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Individual 3D measurements of end users to personalize work wear clothing

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Abstract. Body silhouette 3D measurements need to be performed separately in each country due to significant ethnic differences in body silhouette which preclude the transfer of European data to particular countries. Systematic research allows to update information on the population body silhouette and body proportions as well as select the size changes possible to implement in clothing construction modifications. The diversity in body silhouettes and sizes as well as the issue of clothing fitting encourage clothing producers to provide work wear clothing based on individual measurements of the end users' bodies. In the framework of the carried research, the group of construction workers was selected as the target group of the analysed work wear clothing users. 42 construction workers, men only, were measured. The body silhouette measurement process was non-contact and was carried out with the use of 3D body scanner.
The collected data on the body silhouette allowed to select sizes used to construct the work wear clothing and identify the clothing size. The selected measurement points of the body silhouette underwent statistical analysis to determine the distribution of random variables, here body sizes. The variables distribution characteristics were calculated. On that basis, the fitting appraisal of work wear clothing with respect to the size of the finished product corresponding to the adequate size of individually measured worker/end user was performed. The size overview of the work wear clothing used by the specific professional group and the appraisal of the size fitting to the body silhouette took into consideration the work wear clothing ergonomic functionality with respect to the body posture when performing the tasks, design and clothing construction. The analysis based on the currently gathered end users' remarks and objections concerning the clothing fitting and performed body silhouette measurements allows to modify the existing work wear clothing for the selected group of end users. The research was aimed at the improvement of the work wear clothing fitting thanks to personalization based on individual body measurements at the stage of construction design.

1. Introduction

Functionality of working and protective clothing apart from appropriate selection of the fabric to be used should be correlate with the degree of fitting to user's silhouette, aesthetic appearance and draping. Each of the features mentioned in combination with ergonomics cab decide about functional suitability and influence the quality of product. The basic requirement in the assessment of the working clothing functionality is the possibility of free movements and activity of the man dressed. This is conditioned by the ergonomic structure of clothing with the use of structural accessories with appropriate size on specified spots of clothing, taking into account the properties of fabrics. The selection of working clothing results from environmental hazard and activities carried out during work. If one fails to take into consideration the ergonomic requirements during designing working

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clothing, it can often result in a lack of acceptance by the users obliged to wear it. The ergonomic designing of clothing, particularly protective clothes, reduces the discomfort of their use and decreases the onerousness connected with the movements done during wearing and performing professional job. The consideration of the ergonomics principles facilitates the use comfort increase and in the case of individual protection means and working clothing increases the acceptance of their use [1].

Anthropometric measurements of silhouettes are used not only for ergonomic clothing designing but also for making elements that form the man environment [2, 3]. There are available published reports containing data for designing and ergonomic assessment of machines and equipment [2] destined for designers of the man's work environment and human live. In the sphere of clothing industry, apart from information about the man silhouette in designing and modeling clothes one should assume the functions of particular elements of clothing and consider its purpose. Characteristics of work conditions constitutes all the factors acting on the human organism in the work environment determined by microclimate, technological process and the intensity of man activity [4]. The man physical movements during his work occur in his/her many positions (standing, seating, and lying, kneeling, squatting). The basic measurement data of man silhouette used in clothing industry describe the human body on the basis of measurements carried out in the standing motionless position on persons dressed with underwear. The measurements of man's body with correctly selected structural accessories constitute the basis of optimal clothing structure and consequently comfortable clothes during wearing. Anthropological studies have shown that there are relations between the proportions of: width, length of the whole body and its particular elements as well as the influence of the body position on the values of the features measured, and the ergonomic working clothing should take all these elements into consideration.

