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Anthropometry for children's clothing: difficulties and limitations

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Abstract. Children's wear lacks an anthropometric study to better fit clothes on the body of the child, providing greater comfort for users. Initially, this thesis project in fashion design intended to measure Portuguese children between the ages of 2 to 10 years, enrolled in primary schools in the region of Minho in Portugal. During the data gathering, held in the months of June, July, October and November 2016, about 600 children were scanned and measured using a 3D body scanner. The purpose of this paper is to report the difficulties and limitations experienced during data collection of the anthropometric study and the adjustments that were needed, as well as discuss some of the data collected.

1. Introduction

During the new product development process, especially in design stages of children's clothing, it is fundamental to meet the user's body and its interaction. According to ergonomics, the product "garment" requires the application of a series of scientific knowledge related to methods and techniques to assure that it is designed in the right way, providing comfort, safety and efficacy to the user [1]. The comfort is one of the main features of children's clothing because it needs to respond to the requirements of movements of childhood such as running, jumping, dancing, playing, among other activities. It is through pattern design, with the proper use of anthropometric measurements, that different shapes and volumes give freedom of movements to the target audience. Studies claim that "uncomfortable clothes hamper these movements and could even cause health problems, such as posture, allergic reactions, poor circulation caused by tight clothing (...), psychological problems" [2]. Therefore, the pattern design process provides the means to reflect the designer's worries about the garments characteristics for this active population.

Whenever possible and economically justified, anthropometric measurements should be carried out directly, taking a significant sample of subjects who are users or consumers of the object being designed [3]. When designing ergonomically correct clothing products which meet the physical, psychological, cultural and ethnic needs, it is necessary to use scientific methods in the survey of the anthropometric measurements, requiring an adequate planning and a precise definition of the anatomical reference points (standardization, as well as the position of the child at the time of

measurement). Hence, children's clothing must be functional to allow the growth and to provide comfort, safety and to stimulate a sense of independence.

Motivation to address the issue of children's clothing design came from informal conversations with mothers referring their grievances in buying clothes for their children. One of the biggest complaints were related to the size of clothes, as generally they do not correspond to the body size of the child. A 2-year-old child wears clothes labeled as size 4 or even size 6, expected to be used by 4 and 6 years old. Current tables of measurements used by the industry do not correspond to the anthropometric measurements of the children of today. Approximately 40% of the returns and reasons for consumer dissatisfaction are connected with the measurement standards used, which do not fit properly in the consumer's body. There is an inconsistency of sizes, requiring the consumer to try a great number of pieces to find a size that better fits their body measurements [4].

It is important to highlight that when clothing production moved from individualized and made to measure by home dressmakers to mass-production, there was a need to build a standard size table with body measurements for the different commercial sizes, related to children's age.

> Many clothing experts worldwide in an effort to enhance the quality of RTW garments have comprehensively studied issues of clothing sizing systems. Standard sizing systems have been developed for all populations ranging from babies to adults for both genders. (...).These surveys are conducted mainly to have a better understanding of the human body, so that the range of body shapes and sizes can be established in each particular country. (...).Thus, the main objective of most sizing system research is to find the optimal number of sizes that can accommodate the highest percentage of the target population. These sizes then accurately describe the many actual sizes and shapes found among the sample population [5].

Some researchers performed an anthropometric study of the Portuguese population [6] but infant and children were not included in the universe of the sample. A recent anthropometric study of the Portuguese population started in 2015 using a body scanner technology, but also it does not cover this population. Probably, the difficulties faced in working with children is the reason for not being included in the two studies mentioned above. There are few studies in this area, involving the design of children's clothing.

Hence, the lack of research with children's body measurements for clothing production, justifies the relevance of this anthropometric study of the Portuguese children's population.

The objective of any size system is to choose the size groups in such a way that a limited number of sizes will provide clothing that fits the majority of individuals in the population [7]. However, this does not occur within children's wear, mainly in clothing produced in plain fabric without elasticity. Clothing is part of the basic needs of human beings, as dressing is considered as one of the basic physiological needs. Hence, an anthropometric study is the starting point and has fundamental importance for scientific research of infant's garment design, especially allied with ergonomics, aiming for the development of an optimal design according with the needs of the users.

