in the 41 selected variables were chosen in the first routine by modeling experts and placed in order of importance according to these experts. For the grid has a range of steady progression to the sizes of the bodies an interactive process between the program and the technical in statistics is required because the weights of the variables are adjusted every interaction.

In the grid of female bodies the weights of the individuals are specified depending on the biotype of each individual and the weight assigned to the individual equal to the percentage of biotype to which the individual belongs. In the grid of male bodies there different weights for individuals because these individuals are not classified according to a pre-defined biotype being assigned to each individual weight equal to 1. In applying these statistical techniques to define the sizes of the bodies only two latent variables or unobservable were retained. One of the main components is retained sizes (heights) and the other body shapes (perimeter). Their scores were grouped according to similarities ensuring a strong association between individuals within the group and a weak association between individuals of different groups. Defined groups have been translated into its original variables defining this way the table size of the bodies.

Figure 2 shows flow charts that summarize the steps of development adopted for the preparation of table bodies.

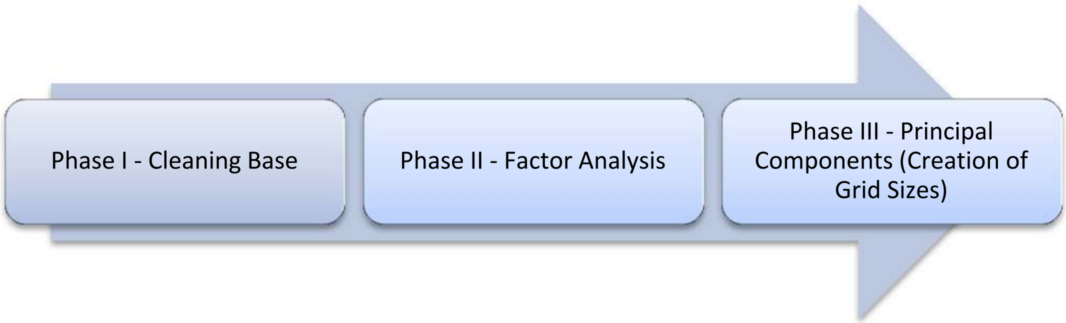

Fig 2. Flowchart overview of the process.

