

Ergonomic clothing design for care-dependent elderly women

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ABSTRACT: This paper describes the development of ergonomic clothing suitable for the corporal characteristics of the care-dependent elderly women at four institutions: two located in the city of Guimaraes (Portugal) and two in the city of Teresina (Brazil). The prototypes were developed based on the needs of the elderly according to some functional factors as well as their physical conditions, aiming at easier handling by the caregiver and comfort for the user. Below, the functional properties of the applied fabrics and accessories, the modeling process, and the garment assembly are described.

1 INTRODUCTION

The integration between design and ergonomics improves the product development. This link is stated by Dul & Weerdmeester (2004) considering ergonomics as an applied discipline to product design, aiming to improve safety, health, and comfort. For Mozota (2002), design is an area that contributes to the resolution of problems from the creation of coordinated and systematic activities, together with management. According to Burdek (2006), product design should answer to specific problems of a target population. This is the case in this study, focused on elderly women. From this perspective, it is necessary to highlight some particularities regarding the body of the elderly people, especially corporal changes due to the aging.

Still, from the linking between ergonomics and design, Gomes Filho (2003) argues that it is made possible knowing the basic ergonomic factors of garment design, such as requirements for comfort, body posture, and safety, as well as visual, tactile and synesthetic actions. The author (Gomes Filho, 2003) also reinforces that the designer must consider the clothing's use, maintenance, and cleaning. The comfort for the user, in this case the clothing for elderly people, is related to the suitability to the body and other requirements, such as practicality, quality, and functionality, as highlighted by Araújo (2009).

The integration between design and ergonomics is one of the intents of this effort, an undergoing PhD study in Textile Engineering at the University of Minho (Portugal). It aims to develop clothing

with greater comfort to care-dependent elderly women, besides facilitating handling in the dressing and undressing by caregivers. Therefore, the ergonomic, sensorial and psychological aspects of comfort for the user assume the central core of this research.

2 THEORETICAL FRAMEWORK

For the users' satisfaction with clothing, when considering ergonomic functions, the garment should be designed according to the variance of height and body shapes of the target population, considering anthropometric data as well as their needs in terms of movement and interaction with others. In the development of the proposed clothing, in addition to the contribution of ergonomics and anthropometry, it is necessary to observe the complex movements of the users, in particular those performed by the caregivers, as they are responsible for tasks that involve the handling of the elders, like dressing and undressing.

All designers, at the time of the development of a product, have the responsibility to guarantee an adequate interaction of the product with the user. It is important to use new assessments, yet in the first design phases, to re-evaluate the design, with the intention of fitting with the human dimensions (Panero & Zelnik 2002). This is of major relevance when a product is going to be in direct and in long term contact with the user, as is the case of clothing.

According to Iida (2005), ergonomics can contribute at different moments, as also identified by

Wisner (1987): during design and after design (correction), to improve awareness or to promote participation. In the design phase, the contribution of ergonomics occurs during the product design. In correction ergonomics, it occurs when it is applied to existing situations, aiming to correct current problems. In the awareness ergonomics, the actions are focused on problems that were not solved during design or correction phase, as well alternative, training programs are promoted. Finally, in participatory ergonomics, the user is involved, aiming to use his practical knowledge when seeking the solution for the problem.

When the proposal is the development of a product focused on the elderly population, the design phase requires a suitability of the product to the user but also an acceptance by the caregivers. This is why a toile (garment prototyping) is so relevant since the caregivers are responsible for handling the elders for dressing, undressing, health caring, and cleaning.

Iida (2005) mentions two authors (McClelland & Brigham, 1990), who share the same view regarding the relevance of ergonomics during product development and also the knowledge of user profile, the product utility, the usability and the interaction with the user, it is recommended to clarify the users' profile, their needs, values, and desires. To reinforce this, Dul & Weerdmeester (2004) show that ergonomics includes aspects such as posture and body movements (sitting, standing, pushing and pulling), environmental conditions (noises, vibrations, lighting and climate), and tasks (appropriate and interesting). The integration of all these requirements allows the development of safe, healthy, comfortable and efficient products for everyday life.

The ergonomics contribution usually occurs in the initial phase of the product design, in the work environment or in specific situations that already exist, aiming to solve problems related to safety, fatigue, quality improvement, etc. Its contribution is being widened as it has been used to improve the interaction between humans and artifacts. This involves both physical and organizational aspects, covering planning and designing activities. Ergonomics aims to promote health, safety, satisfaction and well-being for the individuals.

According to Iida (2005) there are two ways of performing ergonomic experiments: one is under artificially constructed and controlled conditions, like laboratory research, the other, the field studies, from the observation of the phenomenon under real conditions.