2. The experimental planning

The research field planning began with a formal request to local schools to join the study, explaining the importance of the study for different sectors and industries, as well as for the school, as it will access relevant information about the metrics of their students. In a second phase, a letter of authorization, including also a detailed explanation about the study and the methodology used, was printed and delivered in each school to be taken home, in order to obtain their signed permission to participate in the study. It is worth mentioning that both approaches experienced several obstacles, since the way the school welcomes the study and consequently sensitizes parents and staff has a direct relationship with the sample size available to participate in the study. When there is a greater involvement of the direction of the school there were a greater number of parent´s consent allowing their children to be measured. The physical planning, i.e. the definition of the most suitable location is directly proportional to the measuring instruments. To install the 3D body scanner, it was necessary to consider the thermal comfort and enlightenment, because the equipment was sensitive to high

temperatures and direct sunlight incision undermines the sensors, causing that, often, the system failed to measure.

After installation of the equipment, it was necessary to follow a calibration procedure, assuring each of the four sensors were acquiring correctly the image of the body. Then, it was necessary to prepare the space to receive the children in order to be able to register their weight (in a calibrated scale), height and confirmation of head circumference (using a flexible tape measure). Although all data related to the measurements was available in the software of the 3D body scanner, data for each participant was exported and collected in a *Microsoft Excel* spreadsheet, for future processing and statistical analysis. A separate folder was created for each school to store the measurements collected from their students and an identification code of each child was used, both in manual as in the body scanner files. Later, the images generated by the system software were treated, in accordance with the requirements for the study. The knowledge about the shape and measurements of the main parts of the children's bodies, will allow us to identify the most common biotypes of the population, which will be the basis to create and develop a children's pattern design methodology with focus in ergonomics.

3. Anthropometric measurements and 3D body scanner

The anthropometric measurements of the children were obtained through the methodology of 3D scanning technology. The system used was called KBI - *Kinect Body Imaging*, developed by the researchers at University of Texas at Austin and University of North Texas at Denton (USA). This 3D technology is able to capture the real body shape of the children's body, generating automatically 110 body measurements and volumes of the main parts of the body in a ¼ of a second.

The use of 3D technology to measure human body is being used increasingly around the world, making it possible to obtain faster a greater number of human body measurements with a reduced degree of subjectivity, as manual procedures require the definition of accurate landmarks, which can vary from person to person, especially when more than one person is doing the measurements. 3D body scanners methodology are very important nowadays to obtain children's dimensions, as they are very fast to use, provide greater accuracy, as well as privacy and a contactless method to measure children's body. The amount of measurements we have made in three hours would take months in a manual measuring procedure. So, the KBI system facilitates and expedites the procedure of taking anthropometric measurements as well as increased the accuracy of the results. The KBI system uses four *Kinect* sensors to capture the entire human body, as shown in Figure 1 [8]. It provides not only the measurements but also the 3D shape of the bodies that can be manipulated afterwards for several analyses.

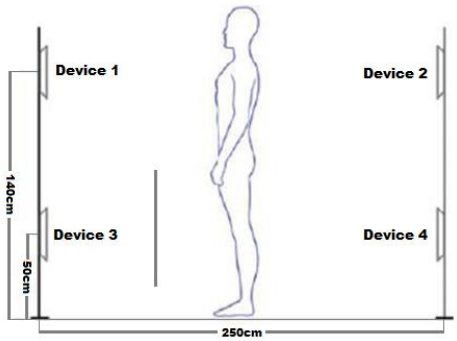

Figure 1. Set up of the KBI system adapted from Bragança et al. [8].

