The Use of 3D Anthropometric Data for Morphotype Analysis to Improve Fit and Grading Techniques – The Results

Joris COOLS[1*], Alexandra DE RAEVE[1], Peter VAN RANSBEECK[2],
Simona VASILE[1], Benjamin VANDERSMISSEN[2], Mathias VERMEULEN[2]
[1] University College Ghent, Faculty of Science and Nature,
Department of Fashion, Textile and Wood Technology, Gent, Belgium
[2] University College Ghent, Faculty of Science and Nature,
Department of Mechatronics, Gent, Belgium

http://dx.doi.org/10.15221/14.046

Abstract

Today, apparel companies are able to offer well-fitting clothing to only 30 to 40% of their clients. This is due to body measurement tables which have not been updated in the last 25 years.
With the financial support of the Agency for Innovation through Science and Technology (IWT), over the last two years University College Ghent carried out a measurement campaign. The measurements and body shapes of the Belgian population were mapped using high-tech 3D body scanners . The results of this campaign led to defining new body measurement tables for women in four age categories and body measurement tables for men in three age categories.
Today, the construction of basic patterns and grading to other sizes is based solely on 1D body dimensions. The grading is proportional or rational, but never taking into account the body proportions. The last decade, several European countries have executed a 3D scanning campaign to depict their population, but these 3D data are often not accessible to the garment manufacturers. The industry does not have the necessary knowledge and skills to work with 3D measurements. In order to reduce the number of prototypes, time-to-market and thus money, many companies are developing software for checking fit, fabric drape and proportions on virtual mannequins in a virtual fitting room. Together with the new body measurement tables, University College Ghent defined for each size in each body measurement table a body model (avatar) which can be used as a virtual mannequin for fitting.
The importance of a proper fit and adequate sizing of clothing are the central themes in this paper.

Keywords: thermo physiological comfort, morphology, sizing, fit, grading, CAD systems, virtual prototyping

Introduction

Besides a trendy design, the feeling of wellbeing and comfort in a particular garment are the key triggers for consumers to proceed to purchase. A garment can only be comfortable and flattering to the wearer if the fit is good. Persons having the same size may have a very different body shape, so this is not evident. A good fit is also one of the main parameters to obtain adequate thermo-physiological comfort and protection. In the development phase of clothing, manufacturers used to focus on the physical (strength, elasticity, insulation, air permeability, …) and sensory properties (hand, colour, smell) of the textile materials in order to obtain the required comfort level. The two-year research project 'Comfortex' has proven that features such as clothing design and especially fit and sizing are for over 50% responsible for wear comfort and ergonomics of the finished garment. One of the key parameters to achieve a good fit is a good sizing. During the two-year research project 'Smartfit' about 2500 persons (0,02% of the Belgian population) were measured on six measuring locations spread over the Flemisch an French part of the country and average measurement tables were determined for each men and women in different age categories.

* Corresponding and presenting author, Joris.cools@hogent.be

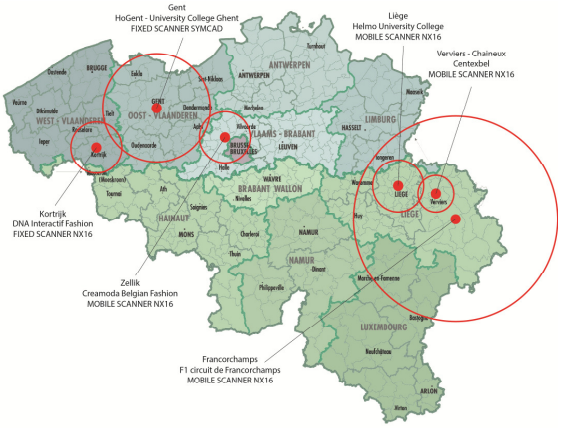


Figure 1: measuring locations in Belgium

Questionnaire

374 women and 155 men from 18 years and older were asked about their body and clothing. Table 1 and figures 2 and 3 show the difference between measured data and self-reported data. About 52% of men said to have a normal weight and 35 % have overweight, which is almost the same result of the measured data. Only 4% find themselves obese, while the measured data show results of 10%. 66% of women have a normal weight, only 43% of them thinks they have a normal weight. Not less than 47% of women find themselves too well rounded while the results of the measured data shows that only 22% have overweight.

