

Sizing of clothing appropriate for overweight and obese children: methodology stages and the preliminary results

R de Campos^{1,2}, M A F Carvalho² and R S Boldt²

1Federal Institute of Rio Grande do Sul, Fashion Department, Campus Erechim, Erechim, RS, Brazil

2University of Minho, 2C2T-Center for Textile Science and Technology, Campus de Azurém, Guimarães, Portugal

raquel.campos@erechim.ifrs.edu.br

Abstract: The article describes the statistical analysis on the main components and the preliminary results for the development of a table of measurements, focused on the overweight and obesity of children from the north of Portugal, as part of an ongoing PhD research in Textile Engineering at the University of Minho, Portugal. In this sense, for the construction of a sample table of measurements, the studies of Huyssteen [1], Silveira [2], and Gill [3], recommend anthropometric studies, health databases and statistical analyzes.

1. Introduction

In Portugal, as in other countries, manufacturers of children's clothing are not prepared to offer clothing suitable for overweight and obese children [4]. A limited supply of clothing that gives them comfort and safety leads this population to wear clothing aimed at other age groups [5]. The use of larger sizes does not take into account their bodies and specificities [6], [7], [8], [9]. For Kim [9], there is a need to segment the tables of measurements of the child population by lean, medium and obese children, in order to increase the coverage of the age range. According to Boguslawska-Baczek [10], it is necessary to find the best way to develop the tables of measurements aiming at designing comfortable and suitable clothing for the body of overweight and obese children [9], [11].

The tables of measurements are the basis for the development of the clothes in series [3], [11], [12]. They have emerged to facilitate commercial practice, provide information to consumers, entrepreneurs and retailers [1], reduce costs and ensure product quality [2]. The tables used for the modelling of garments vary between countries, norms, brands, market segments and fabrics [1], [2], [10], [13], [14], [15]. They are grouped by male, female and child segment [10] from the average population measurements [5], [7], [10], [13], [15], [16], [17], and determine a minimum number of sizes for a maximum number of people [1]. This has an impact on individuals who are far from the average [1], [2], [17], since the tables do not consider their constraints [13], [14], [15], as is the case of overweight and obese children.

As regards the children's segment, the measurement tables show a disparity between body measurements and marks [5] due to the great variation of biotypes between countries [1], [12], [18]. They present the categories: baby, infant and pre-adolescent [5] and can be divided by sex or be unisex. Sizes are represented by age in single numbers (8, 9, 10, 11) or double (8, 10, 12, 14), letters (XS, S, M, L) or words (small, medium and large) [1], [3]. Although many companies use tables formed on the basis of age, this classification is not correct, since it represents poorly the corporal dimensions, given that children of the same age can present different heights [1], [9], [10].

2. Materials and methods

For the development of tables of measurements suitable for clothing of overweight and obese children of the north of Portugal, from the studies of Huyssteen [1], Silveira [2], and Gill [3], it is recommended: current anthropometric studies, selection of the necessary measurements for clothing and statistical analysis.



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

2.1 Sample

It involved 816 children between 2 and 12 years old (434 boys and 381 girls). It is important to note that not all of these children belong to the target population of the study. Data from children not in the target group and children aged 2 to 4 years were not considered. The final sample consisted of 205 overweight and obese children, located in 3 cities in the north of Portugal, aged between 5 and 12 years, of both sexes.

2.2 Data collection and Data processing

The anthropometric data collection lasted 6 months, beginning in June 2016 and ending in November 2016. 3D body scanning technology (KBI) was used along with manual collection. After the data collection started the processing of the data. The processing of data went through different software and phases. To guarantee the quality of the data, the outliers (scan errors, recorded body measurements very large or very small) were excluded according to the definition presented in [19].

