DEVELOPMENT OF TECHNICAL MANNEQUIN BASED ON ANTHROPOMETRIC STUDY OF PORTUGUESE CHILDREN

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ABSTRACT

During the process of design of children's clothing, it is important to consider the activities of each age group, dressing and undressing, clothing functionality and usability, as well as their body shape, anthropometric characteristics and ergonomic needs. It was from the user-focused design that this work was developed. The lack of research on children's clothing, sizing and main biotypes, allowed the creation and construction of an industrial technical mannequin, as a result of an anthropometric study, representing the children of one of the main identified groups, during a Clusters Analysis of Portuguese children aged between four and nine years.

Key Words: Draping dummy, Anthropometry, Garment Sizing.

1. INTRODUCTION

The new 3D body scanning tools have been acquiring a relevant role in product development, including improving and scaling adjustments to human body of garment products, allowing for further study of the body, through the handling of avatars in virtual 3D CAD technologies. The studies of the human body focused on children are still scarce, requiring more stringent criteria of safety and comfort, to respond to the needs of the children's fashion segment. Children are in constant growth and development, with frequent changes in their structure and body mass, being a challenge to fashion designers while creating appropriate products. This study is part of a PhD in Fashion Design and discusses the development of a methodology for 3D pattern design, using a new draping dummy, and the final validation process of prototypes. The study used anthropometric data from Portuguese children, aged between four and nine years, of both genders. The key measurements were obtained using a 3D body scanner (KBI-Kinect Body Imaging) with three hundred and fourteen children, residents in the northern region of Portugal. The statistical data treatment was done using a Cluster Analysis, which has identified three main groups of sizes, resulting in a new table of anatomical measurements. From this table of measurements and the observation of the avatars generated by the KBI system, the main biotypes of the Portuguese children were identified. With a partnership with the Brazilian company *Draft Manequins Industriais*, manufacturer of industrial dummies, it was possible to build a standardized mannequin, representing the intermediate groups of children.

2. ANTHROPOMETRY IN GARMENT CONSTRUCTION

Anthropometric studies of the human body can be used in several areas of knowledge, such as engineering, architecture, health sciences, industrial design, among others [1]. On the construction of clothing, anthropometry allied to ergonomics are of fundamental importance in adjusting to body and its relationship with environment and social context, ethnicity, time and culture, where the user is located. A large quantity of garments that are discarded in the sales points are appointed to result from lack of fit to the user body. Therefore, it is assumed that

each region has specific anthropometric characteristics. "The modern industry needs the anthropometric measurements increasingly detailed and reliable. On the other hand, it is required by the needs of mass production of products such as garments and footwear" [1].
Existing anthropometric studies in Portugal do not include the child population; reported studies refer a range sample between 18 and 86 years old. So, there is a need for studies in this fashion segment [2].
The comfort of children clothing is especially important due to their characteristics and needs, daily activities, sensitive skin and constant growth. Comfort has to be considered in all its variables: ergonomic comfort, thermo-physiological, psychological and sensorial. The ergonomic comfort is related with the shape of the garment, as a result of the patternmaking process in accordance with the expectations of the fashion designer. The pattern design process has to be done based on body studies regarding shape and measurements, as well as the proper use of techniques and methods. Another factor that determines the ergonomic comfort is the textile raw materials used in the assembly of the final product. This study was conducted for woven fabrics, a greater criteria of fashion garment construction.
It is well-known that children who wear clothes that properly fit their body, contribute to the growth and to the development of a healthy body [3].
In order that the anthropometric measurements could effectively respond to consumers through the standardization of products, three steps are necessary: definition of the nature of the anthropometric dimensions required in each situation; perform steps to generate reliable data; and properly apply such data. In this study, the main anthropometric dimensions required for the construction of the garments were defined, data was collected and the analysed and finally applied in new tables of measurements [1].

2.1 Collecting the Key Measurements

The key body measurements were obtained through the use of a 3D body scanner - KBI -*Kinect Body Imaging*. The hardware, involving the use of four *Microsoft Kinect* sensors, and the software programme, provided the capture of 3D body image, automatically generating 110 measurements of the child human body. In addition to these, height and head girth were manually registered and body mass index was calculated for each one.
The four sensors are mounted on a detachable metal structure, as graphically represented in Figure 1, two in the frontal position and two in back position, in order to capture the 3D surface of the body that should be positioned exactly in the middle. The orthostatic position must be followed carefully in order to obtain an image correctly formed. The upper sensors cover the upper body and the bottom sensors the lower body.

