Usage of noncontact human body measurements for development of Army Work Wear Trousers

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Abstract. The paper is based on issues related to imperfections of clothing fit, garment construction solutions and control measurement systems of finished products, which were identified in the research process analysing army soldier work wear trousers. The aim is to obtain target group body measurements using noncontact anthropometrical data acquisition method (3D scanning) for selection and analysis of scanned data suitable for trouser design. Tasks include comparison of scanned data with manually taken body measurements and different corresponding human body measurement standard data for establishing potential advantages of noncontact method usage in solving different trouser design issues.

1. Introduction

The target group of the performed research is Latvian National Armed Force soldiers. Survey, interviewing and investigation of protective trousers, which have already been in use, showed frequent occurrence of tears in crotch area. Such clothing damages result in loss of practical and protective functions. As one of the reasons the improper use of body measurements for pattern making was proposed. Also the selection criteria of uniforms should be considered – the fit evaluation, soldier competence in choosing appropriate size uniform and influences on protective clothing functionality in case of wearing wrong size.

There are possibilities to eliminate the deficiencies in work wear clothing design and supply processes, which are associated with body measurements, if body measurement analysis of a large group of people is done using noncontact measuring method. Significant task is to improve manufacturer data tables of the end user measurements by automated obtaining of a large amount of measurements [1]. It has to be done considering that so far pattern making is performed using body measurement data base, which has not been updated for years, and not taking any additional end user body measurements.

2. Materials and Methods

Body measurements of 150 end users were obtained with noncontact method using 3D anthropometrical scanner Vitus Smart XXL® (©Human Solutions GmbH un VITRONIC GmbH) with Anthroscan software, but control measurements were taken manually using the traditional anthropometry tools - measuring tape and anthropometer [2]. Instruction about the 3D scanning conditions (clothing and body postures) was conducted before the process to avoid possible data inaccuracies, which can occur as a result of test persons' individual behaviour, for example, trying to strain some muscle groups or take an uncharacteristic posture.

The data analysis was made using methods of mathematical statistics; a comparative analysis was carried out between the measurements obtained with noncontact and manual methods, as well as with standard data [3,4] using the linear regression coefficients and formulas necessary for calculation of constructively most significant dimensions of type figures [5].

In order to establish and summarize issues, the analysis of manufacturers' trouser control measurement tables was made and the most common defects of the trousers as a result of use (seam and cloth tears) were collected – defects were visually evaluated, measured and protocoled [6].

3. Results

3.1. Correlation analysis of noncontact and manual methods
The summary of data allows to evaluate the correlations of body measurements necessary for trouser design, which are obtained by both (noncontact and manual) methods, for example, girth measurements - waist girth - 'figure 1', buttock girth, thigh girth and length measurements - inseam length - 'figure 2', sideseam length, etc.
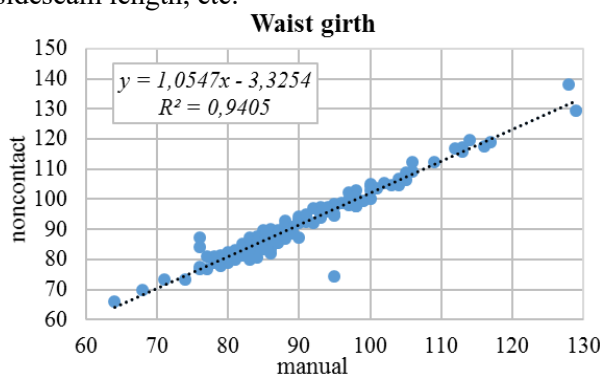
**Figure 1.** Correlation analysis of waist girth measurements – noncontact and manual methods.
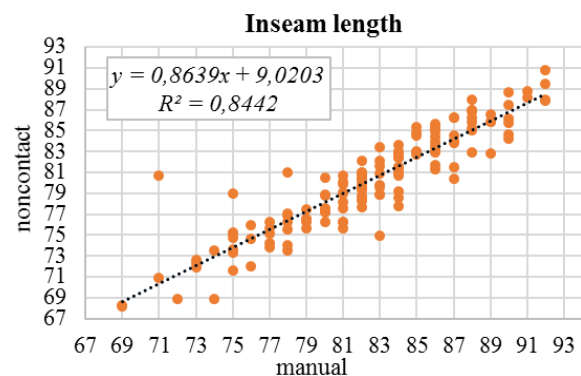
Figure 2. Correlation analysis of inseam length measurements – noncontact and manual methods.

In most cases a reasonably close correlation was observed and it was concluded that noncontact method can serve as a reliable solution in obtaining target group body measurement data in a direct and fast way for improving the clothing order and supply procedure.