2.3 Measurements relevant to the study

The definition of the number of measurements required varies among researchers, standards or countries. According to [19], there is no exact number of measurements, being selected according to the relevance and the segment to which the product will be destined, however, the ideal is to select the measures of height and circumference, covering the dimensions of the trunk and extremities, and that can be easily located. Gill [3] presents several researchers that used 33 to 4 measurements. Gill [3] also says that many measurements are difficult to work with, and cover fewer people, which hampers statistical techniques.

3. Results and conclusions

The data were analyzed using SPSS 21 software (Statistical Package for the Social Sciences). In a first phase, was carried out the statistical analysis of the principal components (PCA), which is a technique of multivariate exploratory analysis associated with dimensionality reduction. Its purpose is to transform a set of correlated variables into a set of independent variables [20].

Of the 110 body measurements pre-established by the KBI system at this stage, 26 important variables for children's clothing were considered. However, the factorial structure obtained was not interpretable, and did not result in valid conclusions in the context of this investigation. According to several authors, children vary in growth according to age, gender, hereditary influences and environmental factors, changing rapidly [1], [21]. In the present study, the relationship between the male and female bodies differentiates between the sexes [1], [22].

After an interview with eight professionals working with modelling, it was decided to withdraw some initial variables. Thus, the PCA was again considered, taking into account the following 18 variables: height, bust circumference, waist circumference, hip circumference, abdominal circumference, thigh circumference, knee circumference, calf circumference, ankle circumference, biceps circumference, elbow circumference, wrist circumference, sleeve shirt, bust height, waist height, hip height, thigh height, and knee height. Subsequently, are presented all the steps and justifications that led to the best factorial solution for both sexes.

3.1 Assumptions Verification

Bartlett's sphericity test and the Kaiser-Meyer-Olkin (KMO) measure of sample adequacy are two statistical procedures that allow testing the validity of the factorial analysis, evaluating the quality of the correlations between the variables [23]. The test was performed for both subsamples. The KMO values obtained – 0.919 for the male gender and 0.923 for the female – indicate a very good adjustment of the factorial model to the data in both sexes [24]. Therefore, there is a very good suitability of the subsamples for the application of the factorial analysis. As for Bartlett's sphericity test, it was obtained as test value $p = 0.00 < 0.05$, so, it is rejected the hypothesis that there are no correlations between the variables. The adequacy of the factorial analysis method is confirmed.

3.2 Extraction of factors

Regarding the number of components to be retained in the analysis, there are four most commonly used criteria [23]. For a number of variables below 30, Pestana and Gageiro [24] advise the application of the Kaiser criterion. Therefore, the Kaiser criterion was applied, that is, choosing components with a value greater than 1, the first three main components should be retained for both male and female genders. It corresponds to a percentage of explained variance of 82% for the male gender and 83% for the female gender, presented in table 1.

Table 1. Total Variance Explained

Comp.	Male						Female					
	Value	% Variance	% Cumulative	Value	% Variance	% Cumulative	Value	% Variance	% Cumulative	Value	% Variance	% Cumulative
1	11,30	66,49	66,49	7,20	42,36	42,36	12,34	68,53	68,53	12,34	68,53	68,53
2	1,62	9,54	76,03	5,65	33,25	75,61	1,49	8,26	76,80	1,49	8,26	76,80
3	1,05	6,19	82,21	1,12	6,61	82,21	1,15	6,39	83,19	1,15	6,39	83,19
4	,60	3,53	85,74				,72	3,98	87,17			
5	,54	3,19	88,93				,46	2,54	89,71			
6	,47	2,77	91,70				,42	2,34	92,05			
7	,33	1,97	93,67				,40	2,20	94,24			
8	,30	1,74	95,41				,23	1,26	95,50			
9	,19	1,14	96,55				,22	1,21	96,71			
10	,17	,98	97,53				,18	1,03	97,74			
11	,14	,82	98,36				,12	,67	98,40			
12	,10	,57	98,92				,09	,51	98,91			
13	,07	,41	99,33				,07	,39	99,30			
14	,03	,19	99,52				,04	,23	99,54			
15	,03	,18	99,70				,03	,17	99,71			
16	,03	,17	99,87				,02	,14	99,84			
17	,02	,13	100,00				,02	,09	99,93			

