De Raeve et al., J Fashion Technol Textile Eng 2018, S4
DOI: 10.4172/2329-9568.S4-009

Journal of Fashion Technology & Textile Engineering

Research Article

A SCITECHNOL JOURNAL

3D Body Scanning as a Valuable Tool in a Mass Customization Business Model for the Clothing Industry

Alexandra De Raeve*, Joris Cools and Simona Vasile

Abstract

Previous research showed that garment fit is one of the most important factors that influence clothing comfort. This paper handles the use of 3D body scanning as a tool to obtain better fitting and customized garments. The study involved (1) a survey about the personally perceived body image and fitting problems of respectively 155 and 374 adult men and women and (2) a measuring campaign using 3D body scanners based on the structured white light technology. The campaign provided a database of 3D body images and 180 body measurements of 2500 persons between 3 and 70 years.

The results showed that with the exception of obese persons, the body image of most men corresponded to the measured data. Unlike a large number of women who judged themselves rather negatively. Especially women mentioned fitting problems at the level of the waist and hips. The analysis of the 3D data indicated that people having similar 1D dimensions often have different body shapes. Also, significant differences were noted between the results of the measurement campaign in 1990 and the one in 2013. Furthermore, the results demonstrated that age or certain professions influence body shape. The results of this study yielded in new size tables for the average population of men and women in different 4 different age categories and avatars in each available size.

Keywords

Mass customization; Fit; 3D body scanning; Virtual prototyping

Introduction

Today fashion industry can be segmented in two main categories: haute couture and ready-to-wear. Ready-to-wear (RTW), or prêt-à-porter, covers any collection that consists of garments produced in volume – distinct from the one-off garments in haute couture and is divided into designer wear and street fashion. RTW can be traced back to the beginning of the 20th century, following the Industrial Revolution and the introduction of the sewing machine. In the beginning it relied on Paris couture and highly skilled dressmakers would copy designs. Although produced starting from standardized sizes it was up until the 1950's predominantly designed and manufactured on a 'made-to-measure' base, with each garment created for a specific customer.

***Corresponding author:** Alexandra De Raeve, Department of Fashion, Textile and Wood Technology, University College Ghent FTI Lab, Buchtenstraat 11, B-9051 Gent, Belgium Tel: +3292432736, +32 478970167; E-mail: Alexandra.deraeve@hogent.be

Received: November 27, 2017 **Accepted:** February 27, 2018 **Published:** March 02, 2018

In the 1970's and 1980's the market became saturated with basic products from Marks and Spencer, C&A and other high street chain stores [1].

Within the Western society consumers underline their personality and status through the purchase of certain consumer goods. Although consumers attach great importance to personalized items, most of them do not want to pay significantly more.

For several decades a business model has been developed that tries to offer a solution to the paradigm customization at mass production cost: mass customization. Within a mass customization-oriented company the production is started after the customer has placed his specific order. Here the supply chain must be organized in such a way that the product can be delivered at a mass production price. Mass customization distinguishes itself from handicraft by production within an industrial setting at maximum efficiency (and low production costs). It has many facets and one of the biggest misconceptions about mass customization is that the manufacturer grants total freedom to the consumer to create a product entirely according to ones specific wishes. Nevertheless, only a very limited number of cases allow this way of thinking [2,3].

Today, clothing collections are developed almost exclusively on the basis of forecast data. The large uncertainty in estimating the demand means that certain collections never find their way to the customer, while for other collections the demand is greater than the supply. When many collections are offered, this consequently results in many small runs that just meet or are below the EOQ (economic order quantity). Furthermore, this requires many switch-overs in production and leads to an increased number of SKUs (stock keeping units) and total inventory. The turnover that one gets with a limited number of successful articles is often largely consumed by the losses of less successful articles. Within a mass customization-based business model this problem is avoided by manufacturing only those garments that are effectively ordered/desired.

Apparel is the perfect product to address the three dimensions of personalization: fit, functionality and design. Products that require adjusting to various physical sizes and functionalities, can be sold at higher prices than products that are personalized by merely adjusting the color or print.

