

# Motion-oriented 3D analysis of body measurements

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**Abstract.** The aim of this project is to develop an ergonomically based and motion-oriented size system. New concepts are required in order to be able to deal competently with complex requirements of function-oriented workwear and personal protective equipment (PPE). Body dimensions change through movement, which are basis for motion optimized clothing development. This affects fit and ergonomic comfort. The situation has to be fundamentally researched in order to derive well-founded anthropometric body data, taking into account kinematic requirements of humans and to define functional dimensions for clothing industry. Research focus shall be on ergonomic design of workwear and PPE. There are huge differences in body forms, proportions and muscle manifestations between genders. An improved basic knowledge can be provided as a result, supporting development as well as sales of motion-oriented clothing with perfect fit for garment manufacturers.

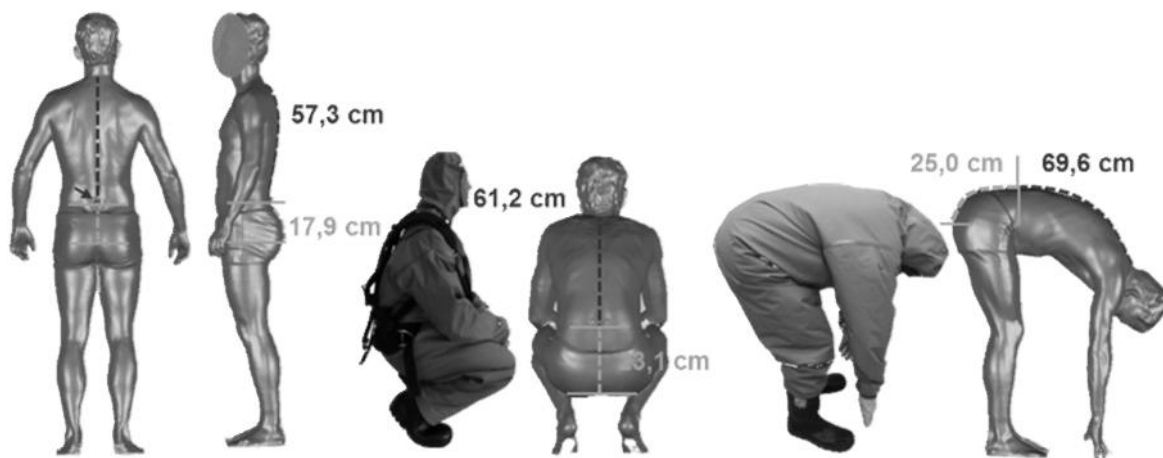
## 1. Introduction

The fit, comfort and fashionable look of workwear and personal protective equipment (PPE) gain in importance. In addition to the protection and functional properties, working and protective clothing demands perfect fit for optimal freedom of movement.

The balancing act between freedom of movement, functionality and the fashion-oriented fit of different target groups offers new complex challenges to the manufacturer of workwear during development and sales.

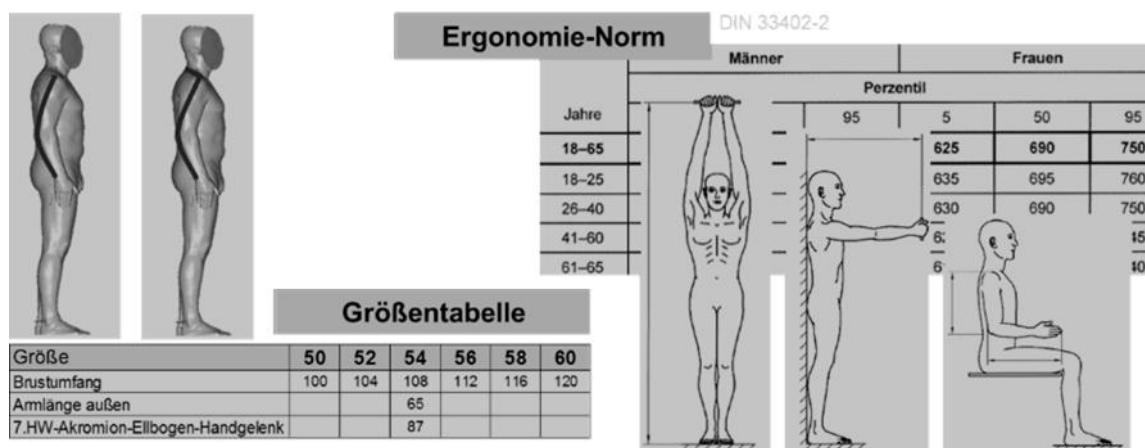
Anthropometric data are used for clothing design, PPE, workstations and man-machine interfaces. Therefore two different measuring systems are used: size charts [1] and ergonomic standards. [2] [3] [4] [5] [6] Size charts are the base for clothing industry, however size charts cannot cover the functional requirements of workwear and personal protective equipment. Body measurements during exercising movements (standing, sitting, kneeling, bending, etc.) deviate significantly from measurements of the size charts, which are measured in standard standing position. Motion of the body and its extremities change the length and circumference dimensions, see Figure 1. The back length (in red) of a male test person with size 50 shows a difference of 12.3 cm between standing position and forward bent body position. This means an extra length of 21.5% due to posture changing. The small measure "hip depth" (in orange) is extended by 7.1 cm, an increase of 39.7%. This leads to a number of questions: What are the right dimensions for garment design to implement optimal ergonomic comfort? Are there dimensional differences between small and large sizes as well as other types of figures, e.g. belly types? Do gender differences exist and if, how do they take place?