3.2. Measurements and sizes comparisons with standards
Several measurements, which can have significant impact on garment constructions, were analysed separately comparing gained data and calculated dimensions according standard [4] regression formulas, for example, thigh girth, buttock girth and inseam length. The initial assumption that the defects of trousers could arise due to different from standard data [4] thigh girth, which may be increased because of developed thigh muscles considering physical loads of soldiers, was not confirmed. Thigh girth of representatives of the target group do not differ compared to standard data [4], when 54% of end users have smaller but 46% larger thigh girth – however in most cases (81%) not significant increase – within 2 cm interval.

Comparing the registered trouser sizes in the end user surveys and suitable standard sizes [3] selected according to body measurements (key dimension – waist circumference), it was concluded that less than 1/3 of the target group (28%) are capable to evaluate and indicate the corresponding trouser sizes to the manufacturer. A part (15%) of respondents are even unable to indicate trouser sizes, but the rest are indicating smaller (23%) or larger size (34%) – 'figure 3'.
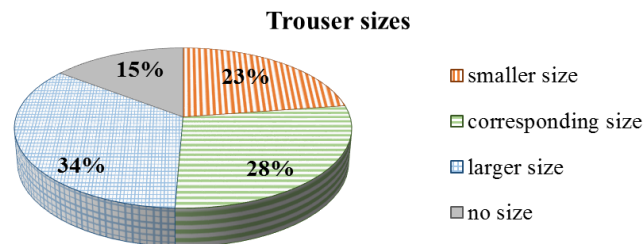
Trouser sizes

Figure 3. Comparison of survey and standard [3] trouser sizes.

Moreover, comparing with manufacturers size system, indicated types of size labelling differ - 87% indicate one-size letter designations (XS-3XL), from which 11% have doubts and indicate two labels (e.g. L/M), 6% indicate two-dimensional numeric labelling (e.g.92/182), and only 7% two-dimensional letter designation, which is implemented by the manufacturer and is used in supply (e.g., L/REG).

By taking into consideration that some of the respondents were unable to indicate trouser size and different types of labels, it was apparent that in the supply of this research group there was no common approach to labelling of clothing sizes to be worn or wearers themselves were confused over the types of labelling of trousers that may encourage receiving unsuitably-sized trousers.

3.3. Trouser wearing habits
During research of the reasons for defects, an analysis of trouser-wearing type was made, i.e. habits of wearers by direct visual evaluations and by using body reproductions obtained in a 3D Anthroscan system - dressed (in trousers) and undressed (in underwear) bodies - 'figure 4'.
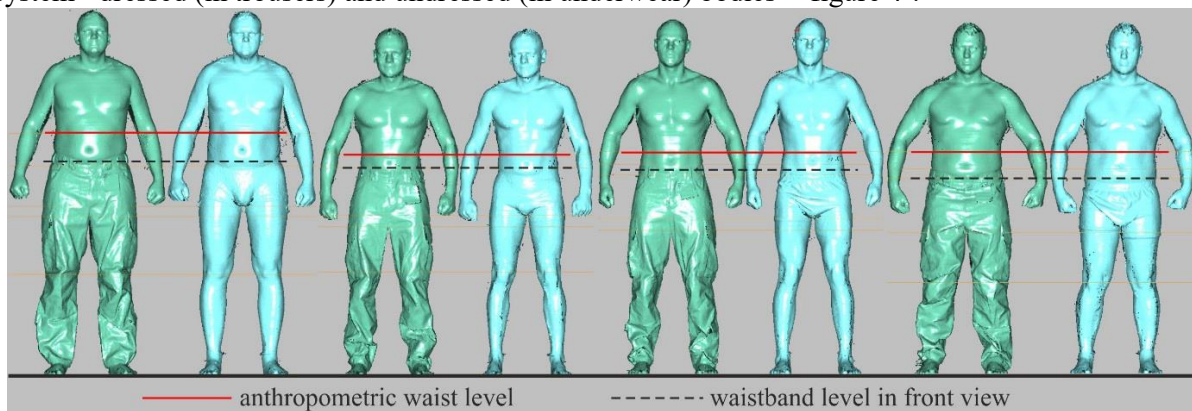
**Figure 4.** Dressed and undressed body reproductions – waist position in front view.

In all cases studied trousers waist level or waistband position is lower than traditionally defined waist in anthropometry. When a wearer chooses a lowered waistband position height as being more suitable or comfortable or customary, and at the same time a designer does not foresee such habits of a wearer during the process of development of patterns, that can lead to a situation when an area of the seat seam is lowered. It is possible that due to the active movements of a combatant amplitudes of leg movements may be restricted, for example, by not being to take a step, to climb, or to squat. Moreover, waistband lowering may cause unsuitable waist (waistband) girth.