Table 2. Communalities

Extraction Male		Extraction Female	
Height	,927	Height	,942
Bust height	,962	Bust height	,967
Waist height	,950	Waist height	,956
Hip height	,916	Hip height	,961
Thigh height	,935	Thigh height	,951
Knee height	,917	Knee height	,896
Sleeve shirt	,575	Sleeve shirt	,684
Bust circumference	,811	Bust circumference	,754
Waist circumference	,843	Waist circumference	,774
Abdominal circumference	,913	Abdominal circumference	,871
Hip circumference	,899	Hip circumference	,938
Thigh circumference	,759	Thigh circumference	,836
Knee circumference	,760	Knee circumference	,754
Biceps circumference	,615	Biceps circumference	,694
Elbow circumference	,733	Elbow circumference	,747
Ankle circumference	,752	Ankle circumference	,682
Wrist circumference	,709	Wrist circumference	,853

As can be seen in the calculation of commonalities in table 2, the commonalities indicate the proportion of the main component of each variable. Variables with high values indicate that they are well represented by the components.

3.3 Analysis and profiling of the main components

The matrix of components presents the loadings (or factorial loads). The loadings represent the correlations between each variable and its main component [25]. According to Pestana and Gageiro [24], the loadings must be very large or very small. Still according to these authors, as well as Larose [26], loadings with an absolute value greater than or equal to 0.5 should be considered significant. Field [27] chooses values in modules greater than or equal to 0.4. It is observed that most of the variables have a high loading on the first factor.

Table 3 Component matrix (male)

	Component		
	1	2	3
Height	,921	-,279	-,037
Bust height	,934	-,296	-,055
Waist height	,925	-,290	-,101
Hip height	,897	-,312	-,120
Thigh height	,899	-,334	-,125
Knee height	,879	-,359	-,127
Sleeve shirt	,720	-,237	,016
Bust circumference	,848	,206	,223
Waist circumference	,758	,496	,152
Abdominal circumference	,878	,377	-,013
Hip circumference	,926	,190	-,081
Thigh circumference	,843	,138	-,173
Knee circumference	,862	,125	,041
Biceps circumference	,675	,220	,334
Elbow circumference	,734	,437	,067
Ankle circumference	,528	-,152	,670
Wrist circumference	,423	,464	-,561

Table 4 Component matrix (female)

	Component		
	1	2	3
Height	,945	-,199	-,102
Bust height	,941	-,254	-,126
Waist height	,947	-,204	-,131
Hip height	,950	-,225	-,094
Thigh height	,919	-,293	-,141
Knee height	,902	-,263	-,117
Sleeve shirt	,775	-,239	-,160
Bust circumference	,842	,181	-,107
Waist circumference	,763	,427	,096
Abdominal circumference	,880	,261	,168
Hip circumference	,959	-,078	,109
Thigh circumference	,897	-,159	,076
Knee circumference	,844	,132	,155
Biceps circumference	,639	,531	-,050
Elbow circumference	,695	,339	,386
Ankle circumference	,525	,501	-,394

