3D IMAGES AND PROPORTIONALITY OF THE HUMAN BODY

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Abstract

Aim of this article is to highlight principles of proportionality and proportionality assessment of the human body on the basis of 3D digital image obtained by scanning the surface of the human body. Measurements made on the figure in digital form based on the principles applied in the standard CSN 80 0090 and octo-segmentation of the body height. The results of measurements realized on a group of thirty young women express the statistical characteristics, correlation and normal Gaussian distribution together with a graphical representation. Research has shown that the octo-segmentation can be used for clothing purposes only indicatively. In the plains eighth division it is not possible to measure the perimeter dimensions because it does not match the anatomical points on the body and the results would affect a standardized typology of characters. However, it can be oriented for creating clothes with ideal proportions of the human body, but also artists, designers and specialists.

Introduction

Proportions are one of the basic structural principles that are important for organizing elements in an image and they are accentuated in all areas of arts – in painting, photography, music, literature, architecture and others, in this case, clothing.

Proportions express the ratio of body parts to the body as a whole. Proportions may be individually different. They may differ by gender, age or race.

Scientists are interested in finding body proportions on a large number of individuals so that they can find total average values in a population or average values of certain types. They express these individual average values by absolute numbers or relative numbers, i.e. compare them mutually and determine the so-called indices.

While artists are not looking for an average figure but mainly a figure that complies with certain aesthetic requirements and they transfer proportions of such figures into their work [1].

The proportions of the human body can differ according to gender, age or, for example, race and they are influenced by many factors. Some of them can be influenced, some cannot. Examples of factors that cannot be influenced are genetics and skeleton structure. Among the factors that can be influenced, there are, for example, the degrees of muscular and fat tissues. A disease can cause a change in body weight and it is closely connected with the change of the girth proportions due to gaining or losing weight, or with a growth disorder, which is related to the figure's height.

The formula by which the size of individual human body parts are determined by multiplication or division of a module is called a "canon". In history, large numbers of canons were devised which differed depending on the concept of human beauty in a given period.

1 Use of canons when determining proportions

G. Bammes applied years of experience and constructed a canon of height, width and depth proportions separately for men and women. He used head height, which is 1/8 of the body height, as a module. J. Kollmann and A. Zeissing used head height, which is contained 8 times in the figure height as a canon too. A. Zeissing declared the rule of the golden ratio to be the law of proportionality. Mark Barr first used the symbol (φ) to indicate the golden ratio, in honour of the Greek sculptor Phidias. [2]. Figure 1 illustrates the geometric relationship [2]. Expressed algebraically:

$$\frac{a+b}{a} = \frac{a}{b} = \varphi \tag{1}$$

where (φ) represents the golden ratio. Its value is:

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.6180339887... \tag{2}$$
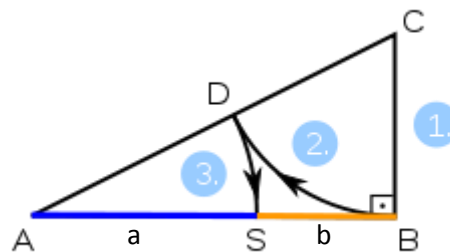

Source: Own based on [2]
Fig. 1: *Dividing a line segment according to the golden ratio*

The golden ratio, according to Zeissing, applies for all parts of the body (even for extremities), so the length of the arm compared to length of the forearm including the hand is in the same proportion as the forearm with the hand compared to the length of the whole upper extremity [1].

Because industrial production makes its products for unknown customers, it needs to know in what dimensions and sizes the products should be manufactured. In this regard, cooperation of anthropologists with light industrial production is necessary; such cooperation necessitates study and knowledge of our population in terms of age groups and their shape, dimensional and proportional specifics.