2. Methodology

The tests performed included the measurements of the silhouettes of workers employed in building sector carried out jobs with different degrees of energetic expenditure and with different movements and positions of body connected with their profession (services of crane, welder, assembler/fitter and carpenter). 42 persons of the male sex, performing building works, wearing selected working clothes were measured. The measurements of the building workers silhouettes were taken in the field, using mobile measuring equipment - Anthroscan 3D VITUS Smart XXL from Human Solutions Company [4]. The apparatus is equipped with 4 scanners located in the corners of room and also computer system for recording over 100 various measurements of human body surface and data analyzing. The measurements of human body surface were made in two positions according to standard used in the clothing PN-EN-13402 [5].

a) b)

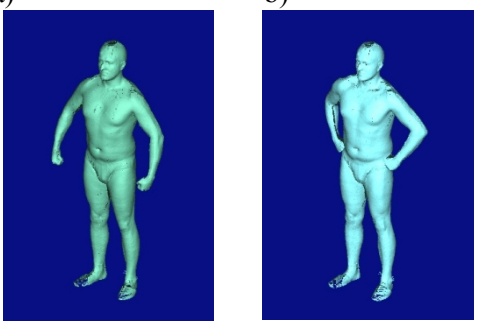

Figure 1. Views of male silhouette according to the measurement procedure used: a) position A; b) position B

The measurements used for the construction of working clothing and identification of the worn clothes size were selected from the collected data of silhouettes.

The selected measurements of silhouettes were subjected to statistical analysis paying attention to the establishment of the distribution of random variable, i.e. body measurement.

The analysis of silhouette measurements was related to garments, assuming the whole silhouette is dressed and the best movement opportunities are provided during performing the work.

In ergonomic designing one must consider the man anthropological data to retain appropriate proportions between body measurements and a device in order to shape the optimal working zone. An important factor affecting the creation of work conditions is professional clothing – working or protective clothing, adapted to the operations and requirements of the technological process. For the test targets two-piece warning garment was selected that had the measurements declared by the measured builders.

Figure 2. Two-piece warning garment

3. Results

There were performed statistic calculation within the scope of the determination of essential differences between the clothing measurements and corresponding user's body measurements, taking into account the structural accessories of the garment (to retain clearances). The measurements of jacket and trousers were collected for analysis. The following body measurements were selected as the basis of the statistic assessment of jacked: chest size (4510), high waist size (6515), size of buttocks (7520), length of the upper limb (8030), neck circumference (1520), width of arms (3030), circumference of arm (8520), back width (3020).

Selected measurements of body for the assessment of trouser fitting: waist size (6510), hip size (9510), knee size (9520), internal length of trouser leg (9020).

The statistic assessment was carried out to determine the regressive relationship between the dimensions of the body of garment users and the dimensions of the ready-made garment used by them. The selected body dimensions have a direct reference to the ready-made garment, taking into account the structural and ergonometric additives connected with the destination of garment and the kind of professional activities carried out while wearing it.

Ascribing the size of clothing to the user with specified dimensions, the following data were taken into account:

- height and size of chest for clothing used in the upper body part, determining the structural addition of circumference from 20.0 to 24.0 cm,
- height and waist circumference for clothing used in the lower body part, determining the structural addition of circumference from 10.0 to 14.0 cm. It was not succeed to fit the dimension of garment elements for 6 persons since in the case of these users, too great

divergence occurred between body dimensions and the ranges of height and circumferences that were assumed in the dimensions of the garment made.

Table 1. Correlation of body measurement points

Body measurement points	Correlation coefficient R	Correlation
4510	0.984	Full dependence
6510	0.981	Full dependence
6520	0.920	Full dependence
6515	0.893	Very high dependence
7520	0.757	High dependence (considerable)
8030	0.599	Moderate dependence (essential)
1520	0.750	High dependence (considerable)
8520	0.720	High dependence (considerable)
9510	0.470	Moderate dependence (essential)
3030	0.208	Distinct but low dependence
9520	0.707	High dependence (considerable)
9020	0.678	High dependence (considerable)
3020	0.754	High dependence (considerable)

For the accepted significance level, p, the values of the coefficient of linear correlation ranged from min 0.208 to max 0.984.
The correlation dependence was obtained for all the analyzed body dimensions, while the extent of this dependence was diversified. (Table1.)

As an example, the diagrams of dependences for the analysis of chest size (4510), waist size and length of upper limb and the internal length of lower limb are presented.

- For the size of chest (4510).

