Garment Fit: Where Do We Stand?

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Abstract

The paper describes the general understandings of the concept of comfort and its various components described in the literature. There is given an insight into garment fit problems and existing evaluation methods. The study aims to explain the importance of the anthropometry and the impact of its change and development on the improvement of garment fit provision. The possibilities and benefits of using 3D body scanning technologies in anthropometric studies are observed to explain options to improve the garment sizing and fit evaluation processes. The possibilities provided by modern computer-aided 3D design systems for development and analyzing clothing products are considered. The study includes examples of 3D scanning and virtual prototyping capabilities for assessing the fit and appearance of clothing, highlighting the shortcomings that hamper research into the interaction between the human body and clothing.

Keywords: Anthropometrics, 3D Body scanning, sizing, fit

1. Introduction

Nowadays garment fit becomes more and more important. In addition to comfort studies, interest in clothing fit is increasing. And this causes discussion about the already changing and volatile problem - comfort cannot be determined unambiguously, neither does fit.
Fit as a component of comfort is mainly associated with measurements. First, it is anthropometry, that is experiencing a change in its very essence - with the strengthening of contactless measuring methods, the possibilities for making such measurements for a wider range of persons increase. Along with this option, questions arise about the interdependence of human and clothing, and how the size of the garment affects its fit and therefore the comfort of the person.
The answer is complicated by the fact that there are no uniform criteria for determining the comfort of clothing - people have a different understanding of the convenience of clothing, the necessary ease, the determination of the heat level (the necessary *clo*), each has different metabolism and different aspects. Hence, it is not possible to give an unambiguous answer about what a good clothing fit is. Besides, the term fit itself bears in a lot of things - from sizing fit, convenience, dynamic convenience, the possible range of motion, and ability to perform appropriate actions. As a result, garment sizing is a difficult task that manufacturers and clothing designers face casually.

2. The concept of comfort

Wear comfort is studied and examined from a variety of factors and their balance - the physiological, psychological, and physical impacts between the wearer, garment and environment. The concept of comfort has been simply described by Mecheels (1977) as a measure of how well clothing assists the functionality of the body or at least impairs it to a minimum [1].
However, there are many attempts by various authors to explain this condition in the literature, for example, by including concepts such as the absence of pain and discomfort, overall convenience, well-being, level of ergonomics, hygiene, as well as aesthetic and psychological comfort.
Favourable factors include unrestricted movements, unhindered heat exchange, exchange of air and water-vapour, maintenance of optimal body temperature and protection from environmental hazards. The subjective perception of individuals, or the psychological component of comfort, is based on their individual preferences, values, and needs according to the particular type of clothing.
The components of the comfort concept are summarized and schematically illustrated in Fig.1.

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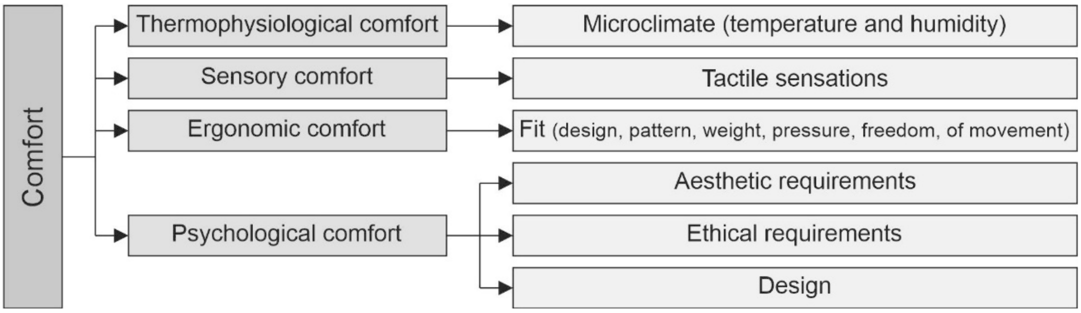

Fig. 1. The components of the comfort concept.