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

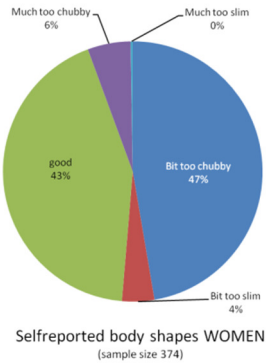


Figure 2: self-reported body shape women

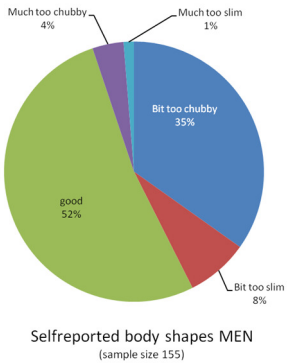


Figure 3: self-reported body shape men

Besides a trendy design, the feeling of well-being and the comfort, price is also a key trigger for consumers to proceed to purchase. Our panel was asked what they spend to their garments (table 2).

Table 2: average spendings for garments

	Shirts / blouses	Trousers	Jackets	Skirts	Dresses
Men	€ 43	€ 59	€ 88		
Women	€ 43	€ 66	€ 125	€ 52	€ 75

91% of the women know their size for trousers and skirts. For T-shirts, blouses and other tops this goes up to 95%. For jeans, about 63% of the women know which size they have.

Only the half of the male panel know their size for trousers (52%) and shirts (56%). For jeans it goes up to 75% and for T-shirts and sweaters even to 95%.

More than 65% of women have one or more fitting problems. With bottoms (trousers, skirts) the most common fitting problem is the ratio between hip girth and waist girth. More than 50% of the fitting problems occur in the waist-hip area. For tops most of the fitting problems occur on the bust and shoulders area. For both tops and bottoms the length of the sleeves and legs is a very common fitting problem (see figures 4, 5).

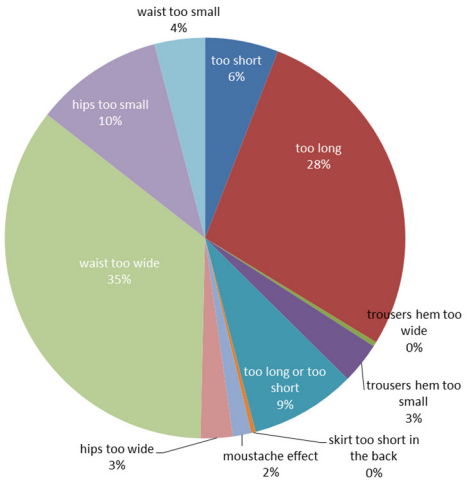


Figure 4: FEMALE trousers and skirts: fitting problems

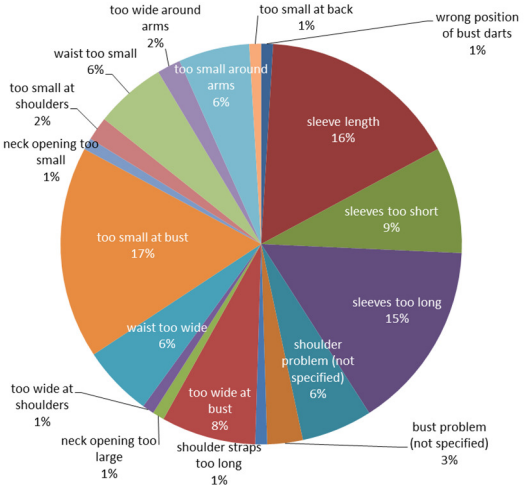


Figure 5: FEMALE tops: fitting problems

For men the most occurring fitting problem is the length of the sleeves and the legs. Less than 20% of the fitting problems with trousers are situated around the waist and with tops around the shoulders (figures 6, 7).