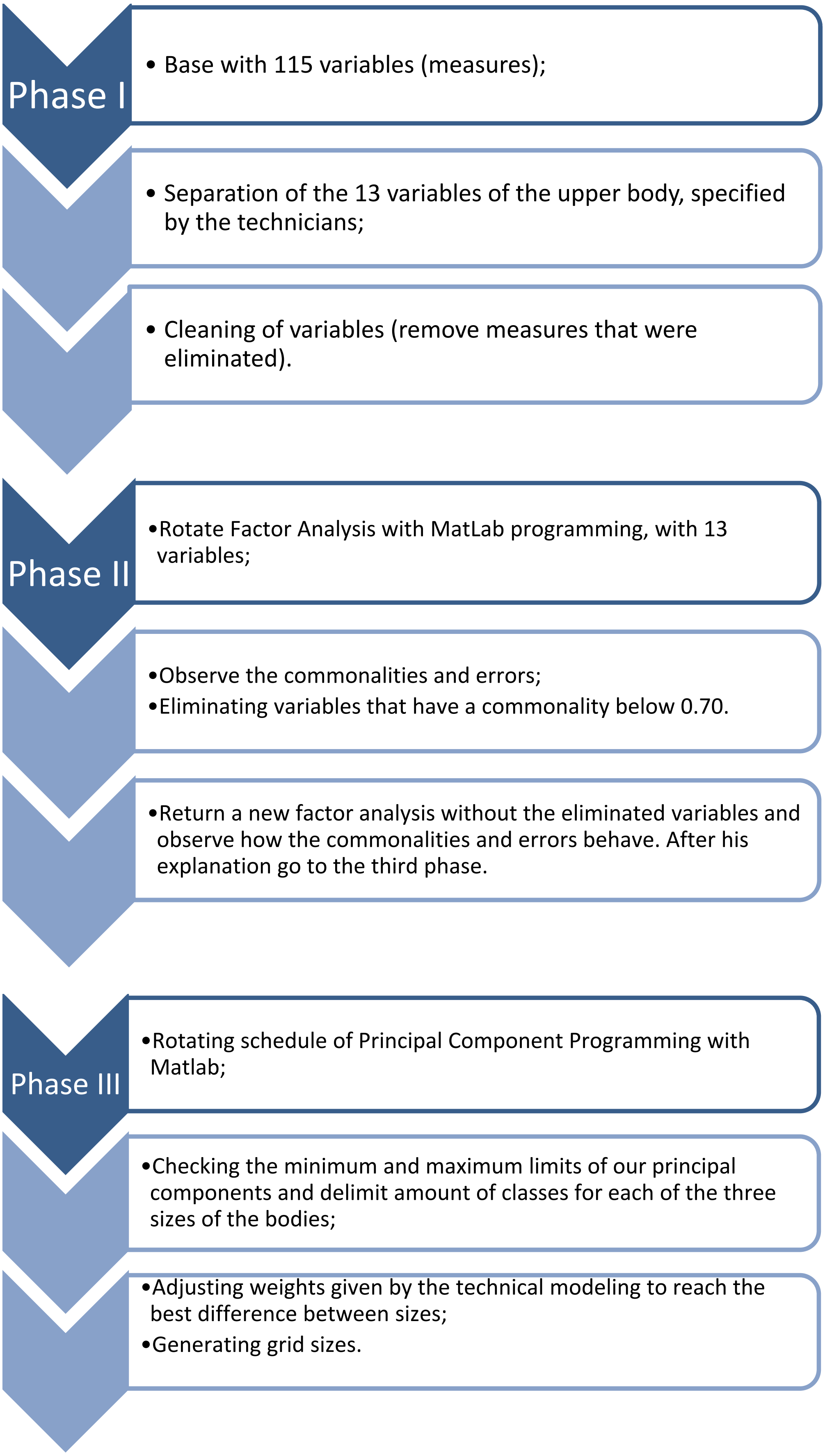

Fig 3. Flowchart of stages of study.

3. Results

In this paper, for reasons of space, we will present only the results obtained for female bodies.
To ensure that the anthropometric data can be analyzed by multivariate statistical techniques, in this case the factor analysis, some care must be taken. For this study it was found that:

1) all study variables follow a univariate normal distribution;
2) the basis used follows a multivariate normal distribution;
3) the Bartlett's test to the significance level of 5% rejected the null hypothesis of correlation matrix identity;
4) Test Kaiser-Meyer-Olkin (KMO) showed a value> 0.8.

The study base consisted of 41 body variables of 3534 female subjects. Table 5 presents the variables studied.

Table 5. Study variables SizeBR.

Order	Variable	Order	Variable	Order	Variable
1	407 Chest/bust girth	15	317 Center-trunck length	29	320 Back Crotch lenght – stand up
2	416 Hip girth/low hip	16	003 Head girth	30	305 Shoulder length
3	409 Waist girth	17	408 Underbust girth	31	008 Elbow length
4	002 Height	18	406 High chest girth	32	402 Arm Scye girth
5	113 Outside leg length	19	412 Low waist girth	33	010 Arm girth – 90°
6	106 Inside leg height	20	414 High hip girth	34	011 Elbow girth – 90°
7	117 Waist to crotch height	21	118 Waist – hip height – right side	35	405 Wrist girth –right side
8	302 Neck to waist contour back	22	116 Waist – knee height	36	012 Hand closet girth
9	301 Center front neck to waist	23	419 Thigh girh	37	325 Across back contour
10	313 Neck to waist length – right side	24	421 Knee girth	38	326 Scy to Scy length – front side
11	324 Shoulder to shoulder length – back side	25	423 Calf girh	39	314 Neck to underbust lengty – right side
12	009 Arm length – 90°	26	426 Low ankle girth	40	312 Neck to bust point length – right side
13	300 Neck height	27	318 Crotch lenght – stand up	41	204 Bust point to Bust point
14	104 Long shoulder height – right side	28	319 Front Crotch lenght – stand up		

With the purpose of eliminating low correlation variables, and possibly also with low variance explained common, factor analysis was performed on the covariance matrix of original data.