Unfortunately, most mass production business model-based clothing companies do not have the structure to supply an individual order within an acceptable delivery time at a mass production price. Furthermore, they can offer well-fitting clothing to only 30 to 40 % of their target group. As a result they miss an enormous potential. Therefore, apparel companies need better tools to adjust the fit of their products [4,5].

Fit is a very effective marketing strategy and interesting tool for mass customization. Besides a trendy design, the feeling of wellbeing and comfort in a particular garment are the key triggers for consumers to proceed to purchase. Furthermore, previous research showed that fit is one of the main parameters to obtain adequate thermal and moisture regulation properties in a garment [6]. Nevertheless, clothing sizes and fit are difficult concepts to explore and analyze as the relationship between the human body

doi:10.4172/2329-9568.S4-009

and the garment is complex and often two-fold. Often methods to create sizes and to assess the fit are based on the dimensions of the 'ideal' customer being represented by a single fit model. Thereafter, the full size range is obtained by applying proportional grading rules to the basic pattern. Finally, a visual and two-dimensional (in length and width) evaluation compares linear clothing measurements and body measurements. Although these methods are useful to evaluate simple fitting outcomes, they are not suited to assess the complexity of the versatile relationship between the body and clothing of a large number of customers with an extended variety of body shapes within one size [7]. In addition many companies use outdated sizing tables.

Methodology

The Smartfit project [8] aimed at acquiring a better understanding of the changes in body dimensions and body shapes since 1990 (time of the last measuring campaign in Belgium) and related fitting errors. As first results new size tables for the average population in 4 age categories and avatars in all sizes were developed.

Assessment of personally perceived body image and fitting problems

374 women and 155 men from 18 years and older were questioned about their personally perceived body image and fitting problems. Table 1 and Figure1 show the differences between the measured data and the self-reported data. About 52 % of the men said to have a normal weight and 35 % considered themselves as being overweight. This largely corresponds to the measured data. Only 4 % found themselves obese, while the measured data indicated 10 %. The data showed 66 % of the women as of normal weight, whereas only 43 % thought to have a normal weight. Over 47 % of the female respondents indicated themselves as being too fat as the measured data only detected 22 % as being overweight.

The results showed that over 65% of the female respondents have one or more fitting problems. In bottoms (trousers, skirts) the most common problem is the ratio between the hip girth and the waist girth. Over 50% of the fitting problems occur in the waist-hip area. For tops most of the fitting problems occur in the bust and shoulders area. For both tops and bottoms the length of the sleeves and legs is a very common fitting problem (Figure 2).

Men reported the length of the sleeves and legs as the most common fitting problem. Less than 20 % of the respondents mentioned fitting problems around the waist and shoulders (Figure 3).

3D body scanning measurement campaign

The last large-scale measurement campaign in Belgium dated from 1990. At that time 5000 persons, geographically spread over all provinces were measured manually with measuring tapes [9]. This method was very time consuming. Furthermore, the measuring of e.g. inseam (floor to crotch) was by some test subjects experienced as unpleasant. At the start of the Smartfit project most Belgian garment manufacturers still used size charts based on the data of this measurement campaign. In 2012 the Belgian Clothing federation issued a new measurement campaign. This campaign was part of the two-year research project Smartfit.

Nowadays, 3D Body Scanning is state of the art and used in

Table 1: BMI classification derived from measured data.

Gender	Underweight (BMI < 17,9 kg/m²)	Normal weight (18,0 < BMI < 24,9 kg/m²)	Overweight (25,0 < BMI < 29,9 kg/m²)	Obese (BMI > 30,0 kg/m²)
	%	%	%	%
Male	8,85	55,56	33,33	10,26
Female	4,01	66,42	22,26	7,30

Table 2: Body measurement alterations due to muscle strain [6].