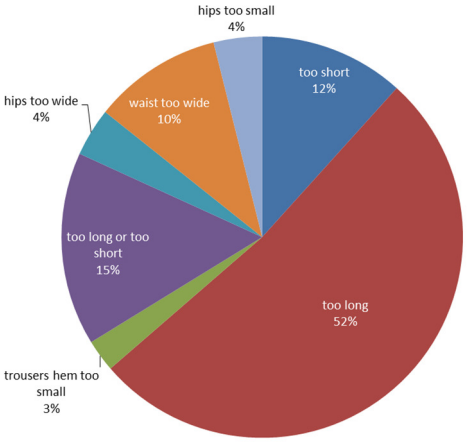


Figure 6: MALE trousers: fitting problems

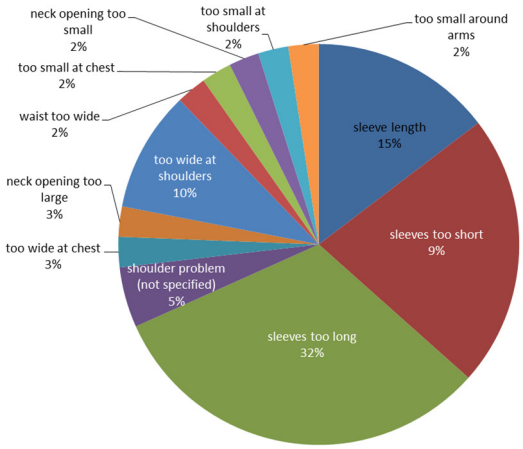


Figure 7: MALE tops: fitting problems

Size survey

During the Smartfit campaign approximately 2500 persons between 3 and 70 years (0,02 % of the Belgian population) were arbitrary chosen and measured. We made use of two 3D scanning booths: a Telmat Symcad and a TC² NX-16 body scanner. Both systems use 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 front and 2 in the rear. The scanning volume of both scanners is comparable. The acquisition time for the NX-16 is 7 to 8 seconds, for the Symcad only 1,5 second, while the measurement extraction time is comparable. With each system, the maximum capacity is about 25 measurements per hour.

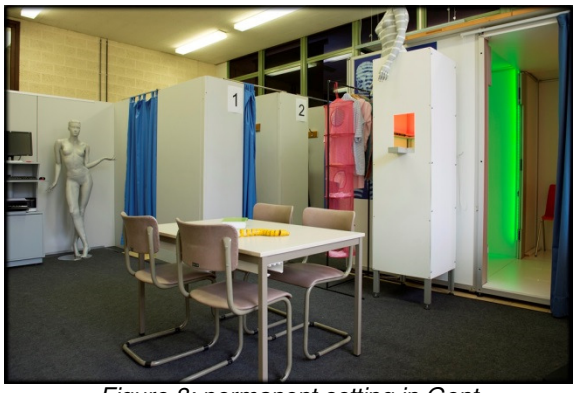


Figure 8: permanent setting in Gent

Figure 9: Temporary setting in Brussels (Zellik)

All participants were measured according to the same measure protocol: standing posture with the head in Frankfort plane, the legs slightly apart, the arms bent while making a fist and breathing normally. 180 measurements were extracted by the software according the standard ISO 8559. Total body height, weight, head girth and waist height while sitting, were taken manually. 75% of these measurements are 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.

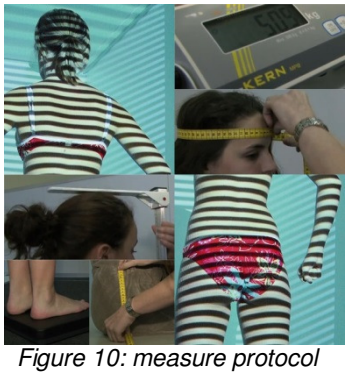


Figure 10: measure protocol

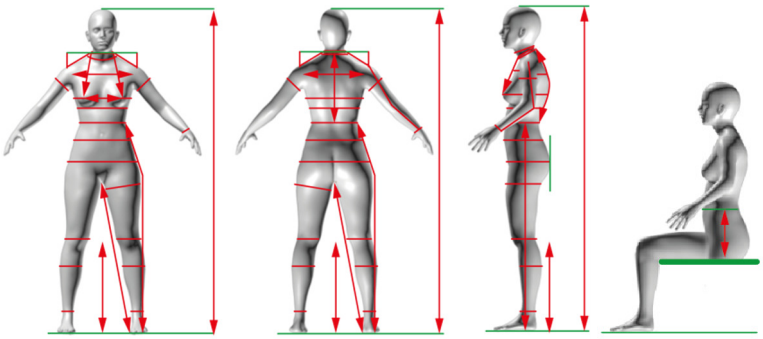


Figure 11: measurents extraction

Body measurement tables

The sample of measurements for small children was too small to calculate reliable averages, so these measurement tables are not yet available. The primary dimension and intervals are according the European Standard 13403 part 3, published in 2013.