The factor analysis presented in Table 6, indicates that eight factors together explain approximately 77.87% of the variance of the original data matrix. However, in this first analysis, we chose to evaluate only 5 factors.

Table 6. Variance Explained by common factors.

Common Factors X Variance Explained			
Factor	autovalue	%Var expl	%total Var expl
1	15.49	37.77	37.77
2	5.69	13.88	51.65
3	4.25	10.37	62.02
4	1.63	3.97	65.99
5	1.49	3.64	69.63
6	1.19	2.89	72.52
7	1.16	2.84	75.35
8	1.03	2.51	77.87
9	0.97	2.37	80.24
...	...	...	...
39	0.04	0.09	99.77
40	0.05	0.12	99.89
41	0.05	0.11	100.00

The method of principal components was used to estimate the loads of the five factors retained. From Table 7 it can be observed in specific commonalities and the variances (Var. error), the variables orders 12, 16, 21, 26, 31, 32, 34, 35, 36, 37, 38, 39, 40 and 41 clashes with the model and must be removed.

Table 7. Estimation of factors.

Order	Variable	Load F1	Load F2	Load F3	Load F4	Load F5	commonalities	Var. error
1	407 Chest/bust girth	0.92	-0.22	0.04	0.02	-0.01	0.90	0.10
2	416 Hip girth/low hip	0.90	-0.12	-0.13	0.05	0.14	0.87	0.13
3	409 Waist girth	0.89	-0.28	0.18	0.03	0.09	0.91	0.09
4	002 Height	0.29	0.90	0.08	-0.07	-0.01	0.91	0.09
5	113 Outside leg length	0.28	0.88	-0.27	0.11	-0.09	0.94	0.06
6	106 Inside leg height	0.08	0.82	0.24	0.37	-0.10	0.88	0.12
7	117 Waist to crotch height	0.38	0.16	-0.73	-0.13	-0.04	0.72	0.28
8	302 Neck to waist contour back	0.27	0.30	0.68	-0.38	0.11	0.78	0.22
9	301 Center front neck to waist	0.45	0.12	0.59	-0.44	0.09	0.77	0.23
10	313 Neck to waist length – right side	0.51	0.15	0.63	-0.44	0.03	0.87	0.13
11	324 Shoulder to shoulder length – back side	0.56	-0.13	0.07	0.05	-0.68	0.80	0.20
12	009 Arm length – 90°	0.32	0.58	0.10	0.18	0.07	**0.49**	0.51
13	300 Neck height	0.37	0.76	0.43	-0.03	0.00	0.90	0.10
14	104 Long shoulder height – right side	0.31	0.91	0.06	-0.08	0.00	0.94	0.06
15	317 Center-trunck length	0.73	0.16	-0.11	-0.43	0.13	0.78	0.22
16	003 Head girth	0.35	0.18	0.01	0.17	-0.06	**0.19**	0.81
17	408 Underbust girth	0.90	-0.23	0.02	0.05	0.00	0.87	0.13
18	406 High chest girth	0.92	-0.20	0.04	0.03	-0.08	0.89	0.11
19	412 Low waist girth	0.92	-0.24	0.03	0.04	0.11	0.92	0.08
20	414 High hip girth	0.93	-0.23	-0.04	0.04	0.12	0.93	0.07
21	118 Waist – hip height – right side	-0.31	0.40	-0.51	-0.14	-0.03	**0.54**	0.46
22	116 Waist – knee height	0.29	0.65	-0.58	-0.07	-0.08	0.85	0.15
23	419 Thigh girh	0.77	-0.01	0.05	0.36	0.10	0.73	0.27
24	421 Knee girth	0.76	0.03	0.04	0.31	0.13	0.70	0.30
25	423 Calf girh	0.80	-0.05	0.02	0.25	0.10	0.71	0.29
26	426 Low ankle girth	0.48	0.23	0.01	0.07	-0.07	**0.30**	0.70
27	318 Crotch lenght – stand up	0.65	0.02	-0.70	-0.22	0.05	0.96	0.04
28	319 Front Crotch lenght – stand up	0.69	0.02	-0.63	-0.14	0.03	0.90	0.10
29	320 Back Crotch lenght – stand up	0.57	0.03	-0.72	-0.27	0.06	0.91	0.09
30	305 Shoulder length	0.19	-0.03	0.10	-0.06	-0.82	0.73	0.27
31	008 Elbow length	0.29	0.53	0.09	0.14	0.10	**0.40**	0.60
32	402 Arm Scye girth	0.35	-0.06	0.11	0.14	0.11	**0.17**	0.83
33	010 Arm girth – 90°	0.79	-0.22	-0.01	0.12	0.09	0.70	0.30
34	011 Elbow girth – 90°	0.65	-0.02	0.03	0.16	0.03	**0.45**	0.55
35	405 Wrist girth –right side	0.71	-0.05	0.07	0.13	0.10	**0.53**	0.47
36	012 Hand closet girth	0.49	0.15	0.11	0.11	-0.03	**0.29**	0.71
37	325 Across back contour	0.69	-0.17	0.10	0.05	-0.30	**0.60**	0.40
38	326 Scy to Scy length – front side	0.59	-0.09	-0.05	-0.16	-0.17	**0.41**	0.59
39	314 Neck to underbust lengty – right side	0.52	-0.21	0.16	-0.14	-0.04	**0.36**	0.64
40	312 Neck to bust point length – right side	0.74	-0.15	0.13	-0.18	-0.04	**0.61**	0.39
41	204 Bust point to Bust point	0.63	-0.12	0.09	-0.05	-0.10	**0.43**	0.57