As the human body and skin to a greater or lesser extent are in constant contact with clothing, psychophysiological comfort is also considered as an essential component of the comfort, ensuring the undisturbed functioning of the human sensory system (including sensors of sight, touch, hearing, smell and taste). With the touch, a person can evaluate clothing surface factors such as softness, stiffness, smoothness, roughness, elasticity, as well as heat, thickness, volume and crease [2]. Direct skin contact must exclude allergic reactions and abrasion caused by clothing, clinging to the skin etc. [3].

One of the important and widely studied, however nowadays not only one sense of comfort, is thermal comfort - at both reduced and elevated temperatures. This may include studies of the sensations of the heat on the skin, air and vapour permeability, as well as perspiration and sweat removal. The recommendations of different standards based on providing a microclimate that is acceptable to most wearers are used to determine the thermo-physiological comfort. However, it is not possible to speak unambiguously about a microclimate in clothing that is suitable for all individuals. Research equipment and related industry standards are developed to test fabrics and garments or sets of garments for physiological effects, for example, measurements of thermal insulation, thermal resistance and water-vapour resistance [4,5,6,7].

In the context of physiological comfort, the emphasis is often placed on a fit - as garment compliance with the anthropometric characteristics of the wearer and the provision of the convenience of body movements. So far, no quantitative definition of fit has been introduced. Fit as a component of the concept of comfort is generally associated with measurements, that is, the compliance of a garment to a figure. With a different understanding of the convenience of clothing, fit can be viewed from sizing fit; the sufficiency of ease; dynamic convenience and a possible range of motion or ability to perform necessary actions. The effects of fit on overall comfort perception include the following: provision of general garment performance; its functionality; mobility and well-being of the wearer.

Comfort concept can be focused specifically on clothing pressure, which can be influenced by the fabric properties, the chosen ease allowances, as well as the type of a product and the design methodology. Given the moving nature of the human body, the importance of fit can be observed not only in standing but also in dynamic conditions, focusing on either the most common daily movements or specific work activities.

2. Evaluation of garment fit

Size compliance or sizing fit is the first factor a wearer can appreciate when first putting on a garment. Thus, it is assessed whether the size of the garment is appropriate, and it is only afterwards that other comfort factors are identified. For example, already in the course of everyday activities, it is possible to assess whether there are any individual parts or details of the garment that restrict body movements. At the same time, appearance is evaluated as the result of garment fit [8].

These subjective judgments play a major role in garment fit evaluation, starting with visual assessment and ending with some purposeful surveys to find out a variety of factors, including fit. Questionnaires allow to determine the satisfaction of a larger group of wearers (end-users of uniforms and *PPE*) of the same type of clothing. Such clothing is produced, purchased and supplied within the existing sizing system. Questionnaires and fit assessment sessions allow to find out whether the purchased or supplied garments (for example by primary body dimensions) match their bodies [9].

The capabilities of 3D scanning can also be used to search garment fit evaluation possibilities. For example, studying the interactions between the body and the garment layer, which can be achieved by superimposing undressed and dressed body scans and analyzing fit in different areas of the body by studying distances between layers, balance according to different body parts, creases in different parts of garments etc. Examples of superimposition of scans and usage of cross-sections for fit evaluation are shown in Fig.2.