For women we have tables available in 4 age categories: 14 – 17 years, 18 – 25 years, 26 – 50 years and 51 – 70 years. The tables garments for full body and upper body (table 3) look nearly the same. This table is to be used for all garments above waist (tops) and for dresses. But please pay attention: for dresses the proportion waist to hip is very important. Because the primary dimension here is the bust girth, the waist and hip might be a couple of cm too large for age categories till 50 years. Above 50 years the waist and hip might be 2 or 3 cm too small in the larger sizes. For a correct proportion waist to hip, we refer to the table 'garments for lower body' where the primary dimension is the hip girth.

For age category 14-17 years we go from size 32 to 44. The average body height is 165 cm.
Age categories 18-25 and 26-50 goes from size 34 to 50, with an average body height of 166 cm.
Age category 51-70 goes from size 36 to 50. The average body height here is 164 cm.

The tables 'garments for lower body' (table 4) are to be used for all garments below the waist, so trousers and skirts. As mentioned before, the proportion hip-waist is extremely important to guarantee a perfect fit. In this table, the hip girth is chosen as primary dimension, so we get a total different proportion as in the table 'garments for full body'. In the published European Standard, the waist girth is mentioned as primary dimension, but most European countries already agreed for a revision: in the next version of this standard, the primary dimension will be hip girth.

Table 3: Body measurement table female for upper body

SIZE	32	34	36	38	40	42	44	46	48	50
BUST GIRTH	74-78	78-82	82-86	86-90	90-94	94-98	98-102	102-107	107-113	113-119
14-17 AVERAGE HEIGHT 165 CM										
18-25 AVERAGE HEIGHT 166 CM										
26-50 AVERAGE LENGTH 166 CM										
51-70 AVERAGE HEIGHT 164 CM										

Table 4: body measurement table female for lower body

SIZE	32	34	36	38	40	42	44	46	48	50
BUST GIRTH	80-84	84-88	88-92	92-96	96-100	100-104	104-108	108-112	112-117	117-122
14-17 AVERAGE HEIGHT 165 CM										
18-25 AVERAGE HEIGHT 166 CM										
26-50 AVERAGE LENGTH 166 CM										
51-70 AVERAGE HEIGHT 164 CM										

For teenage girls, it's not always easy to define which size table is most suitable. Some girls can already wear women's clothing, while others still feel more comfortable in children's clothing. Besides the size measurement tables based on bust and hip girths, we also offer measurement tables based on age (table 5) and on body length (table 6).

Table 5: Body measurement table female 14-17 years based on age

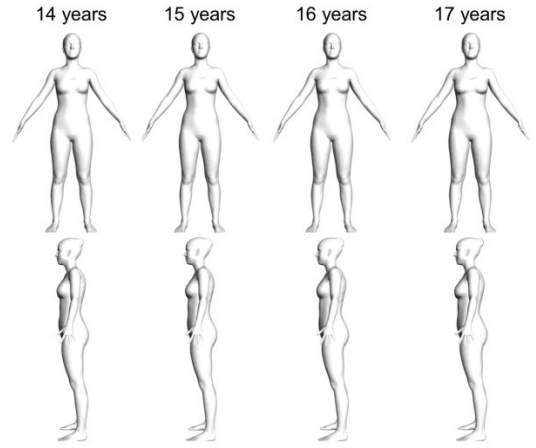
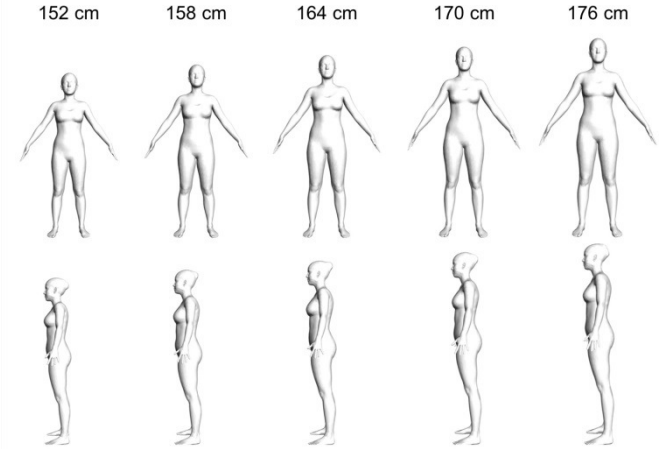


Table 6: body measurement table female 14-17 years based on total body length



For men we have tables in 3 age categories: 18 – 25 years, 26 – 50 years and 51 – 70 years. The tables garments for full body and upper body (table 7) look nearly the same. This table is to be used for all garments above waist (tops) and coveralls and the primary dimension is the chest girth.