It is also observed that it is not possible to secure an interpretation of the first five factors. For example, the values highlighted in the load of the first factor in the variables have high values relating to the diameters and lengths. Moreover, the fourth factor loads do not allow the interpretation presented by low values of all the variables.

A new factor analysis was performed eliminating variables underperforming. In this analysis, the first five factors have values above 1 - see Table 8, representing a total of 86.44% of the total variance 69.63% against the previous model. In this way, it is concluded that the removal of the three variables was right.

Table 8. Variance Explained by common factors.

Common Factors x Variance Explained			
Factor	Autovalue	%Var expl	%total Var expl
1	11.76	43.55	43.55
2	4.83	17.88	61.43
3	3.87	14.34	75.78
4	1.50	5.57	81.34
5	1.38	5.10	86.44
6	0.82	3.06	89.50
7	...	....	...
8	0.06	0.21	99.67
9	0.04	0.16	99.82
10	0.05	0.18	100.00

The factor loadings of the first five principal components are presented in Table 9. It can be seen that the commonalities are greater than 0.70 and that the variances are shown specific low, which again shows that this model of 27 variables is greater than 41 variables.

Table 9. Factor loadings.

Order	Variable	Load F1	Load F2	Load F3	Load F4	Load F5	Commonalities	Var. error
1	407 Chest/bust girth	0.90	0.21	0.13	-0.04	0.01	0.88	0.12
2	416 Hip girth/low hip	0.93	0.15	-0.02	-0.04	0.11	0.89	0.11
3	409 Waist girth	0.87	0.25	0.27	0.00	0.08	0.90	0.10
4	002 Height	0.29	-0.91	-0.05	0.03	0.00	0.91	0.09
5	113 Outside leg length	0.30	-0.82	-0.41	-0.18	0.00	0.98	0.02
6	106 Inside leg height	0.06	-0.85	0.08	-0.46	0.08	0.95	0.05
7	117 Waist to crotch height	0.44	-0.05	-0.72	0.11	-0.09	0.73	0.27
8	302 Neck to waist contour back	0.24	-0.43	0.67	0.37	-0.01	0.83	0.17
9	301 Center front neck to waist	0.43	-0.23	0.62	0.39	-0.05	0.77	0.23
10	313 Neck to waist length – right side	0.47	-0.28	0.65	0.38	-0.09	0.87	0.13
11	324 Shoulder to shoulder length – back	0.54	0.11	0.13	-0.21	-0.67	0.82	0.18
13	300 Neck height	0.35	-0.84	0.31	-0.01	0.02	0.91	0.09
14	104 Long shoulder height – right side	0.32	-0.92	-0.07	0.03	0.02	0.95	0.05
15	317 Center-trunck length	0.76	-0.15	-0.05	0.43	-0.04	0.78	0.22
17	408 Underbust girth	0.90	0.22	0.12	-0.04	0.01	0.86	0.14
18	406 High chest girth	0.90	0.18	0.13	-0.05	-0.04	0.87	0.13
19	412 Low waist girth	0.92	0.24	0.13	-0.02	0.09	0.93	0.07
20	414 High hip girth	0.94	0.23	0.07	-0.02	0.10	0.94	0.06
22	116 Waist – knee height	0.33	-0.55	-0.66	0.03	-0.05	0.86	0.14
23	419 Thigh girh	0.78	0.02	0.13	-0.41	0.17	0.83	0.17
24	421 Knee girth	0.77	-0.01	0.12	-0.34	0.16	0.75	0.25
25	423 Calf girh	0.81	0.07	0.11	-0.28	0.12	0.76	0.24
