The influence of human body posture on the determination of total dimensions (morphological characteristics)

I Dabolina, E Lapkovska and A Vilumsone
Riga Technical University, Faculty of Material Science and Applied Chemistry, Institute of Design Technologies, Kipsalas street 6-220, Riga, LV-1048, Latvia
Inga.Dabolina@rtu.lv

Abstract. Most important human body measurements are used for sizing uniforms and workwear. If the measurements are gained and used inappropriate, the garments may be unsuitable for the end-user. The target group is soldiers which are provided with uniform jackets which appropriate fit is significant for successful accomplishment of their daily tasks. Anthropometry as a method studies total morphological characteristics which measurement procedure can be influenced by different factors – the chosen measuring tools and equipment, the influences of body posture and their changes. The aim of the research is investigation of chest circumference – factors affecting the measurement precision and differences between manual and 3D scanning anthropometrical methods. Different measurements of the chest circumference also in different body postures show that the manually obtained chest girth is closer to the chest girth perpendicular to the axis of the torso, rather than the horizontal chest girth which is most significant dimension in patternmaking of upper body garments.

1. Introduction
Size labelling rules support satisfaction ability of multiform anthropometric demand of clothes for different consumers allowing various height, girth and drop interval combinations if suppliers would comprehend complexity of the applicable demand [1]. For sizing and ensurance of uniformity and fit of uniforms and workwear most important body measurements (primary and secondary dimensions) are used. The absolute values of the dimensions used for developing sizing system must be as large as possible. Main body dimensions used for sizing protective clothing are chest girth, body height and waist girth [2].

Anthropometry studies the total dimensions of the body - total morphological characteristics which comprise the major anthropometric indicators: body height, chest circumference, and body mass. They reflect the external form of a human body and are the most significant indicators of physical development, therefore, their interrelationships, as well as body proportions and stature, external forms of individual parts of the body, sex and age characteristics, etc. are investigated. The constitution of a human body depends on many characteristics, for instance, the distribution of adipose tissue in the body, development of muscular system, person's age, the size and shape of the skeleton, the shape of the thorax and the thoracic region, as well as the shape of the abdomen and spine [3].

The horizontal chest circumference, which is the most significant body dimension in all methods of patternmaking of upper body garments and is used to calculate the total width of the garment, is used widely for setting the core aspect of sizing system. It is relatively arbitrarily possible to allocate any desired number of matching intervals, which may vary from 4 up to even 10 cm and are chosen...
depending on garment type. Among the end users of garment standardized to the fit range, no one would have encountered the disproportion between the actual values of his unique body measurements and the average value of the standard intervals in proportion to the standardized dimensions of the designed apparel. If the measurement is made inappropriate to the patternmaker’s method and/or practice, it may turn out to be in another fit range and the end product is inappropriate for the end-user, thus wearing comfort would not be provided [4].

There are two types of human body measurement acquiring methods: manual anthropometry methods (contact methods) and optical anthropometry methods (non-contact methods). Traditional methods use different manual tools (measuring tape, anthropometer, etc). As the technologies develop, new tools are being created and/or the existent ones are improved. The aim of this research is investigation of chest circumference – factors affecting the precision of measurements and differences between manual methods and 3D scanning anthropometrical methods.

2. Chest girth in pattern making
When using the methods of patternmaking of upper body garments, the chest circumference is used for calculation of the total width of the garment, whereas the total width of the pattern is divided into the back, armhole, and front in different variations. As soon as in beginning of the 20th century, the master-tailor Levitanus had suggested that the width of an armhole shall be defined as ¼ of chest circumference. The beginnings of the search for standard proportions date back to the mid-20th century. According to the most typical example, a half of chest circumference shall be divided in proportions as follows: 3/8 for the back, 2/8 for the armhole, and respectively 3/8 for the front. In some systems, this ratio is not so clearly defined and is used only to determine a pattern block. Also features of garment assortment reflected in form of ease allowances or different adjustment coefficients shall be considered. The most common methods were those according to which all body measurements were calculated only by means of body height and chest girth. The renowned M. Müller & Sohn method of patternmaking uses proportional body measurements which are calculated by taking into account four key dimensions: body height, chest, waist, and hip girths. The proportional methods do not, however, always provide clear distinctions between body measurements and sizes of pattern line segments of the garment or drawing.