Pose	arm length (shoulder to wrist)	Arm girth (biceps)	waistband sligthly inclined	waistband strongly inclined	chest girth (maximum)	back width (under arms)	back length (to waistband)
Strained	64	26.8	85.4	85.4	110.6	44.1	48.5
Relaxed	59.1	32	84.9	94.7	106.8	37.7	52.4

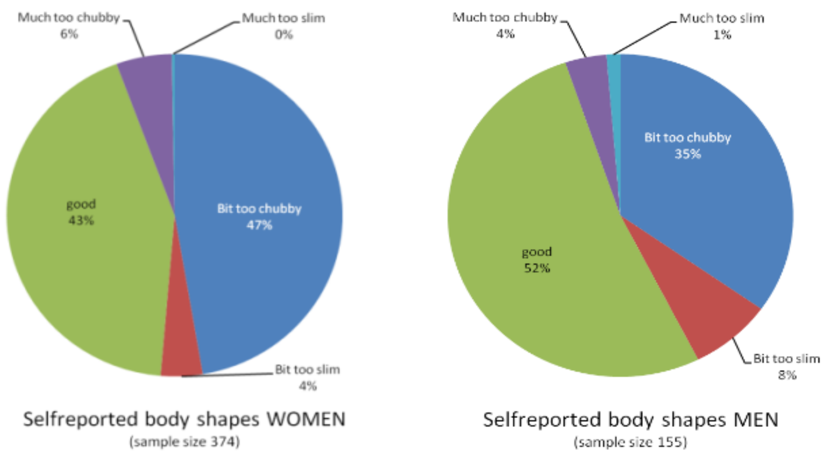

Figure 1: Self-reported body shape of women (left) and men (right).

doi:10.4172/2329-9568.S4-009

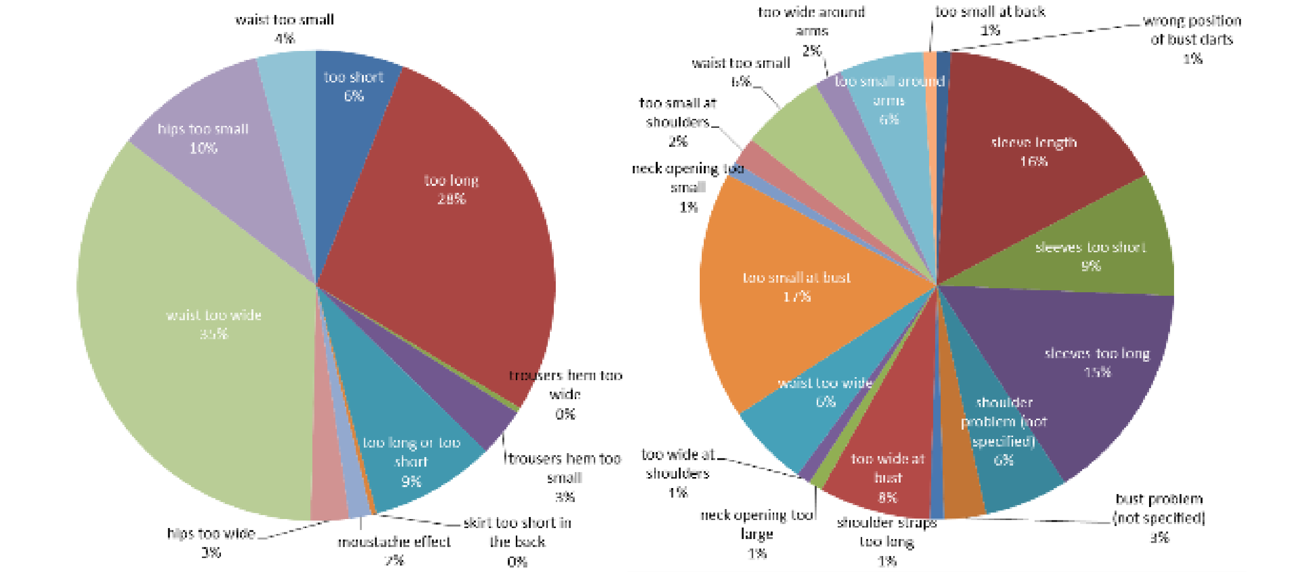

Figure 2: Fitting problems female bottoms (left) and tops (right).