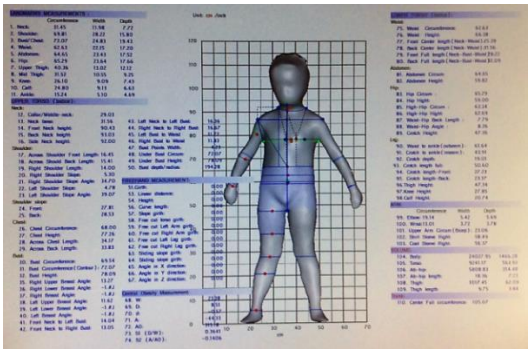

Figure 2. Example of all obtained measurements from KBY software

4. Selected measurements for the study

For the purpose of this study, a reduced number of forty-eight measurements were selected among all automatically collected from the child's body by the3D body scanner. The selection criteria was based

in the relevance that each measurement had for the pattern design process. These selected variables were similar to the variables collected by other studies [9]. The measurement of the head in this segment of the population is important for the design of children's ergonomics clothing and was not properly obtained with the body scanner. Therefore, the dimensions of the greater perimeter of the head of each child participant was obtained manually, using a flexible measuring tape. The results of all measurements for one participant can be observed in Figure 2.

5. The survey of anthropometrics' data of Portuguese children

Data collection was conducted in schools in the Northern Region of Portugal, Minho. The first contact was carried out with the school directors to obtain the needed authorizations for the study. There are several schools in each District of the Region, but only those who had a significant number of acceptances to participate in the study were selected, considering also the distance, to minimize logistics. At District A, we got agreement with three schools: 14children in first school, 24 in second and 60 in third school. It´s worth noting that the majority of consents obtained came from parents of younger children, who had a daily routine of checking their child's backpack and, therefore, accessing the formal letter regarding the study. Older children had forgotten to warn their parents. At District B we were very excited because there were 1116 children enrolled, although only 693 children fitted the research profile. We waited fifteen days to obtain responses from parents. The return in 4 schools was: 34 children in first school, 63in second, 50 in third and 43 children in the fourth, resulting in a total of 190 children. Data was also collected at a local Association, connected with a large school, *Casa do Povo*, where 49 children were measured.

A first analysis of collected data was performed and Table 1shows the absence of a constant difference between the measurements of each age group, which implies on difficulties to create a standard for graduation for children sizes. Although the data is not yet enough to a final conclusion, as only were considered 60 children from the third school of District A, it gives us an idea of the main body differences found in the children's segment with distinct variations between sizes.

Table 1. Comparison of the arithmetic mean of the measurements of head circumference, height and weight by Age between girls and boys– Sample of 60 children from one of the schools at District A

Age		3	4	5	6	7	8	9
Head circumference mean (cm)	**girls**	-	50,13	50,0	52,0	53,44	55,13	54,14
	boys	53,15	50,88	48,5	51,75	54,19	53,69	53,32
	difference	-	+ 0,75	- 1,5	- 0,25	+ 0,75	- 1,44	- 0,82
Height mean (cm)	**girls**	-	105,5	116,6	117	127,2	134,7	141,7
	boys	102	107	110,5	120,25	127,38	131,13	117,25
	difference	-	+ 1,5	- 6,1	+ 3,25	+ 0,18	- 3,57	- 24,45
Weight mean (cm)	**girls**	-	17,3	22,2	22,4	26,9	39,1	36,4
	boys	17,4	17,68	17,65	30,93	27,2	29,6	33,6
	difference	-	- 0,38	+ 4,55	- 8,53	- 0,3	+ 5,5	+ 2,8

The book "*Devenir modéliste*: le vêtement d' enfant" proposes two infant measurement tables for German, Portuguese, Norwegian and Korean children: one first table for 2, 3 and 4 years and a second table for 5, 6,7, 8 and 9 years, as shown in Table 2[10]. Other measurements tables of different authors do not include the child's head circumference, using only the neck base girth. Head perimeter is a measurement of fundamental importance in designing children's clothing, as it has direct impact in children's comfort, causing difficulties in dressing/undressing when not properly considered.