The significance of the chest girth becomes apparent also when determining other relevant sizes of both horizontal and vertical drawings. Some proportional methods use specific empirical regularities to calculate the depth of the armhole. Levitanus suggests to allocate, along the centre line of the back, 1/4 of the sum total of the back length and chest half-girth. According to M. M&Soehn - 1/10 chest girth + 10.5 cm. In other it is calculated: chest girth/ 3+4 cm. As for the proportional pattermaking methods, the width of the neck line, and the width of the sleeve are associated with the chest circumference. In all these empirical formulas, coefficients have great significance, whereas coherences are to be used for a limited number of figure types, a minor group of sizes, and for a particular garment assortment. Since the width of the back can be logically associated with the respective body measurement – the back width, later methods mostly use this coherence. It is rather difficult to associate the width of the armhole with the direct body measurement. The sagittal diameter of an arm is used by SEPP method, as other methods mostly use a part of the chest girth.

3. Body stature and posture characteristics
Factors influencing the accuracy of body measurements are the human's stature and body position during the measurement. The stature is the usual configuration of a natural standing position of the human body, i.e., without muscle tension, and is characterized by several features: the shape of the spine, the head and shoulder position, pelvic inclination, abdominal circumcision, limb position, muscle development, fat distribution. In turn, these characteristics are determined by heredity, sex and age, nature of a person's work, performance of central nervous system, and other causes [5].

Anthropological studies deal with different typological distinctions of body statures, and the identification of the main types allow usage of stature regularities in textile science. When drafting the patterns, the most convenient approach of classification is usage of the sagittal (profile) contour of the
torso. Stature can be divided by 3 types – stooped, normal, and curved. Simple estimation of the stature can be done by some main measurements: – body position (Ks), – depth of lumbar lordosis (LVdz), – lumbo-pelvic lordosis (GVdz) [5].

The depth of lumbar lordosis (LVdz) has little impact on the fit of loose and semi-tight upper body garment. In textile science, greater attention is being paid to the body position (Ks). Solutions to prevent the deficiencies of sagittal imbalance have been sought using constructive technological methods. They can be reduced by patterning a larger neck line. In such case the garment depends less on the individual profile type of end-users.

A complex muscular system is responsible for the posture and movements of the human body. There are various groups of muscles: head, neck, upper extremity, trunk and lower extremity. Even small-scale body movements may involve several muscles and their groups, which contribute to changes in the external form of a body. Smaller muscles, for instance, act to move the scapula up and inwards. Other muscles contribute to the movements of the ribcage during breathing [6,7].

Factor affecting the measurement results is the breathing of the test person. In dynamics studies, which deal with the changes in body measurements caused by movements, a separate position is the dynamic indicators during the deep breathing. One of the studies shows that the chest girth dynamic effect of men was, on average, 2.61% of the indicator in a static position [8]. The results obtained in statics may be influenced by slight changes in thoracic form during normal breathing. When breathing in – the lower ribs are lifted up and out to the sides. The breastbone also moves out and contractions of the intercostal muscles causes the ribcage to expand both sideways and front to back [6,7].

Furthermore, fat percentage of the body and adipose tissue distribution depending on their location may both intensify and lessen a hump, waist, chest or hip protrusion, and other posture characteristics.

4. Methods and procedures
The target group of the performed research is Latvian National Armed Force soldiers, namely, a group comprised of 171 men with an average age of 30 years (aged 19-52), average body height of 180 cm (160.3 – 195.2 cm), and average body weight of 87kg (62.4 – 141.6 cm). Soldiers are supplied with uniform jackets, which are fitted with primary dimensions: chest girth and body height. Incorrect body measurements, especially in the case of a chest circumference, can result in an inappropriate size, which, for example, in the case of a smaller size, results in a poor fitness and movement limit during the soldier's daily tasks.