Age category 18-25 goes from size 42 to 54, where the average body height is 178 cm.
For age category 26-50 we go from size 42 to size 60. The average body height here is 180 cm.
Age category 51-70 starts with size 44 and goes to 62, with an average body height of 176 cm.

The tables 'garments for lower body' (table 8) are to be used for all garments below the waist, so trousers. In this table, the waist girth is chosen as primary dimension, so we get a total different proportion as in the table 'garments for full body'.

Table 7: Body measurement table male for upper body

SIZE	42	44	46	48	50	52	54	56	58	60	62
BUST GIRTH	82-86	86-90	90-94	94-98	98-102	102-106	106-110	110-114	114-118	118-122	122-126
18-25 AVERAGE HEIGHT 178 CM											
26-50 AVERAGE HEIGHT 180 CM											
51-70 AVERAGE HEIGHT 176 CM											

Table 8: body measurement table male for lower body

SIZE	42	44	46	48	50	52	54	56	58	60	62
BUST GIRTH	82-86	86-90	90-94	94-98	98-102	102-106	106-110	110-114	114-118	118-122	122-126
18-25 AVERAGE HEIGHT 178 CM											
26-50 AVERAGE HEIGHT 180 CM											
51-70 AVERAGE HEIGHT 176 CM											

Analysis of body measurements

Statistical analysis of the anthropometric data has shown that, irrespective of an increase or decrease of the body weight, the body shape changes significantly as a function of the age.
When people age, we notice a significant increase in waist circumference which is much less prominent at the level of the hip. For females, this phenomenon manifests itself from the age of 51. For male this phenomenon is already present at the age of 26. For females, as the waist girth increases, it becomes more rounded in shape. With age there is an increase of about 7 cm in total. The hip girth, however, is asymmetrical in shape and stays the same over the years, but looking at the intersection of the hip, the shape changes.Younger women have more pronounced buttocks whereas older women have a more pronounced lower abdominal region. Figure 12 shows clearly the evolution of the morphology of women in size 40 and 44 in terms of age.

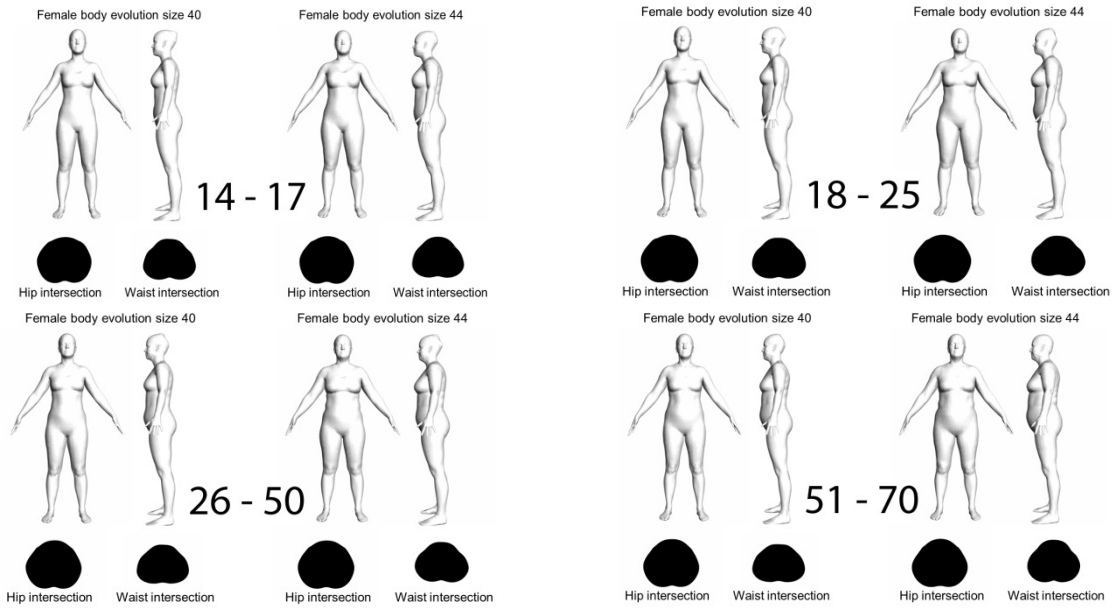


Figure 12: evolution of body shape in terms of age (female)

For males the waist girth remains the same with age, but the waist line changes from slightly horizontal for younger men and small sizes to strongly inclined for the older age category. This is shown in figure 13.