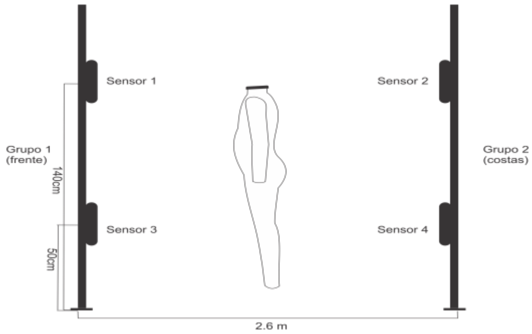

Figure 1 –KBI Body Scanner. Adapted [4]. Autor (2019)

The KBI provides automatically the main body measurements of circumference, height, width, depth and volume. A 3D body image is generated by the system allowing to observe the body from the front, side and rear positions, functionality ideal for the body shape analysis, during the definition of the main biotypes. The avatar generated for each child has represented the landmarks of the main lines of the body and a grid with all the measurements automatically obtained and recorded on a list of measurements. [5]

2.2 Anthropometric Analysis

The analysis of the anthropometric data was based on the methodology used by Zakaria [6] and was conducted in three stages. The first is subdivided in the following steps: preparation of the field work; anthropometric planning, anthropometric survey and anthropometric analysis. The second stage corresponds to the scaling analysis, consisting in multivariate analysis using the techniques of principal components analysis and cluster analysis [7]. The third step, related to development of sizing, is subdivided into three steps: definition of the tables of measurements by age, grouping and designation of each size.

2.3 Results Analysis

In the year of 2016, data from approximately 700 children, between the ages of two and ten years, of both genders, were collected. For various reasons, the study the children with two, three and ten years of age, were discarded. The younger ones by the fact that most of the 3D images had poor quality, due to the difficulty of keeping them on the correct standing position, and the older ones by the fact that from the age of nine, it was found that girls begin to assume a body of an adult female, with the development of breasts, precluding the possibility of grouping both genders in the same table of measurements. Thus, this study obtained a sample of 314 children (45.54% female and 54.56% male).
The analysis was initiated by factorial analysis via principal components (PCA) with the objective of selecting the variables that contribute significantly to the explanation of data variability. After the selection of the main measurements to be considered in the cluster analysis, three main groups of children were defined, according to their characteristics relating to the measurements used. After groups formation, they were characterized according to the age of each child, by means of descriptive measurements and graphical analysis.

2.3.1 Sample Definition

An initial statistical analysis of data, based on exploratory data analysis [8], was held for the verification of the consistency of the values of the measurements, excluding some observations from the original data bank. The measurements on children were obtained more than once, and were considered in the analysis, the respective mean values.
All children in the defined age group, were invited to participate in the study, but only those with parental consent were allowed to participate. This way, the sample is classified as a convenience sample, not probabilistic. Thus, the studied sample was composed by 13.06% of children with four years old; 12.42% with five; 22.29% with six; 21.66% with seven; 14.33% with eight; and 16.24% with nine.

2.3.2 Cluster Analysis

Cluster analysis is a method of multivariate data analysis which seeks to divide the sample into groups with homogeneous characteristics, on the basis of a measure of distance. Here, the Euclidean distance. In this study was adopted the more distant neighbourhood method (complete linkage) shown to be more efficient.

To check what would be the best grouping structure, were considered formations within three to six groups, since there are six tracks of age. The one that obtained the best result was the formation with three groups, as in the others, the kids with 4, 5 and 6 years were concentrated in two groups.

Table 1 - Distribution of Children by Groups defined by Cluster Analysis by Age for the Formation of Three Groups from the Selected Variables

Age / **Group**		**1**	**2**	**3**	**Total**
4	N	-	-	41	41
	%	-	-	100	100
5	N	-	2	37	39
	%	-	5,13	94,87	100
6	N	1	9	60	70
	%	1,43	12,86	85,71	100
7	N	7	38	23	68
	%	10,30	55,88	33,82	100
8	N	13	26	6	45
	%	28,89	57,78	13,33	100
9	N	24	23	4	51
	%	47,06	45,1	7,84	100
	Total	**45**	**98**	**171**	**314**

The analysis of Table 1 shows that children with 4 and 5 years old were almost all allocated in Group 3. Only 5.13% of this group were designated for Group 2. This fact, together with the analysis of descriptive measurements, leads to the conclusion that Group 3 is formed by children whose measurements tend to be smaller in general.
Almost all children with 6 years old (85.71%), were classified in Group 3, which indicates that these children have a similar body profile as the children with 4 and 5 years old. Thus, it is possible to observe that children of 4, 5 and 6 years old can be considered as belonging to the same group (Group 3).
Most children of 7 years were distributed between Groups 2 and 3, as 55.88% were allocated to Group 2 and 33.82 % to Group 3. Most children with 7 years old have their measurements in general greater than the children with 4, 5 or 6 years old, but there are also children with similar development to those children of minor age.
Children with 8 and 9 years old were distributed among Groups 1 and 2, with a few cases in Group 3. Regarding children with 8 years old, the majority (55.88%) has, globally, similar measurements to the children of 7 years, being classified as belonging to Group 2. But there are children more developed, being classified as belonging to Group 1.