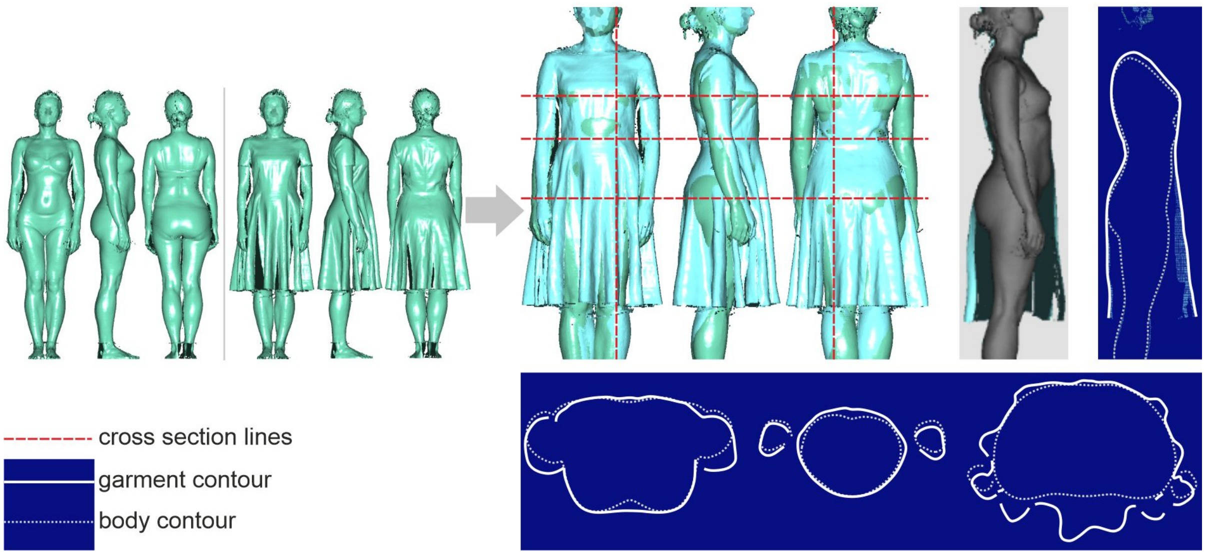

Fig. 2. Superimposition of scans and evaluation with cross sections (AnthroScan).

The next step towards the application of modern technologies in clothing fit evaluation is 3D simulations using *CAD/CAM* systems. Virtual products are intended to reflect appearance (fit), design and texture characteristics of garments. Virtual garment simulation is a creation and drape simulation of virtual garment for virtual human body using a virtual garment pattern, virtual sewing and bounding volume [10]. The garments are virtually prototyped either on a parametric or virtual human body (avatar) or even on virtual clone (scanatar) as a result of a 3D scan. Different systems provide options for the evaluation of fit in relation to different parts of the body, garment pressure, creases and overall fit in terms of appearance and proportions. Examples of virtual prototypes of jacket in two systems (Lectra and Vidya (Assyst)) are shown in Fig.3. where differences in the visualization of appearance and fit are visible.

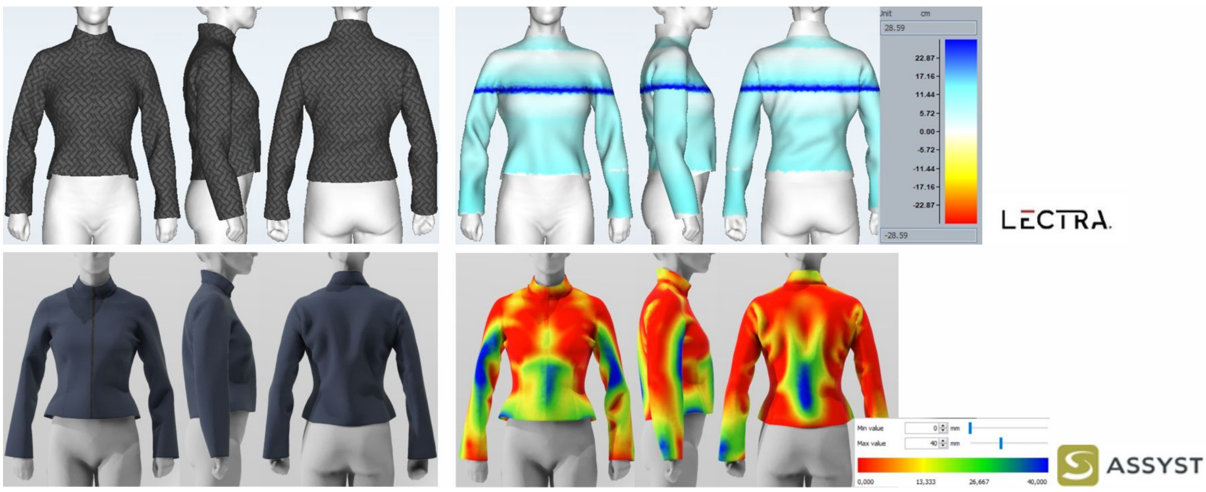

Fig. 3. Virtual prototypes of jacket (Lectra, Assyst).