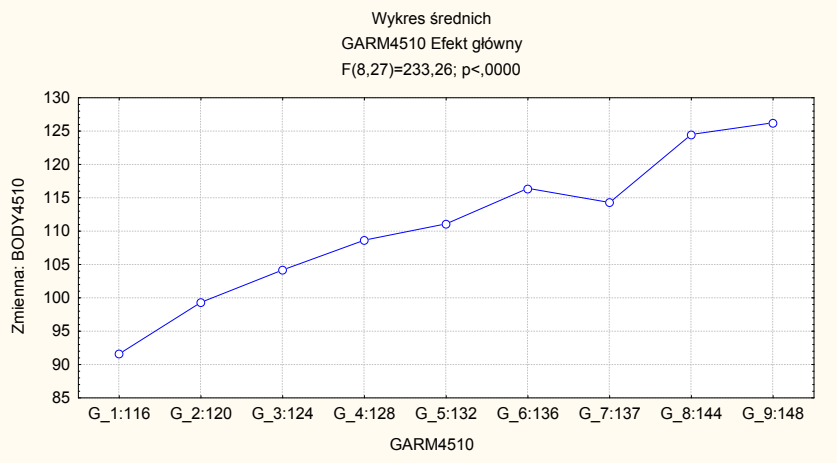

Diagram 1. Size of chest (4510)- Dependence of garment dimension on the body dimensions

Diagram 1 shows the linear relationship between the real size of the person measured and the corresponding size of garment.

Diagram 2 presents the difference with a value of about 20.0 cm in chest size between the real size and the garment size. From the diagram it follows that the correct tolerance has been retained.

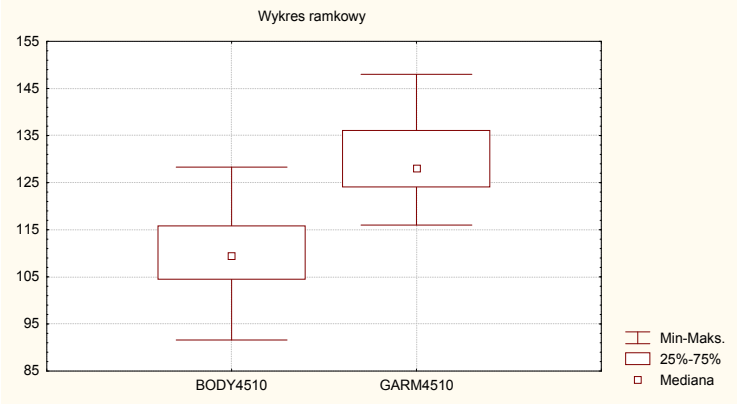

Diagram 2. Results of body measurements and measurements of clothing for the upper body part for the chest size (4510)

- For the size of waist girth(6510)

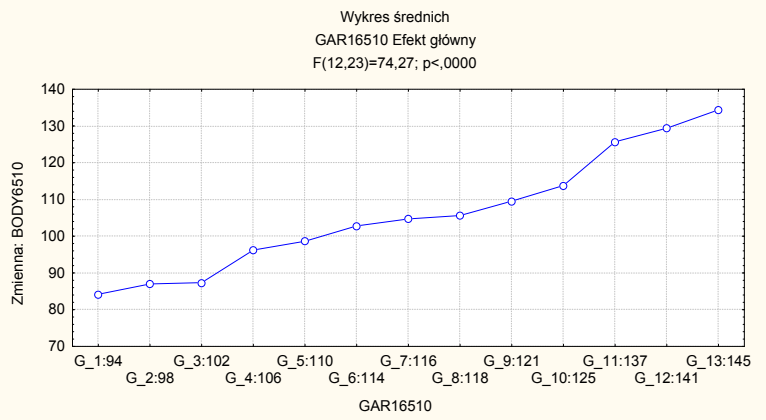

Diagram 3. Waist circumference (6510) - dependence of the garment size for the lower part of body on the body size