Not only visually and during the 3D scanning, but also by taking control measurements with the contact method, it was established that the actual level of wearing of trousers waistband is lower than anthropometric waist that is indicated by the wearers themselves. Moreover, according to calculations, it is apparent that as a body has bigger belly, i.e. when waist circumference increases, a value of lowering

a waistband also increases, which should be taken into account in analysis and development of users group sizes system or database. Or other way of wearing should be introduced.

3.4. Waist and waistband comparison

In 3D system a body measurement Waistband (ID number - 6520) is available as one of automatically retrieved measures that is always placed lower than traditional anthropometric waist, and in most cases it is automatically placed at a level where wearers place the waistbands of nether garments. When undressed (in underwear) on/slightly above the upper edge of underpants - 'figure 5', but when dressed (in trousers) on/slightly above the waistband of trousers.
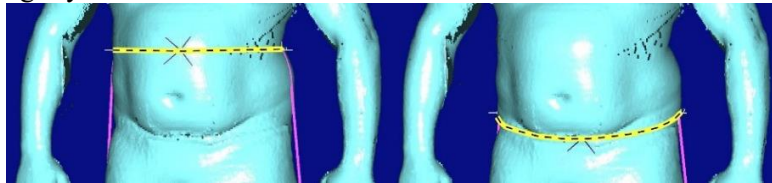

Figure 5. Waist level and Waistband level in system Anthroscan.

In the Anthroscan system instructions this size has the following definition: Waistband location is calculated as a simulation of a physical waist belt on a pair of trousers. This circumference is often placed between a waist (ID number - 6510) and high hips (ID number - 7510). As inclination of a measuring tape is calculated automatically its position may not be parallel to floor level. In 'figure 6' differences between positions of a Waist level and Waistband level on side, front and back are demonstrated, moreover, measurements of such deviations are automatically obtained in the system.
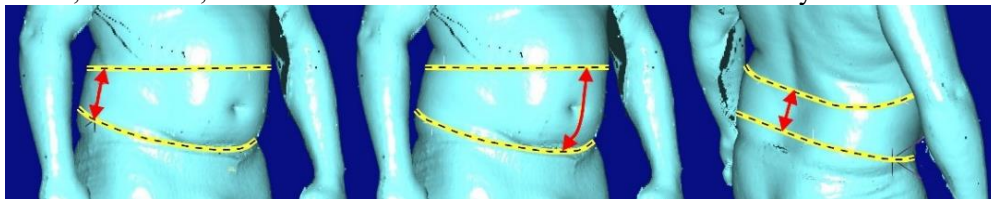
Figure 6. Deviation - Waistband level from Waist level in system Anthroscan.
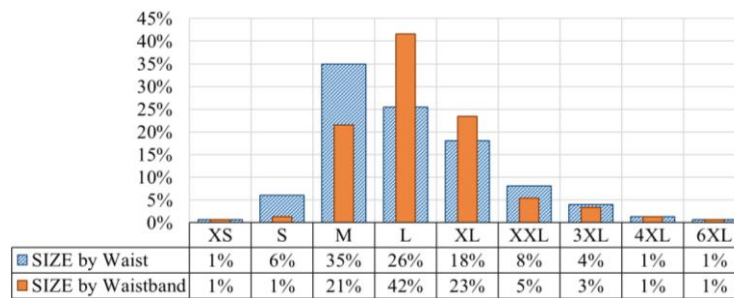
In order to compare what differences are observed between a traditional anthropometric waist and a waistband measurement - 'figure 7', a calculation of deviation of circumferences has been made. In the research, 67% of all the 150 measured soldiers have a value of waistband that is larger than the waist circumference, but in 33% of cases it is smaller, showing deviation values from -14,6 to +9,5 cm.
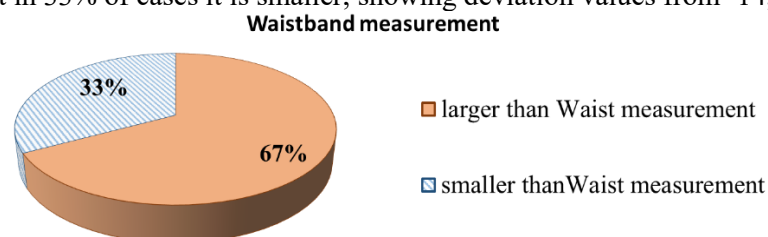
Figure 7. Waistband and Waist level measurement comparison.