Also, in this type of garment fit evaluation, users, depending on the capabilities of the system, will be asked questions, for example, whether the built-in avatars in 3D model library are suitable for garment fit evaluation in relation to the selected target group; whether the possible changes in the avatar parameters are sufficient to represent the target group somatotypes (are there enough changeable body measures). Moreover, appears a question whether the anthropometric data for changing avatar parameters are reliable. It must also be understood how wide the options are to define fabric properties (virtual fabrics – for example, weight, thickness, tensile modulus, bending rigidity, shear resistance [10]); what are the potentials to simulate sewing technologies (types of seams). Finally, how to objectively evaluate or verify whether the simulations are reliable.

When experiments for checking virtual garment simulations are undertaken, appears that 3D garment simulations are calculated symmetrical, fabric properties are uncertain and does not reflect real garment appearance [11]. Fig.4. shows differences in appearance of real skirt photos, scans and virtual prototype, as well as in superimposed transversal planes.

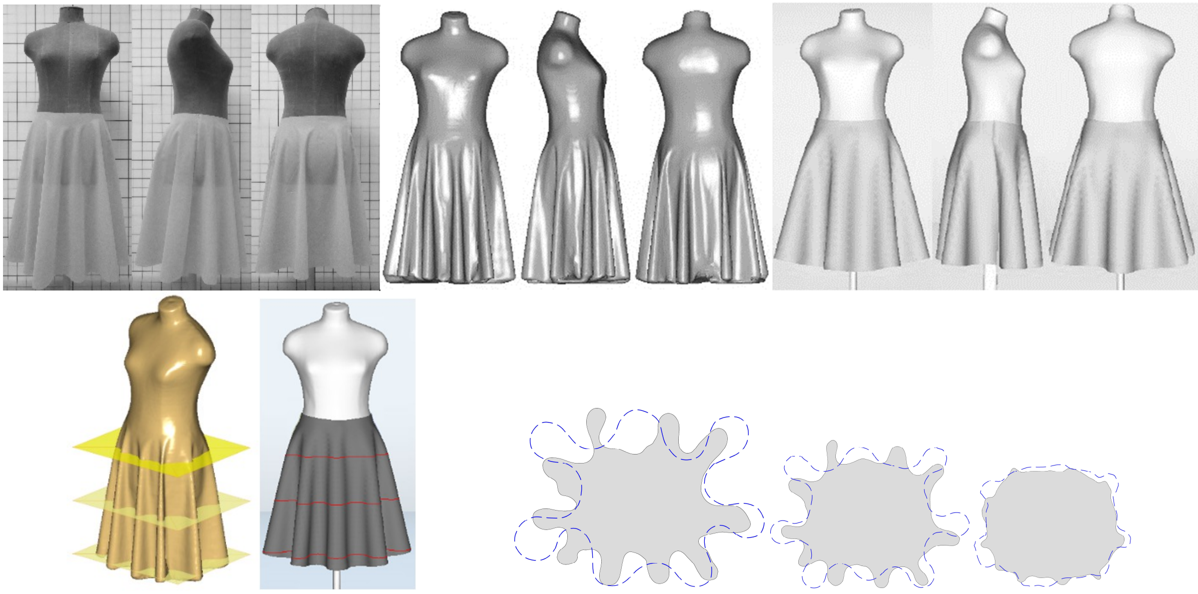

Fig. 4. Appearance of real, scanned and virtual skirt [11] (AnthroScan, Lectra).

Digital fitting – qualitative and/or quantitative evaluation of overall and/or specific simulation of garment fit through the analysis of the garment balance, gap between body and garment (which includes cross sections), heat map, surface wrinkles, etc. [10]. The definitions of virtual body measurements may vary from system to system. ISO 18825 is a series of standards with a main goal to define a virtual human body to be used for visual confirmation of size, shape, fit and design [12]. The virtual human body is intended to reproduce the actual shape and size of the human body with a known reliability. However, the introduction explains that virtual human body landmarks are closely associated with anatomical landmarks on human body despite that virtual human body is not defined based on human anatomy. The point is that the surface of the virtual human body cannot be touched in reality, so dimensions of it need to be defined in three-dimensional virtual space [13].