3. CONSTRUCTION OF THE INDUSTRIAL STANDARD MANNEQUIN (DUMMY)

The industrial standard mannequins (dummy) are largely used by the industrial textile and clothing sectors. There are several types found in the market for various functionalities. The present study deals with the construction of a mannequin, the can be used for the analysis of prototypes by the garment industry to validate the designer collections, as a body of evidence (fitting) and for the study of the body and its shape, both in design and in 3D patternmaking methodologies (draping/moulage).
In partnership with a Brazilian company of industrial standard mannequins, as a result of the anthropometric study, a dummy was developed with the measurements of Portuguese children

(Table 2), considering the shape of the obtained avatars of the children (Figure 2).The dummy was used to develop a new children patternmaking methodology with a focus on ergonomics.

Table 2 – Median measurements used for the construction of the dummy

Height/Circumference(cm)	Median[1]	Length/Width/Height(cm)	Median[1]
Height	130,0	**Shoulder width**	13,8
Head	54,0	**Chest width**	17,2
Neck	30,2	**Back width**	17,2
Bust	64,2	**Bust height**	92,2
Waist	60,8	**Total Front length**	29,8
Abdomen	67,1	**Total Back length**	32,0
Hip	72,4	**Hip height**	17,2
Knee	29,4	**Inside leg length**	56,1
Ankle	19,6	**Knee height**	34,9
Arm	20,0	**Waist height**	78,4
Elbow	20,2	**Crotch Front length**	28,8
Wrist	14,5	**Crotch Back length**	28,9

[1]Median of the measurements of the children of Group 2

The whole process of interpretation of measurements and the way that it was intended to play physically at the mannequin, was discussed regularly with the producer. A first draft of the technical drawing of the mannequin was elaborated showing the measurements and the physical characteristics of the Portuguese children.

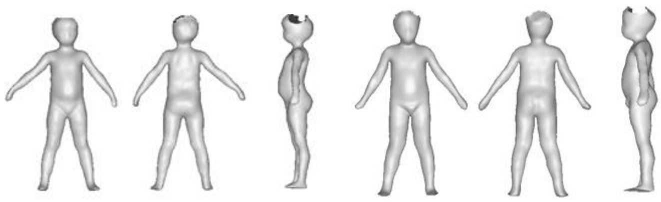

Figure2 – Avatar Images of Children with seven and eight years of old.

The standardized mannequin, customized with the anatomical measurements of the Portuguese Group 2 children, is represented in Figure 3. To facilitate transport and handling, the dummy was made with one removable leg, two arms and head.

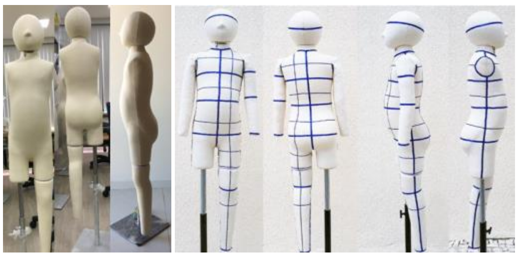

Figure 3 – Industrial Customized Mannequin with Anthropometric Measurements of Portuguese Children, Group 2 (Author, 2018)

The mannequin was provided with a technical datasheet, referring the anatomical measurements of the population under study, corresponding to Group 2, constituted preferably by children with seven and eight years-old, with an average height of 130 cm and a body mass

of 28.3 kg. The dummy was produced with the body shape of the Portuguese children and the main lines used by the 3D body scanner were marked with tape, including the girth lines of cleavage, bust, waist, hip, thigh, high and low, knee, calf, ankle, elbow, wrist, biceps, followed by lines of width and length, as shown on Figure 3.
The accuracy of the measurements is of fundamental importance, so the three-dimensional patternmaking process could be well executed. Studies define the mannequin as the “Body in actual size, created with a specific set of measurements, used for draping and clothing adjustments. Its padded surface allows the use of pins" [9].

4. FINAL CONSIDERATIONS

Garment manufacturing industries have been appropriating the 3Dpatternmaking technique (draping/moulage) because this technique allows an immediate preview of the product, check the shape and fit of the fabric, as well as the proportions and balance directly in the body, represented by the mannequin.
Basic pattern groups are run with better accuracy when developed on a mannequin constructed from anthropometric measurements, allowing to increase the hits, as they are developed using actual data of the target population.
Through the analysis of anthropometric data and body shape, and with knowledge of the needs of children, in particular their ergonomic needs, it was possible to develop and validate a new patternmaking process for the construction of basic pattern blocks, fundamental to the development of different styles of children's clothing collections offered by the Portuguese garment industry designers aiming both the Portuguese market but also the international market.

5. ACKNOWLEDGMENTS

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