2 Experimental Part

This research is focused on a non-contact method of scanning the human body surface by the system MaNescan. The MaNescan body scanner Figure 2a) utilizes 2D active triangulation. The active component of the system is a class II laser beam. The system consists of the object of calibration, a turntable controlled by a stepper motor and a shoulder rack with a sensor (digital camera and laser) fastened on the shoulders. The surface of the human body is scanned in a dark room of 3x4m. The system was developed at the Technical University in Liberec Clothing Department [3].
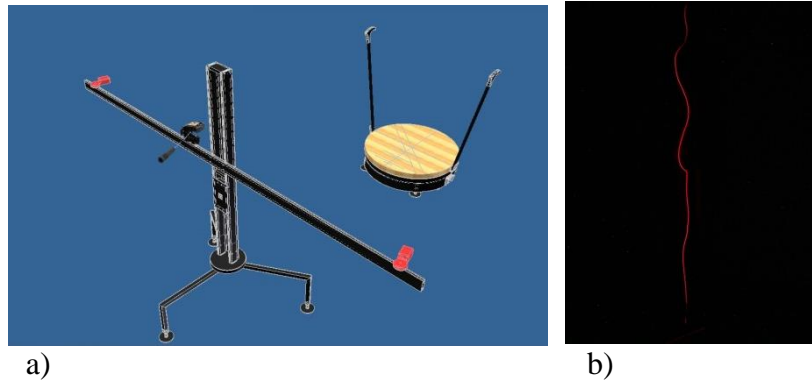
Fig. 2: *a) Diagram of the workplace for scanning human body surface, b) Example of an image of a line scanned on figure*

Scanning is conducted on figures standing barefoot on the turntable in minimal clothing of pale colour, i.e. women and girls in knickers and a bra and men and children in underpants (briefs), with goggles and a pale head covering. The scanned images record the contour of the incident laser beam on the figure in Figure 2b), that is the contour of the silhouette of the figure at a particular angle of rotation on the turntable. The resulting scanned images are processed using Matlab, Excel, or Mit_MaNescan software – the output is 3D coordinates, which are loaded into the CATIA 3D program, where the figures are measured using software tools.

2.1   Determining height dimensions

A non-contact investigation was carried out on a set of thirty young women aged 21 to 28 years. The measuring of these women's figures in 3D digital form was carried out in the program CATIA as follows:

- in positions passing through somatometric points on the body according to standard (ČSN 80 0090) [4]; Figure 3a), 3b)

- in positions of octo-segmentation of the figure height, that is, as if the body height were segmented equally into 8 parts; Figure 3c)
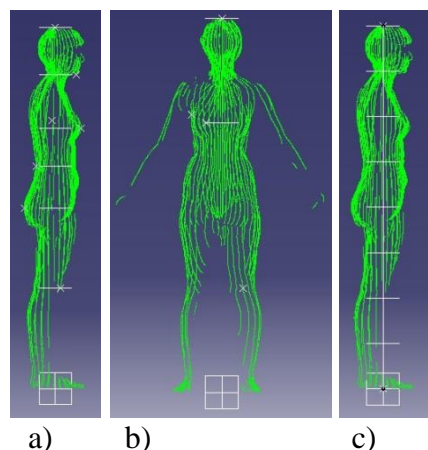
Fig. 3: *Images of somatometric points on the body – the side view a), front view b), display planes on the body, breakdown of body height into eight parts c)*

The monitored dimensions are height dimensions figure height (Fh) [4], head height (Hh) - height from a point (vertex) to a point (gnathion) [5], height of the front armpit point (Ah),

breast point height (Bh), height rear waist point (Wh), sitting point height (Sh), height knee point (Kh), waist girth (Wg), sitting point girth (Sg) and chest girth (Chg) [4]. Dimensions Fh, Ah, Bh, Wh, Sh, Kh are height dimensions measured from the ground to the levels passing through the somatometric points on the body Figure 4a), 4b). Girth dimensions Chg, Wg, and Sg are measured in the plane at the height of the chest, waist and sitting point.

The dimensions measured from the ground to the skull in the places of octo-segmentation of the figure height are: 8/8 - Fh_p=Fh, 6/8 – Ah_p, 5/8 - Wh_p, 4/8 – Sh_p, 2/8 – Kh_p and 1/8 – Hh_p Figure 4c), 4d). Girth dimensions Wg_p and Sg_p are measured in the level between levels corresponding to 5/8 and 4/8 of the figure height. The results of measuring for both variants are displayed in Figure 5.