27	318 Crotch lenght – stand up	0.71	0.09	-0.64	0.24	-0.05	0.97	0.03
28	319 Front Crotch lenght – stand up	0.74	0.08	-0.58	0.16	-0.03	0.92	0.08
29	320 Back Crotch lenght – stand up	0.63	0.09	-0.65	0.29	-0.06	0.91	0.09
30	305 Shoulder length	0.18	-0.01	0.12	-0.21	-0.88	0.87	0.13
33	010 Arm girth – 90°	0.79	0.23	0.09	-0.09	0.08	0.70	0.30

Table 9 gives a highlight only on the factors not rotated. In the analysis of loads of factors, the variable Crotch Length-stand up can be interpreted by loads of factors 1 and 3 and the same happened with the variable Back Crotch Length-stand up. Thus, the array of factors was rotated to ensure a common understanding of the factors insurance.

Table 10 shows the rotated factors. You can check the charges highlighted that factor 1 represents the variables related to the circumferences, factor 2 represents the heights above the ground, the third factor is the relative heights, the factor 4 and 5 represent relative lengths.

Table 10. Rotated factor loadings.

Order	Variable	Load F1	Load F2	Load F3	Load F4	Load F5
1	407 Chest/bust girth	0.86	0.04	-0.25	0.22	-0.13
2	416 Hip girth/low hip	0.86	-0.04	-0.36	0.13	-0.03
3	409 Waist girth	0.88	0.11	-0.14	0.30	-0.07
4	002 Height	0.00	-0.89	-0.18	0.30	0.00
5	113 Outside leg length	0.03	-0.92	-0.35	-0.08	-0.03
6	106 Inside leg height	0.02	-0.94	0.27	-0.04	-0.02
7	117 Waist to crotch height	0.16	-0.16	-0.79	-0.23	-0.05
8	302 Neck to waist contour back	0.10	-0.25	0.22	0.84	0.00
9	301 Center front neck to waist	0.29	-0.10	0.09	0.81	-0.06
10	313 Neck to waist length – right side	0.31	-0.15	0.10	0.85	-0.11
11	324 Shoulder to shoulder length – back	0.44	0.00	-0.11	0.09	-0.78
13	300 Neck height	0.15	-0.81	0.10	0.48	-0.03
14	104 Long shoulder height – right side	0.02	-0.91	-0.20	0.30	0.02
15	317 Center-trunck length	0.45	-0.14	-0.56	0.50	-0.02
17	408 Underbust girth	0.86	0.05	-0.25	0.20	-0.13
18	406 High chest girth	0.85	0.02	-0.25	0.21	-0.18
19	412 Low waist girth	0.90	0.07	-0.26	0.22	-0.05
20	414 High hip girth	0.90	0.05	-0.31	0.18	-0.05
22	116 Waist – knee height	-0.01	-0.63	-0.66	-0.15	-0.01
23	419 Thigh girh	0.88	-0.24	0.01	-0.05	-0.05
24	421 Knee girth	0.83	-0.24	-0.03	0.01	-0.03
25	423 Calf girh	0.85	-0.15	-0.09	0.04	-0.07
27	318 Crotch lenght – stand up	0.41	-0.03	-0.89	-0.07	-0.02
28	319 Front Crotch lenght – stand up	0.48	-0.06	-0.82	-0.08	-0.04
29	320 Back Crotch lenght – stand up	0.32	0.00	-0.90	-0.06	-0.01
30	305 Shoulder length	0.05	-0.03	0.00	0.05	-0.93
33	010 Arm girth – 90°	0.80	0.06	-0.20	0.11	-0.06

In this way, factors 1 and 2 relate to a large part of the 27 variables selected before and together explain 61.43% of total variance, as shown in Table 8 was selected for continuing the task of obtaining the grid size.