3. Fit and anthropometrics

The importance of anthropometric data can be observed in a variety of industries, ranging from the design of the human surrounding environment (workplaces, housing, transportation, etc.), to sport and medical product development, and clothing, footwear and personal protective equipment production. Depending on branch, requirements regarding the number and type of measurements needed and the accuracy demanded may differ.

The necessity of reliable, sufficiently comprehensive and segmented data is unquestionable, however there are various difficulties involved in obtaining them: there is a great variety of people (end consumers) - gender, age, race; individuals differ in their volume of fat tissues, their physical development, and their body part proportions; data acquisition is time-consuming and costly; it requires skilled professionals; it is not always possible to access enough test-persons to obtain a reliable data sample for statistical analysis.

3.1. Anthropometrics, methods, standards

Nowadays, 3D scanning is an effective non-contact body measurement method that provides reliable and fast anthropometric data, as well as the creation of a digital human body model for use in body shape analysis and three-dimensional design. Are identified both the shortcomings of conventionally used manual techniques and directions for improving 3D scanning technologies. Nevertheless, manual methods can be prohibitively costly and time-consuming to obtain extensive data, and possible impacts on the reliability of the results must be taken to account - for example, skills of the anthropometrist (e.g. ability of correct identification of anthropometric points, knowledge of measuring methods), feelings and fatigue of test-persons, soft tissue impacts on measurements, etc. factors. However, human body 3D scanning also has its drawbacks, such as the inaccessibility of certain areas of the body ("unread zones") and the cost of implementing equipment and data-processing systems. Moreover, persons with large amount of soft tissues are hard to measure either manually or by scanning.

The basis for obtaining reliable and widely usable anthropometric data is a clear definition of how measurements are made, which include finding and fixing anthropometric points, the correct use of tools or devices in relation to the human body. Attempts to harmonize these conditions are observable in various industry standards. For example, ISO 8559-1 includes list that guides how to take anthropometric measurements for ability of practitioners to create size and shape profiles for development of garments. It summarizes 26 landmark points and levels and 5 lines and planes. In addition, 4 postures with different arm positions are described [14].

One problem is to get reliable anthropometric data, however, the next step and question is the amount and the usage of anthropometric data in the development of manufacturing sizing tables and clothing patterns. ISO 8859-2 specifies primary (*PD*) and secondary (*SD*) dimensions for specified types of garments to establish size designation system that can be used to indicate body dimensions of the person that the garment is intended to fit. For example, jackets (upper-wear) for men should be indicated by chest girth (*PD*) and height, waist girth or back shoulder width can be used as secondary dimensions [15]. In turn, jacket for women – by bust girth (*PD*) and height, waist girth or hip girth as secondary dimensions.

Standard ISO 8559-3 [16] illustrates the industry needs related to anthropometric data. The sizing process by which finished clothing articles (in each size) reach the end consumer is explained. In good practice, this process starts with a body dimension survey by obtaining raw data (from selection of population) that can be further processed according to sizing needs. Furthermore, if 3D scanning technologies are applied, human body virtual 3D models are gained in addition to body measurements. However, nowadays the clothing manufacturing process is mostly based on already existing size charts that are not derived from anthropometric data of a specific population or target group. They are used for mass production and rarely provide a customized approach. Based on these size charts, patternmaking is performed, and grading rules are developed according to the indifference interval. In mass production, the garment is designed based on certain type-figure and is intended to serve as wide range of end-users as possible. In this case, there can be no question of adaptability to different proportions of figures or other specific characteristics of individual consumers.

3.2. Usage of human body measures

At different times various garment design methodologies have been implemented and developed which provides usage of various amounts and types of body measures. Part of the methodologies includes descriptions of the required measures, the acquisition of which is based on experience and knowledge gained over time.

Nevertheless, the question is whether, when using some design methodology, the measurement data will meet these requirements or vice versa - whether the method was based on correctly acquired body measures at one time. Consideration is also given to the passage of time when the methodology may no longer be adapted to the changing body characteristics of some part of people. Climate change, as well as the development of medicine and trends in the food industry over time, are constantly leading to changes in the shape of the human body. Will a method based on historical anthropometric data be appropriate for such groups and overall trends in general? Also, must be considered whether the chosen methodologies have the optimal number of measures, how significant each of measure is in the pattern, and what consequences may appear if measures are not obtained as in indications.