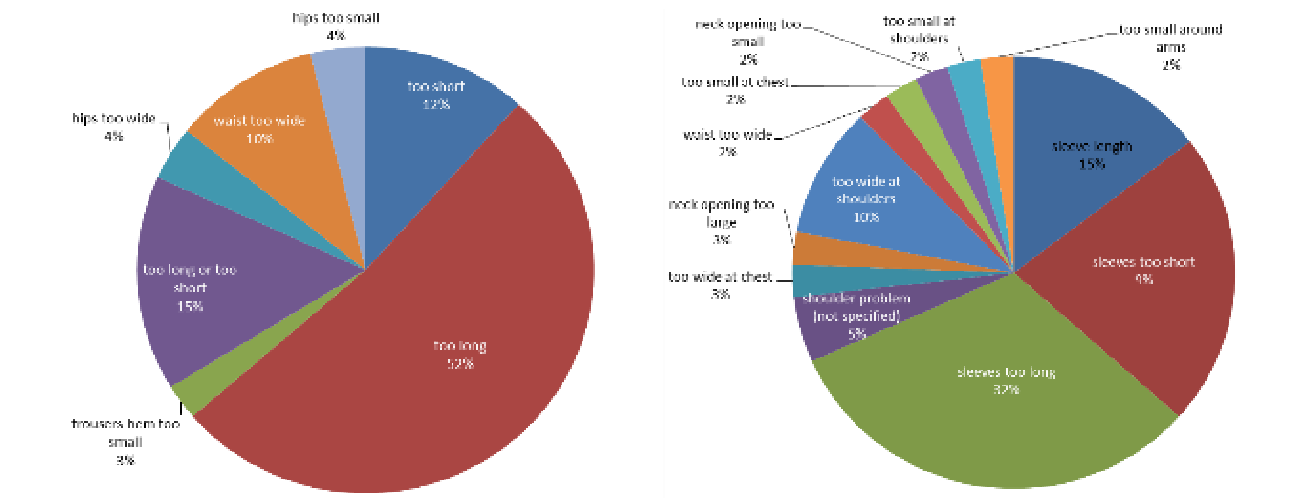

Figure 3: Fitting problems male bottoms (left) and tops (right).

the latest sizing surveys all over the world (Size Germany, Size UK, Caesar, …) because of diverse benefits. In a short period of time a large group of subjects can be measured without any body contact. Furthermore, the specialized software allows quick and comprehensive measurement extractions. The measurements are reliable and reproducible, interpersonal errors are minimized and transmission errors are excluded. All results are at all times verifiable and a plausibility check of the measurements with the 3D data is possible. In addition, postures, cross sections and volumes can be analysed and compared. Finally, the 3D volumes can be used for generating digital body forms for use in common 3D CAD pattern making software which could be an added value to the parametric avatars offered by CAD suppliers. Nevertheless, some limitations applying to high accuracy booth scanners should be taken into consideration such as: high prices; insufficient mobility; subject is scanned in underwear [10,11].

During the Smartfit campaign approximately 2500 persons between 3 and 70 years (0.02 % of the Belgian population) were arbitrary chosen and measured on six locations, spread over the Flemish and French part of the country. An NX-16 scanner of TC^2 and a Symcad scanner of Telmat were used for the purpose. Both systems use the structured white light technology and have a 3D-point accuracy of less than 1 mm. The circumferential accuracy for measurement extraction is less than 3 mm. The NX-16 scanner has 32 camera's, 8 in each angle. The Symcad scanner has 4 camera's, 2 in the front and 2 in the rear. The scanning volume of both scanners is approximately identical. The acquisition time for the NX-16 is 7 to 8 seconds, for the Symcad only 1,5 seconds, while the measurement extraction time is similar. Each system has a maximum capacity of about 25 scans and measurement extractions per hour.