The factor analysis allowed to select important variables for the study, as well as the number of factors and their interpretations.

The next develop a principal component analysis with selected variables in the factor analysis. The analysis was performed as adapted from Veitch 2007 [4].

The component 1 (CP1) is interpreted as the perimeter body and the component 2 (CP2) such as length, i.e. CP1 represents CP2 body shape and size.

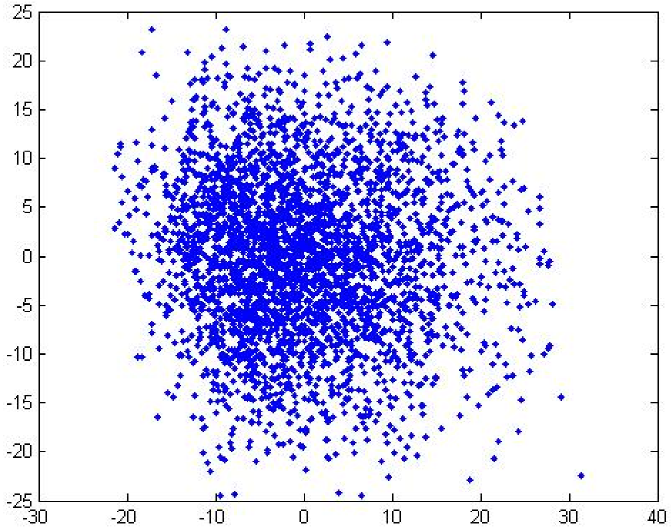

Fig 4. Component 1 x Component 2.

Figure 4 shows the distribution of factor scores on components 1 and 2 in each of the 3534 individuals measured. As the component 1 represents the shape of the body, their scores were divided into three regions called High, Medium and Low which can be associated with athletic bodies, Normal and Special, according to ABNT NBR 10060:2012. Similarly, the scores in the second component were divided into fourteen classes, i.e. for each body type High (H), Medium (M) or Low (L) there are 14 bands of sizes forming the pairs H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H11, H12, H13 and H14. The same applies to M and L, totaling 42 standards bodies.

The scores in the component 2 were assigned such that the central strip presents 66% of individuals in the population and had as the medium center 50th percentile. The other tracks, High (H) and Low (L), divided the remaining 34% of the population equitably, taking to heart the average 50th percentile.

The scores in component 1 were divided to present a constant value of 4 cm in variable difference Chest/bust girth, in each of the standardized forms bodies.

After the distribution of scores on a grid of size or Clusters, you must process the calculation processing of the centroids of the scores of individuals on approximate measures on the original variables. These measures represent approximate measures for each of the bodies developed by crossing scores on components 1 and 2. Table 11 presents the results found.

The method allows to calculate the percentage of individuals that falls in each of the bodies determined standards. As an example, for the sample, Figure 5 shows that the standard body Medium body 4 is 9.3% quota studied.