There are also differences in the recommendations for usage of ease allowances or some dynamic allowances that allow the wearer to make the necessary movements. Sufficient ease allowances and dynamic ease allowances allow the product to be suitable for wearers with different body characteristics yet strike a balance between the desired look and functionality. Factors that influence fit can also be linked to the shape of the garment design as well as the number and position of cut details.

4. Tests and results

As mentioned before, end users of specific garment can vary greatly. The use of 3D scanning technologies may face difficulties to obtain data of people with high fat tissue content. Although, it is also clear that obtaining manual measures may not be easy. 3D anthropometric scanner Vitus Smart XXL® (© Human Solutions Group GmbH) with the AnthroScan data processing system was used within these studies. Fig. 5. summarizes some examples of female figures who have had the incomplete acquisition of automatic measures in system AnthroScan. As can be seen, even with the legs spaced apart on special footmarks of the scan platform, it is not possible for individual figures to adequately obtain the inside leg length and other measures related to the thigh area. Also, obtaining a waist circumference is conditional, considering the large tissue folds in the torso area. The picture also shows an example when the system can be distracted by defining some areas of the body - such as the circumference of the left arm. In contrast, the circumference of the right arm, given the position of the arms close to the body, is likely to be increased.

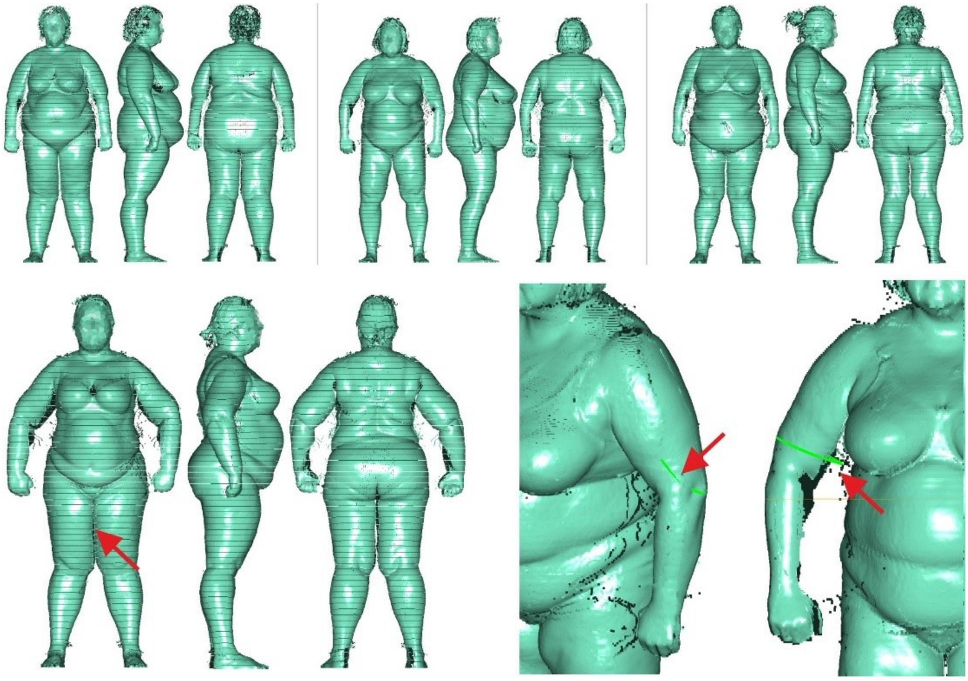

Fig. 5. Body scans of women with a high fat tissue content (AnthroScan).

However, not only with people of high soft tissue content and skewed appearance can be problems with measurement obtaining, also individuals with very physically developed body segments (muscle groups) can be measured with some drawbacks. An example is shown in Fig. 6. - a male body with a highly developed back muscles, for which the system has not been able to recognize the chest circumference showing only 89.0 cm value, although the resulting cross-section reveals that the actual chest circumference is 125.3 cm.