The two measurements presented in Table 3, were extracted from the book "*Metric pattern cutting for children's and babywear*" for the standard American public [11]. The author includes in the same table the ages from 3 to 14 years old, although, there is no information on how the table was built,

where and how the measurements were obtained. The difference of head circumference between the ages varies 0,4 cm within the ages of 3-5y; 0,6 cm within the ages of 5-7y; and again 0,4 cm within the ages of 7-9y. It is also possible to observe that the difference of neck base between ages also varies.

Table 2. Head and Height measurements of children by Age (Wargnier, 2014, p. 29, p. 39)

Age	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Head circumference (cm)	52	53	53	54	54	55	55
Height (cm)	98	104	110	116	122	128	134

Table 3. Head, Neck and Height measurements of children by Age (Aldrich, 2009, p. 17)

Age	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Head circumference (cm)	51,2	51,8	52,4	53	53,6	54	54,4
Neck circumference (cm)	26,6	23,6	24,4	25,2	26	27,1	28,2
Height (cm)	98	104	110	116	122	128	134

6. Children's behaviour

As the study was moving, some amendments were necessary, as working with children results in increased difficulties. A first amendment was related with the ages of the children. Although the first plan considered ages from 2 to 10 years we were forced to redefine the range as 3 to 9 years. It was not possible to carry out the study with children of two years of age, as it was not possible to maintain them in the correct position during acquisition to allow an accurate image. Some were scared by the dark color of the cabin, refusing to go inside alone and others. In future, a more attractive decoration of the interior of the cabin is recommended for younger children. Another factor identified was that children at this age still wear diapers, affecting important measurements, like the circumferences of hips and thighs. A second amendment was related with ages above 9 years, excluding the 10 years old age range, since the goal is to develop an unisex table of measurements, and at the age of 10 girls are already in the process of changing through a female body.

7. Undressing and dressing

Despite the measuring process had been explained in the formal letter to parents, referring that the measuring process consisted of a 3D image of the child's body, identified as a single code, with no name, some parents did not allow the participation in the research. Children were requested to bring their bathing suit or underwear close to body. The process starts with the child positioned inside the body scanner cabin, to undress. If he/she has difficulty, the teacher or an auxiliary is there to help. The child is requested to position in the scale to obtain the body mass in kilograms. The child's height and head circumference is than manually measured with a flexible measuring tape. We found that the task of undressing and dressing was the most time consuming, where girls took longer as they are required to properly trap and loosen the hair. To expedite the process, whenever possible, boys from girls were measured separately. The period of the year in which the study was carried out also interfered in the process, whereas in the Summer the process was easier and faster due to the use of less clothes and easier to undress and dress. In winter was harder, due to the climate and the amount of clothes that the children used, usually 3 sweaters, jacket, socks, and tights, among other pieces. One relevant observation during the study was that the neck of t-shirts and sweaters of the majority of children was very tight to pass through their head.

8. Final considerations

Anthropometric studies with children revealed to be much more complicated than in adults. Since the first day of measurements, during the pre-test stage, we realized that it would not be easy to work with this public, due to the peculiar characteristics of child development, the acceptance of school directors

and mainly their parents, in allowing their children to participate on the research, as well as the will of the child. Often parents had given the consent and the child has rejected to participate in the moment it was requested; sometimes the opposite occurred, when parents didn't give permission but the child observes his/her colleagues involved in the study and convince his/her parents to participate. It is unpredictable the number of children able to participate in the study in each school until the time of data collection.

During the undress and dress process it was realized that the neck collar of t-shirts and sweaters are too small to the average child's head circumference, corroborating with the need of an anthropometric study to develop a new table of measurements, representing the reality of the new Portuguese children. It was also perceived that the width of the legs of the trousers, in general, were very fair, hindering the constant movements of the children, blocking blood circulation and the movement of legs. For this reason, many children requested help to undress and dress pants. Through this research we can realize the importance of a further study on the anthropometrics and shape of the children's average body, considering their ergonomics and types of clothing used, in order to develop updated standard tables of measurements, that will provide the needed information for the pattern design process, with greater precision, and therefore, providing greater comfort for these children and reliable data for the industry.

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