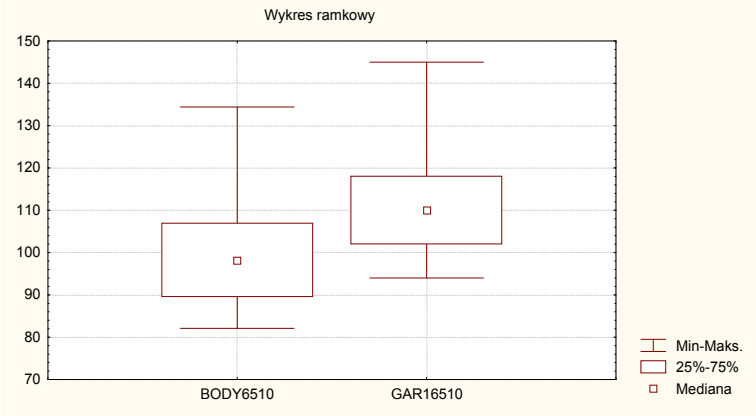

Diagram 4. Results of body measurements and size of garment foe the lower body part – for waist circumference (6510).

In the case of the circumferences considered, the body dimensions assume decisively lower values than the adequate dimension of clothing. This is connected with the necessity of providing appropriate freedom of movements during wearing the working garment during performing professional activities.

- For the size of the upper limb length

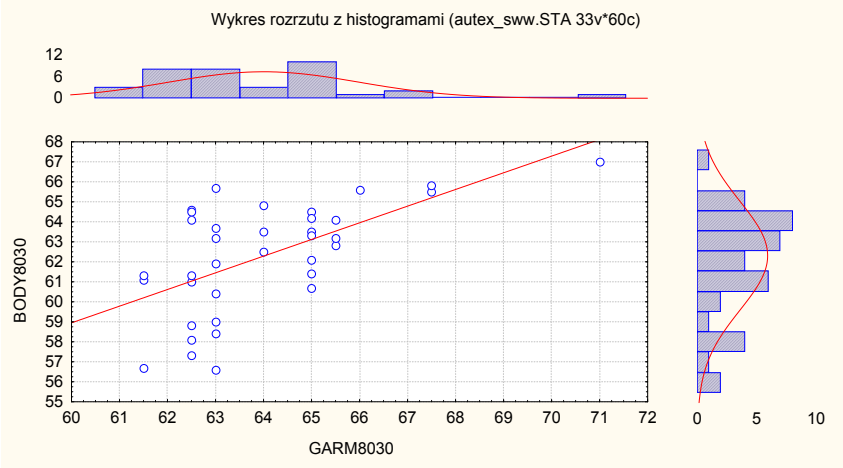

Diagram 5. Length of the upper limb (8030) – dependence of body dimensions and garment dimensions

In relation to the length of sleeve, there occur greater differences between body dimensions and clothing dimensions, from which results a lower linear correlation. For the group of users with different arm lengths, one sleeve length is anticipated. It is not advantageous with respect to fitting ability and use agronomy. This observation of the fitting capability of sleeve length is also noticeable in Diagram 6. The value of median of body dimensions and garment dimensions are comparable but the range of tolerance garment size is distinctly shifted towards higher values, opposite to the range of the body size tolerance.

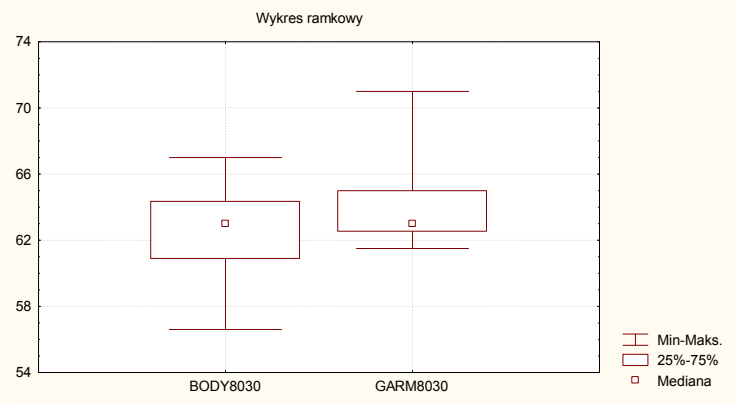

Diagram 6. Length of the upper limb (8030) – results of body measurements and clothing measurements