Furthermore, to reach this study goal, it is of paramount importance to apply anthropometric data. Anthropometry is the scientific area related to the study of the human body, volumes, forms, their movements and joints (Petroski, 2007). Anthropometry is also useful for the nutritional analysis of the elderly, as it is a simple and good prognosis method

for studying possible diseases, functional disability and mortality, and can be used for both diagnosis and disease monitoring (Brazilian Health Ministry, 2011).

3 METHODOLOGICAL STAGES

3.1 Process for the design of clothing

The proposed design was based on main body measurements, collected from a group of 101 participants, aged over 65 years for the evaluation of the physical and psychological conditions regarding the selection of the profile of the probable participants of the anthropometric study, resulting in the collection of 79 measurements of the body. This data allowed the development of an experiment to define values of more specific measurements for the development of a basic pattern block supporting the design of basic clothing prototypes for dependent elderly. The basic sewing pattern block was designed in medium size (M), in order to reach a wider range of users. For Jones (2005) and Heinrich (2005), the measures applied in the basic designing process are defined by the companies, by designers, or by the norms for clothing sizes developed by countries that have already performed anthropometric studies. The medium size makes easier designing larger and smaller sizes and can be used for elaborating graduation sewing patterns.

By using these clothing design techniques, it is possible to structure the product development, keeping the focus on the proper understanding of the design. According to Fischer (2010), this requires a good observation on the design proportions. In this way, the body shape should be observed (considering the most adequate ease values for each part of the sewing pattern block) as well as the marks insertion (location of the clothing' parts in pockets, openings, hems, among others) and other sewing parts (like the pockets, the collars, and so on).

Still, for designing ergonomic clothing, it was imperative to consider the social, physical and psychological needs of the users, and their caregivers' tasks, through the analysis of the collected data from the registered elderly women and the work practices of their caregivers through direct observation and photographic registration. The method used involved the observation of two caregivers, with different years of experience in their functions, in the performance of their activities. This way, it was possible to understand that with experience in their function, practicing the same tasks on a daily basis, the handling of the elderly women is performed in a mechanized way, meaning that the task becomes more simplified. Ferreira, Leal and Guimaraes (2004) report that observation constitutes a subjective interaction between observed and observer, which are em-

bedded in a single reality from which the findings occur.

Through the use of the basic patterns block, it was possible to structure the development of the product, keeping the focus on the adequate understanding of the model regarding the corporal modification that the person acquires in the course of aging. According to Fischer (2010), this understanding requires a good observation about proportions. Therefore, the body shape must be observed (considering the most appropriate ease values for each part of the pattern), insertion of notches (location of relevant parts of the garment) and the addition of other parts (such as pockets, collars, etc.).

The garments were designed according to the specific needs and local context of the elderly participants of the cities of Guimaraes (Portugal) and Teresina (Brazil).

3.2 Elderly from Guimaraes, Portugal

Five models were designed for use during pleasant temperatures days, near Summer, the hottest European season. The values of the average monthly temperature change regularly during the year, reaching the highest values in the summer ($> 27^{\circ}\text{C}$) during the months of July and August. The lowest monthly average temperature occurs from December to February, reaching below zero temperatures in the highest altitude areas of Spain and Portugal (Climatological Atlas of the Iberian Peninsula, 2011).

Besides taking into consideration the environmental characteristics, it was also necessary to know some behavioral aspects of the elderly and to analyze information provided in the caregivers' surveys. The pieces selected for prototyping are composed of dresses, trousers, skirts, blouses, considering complementary details of the models, such as raglan sleeves (diagonal cut lengthening to the neckline) and kimono sleeves, soft scoop necklines and narrow collars, easy openings with zippers and buttons. $\frac{3}{4}$ sleeves models were designed both in raglan and kimono formats. Two of these models, do not require the definition of the shoulder slope. The $\frac{3}{4}$ sleeves were used as an option for the long sleeves, in consideration that this is preferred due to the extended cold period of the region.

3.3 Elderly from Teresina, Brazil

In Teresina the garment was developed especially for the summer, considering that in this region the hot days last almost all year. Teresina's monthly average temperature varies from 26.9°C to 37.1°C , reaching extreme temperatures (above 40°C). Also, the relative air humidity reaches 75% to 83% in the urban area (Medeiros, 2014). In addition to data collected from the caregivers' surveys, other observations such as physical and financial conditions, be-

yond the climatic conditions, were important for the clothing design, and wider fits were proposed.