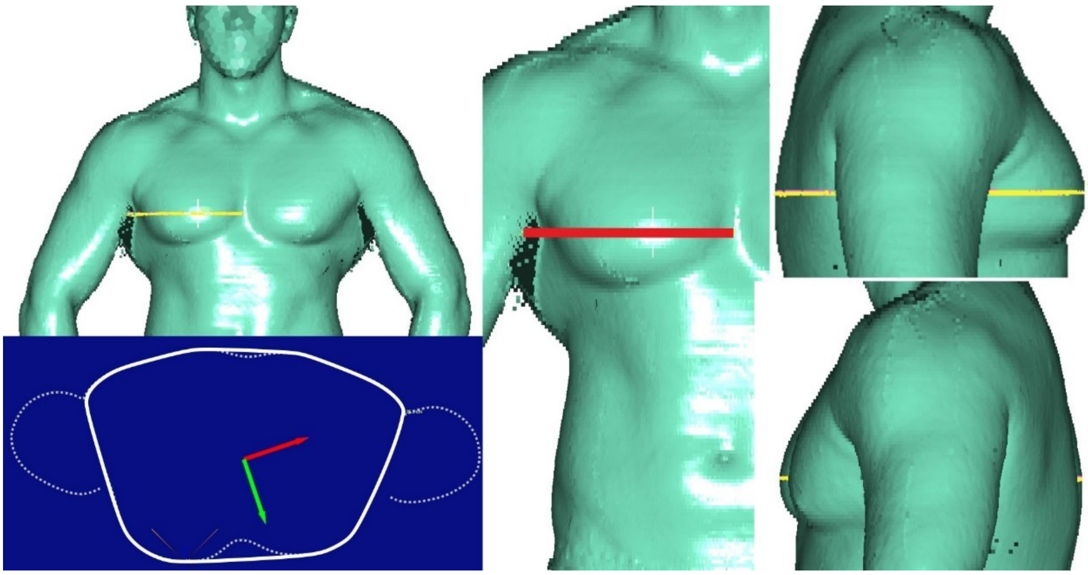

Fig. 6. Body scans of physically developed man (AnthroScan).

Also this kind of inadequacies are faced in usage of pattern making and construction methods – such body is to be measured manually with highest uncertainness. Because of developed and dropped body it is hard to measure circumferences horizontally – measuring tape slips over the muscles and it is hard to keep it in place.

Anthropometric dynamics studies are limited considering body areas that are not scanned when taking a position different from the upright standing posture. A couple of examples are shown in Fig. 7.

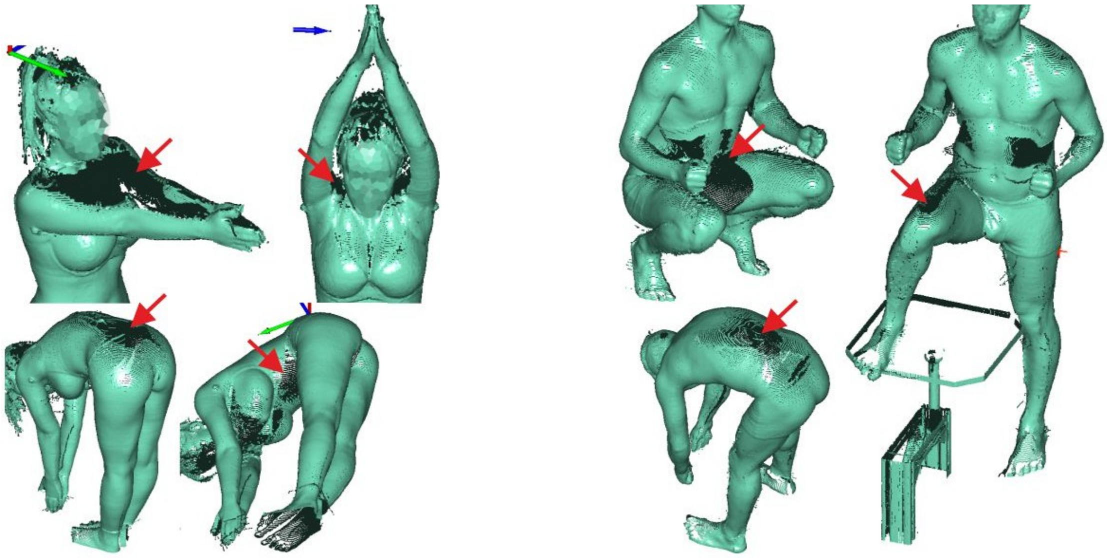

Fig. 7. Scans in dynamic postures (AnthroScan).