All participants were measured according to the same measurement protocol: standing posture with the head in Frankfort

Figure 4: Measurement protocol.

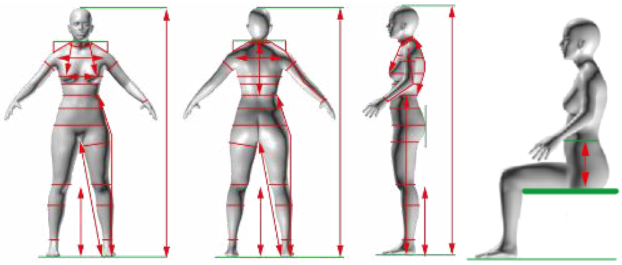

Figure 5: Measurement extraction.

plane (Figure 4), the legs slightly spread, the arms bent while making a fist and breathing normally.

As depicted in Figure 5, 180 measurements were extracted by the software according to the standard ISO 8559. Total body height, weight, head girth and waist height while sitting, were taken manually. 75% of these measurements were stored for future applications, 45 variables were used for the calculation of 25 average body measurements in 7 different body measurement tables, each split into 3 tables: garments for full body, upper body and lower body.

Results

All data was analyzed through PCA, determination of mean, percentiles, standard deviation, correlation and clustering (1D measures). Subsequently, measurement tables of which the primary dimensions and intervals are chosen according to the European Standard EN 13402 part 3, published in 2013 [12,13] were drawn up. For womenswear, new size charts became available for full body, upper body and lower body in 4 age categories: 14 – 17 years, 18 – 25 years, 26 – 50 years and 51 – 70 years. Due to the large differences in developmental stage of the body of teenage girls it is not always easy to define whether children's size charts based on body height or women's size charts based on bust and hip girths are to be used for clothing development for teenagers. Some girls can already wear women's clothing, while others still feel more comfortable in children's clothing. Therefore both types of size charts were developed for this age category. For men, size charts for full body, upper body and lower body garments were developed in 3 age categories: 18 – 25 years, 26 – 50 years and 51 – 70 years. The number of young children (age 3 - 12) that were measured, was too small to calculate reliable averages, therefore these measurement tables are not yet available. We compared the new size charts with the charts that were developed in 1990. In addition, a comparison was made with the size chart used by one of Belgium's premium garment manufacturers in 2013. We noted that in 1990 the average difference between waist girth and hip girth was, depending on the size, between 26 and 31 cm. In 2013 the difference ranged between 20 and 27 cm. The size chart used by the garment manufacturer showed hardly any differences with the size chart based on the average body measurements in 1990. Figure 6 depicts the differences between the size tables based on the measurement campaign in 1990, the size table of a randomly chosen Belgian premium brand and the newly developed size tables.

Analysis of the 3D images of the scanned subjects showed that persons having the same size may have very different body shapes. Figure 7 shows the body form variance and intercept of the hip of three subjects with approximately the same ($\Delta \leq 2$ cm) bust, waist and hip girth. All of them would wear the same garment size in Belgium. It is clear how different body shapes can be in spite of fairly equal dimensions. It is therefore impossible to dress all of them with the same garment. Furthermore, specific target groups like sports athletes show fundamental differences in body measurements compared to the average population (e.g. Figure 8). Corresponding to their sports discipline they develop bigger circumferences in body regions like bust, upper arm, thighs and calf. As shown in Table 2, muscle movement significantly increases or decreases circumferences and lengths. This can be an additional problem in clothing development for athletes. If for instance a trained subject strains its muscles during exercise e.g. back width may increase up to 6.5 cm and arm length may increase with 5 cm. Each size has a scope of 4 cm, which means that small movements can lead to a difference of almost two sizes. Sports garments have to ensure great freedom of movement and a perfect fit and thus cover these alterations. If not, this will not only be detrimental to the wear comfort and aesthetics but also to performance as the desired functionality will not be achieved in case of wear performance and intelligent clothing. Research has shown that in fact, compression / supportive clothing yields only result when the fit is perfect and the functional material is incorporated in the right place. For instance, well-fitting speed wear can lead to 134 seconds profit over a cycling distance of 40 km [14]. As depicted in Figure 9 and Figure 10, another important aspect is the change in body form with age. The 3D images showed that for women, when ageing, the hip girth stays the same, but looking at the intersection of the hip, the shape changes. In each size we noted in increase of the waist of approximately 7 cm. When men age the waist girth remains the same,