In order to obtain a more simplified and interpretable structure, there are different rotation methods that seek to eliminate intermediate loadings [24]. In fact, the first component extracted represents a general factor [26]. An orthogonal rotation method – Varimax – was used. This method minimizes the number of variables with high loadings [26]. In the matrixes of components of the rotated solution, presented in tables 5 and 6, the component to which the variable contributes with greater weight was selected. For the male gender, the first component is associated with the variables of height (thigh, bust, knee, hip and waist height, sleeve, height), while the second component is associated with the variables of circumference (waist, abdomen, elbow, bust, hip, knee, biceps and thigh). The third component is associated with the circumferences of the ankle and the bust, which correspond to the smallest circumference measurements of the lower and upper part, respectively. According to [22], the perimeters of the ankle, wrist and neck reveal a complex pattern. In the case of the female gender, there are some nuances compared to those described for the male gender. Thus, the first component is also associated with height (thigh, bust, knee, hip and waist height, height, sleeve), however, it is also associated with the variables of circumference of the thigh and the hip. This association is justified and explained by [22], who report that the distribution of adipose tissue is different between males (it is more abdominal) and females (it is distributed more in the hip and thigh), so the measurements have a greater agreement between the participants of the male gender. The second component is associated with the variables of circumference of biceps, waist, ankle, knee, elbow, calf, bust and abdominal. The third component is associated with the circumference of the wrist. Some variables, such as the female

knee circumference, although presenting a lower factorial loading, remained in the model because they were considered relevant.

Table 5 Rotated component Matrix (male)

	Component		
	1	2	3
Thigh height	,916		
Knee height	,916		
Waist height	,903		
Bust height	,902		
Hip height	,899		
Height	,878		
Sleeve shirt	,687		
Waist circumference		,886	
Abdominal circumference		,838	
Elbow circumference		,807	
Bust circumference		,752	
Hip circumference		,717	
Knee circumference		,659	
Biceps circumference		,677	
Hip circumference		,604	
Ankle circumference			,695
Wrist circumference			-,674

Table 6 Rotated component Matrix (female)

	Component		
	1	2	3
Thigh height	,927		
Bust height	,919		
Hip height	,901		
Waist height	,897		
Knee height	,890		
Height	,885		
Sleeve shirt	,788		
Thigh Circumference	,776		
Hip circumference	,772		
Biceps circumference		,800	
Waist circumference		,790	
Abdominal circumference		,723	
Ankle circumference		,701	
Elbow circumference		,686	
Bust circumference		,628	
Knee circumference		,596	
Wrist circumference			,895

4. Future perspectives

Although the 3D scanning system has contributed to the garment industry, anthropometric studies are time-consuming and data processing is required in order to obtain a valid and representative sample. Such studies are of supreme importance to the clothing industry in order to support the design of clothing appropriate to specific populations. Based on the identification of overweight and obese children, the corporal measurements relevant to the development of children's clothing were analyzed through the statistical method of principal components. In a subsequent step, the analysis of clusters will be performed to formulate the tables for this segment. This will contribute to improve the comfort and usability of children's clothing, as well as their self-esteem.

Acknowledgments

This work is financed by Federal Institute of Rio Grande do Sul, Brazil and FEDER funds through the Competitive Factors Operational Program (COMPETE) POCI-01-0145-FEDER-007136 and by national funds through FCT-Portuguese Foundation for Science and Technology, under the project UID/CTM/000264.

References

- [1] Huissteen S V 2006 Development of standardised sizing systems for the South African children's wear *PhD thesis* University of Stellenbosch
- [2] Silveira I 2008 Usabilidade do vestuário: factores técnicos-funcionais *Moda Palavra - periódico* Ano 1 no jan-jul pp. 21–39
- [3] Gill S A March 2015 Review of research and innovation in garment sizing, prototyping and fitting *Textile Progress* Vol **47** no 1
- [4] Campos R, Carvalho M, Lopes H and Xu B 2017 Anthropometric data collection of Portuguese children with