When using the traditional manual measurement methods, during the measurement of the chest girth, the person usually lowers the hands letting them hang down freely (schematically ‘figure 1 a’, 3D scanning reproduction of the front - ‘figure 1 b’), whereas the laser scanning technology requires adjusted position with arms moved away from the body, thus not covering the sides and allowing laser rays to cover as much as possible (schematically ‘figure 1 c’, 3D scanning reproduction of the front - ‘figure 1 d’). Combined images (‘Figure 2’) shows differences in postures.

Figure 1. Measurement positions: schematic and 3D reproductions.

Figure 2. Combined images of postures.
The horizontal chest girth is defined as the greatest body measurement of the horizontal perimeter of the trunk at bust points level. As emphasized, during the measurement procedure, the measuring tape at all times must be positioned horizontally, which in contact method can be a condition rather difficult to control, in particular, when the measurements are taken by one person. The position of the measuring tape will most likely be subject to the location of torso axis of the subject.

The 3D system captures two types of chest circumferences, both of which are made across the bust point landmarks, while the first one “Bust/chest girth (horizontal)” is measured parallel to the standing surface (‘figure 3 a’), but “Bust/chest girth” is perpendicular to the axis of the torso (‘figure 3 b’).

End-users body measurements were obtained using both methods, for the contact method using measuring tape and anthropometer, but for the noncontact method using 3D anthropometrical scanner Vitus Smart XXL® (©Human Solutions GmbH and VITRONIC GmbH) with data processing system AnthroScan. Scanning measurements include 153 different body measurements, whereas the control measurements of chest girths were made manually. The research deals with the comparison of the both 3D and conventional manual chest girths by analyzing measurement differences.

Chest horizontal circumferences (gained manually and by 3D scanning) analysed for a separate group comprised of 22 men. For the pilot-experiment manual measurement precision, horizontal line (transversal plane at the level of bust points) is marked by placing additional measuring points on the back (‘figure 4 a,b’). For more precision, the measurements were taken by two persons, one of which provides stable positioning of the measuring tape on the front, while the other – on back (‘figure 4 c’).

The postures of the subjects were analyzed, by determining stature indicators (Ks). For the calculation of the body position, the differences between two body measurements of the 3D scanning system, namely, the ‘Distance 7CV’ (7CV - the vertebra prominent) and the ‘Distance scapula to vertical’ were used. The type of the profile identified by calculating the deviation of the individual body position from the standard numerical value.

5. Results
The comparison of both the 3D and manual chest girths shows that, in the case of the horizontal girth, the differences from the manual chest girth vary from -3.9 to 8.8 cm (the average difference 1.8 cm), while from those of the girth perpendicular to the axis – from -5.4 to 6.1 cm (the average difference 0.4 cm). After having grouped the differences (‘figure 5’) with the frequency of 1 cm, it could be concluded,
that the chest girth perpendicular to the axis of the torso is closer to the manually obtained chest girth, mostly exceeding the value by 0 to 1 cm. However, in the great majority of cases, the 3D horizontal chest girth difference from the manual chest girth is about 2 to 3 cm larger, which, in turn, confirms the assumption that, if during the manual measurement no additional body markers are used, the obtained measurement will not be the horizontal chest girth, but rather a measurement perpendicular to the axis of the torso.

Figure 5. 3D chest girth (both) differences from manual chest girth.

As for both types of 3D chest girth (horizontal and perpendicular to the axis of the torso), the frequency of occurrence was determined by selecting the chest girth intervals by means of the tables of control measurements of producer's jackets to be used for the sizing. The obtained distribution (the chart in ‘figure 6’), indicates that the sizes of the garments to be produced or provided tend to differ from the selected chest girth type, which is either horizontal or perpendicular to the axis of the torso.