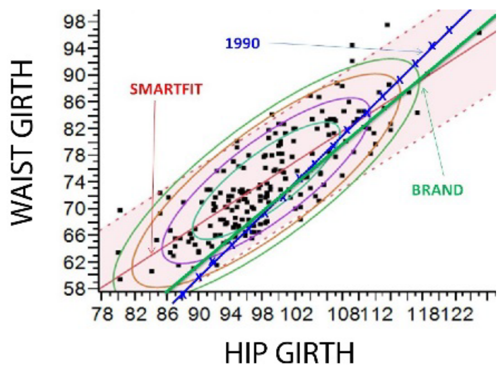

Figure 6: Smartfit size chart (red) versus 1990 size chart versus brand X size chart.

doi:10.4172/2329-9568.S4-009

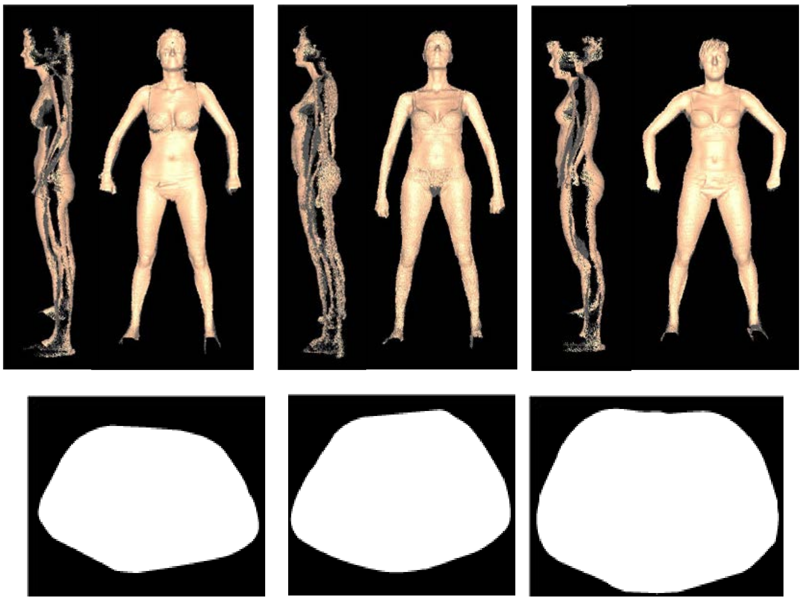

Figure 7: Hip intercept of 3 subjects with difference in hip girth of less than 2 cm.