Differences can be clearly demonstrated with potential frequency of sizes (primary key dimension – waist circumference) if they are developed by gained Waist or Waistband circumferences - 'figure 8'. More distinctive differences are observed exactly in the broadly represented size groups M, L and XL.

|	XS	S	M	L	XL	XXL	3XL	4XL	6XL
SIZE by Waist	1%	6%	35%	26%	18%	8%	4%	1%	1%
SIZE by Waistband	1%	1%	21%	42%	23%	5%	3%	1%	1%

Figure 8. Waistband and Waist level measurement comparison.

This Waistband circumference could be used as a one of key dimension for design of nether garments by taking into consideration that it is obtained at a level and inclination suitable to the actual position of the waistband of the trousers.

3.5. Noncontact measurement applications

Considering that most defects during exploitation are observed directly in the crotch area, options of the Anthroscan system in automatically acquiring inseam lengths (in underwear and in trousers) - 'figure 9', and crotch lengths are mentionable. First, inseam length measurements may be applicable to review size scales of manufacturers to use them as a secondary key dimensions as recommended in standard [3] and not body height measurements as this far. This solution is negotiable regarding observations in research, when leg lengths or proportions differ within one body height group, but manufacturers leg length intervals of body height groups are insufficient wide (currently 6 cm). By actual measurements leg length ranges in one height group occurs from 5 cm to 11 cm.
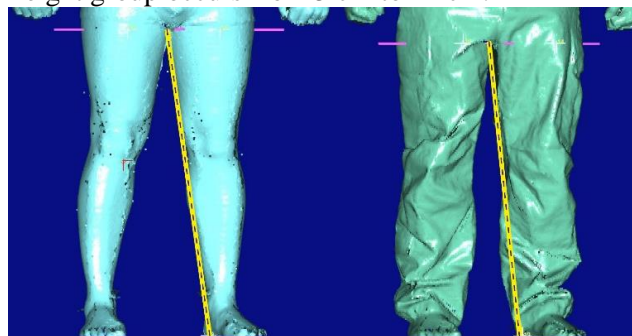
Figure 9. Inseam lengths in underwear and in trousers.

Secondly, automatically obtainable crotch length measurements at Waist and at Waistband - 'figure 10', allows to analyse and compare human body surface with finished garments, for example, to determine potential excess volume in crotch area which occurs as a result of lowering the waistband or belt level. According to measurements taken in the research – crotch lengths of finished products, undressed and dressed scanned bodies, it is concluded that trousers are designed for wearing the waistband at traditional anthropometric waist level, but already dressed bodies measurements show that all the excess volume of garment is placed in the crotch area when wearer chooses to lower waistband level.
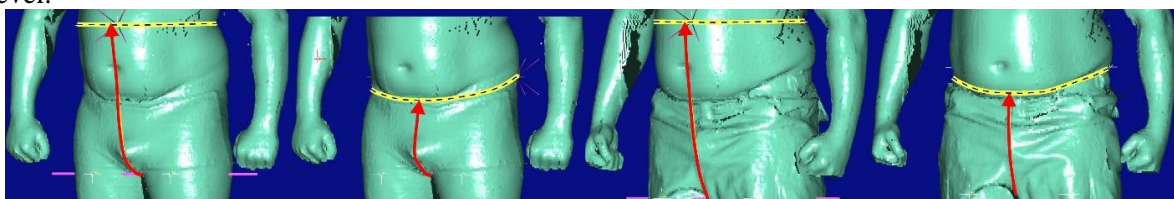
Figure 10. Crotch lengths - at Waist and at Waistband, in underwear and in trousers.

4. Conclusions and Discussions

The noncontact measurement method has advantages in obtaining body measurements of a big group of people and further use of the data in different garment design. First of all, it is a reliable data collection device showing sufficiently close correlation with manually gained and standard data. Secondly, a large number of body measurements (153 somatic measure values) are obtained in a fast way (one scanning ~12 seconds) and they are not influenced, for example, by skills of a measurer, movements and breathing of a measured person and compressibility of soft tissues [7]. 3D body reproductions can be used for further profound studies in different 3D systems, for example, virtual fitting of clothing.

The potential of the noncontact method lies in the arrangement of size systems for large target groups, when the obtained information is centrally processed and used further for supply implementation preventing disparities in sizing system, which can occur if the necessary sizes are indicated by each wearer. For clarity, labelling of clothes in accordance with EN 13402-3:2014 [Size Designation of Clothes. Part 3: Body measurements and intervals] interval pictograms supplemented by letter designations may be used.

Garment fit analysis is possible to continue by defining different user group wearing habits, which should be taken into consideration when designing patterns. Not only mentioned lowered waistband level height but, for example, effects on trousers displacements on body surface in case of fully filled pockets and possible improvements in fit if suspenders are worn.

Further research work is focused on the search of coherencies not only in body measurement and trouser construction direction, but also the influence of cloth properties, human body life action products (sweat) and garment care conditions on trouser use indicators.

5. References

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