Puccini & Wolf (2015) carried out a study focused on the development of garments for the elderly population. The authors realized that dresses are considered the most comfortable garment by the individuals. This statement is in accordance with the proposed design by this study, emphasizing the dresses with wider and short raglan sleeves, wider kimono sleeves with lappers, boat and V-shape necklines, seam finishes with the same fabric of satin taping, and easy openings (with buttons and zipper). The design was focused on necklines, specifically the place of openings that provide inserts such as various types of collars. Models with larger round necks, boat neckline, and V-shape were designed. In some models, narrow collars and half collars (a type of collar that ends at the shoulder) were inserted with external finishes to avoid discomfort in the neck region. Regarding the sleeves (most of them are designed to be fixed in the armhole), the arm movements were taken into consideration. The body movements were observed, avoiding overlapping seams and cuts located in places with more skin contacts due to body movements.

One of the peculiarities in most of the designed models with sleeves is the raglan sleeve. This type of sleeve allows for better body heat release when compared to the sleeve with the armhole at the shoulder. This is because it shifts the armhole (commonly located where the arm is joined to the torso) for the neckline, in a diagonal line; that is, the shoulder slope, providing a greater area in the direct contact with the arm. Another type of sleeve, the kimono sleeve, was also used by moving the seam from the shoulder cavity to the lower triceps branchial (upper arm muscles). These sleeves do not have direct contact with the arm joint, this to avoid friction during upper limb movements. As an example, in the study by Schiehl, Silva, and Simoes (2014), with groups of women with some difficulty in dressing and undressing, the long-sleeved blouse with a defined and adjusted shoulder height was the most difficult for the participants because of the reduction in the amplitude of the armhole's encounter with the sleeve, limiting the arm extension when combined with the forearm flexion movement.

4 MATERIALS, METHODS AND RESULTS

Flat fabrics of plain textile structure were used requiring enough openings to fit the user's body, as this textile structure does not provide enough elasticity (except when composed of elastane). In this study, cotton fibers were the most used, due to its characteristics allowing a greater versatility. This natural fiber has several advantages such as a soft touch, low tendency to cause allergies, absorbability,

good tensile strength, wash resistance, easy dyeing, and breathability. When combining cotton with other fibers, the fabrics present excellent comfort levels and maintenance properties. Table 1 represents the main characteristics of the materials used in the clothing of the elderly in both cities.

Table 1. Main characteristics of the materials used.

Origin	Portugal		Brazil		
Reference	TC64	5150	5170	T-2133	T-1318
Description	TC64	Techno Polo	Techno Fit	Ferrari	Fio Tinto
Supplier	Somelos	Santista Tavex	Santista Tavex	MN A. Gerais	Marango
Structure	Plain	Plain	Plain	Plain	Plain
Composition	96CO 4EA	100CO	62CO 35PES 3EA	100CO	100CO
Density (y/cm)					
Weave	66	49	58	59	60
Weft	38	27	29	30	34
Weight/m ² (g/m ²)	142	168	181	106	119

The first prototypes were produced using 100% cotton fabrics (Figure 1), to analyze the ease values and the garment assembly methods. The second prototypes used 50% cotton and 50% polyester fabric (Figure 2), the type of fabric that has the most similar texture when compared to the 100% cotton fabrics. The designed models were evaluated on a manikin to detect the defects regarding the positioning of openings, necklines, collars and sleeves, and also to define the best seam finishes for the garment assembling.



Figure 1. First toile prototype.

In order to obtain more comfortable garments, cuts for seaming were avoided, as any seam can cause skin irritation and increase friction in some body parts. The proposed garment was designed

with appropriate openings and closures, repositioning the seams, taking into account the elderly skin, which becomes more sensitive with aging.

The garment assembly process took into consideration the required sewing machines according to the type of fabric, model, and seam types, the appropriate accessories for each model and the required quality.

The essential qualities offered by a product suggested by Iida (2005) are technical-constructive qualities (specifically in the case of clothing, the modeling and assembling), ergonomic qualities (comfort and safety), and aesthetic qualities (visually pleasing). These are quality requirements that enable the design of artifacts with characteristics that meet human needs. Sensory comfort was also taken into account when choosing an appropriated type of sewing and seam finishes, in this case, lapped seam and seam finishes with satin taping, hiding the external seams. In openings with zipper, a zipper fly with double lining was used (Figure 3). These finishes provide less friction on contact with the skin of the user and a better visual aspect for the garment.



Figure 2. Second toile prototypes.

In the prototypes' finishing, clasp accessories such as zippers and buttons were used. The polyamide zippers were chosen due to their easy handling and smoother (less rough) touch. Polyamide zippers were chosen due to their easy handling and less harsh touch, allowing better sensorial comfort.