However, the advantage of 3D scanning is that, unlike manual methods, users can be confident that horizontal measures are obtained according to requirements – the horizontal circumferences are measured parallel to the standing surface. Horizontal bust/chest girth in main cases of pattern development methodologies is the main measure for defining upper-wear width, therefore, obtaining it properly can be critical. An example of how the bust circumference can vary when measured horizontally or perpendicular to the torso axis is illustrated in Fig. 8. The superimposed cross-sections serve to compare these two types of bust girths.

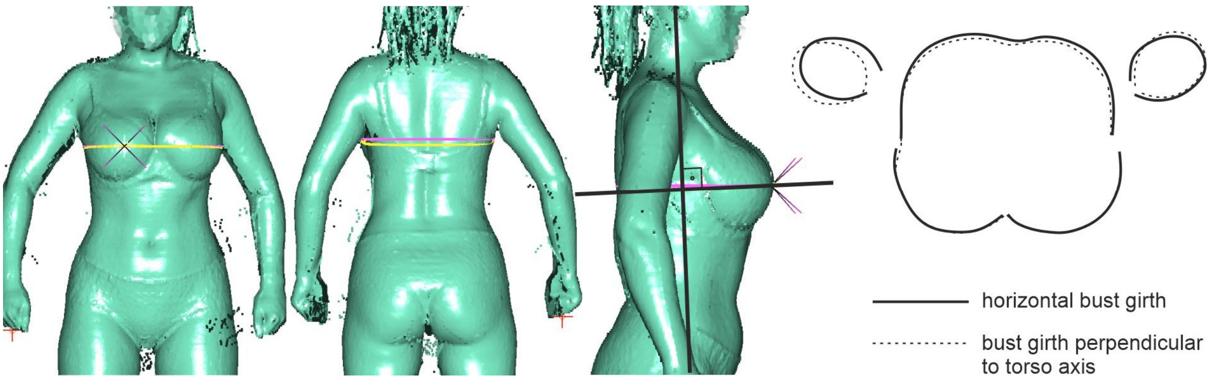

Fig. 8. Bust girth comparison (AnthroScan).

For manual measurements of the horizontal girths (not only the bust/chest but also the waist, hips etc.), it would require the involvement of at least two measurement specialists to be able to fix the horizontal position of the measuring tape parallel to the standing surface.

6. Conclusions

It is invariably difficult to quantify individual comfort indicators or components and the comfort concept in general, taking into account the numerous factors involved, as well as the changeable and unpredictable preferences and necessities of individual wearers, which depend on both the purpose of clothing and the individual experience accumulated over time.

The movements of the human body and inability to identically repeat the posture to precisely superimpose scans is still a source of difficulties - however, it is a good enough approach for drawing general conclusions.

Although, each 3D simulation system include possibility to define textile properties, 3D simulation is more suitable for marketing and design purposes rather than for fit assessment. As textile properties are described poorly, the simulation is done symmetrical not taking into account real textile drape, behavior and hysteresis.

Until we do not understand how the measurements differ from those obtained previously, the fit will also be difficult to achieve. Nowadays we have different approach to measuring. 3D non-contact measuring systems appears to be more accurate, more fast, all measurements are taken simultaneously, therefore measurements are reliable and also measured body can be measured again and again without doubts (scanatar doesn't change posture during measurements, it is not shy and it is accessible every time needed with the repeats). Approach to the pattern making is not standardized, every skilled professional has its own methods for pattern making and measurements used. Also – almost all methods are suited to the measurements taken manually which appears to be slight different from scanned measurements because of human body properties and measuring limits (standing still of body measured for long period is tiring, measurers skills and understanding of measurement character, repeatability of measurements, etc.) and other factors which can make an impact of quality of measurements. Therefore, one can conclude that manual measurements are suited to the existing (manual) constructing methods.

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