- overweight and obesity In: *Proceedings of the 8th International Conference on Applied Human Factors and Ergonomics* Los Angeles
- [5] Kang Y, Choi H S and Do W H A 2001 Study of the apparel sizing of children's wear. An analysis of the size increments utilized in children's wear based on an anthropometric survey *J Korean Home Eco Assoc Eng* **2** (1)
 - [6] Betti M U 2014 Beleza sem medidas: corpo, gênero e consumo no mercado de moda plus size *Dissertação de mestrado em Antropologia Social* Universidade de São Paulo
 - [7] Nafiu O and Burke C 2013 Large Clothing Size in Children Is Associated with High Body Mass Index and Clustering of Medical Comorbidities *ISRN Obesity Volume*
 - [8] Shin S J H and Istook C L 2008 Sizing Systems for Children's Wear in the United States *Texas Tech University* Lubbock TX USA
 - [9] Kim H and Damhorst M L 2013 Gauging Concerns with Fit and Size of Garments among Young Consumers in Online Shopping *JTATM* Vol **8** Issue 3 Winter
 - [10] Boguslawska-Baczek M 2013 Analysis of the contemporary problema of garment size *Conference: The 7th Textile Science 2013 conference At Liberec* Czech Republic
 - [11] Liu K, Zengc X, Bruniauxc P, Wangb J, Kamalhac E and Taoc X 2017 Fit evaluation of virtual garment try-on by learning from digital pressure data Knowledge-Based Systems **133** pp. 174–182
 - [12] Olaru S, Spânachi E, Filipescu E and Salistean A 2013 Virtual Fitting – Innovative Technology for Customize Clothing Design *24th DAAAM International Symposium on Intelligent Manufacturing and Automation*
 - [13] Boueri J J 2008 Sob Medida: antropometria, projeto e modelagem. Pires D B (Org) *Design de Moda: olhares diversos* São Paulo Estação das Letras e Cores pp. 347–369
 - [14] Heinrich D, Carvalho M and Barroso M Julho 2008 Ergonomia e Antropometria aplicadas ao vestuário—discussão analítica acerca dos impactos sobre o conforto e a qualidade dos produtos *Diseño en Palermo* Universidad de Palermo
 - [15] Sabrá F, Rosa R A, Santos C S and Brito L F F 2013 Desenvolvendo uma nova referência de medidas para o vestuário através da tecnologia de escaneamento de corpos 3d
 - [16] Campos R, Carvalho M A and Xu B July 2018 Anthropometric Data Collection of Portuguese Overweight and Obese Children using a Kinect Body Image system: Preliminary Results *9th International Conference on Applied Human Factors and Ergonomics (AHFE)* USA
 - [17] Alemany S, Gonzalez J C, Nacher B, Soriano C and Arnaiz C 2010 Anthropometric survey of the Spanish female population aimed at the apparel industry
 - [18] Capelassi C H 2013 A evolução histórica do dimensionamento do vestuário *Anais*
 - [19] Murteira 1993 Análise Exploratória de dados – Estatística Descritiva McGraw-Hill Lisboa
 - [20] Maroco J 2007 Análise estatística com utilização do SPSS (3ª ed.) Lisboa: Edições Sílabo
 - [21] Zakaria N 2010 The development of body sizing system for school aged children using anthropometric data *PhD thesis* Universiti Teknologi Mara Malaysia
 - [22] Loeffler-Wirth H, Vogel M, Kirsten T, Glock F, Poulain T, Koßner A 2017 Body typing of children and adolescents using 3D-body scanning *PLoS ONE* **12**(10): e0186881
 - [23] Pereira A and Patrício T 2013 SPSS: guia prático de utilização: análise de dados para Ciências Sociais e Psicologia 8.ª ed Lisboa: Sílabo ISBN 978-972-618-736-3
 - [24] Pestana M H and Gageiro J N 2008 Análise de dados para ciências sociais: a complementaridade do SPSS (5ª ed.) Lisboa: Edições Sílabo
 - [25] Abdi H and Williams L J 2010 Principal component analysis. Wiley Interdisciplinary Reviews: Computational Statistics, **2**(4) pp. 433–459 doi:doi:10.1002/wics.10
 - [26] Larose D T 2006 Data Mining Methods and Models John Wiley & Sons, Inc
 - [27] Field A P 2009 Discovering statistics using SPSS: (and sex and drugs and rock 'n' roll) (OKS Print.) Los Angeles [i.e. Thousand Oaks, Calif.: SAGE Publications]