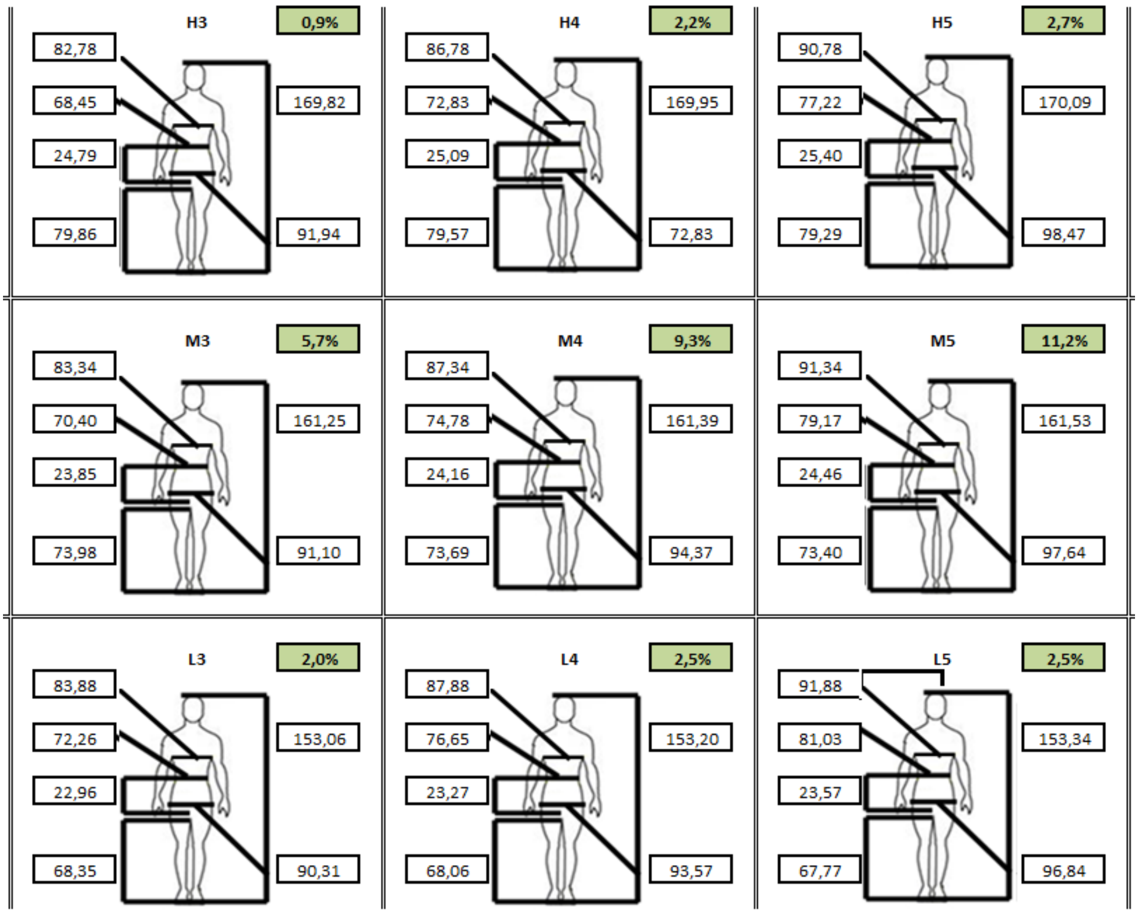

Fig 5. Extract of body shape.

The grid sizes shown in Table 11 does not include all individuals in the sample, because some have been removed, or display values outside the three deviations or adequacy of the components in the division into classes. Table 12 shows the percentage achieved in the study.

Table 11. Outcome superior measures female – Southeast – Sizing systems.