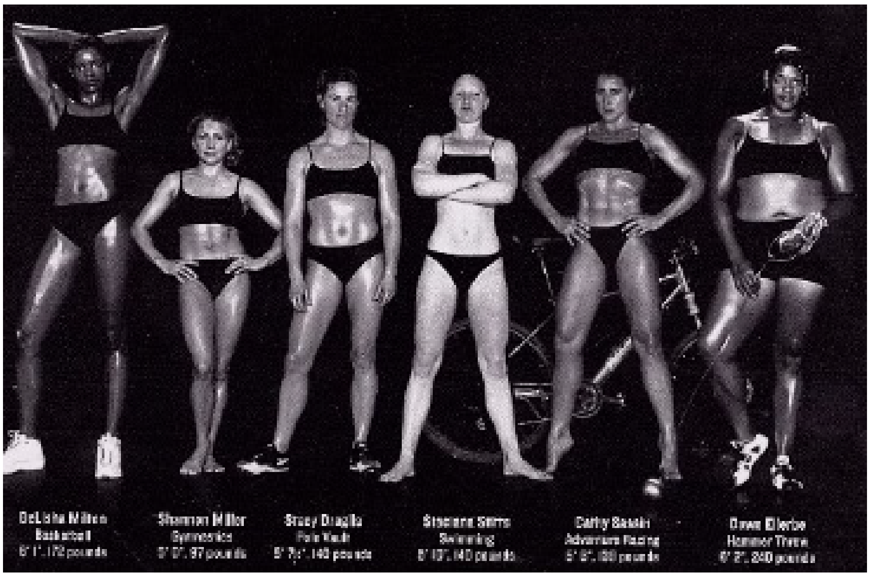

Figure 8: Body form variance of female athletes corresponding to sports discipline [13].

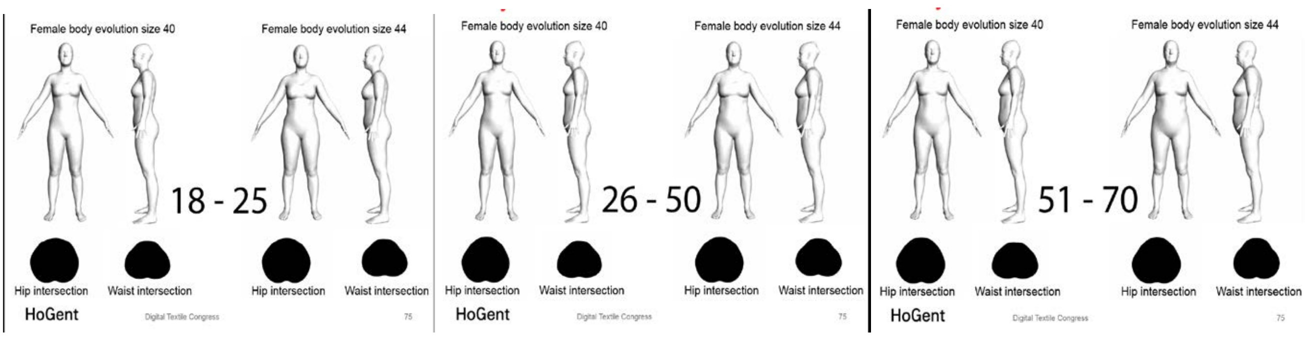

Figure 9: Changes in female body shape corresponding to age [8].

doi:10.4172/2329-9568.S4-009

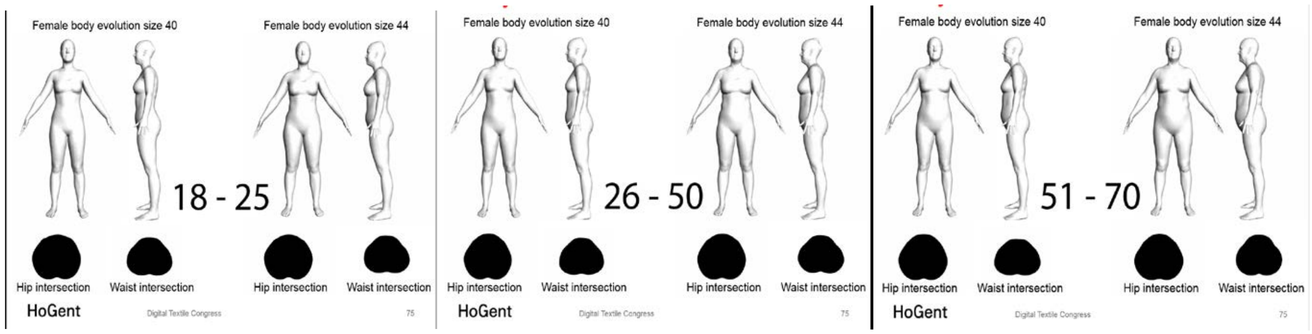

Figure 10: Changes in male body shape corresponding to age [8].

but the waist line changes from slightly horizontal for younger men and small sizes to strongly inclined for the oldest age category.