**Figure 1.** Change of body measurements in different body positions

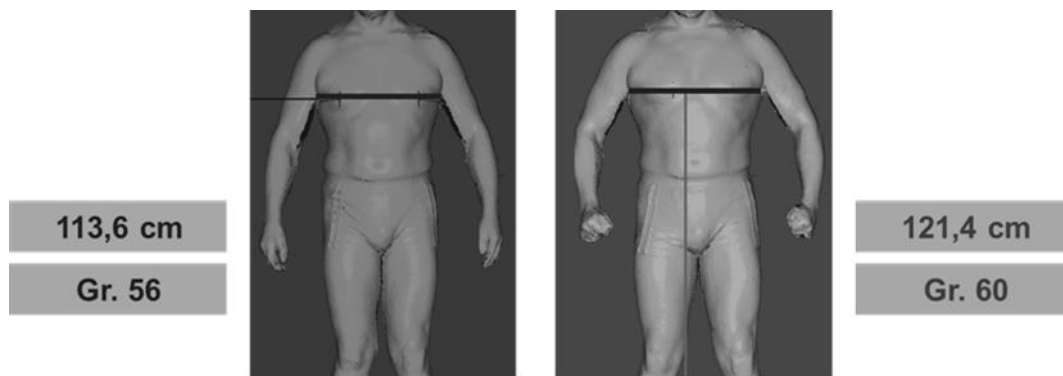
The motion-related variability of body dimensions is partly reflected in ergonomic standards [2] [3] [4] [5]. They describe different modes of motion, e.g. arm range, without any size references, which are important for clothing design. Therefore the correlation between the two systems is missing (see Figure 2).



**Figure 2.** Comparison between size chart and ergonomic standard by example of arm length

Furthermore ergonomic measurements are usually reproduced as 5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentile and they differentiate by gender and age groups. However percentiles only indicate the percentage distribution of a measurement within a random sample of people. A measurement standard which considers the size reference as well as function-oriented motion of the body at work, is currently not available.

In addition, motion-dependent dimensional differences significantly affect the elementally important scale for leasing of working and protective clothing of order and online business. This is because the chest circumference, which defines the size for dressing as a primary measurement, changes considerably as shown in Figure 3. During a slight simulated lifting movement, the size of the test person varies between size 56 and 60. The range therefore comprises three possible sizes. But what size is actually to be attributed to this person, that, for example, a work jacket isn't neither too narrow nor too wide?

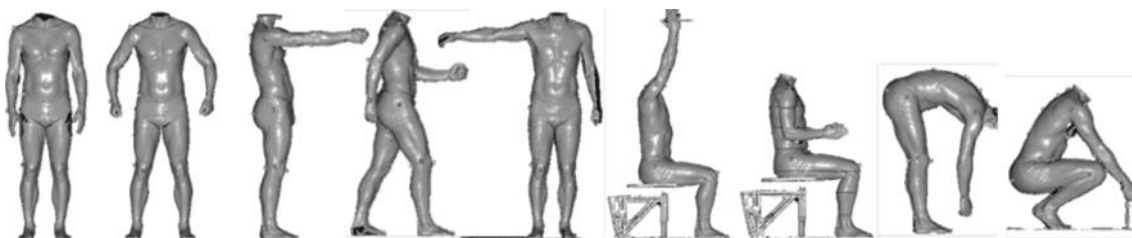


**Figure 3.** Changes of the chest circumference with slight lifting movement of the arms

## 2. Methods

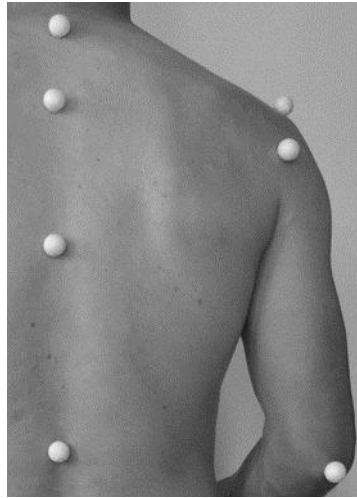
The motion-related variability of body measurements shall be investigated and converted into a new size system during the project "Functional dimension" (IGF 18993 N, duration: 01.01.2016 to 30.06.2018) [7]. The aim of the project is to correlate the traditional size systems with the ergonomic dimensions and to develop a new motion-oriented size system - a functional standard. Men and women have to be examined separately. The following work steps are in the presented project:

- Analysis and classification of work-related postures (standing, sitting, kneeling, bending, etc.): The focus was to identify and classify representative forms of movement, which reflect as many professional activities as possible. The challenge was particularly to define postures in a way that test persons can define these postures in a reproducible and repeatable manner. In addition it was necessary to specify postures that enable the Bodyscanner Vitus Smart XXL to capture all relevant body areas.
- Posture capturing by using 3D-scanner technology:  
Each test person was scanned in 10 different postures in total. Figure 4 shows the 10 different scan postures.



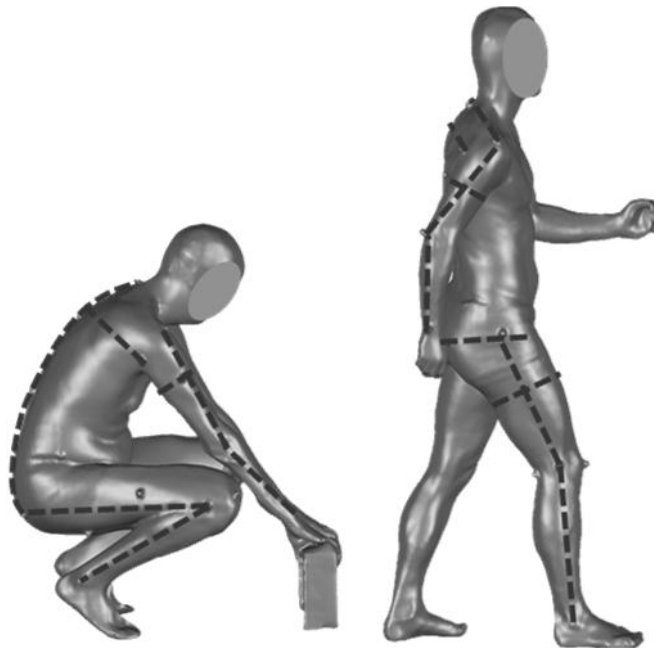
**Figure 4.** The ten defined postures for analyzing the range of motion

In order to be able to analyze and measure the differences in length and circumference reproducibly, a total of 16 physical markers have to be applied on test person's bodies at specific anthropometric measuring points before scanning. Figure 5 shows exemplary the physical markers.



**Figure 5.** Physical markers on human body

- Identification of changes in motion-dependent body shape and analysis of the extrema:  
In the first step body measurements, which are to be recorded, were determined on the basis of the respective attitudes. Recording and evaluation of the fit-relevant body measurements which were decisive for the ergonomic comfort was the goal. Important aspects are the chest circumference, arm, leg and back lengths, back and chest widths as well as leg and arm circumferences. Figure 6 shows exemplary the detection of individual body measurements at two scan postures.



**Figure 6.** Exemplary presentation of the body movement measurements

- Statistical evaluation of ergonomic dimensions according to size and figure types
- Development of ergonomic and motion-related size systems for men and women

### 3. Results

The results shall be converted into an ergonomic and motion-oriented system for efficient use of functional dimensions in clothing industry. This includes functional measurement tables for the various figure types and size series and - this is the new approach - for the relevant different forms of movement. A multidimensional presentation of the measurements is required. The connection between the traditional clothing sizes and known size designations ensures the acceptance and application of the new size system in practice. Research focus shall be on the ergonomic design of occupational and protective clothing and therefore analysis of work-type body postures and movements. Many of these movements coincide with different types of sports. In the first step, it is useful to limit the wide range of analytics to the field of application, and then in the second step to examine the transfer to other fields of application. There are large differences in the body forms, proportions and the muscle manifestations between the genders [1] [4] [8].

### 4. Conclusions

The challenge consists of the systematic derivation of new functional dimensions as well as their conversion into optimized clothing products in addition to reproducible detection of the ROM (range of motion). The correlation to the textile material and its respective extensibility is a central subject. This is to be solved afterwards. An ergonomically based size system especially for workwear and PPE saves time and money in product development. Further the process of size reduction or allocation can be effectively supported and thus leads to a reduction of large change efforts, returns and complaints in e.g. textile leasing business. The results can also be used to develop standards.

### Acknowledgments

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