	Chest/bust girth	Hip girth/low hip	Waist girth	Height	Outside leg length	Inside leg height	Waist to crotch height
H1	74.8	85.4	59.7	169.5	104.6	80.4	24.2
M1	75.3	84.6	61.6	161.0	97.8	74.6	23.2
L1	75.9	83.8	63.5	152.8	91.3	68.9	22.4
H2	78.8	88.7	64.1	169.7	104.6	80.2	24.5
M2	79.3	87.8	66.0	161.1	97.8	74.3	23.5
L2	79.9	87.0	67.9	152.9	91.3	68.6	22.7
H3	82.8	91.9	68.4	169.8	104.6	79.9	24.8
M3	83.3	91.1	70.4	161.3	97.8	74.0	23.9
L3	83.9	90.3	72.3	153.1	91.3	68.3	23.0
H4	86.8	95.2	72.8	170.0	104.6	79.6	25.1
M4	87.3	94.4	74.8	161.4	97.8	73.7	24.2
L4	87.9	93.6	76.6	153.2	91.3	68.1	23.3
H5	90.8	98.5	77.2	170.1	104.6	79.3	25.4
M5	91.3	97.6	79.2	161.5	97.8	73.4	24.5
L5	91.9	96.8	81.0	153.3	91.3	67.8	23.6
H6	94.8	101.7	81.6	170.2	104.7	79.0	25.7
M6	95.3	100.9	83.6	161.7	97.9	73.1	24.8
L6	95.9	100.1	85.4	153.5	91.3	67.5	23.9
H7	98.8	105.0	86.0	170.4	104.7	78.7	26.0
M7	99.3	104.2	87.9	161.8	97.9	72.8	25.1
L7	99.9	103.4	89.8	153.6	91.4	67.2	24.2
H8	102.8	108.3	90.4	170.5	104.7	78.4	26.3
M8	103.3	107.4	92.3	161.9	97.9	72.5	25.4
L8	103.9	106.6	94.2	153.8	91.4	66.9	24.5
H9	106.8	111.5	94.8	170.6	104.7	78.1	26.6
M9	107.3	110.7	96.7	162.1	97.9	72.3	25.7
L9	107.9	109.9	98.6	153.9	91.4	66.6	24.8
H10	110.8	114.8	99.1	170.8	104.7	77.8	26.9
M10	111.4	114.0	101.1	162.2	97.9	72.0	26.0
L10	111.9	113.2	103.0	154.0	91.4	66.3	25.1
H11	114.8	118.1	103.5	170.9	104.7	77.6	27.2
M11	115.4	117.2	105.5	162.4	97.9	71.7	26.3
L11	115.9	116.4	107.3	154.2	91.4	66.0	25.4
H12	118.8	121.3	107.9	171.1	104.7	77.3	27.5
M12	119.4	120.5	109.9	162.5	97.9	71.4	26.6
L12	119.9	119.7	111.7	154.3	91.4	65.8	25.7
H13	122.8	124.6	112.3	171.2	104.7	77.0	27.8
M13	123.4	123.8	114.2	162.6	97.9	71.1	26.9
L13	123.9	123.0	116.1	154.4	91.4	65.5	26.0
H14	126.8	127.9	116.7	171.3	104.8	76.7	28.1
M14	127.4	127.0	118.6	162.8	98.0	70.8	27.2
L14	127.9	126.2	120.5	154.6	91.4	65.2	26.3

Table 12: Percentage Distribution of the sample on the grid sizes.

L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	
0.2%	0.4%	2.0%	2.5%	2.5%	2.3%	1.7%	1.8%	1.1%	0.8%	0.3%	0.2%	0.0%	0.0%	**15.9%**

M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
0.5%	1.8%	5.7%	9.3%	11.2%	9.7%	7.9%	5.8%	3.5%	2.6%	1.0%	0.9%	0.3%	0.0%	**60.3%**

H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	
0.1%	0.3%	0.9%	2.2%	2.7%	2.4%	2.0%	1.7%	1.4%	0.5%	0.4%	0.3%	0.1%	0.0%	**15.0%**

Total	**91.2%**

4. Conclusion

This work was dedicated to the presentation of the methodology applied in the definition of female upper bodies of southeastern Brazil. These results are part of a large nationwide study - SizeBR – created, developed and applied by Senai CETIQT, with the goal of establishing standards bodies of the Brazilian population, segmented by five regions, to meet those interested in modeling clothing in general such as: pants, Dresses, Overalls, Shirt, jacket or jackets.

To set the grid sizes of bodies was developed a methodology which applies multivariate statistical methods.

The anthropometric data base of individuals was treated and suitability tests were carried out to justify the application of the methodology adopted.

The factorial analysis ruled out fourteen variables that, although they were pointed by the technician in modeling, were not in agreement with the rest of the group.

There were retained five main components, two of which were part of the calculations for the effective definition of the grid sizes.

The component 1 is associated to the bodies while the component 2 is associated to size.

It was sought on the basis of certain weights to the variables under study, an order of preference for the same modeling of upper garments. This order was maintained in the study, required adjustments in the weight values for obtaining a constant value of 4 cm at the most important variable, in this case, the Chest/bust girth.

The obtained grid crosses three classes of forms against fourteen of sizes, totaling 42 standard bodies and 91.2% of the population framework.

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