Conclusion

To satisfy customers' needs and to increase the actual size coverage of about 31.3 % it is evident for producers to know about the specific body proportions of the target group. For target groups with body proportions that differ from the average special sizing charts are needed. Therefore, measuring campaigns for different groups (e.g. big size women and men, wheelchair athletes) were conducted in some countries and sizing tables were developed [15-18]. Studies [19,20] have analyzed 3D body scans of athletes from various sport disciplines (e.g. basketball, golf, rowing, cycling) and highlighted statistical significant differences between body dimensions of male athletes and average population but no sizing tables have been developed for sportswear.

It is also possible to develop avatars from the 3D scans which can be used as virtual manikins in 3D CAD software such as CLO3D, Browzwear, Optitex, Gerber, Lectra, Vidya or Marvelous designer to assess fit and adjust the patterns and design. This is an improvement to the parametric avatars available in 3D prototyping software which only permit to adapt the size, but not the shape. Basic patterns can thus be automatically adjusted to customized patterns which will strongly reduce lead time for product development. The results of the Smartfit project have proven that 3D body scanning can be an important support for companies willing to adapt to a mass customization business model. The innovative aim of the follow up project 'SHAPE – Adapted Performance Wear (2017-2019) is to generate specific sizing charts and provide comprehensive information about body proportions as well as postures to enable the SME community to develop customized sports garments.

References

1. Renfrew E, Renfrew C (2009) Basics Fashion design - Developping a collection. Ava publishing, Lausanne, Switzerland.
2. Blecker T, Friedrich G (2006) Mass customization: chalenges and solutions. International series in operations research & management science, Springer, Berlin.
3. Piller F, Mass customization - Ein wettbewerbsstrategisches Konzept im Informationszeitalter. Springer, Wiesbaden, Germany.
4. Walter L (2007) Mass Customization - A business opportunity for belgian textile and fashion companies.
5. Miller K (2010) Studying body size is key to market fit.
6. A. De Raeve, Cools J (2011) Comfortex.
7. Gribin E, Thery D (2014) How to make fashion fit.
8. Raeve A De, Cools J, Deruyck F (2014) Smartfit.
9. Nyssen E, Cornelis en J, Vounckx R (1990) Belgische lichaamsmaten voor bovenkleding.
10. Kouchi M (2014) Anthropometric methods for apparel design: body measurement devices and techniques.
11. Papahristou E, Bilalis N (2016) Can 3D Virtual Prototype Conquer the Apparel Industry? J Fashion Technol Textile Eng 4.
12. Cen, Nbn EN (2013) Size designation of clothes: Body measurements and intervals.
13. Schatz H (2002) Sports Illustrated. It's gotta be the suit.
14. Velonews (2002) It's gotta be the suit.
15. Eureka project (2016) New paradigm of processes and market services for garments of obese and elderly people.
16. Morlock S, Schenk A, Harnisch M (2015) Passformgerechte und bekleidungsphysiologisch optimierte Bekleidungskonstruktion für Männer mit grossen unterschiedlicher Körpermorphologien.
17. Klepser A, Gerhardts en A (2014) Wölfling, „Entwicklung von Sportbekleidung für Rollstuhlfahrer unter Berücksichtigung physiologischer und hautsensorischer Einflussfaktoren.
18. Morlock S, Wendt E, Kirchdörfer E (2009) Grundsatzuntersuchung zur Konstruktion passformgerechter Bekleidung für Frauen mit starken Figuren.
19. Giachetti A, Francesco P, Valentina C, Carlo Z (2015) Automatic analysis of 3D scan of Professional Athletes.
20. Vasile S, Deruyck F, Cools en J, De Raeve A (2017) Shape - Adapted Performance Wear.

Author Affiliations Top

Department of Fashion, Textile and Wood Technology, University College Ghent FTI Lab, Buchtenstraat 11, B-9051 Gent, Belgium