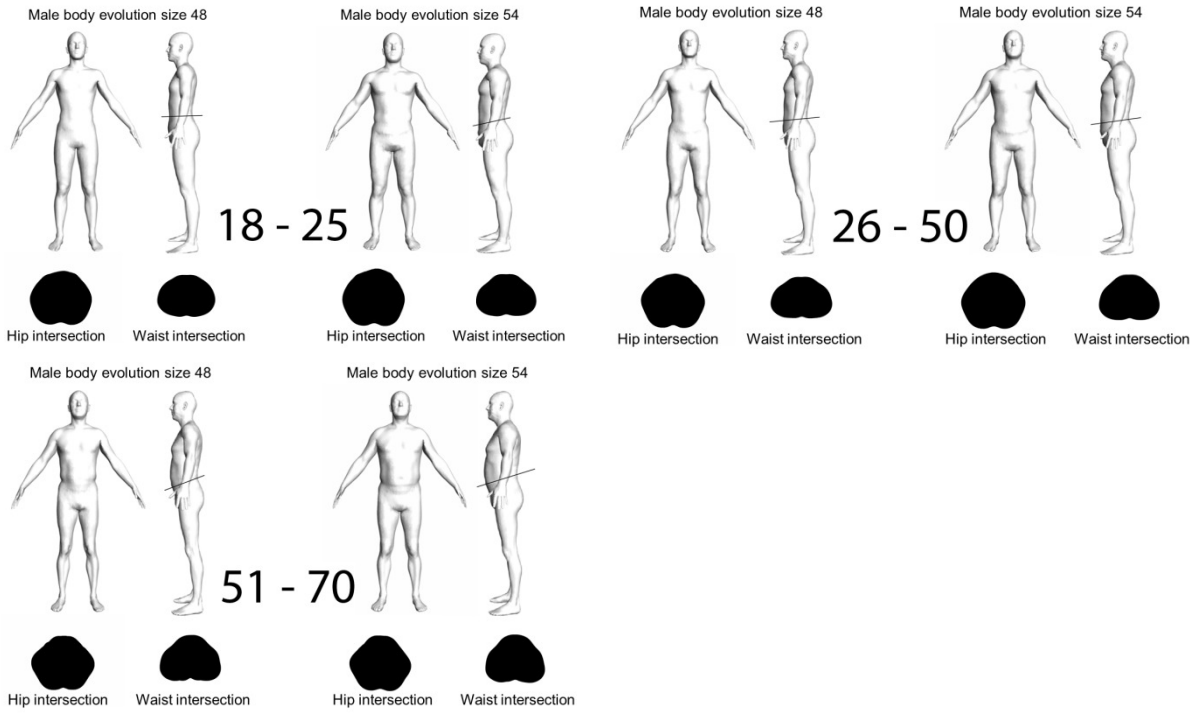


Figure 13: evolution of body shape in terms of age (male)

Comparison of the Smartfit results with current measurement tables

The previous measurement campaign in Belgium dates from 1990. Current measurement tables used in industry are still based upon the results of this campaign (figure 14). In 1990 the average difference between waist girth and hip girth was between 26 and 31 cm, depending on the size. Today this difference is between 20 and 27 cm. Figures 15, 16 and 17 show the size table different brands compared with the Smartfit results.

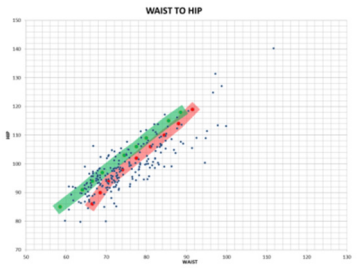


Figure 14: Smartfit (red) versus Belgian size survey 1990 (green)

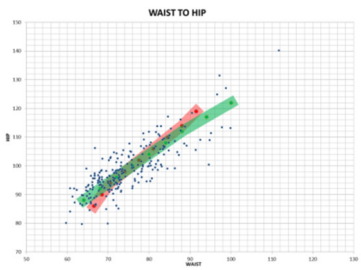


Figure 15: Smartfit (red) versus Brand X (green)

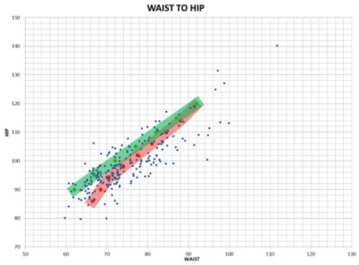


Figure 16: Smartfit (red) versus Brand Y (green)