- For the lower limb length

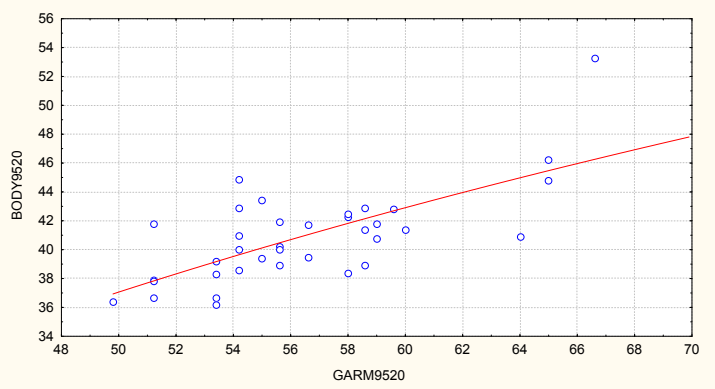

Diagram 7. Relationship of body dimensions and clothing dimensions for the lower body part for the length of lower limb measured from the base to the step (9020).

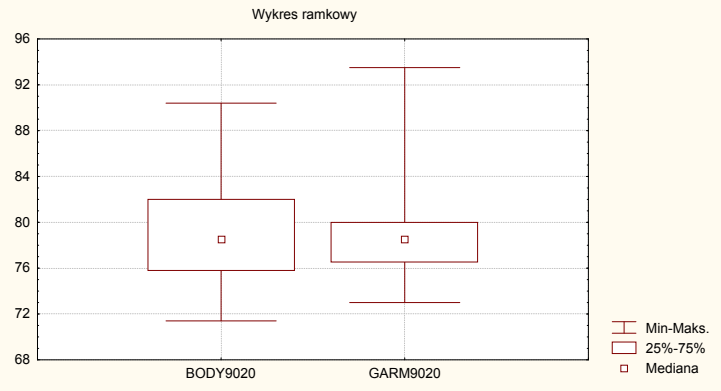

Diagram 8. Results of measurements of body and clothing sized for the lower body part for the length of lower limb measured from base to step (9020).

In the case of the length of internal trouser leg, the body size is measured from the base, thus it is naturally it is higher in relation to the size of clothing (trouser leg is shorter by 2 cm to provide the freedom of movements). Hence visible differences between assessed sizes and higher values obtained for body size. The value of correlation coefficient shows a lack of strong monotonic relationship between the considered sizes, which suggests that in the tested population occur cases of both too short and too long trouser legs. This means that one should make changes in the construction of trousers to fit the length of trouser legs for the needs of users, which is particularly essential for working clothing, its ergonomics and the safety of use.

The observed differences and a strong divergence of the measurement results under discussion may be perceived with respect to implementation of changes in the structure of garment in this range, with simultaneous assurance of the ergonomics of movements of the working clothing users.

The basic structure of the garment under analysis was subjected to modeling treatment consisting in providing a clearance in the area of the jacket back by the formation of fabric excess in the form of folds(with a depth of 3.0 cm). Therefore, it seems that there is a sufficient clearance that allows one to carry out professional activity.

4. Conclusions

The studies of the dimensional analysis of man during his labor constitute an interdisciplinary issue necessary to observe the safety and comport of using his clothing. The system of determining the size of clothes is closely connected with the rules of constructing fabrics and the formation of dimensional lines. A correct garment adapted to body dimensions takes into account the movement dynamic of user during performing his work and optimally covers his silhouette.

Taking into consideration the basic dimensional features of users, there is a possibility of fitting the garment size according to regulations to the size, ranges of body height and circumferences. The comparative analysis of body dimensions essential, with respect to usability, to the structure of clothing and having an influence on the fitting capability and dimensions of ready-made garment, indicates what optimal structural accessories should be used in the construction of garment.

Based on the analysis of the results obtained it has been found that there is a need for personalization of working clothing on the basis on individual measurements of silhouettes, which will make it possible to improve the garment fitting to silhouettes and the comfort of use under work conditions.

For the parameters of chest and waist sizes, a correct tolerance was observed, while for the parameters of the upper limb length and internal length of lower limb, there is a lack of strong dependence between the sizes considered, which suggests that in the tested trial are cases of too short and too long products, both sleeves and trouser legs.

The differences observed and a high divergence of the result sets under discussion may be noticed with respect to the implementation of structural changes in this range, providing the movement ergonomics of the working clothing users at the same time.

Acknowledgment

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