For the production of the final prototypes, plain fabrics were used, according to Table 1, all available in the Portuguese and Brazilian markets, with ideal characteristics and attributes of comfort, addressing

the identified characteristics and needs of the users. Although texture perceptions are subjective in nature, the user's sensitivity and preference can be related to the materials structural properties and are more commonly found in flat fabrics.



Figure 3. Zipper fly with double lining.

Regarding the buttons, none of the available options in the market offered features of flexibility, elasticity and touch softness, which could avoid the users' discomfort and facilitate the caregivers' tasks. To meet this specific need, flexible buttons were developed (Figure 4) through a partnership with researchers from Mechanical Engineering Department of the University of Minho. Prototypes of a new button were developed using a 3D printer - *Prusa Model 13*. Different types of flexible filaments (named thermoplastic elastomer - TPE) were tested. In a second phase, for technical reasons, such as calibration and productivity of the available 3D printer at University, as well as due to the high production costs, a company was contacted, allowing the button to be obtained in the colors and formats required. Löbach (2001) reinforces the conclusion that the design allows the materialization of an idea in the form of designs and models, resulting in a possible innovation to be industrially produced.

The button produced is composed of a plastic component (polyvinyl chloride), commercially known as *Plastisol L/100 Bianco Ral 901*. It is composed of a material that has plasticizing additives such as phthalate, with viscous appearance, that must be protected from freezing and stored at temperatures ranging from + 5°C to + 35°C. Also, the four-hole button was chosen because it can be better fixed to the fabric when compared to the two-hole button that with daily manipulation can be easily loosened and subsequently removed. This ensures higher safety levels to users, like in the example reported by a caregiver of an elderly woman, who

used to remove the buttons from her clothing and swallow them. The button developed is characterized by its flexibility, being foldable, and presenting a good resistance with greater comfort to the touch.

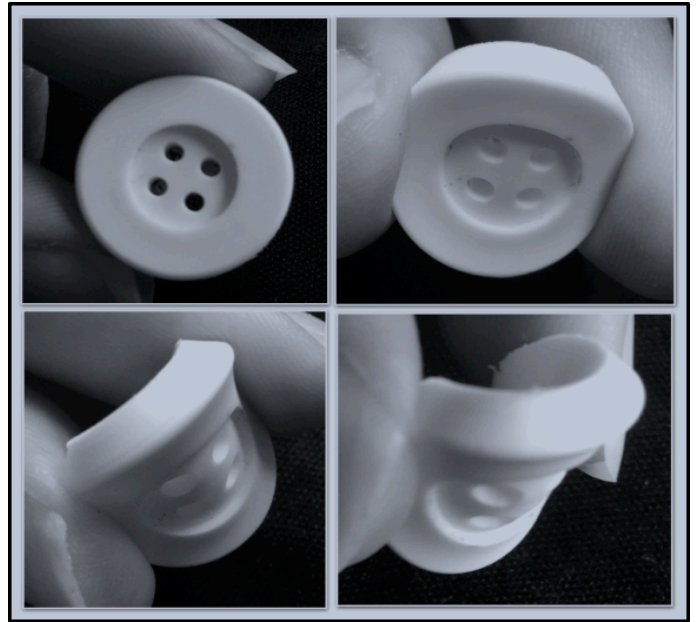


Figure 4. Flexible buttons.

5 CONCLUSIONS AND FUTURE WORK

In this research, it was possible to identify the main needs of the care-dependent elderly women, to understand their limitations regarding the use of clothing, as well as the impact that this has on their caregivers during dressing/undressing and cleaning tasks. The anthropometric characteristics and ergonomic needs were considered during the development of the clothing pattern design blocks for these specific individuals, considering the aging effects on their bodies. The first developed toile prototypes took into account this information, as well as the suggestions of the caregivers. Different fabrics and accessories were also tested in the prototypes that will be evaluated by the elderly of the two cities. The final prototypes were developed using flat plain fabrics, available in the Portuguese and Brazilian markets, which present ideal characteristics and attributes of comfort. In the last research stage, the validation process (usability, adjustability, handling, and functionality) of the prototypes was defined, considering three basic comfort requirements (ergonomic, sensorial and psychological) for the elderly comfort, and weighted according to the caregivers' point of view: ergonomic comfort (60%); sensorial comfort (30%); psychological comfort (20%). For this procedure, user and caregiver surveys were applied, with analysis and discussion of the results for

validation of the proposed clothing. The result of this last phase of the study will be presented in a future paper.

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