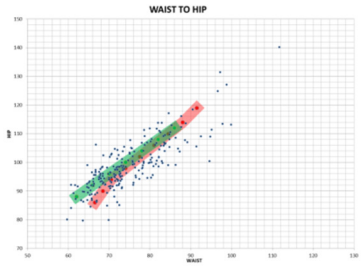


Figure 17: Smartfit (red) versus Brand Z (green)

This is clearly illustrated by a pair of trousers made according to the measurement tables of 1990 and 2014. Trousers made according to the 1990 tables fit on the hip but are too small on the waist.

Figure 18: Trousers based on measurements of 1990 and 2014

Creation of 3D virtual manikins

Based on 26 body measurements for female avatars and on 23 measurements for male avatars, virtual manikins were created in each size and each age category.

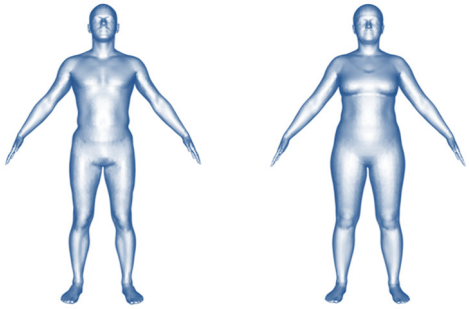


Figure 19: virtual manikins

These avatars 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, but also in the 3D virtual engineering platform where a computational fluid dynamics or CFD tool is integrated in a user friendly mechanical CAD system. The COVER project aims at developing a validated virtual engineering model that will permit us to predict how thermo-physiological comfort of protective garments will change under the influence of design issues and fabric selection. The strategy is based on the development of a 3D virtual engineering platform where different heterogeneous software/computational tools are coupled: (1) a user-friendly mechanical CAD system; (2) an integrated computational fluid dynamics or CFD tool for the 4D transient flow and heat transfer simulation around a virtual clothed manikin and (3) interacting with a human thermo-regulation model and comfort model. It seems clear that the virtual manikin or avatar has a key role in the success of the virtual platform.

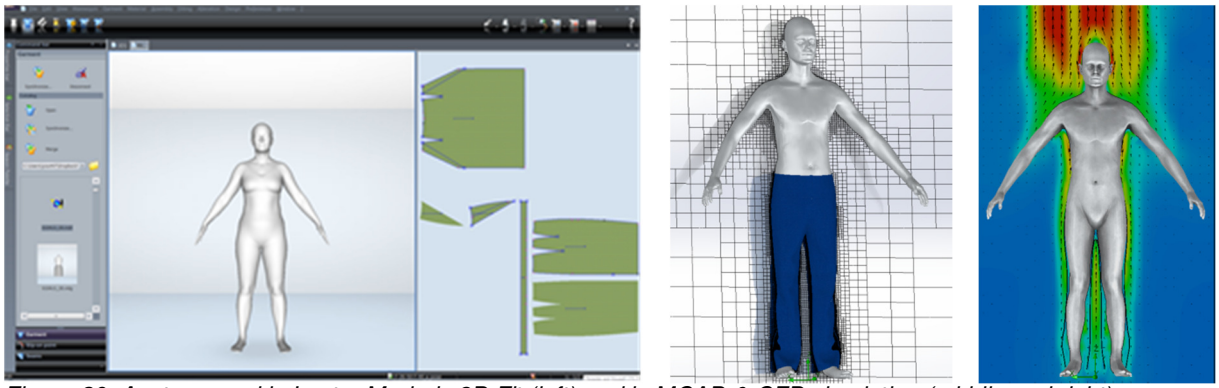


Figure 20: Avatars used in Lectra Modaris 3D Fit (left) and in MCAD & CFD simulation (middle and right)

Conclusion

The data collected during this size survey resulted in body measurement tables and 3D virtual manikins. The body measurement tables are already in use with several Belgian clothing manufacturers and the first results will be visible in the spring-summer collections of 2015. The 3D virtual manikins are being used as virtual manikins in 3D CAD software to assess fit and adjust patterns and design. The use of 3D virtual manikins in the virtual engineering model will permit us to predict on a short term basis without having to produce several prototypes how thermo physiological comfort of garments will change under the influence of design and fit issues.