Figure 6. Jacket size distribution by two 3D chest girths.

As a result of a pilot experiment, it is observed that, compared with the manually measured chest circumference, the horizontally marked chest circumference values are less distinct from the 3D scan target when the difference varies from -2.7 to 5.1 cm. However, it is necessary to increase the research group so that it is possible to exclude erroneous measurements and to find reasonable regularities with other human body measurements.

It was concluded that soldiers within the target group mostly have a normal stature or body position. However, to great extent, the occurrence of subjects with stately and stooped posture can be observed. No correlation between the stature indicator (Ks) and differences between both 3D chest girths and manual chest girths have been observed, which indicates that the stature indicators of the individuals cannot be directly used within the particular group, in order to analyze the tendencies of the changes in measurements arising from the results of 3D scanning and manual measurement as a result of change of the body position (with arms down and moved away from the body). The differences in statures within the particular group could have been affected by such factors as heredity, physical development, and influence of physical activities. As from the very moment the soldiers join the military, their everyday
activities involve carrying of heavy loads - backpacks, weapons, and equipment, which may occur in various conditions, as walking, running, overcoming barriers in different environments (meadows, forests, swamps, steep ascent areas), which, in turn, may contribute to the change in the posture, as the center of gravity needs to be shifted. On many occasions, changes in the posture are associated with person's age and ageing impacts. Given that the target group is comprised of men aged 19 to 52, the regularities between the age and body condition were analysed; however, no correlation between the age and stature of the subjects has been observed.

6. Conclusions
By manual anthropometric methods is hard (nearly impossible) to measure precise transversal measurement. By usage of human body laser scanning method, the transversal measurement is obtained precisely, therefore it is larger than manually measured. In the cases of the unique body measurement value is close to the boundary of the range of measurements, it causes problems with appropriate size choosing for individual wearer.

The comparison of the 3D and manual chest girths, as well as the analysis of the results within the particular group confirm the assumption that the manual chest girth would be closer to the chest girth perpendicular to the axis of the torso, rather than the horizontal chest girth, this being affirmed by smaller occurring differences.

The occurrence of chest girth differences as a result of the change of the position may be influenced by many different factors - in a way, the aforementioned posture, the amount of soft tissue, the impact on the body area to be measured, as well as the development of the muscles of the thorax, breathing indicators, the precision of measuring tools and skills of the person taking the measurements, the individual behavioral of the person to be measured, and the ability to precisely follow the given instructions, etc.

Acknowledgments
This research work was partially financed by the European Union’s European Regional Development Fund, through the INTERREG BSR Programme, which awarded a grant to the SWW project (#R006). The authors gratefully acknowledge the received financial support.

References
[1] EN 13402-3:2017 (standard) Size designation of clothes - Part 3: Size labelling based on body measurements and intervals
[2] EN ISO 13688:2013 Protective clothing - General requirements
[3] Конопальцева Н М, Волкова Е Ю, Крылова И Ю 2014 Антропометрия индивидуального потребителя. Основы прикладной антропологии и биомеханики: лабораторный практикум (Москва, ФОРУМ-ИНФРА-М) 256 с
[4] Song G 2011 Improving comfort in clothing (Woodhead Publishing Limited) p 496
[5] Шершнева Л П, Пиряева Т В, Ларкина Л В 2004 Основы прикладной антропологии и биомеханики (Москва, ФОРУМ-ИНФРА-М) 144 с
[6] Cohen B J, Hull K 2016 Memmler’s structure and function of the human body (Wolters Kluwer) 11th edition p 512
[7] “The human body”. An illustrated guide to your body and how it works 2017 ed P Abrahams, (London: Amber Books Ltd) pp 68-103
[8] Коблякова Е В, Куршакова Ю С, Зенкевич П И, Дунаевская Т Н 1974 Размерная типология населения стран – членов СЭВ (, Москва: Легкая промышленность) 440 с