a) b) c) d)
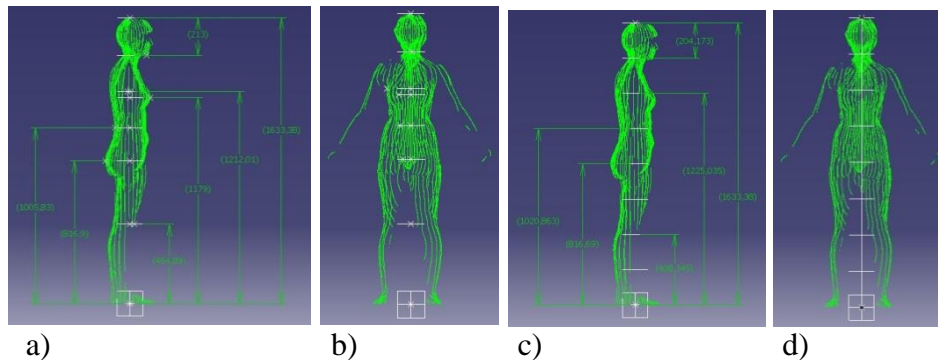
Source: Own

Fig. 4: *Image of levels and marking body dimensions – passing through somatometric points a), b); passing through places of octo-segmentation of figure height c), d)*
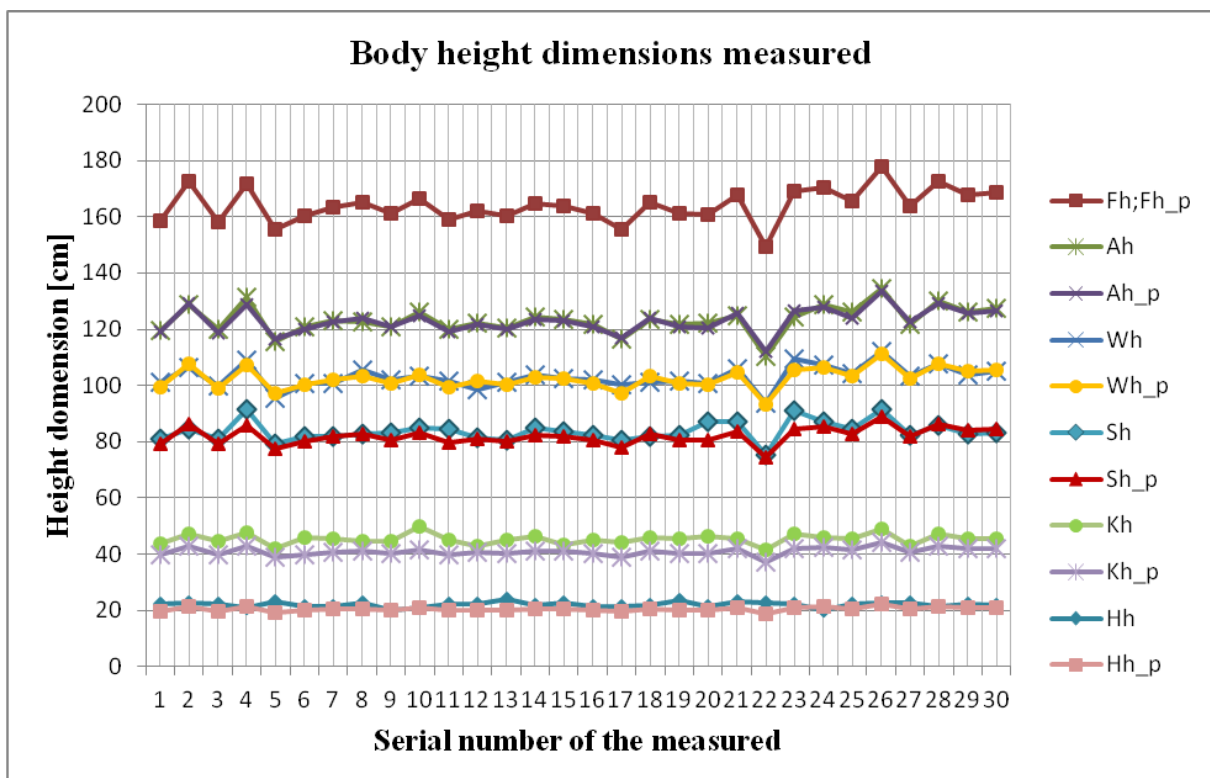
Source: Own

Fig. 5: *Chart of non-contact method of measuring body height dimensions of both variants*

From the graphic display and when comparing the results of measurement we can say: if the figure height is divided into eight equal parts, then the position of the waist height, with which

3/8 of the figure height corresponds, is almost identical to the waist height measured on the body according to the standard ČSN 80 0090 [4]. As for the dimension of the height of the armpit point, it is the same. The biggest differences when comparing both variants of measurements seem to be found at the knee and head heights. Head height should, according to afore-mentioned artists such as G. Bammes, J. Kollmann and A. Zeissing, fit into the figure height eight times.

If we take an average head height, which is, based on our calculations, 22.09 cm, then the overall height of the figure should be 176.8 cm. In our case, the real average figure height is equals to 164cm. The difference between figure height determined by multiplying the head height by eight and the average height is +12.8 cm. Out of thirty people examined persons, the head height approximately corresponds to approximately 1/8 of the body height and the waist height to 5/8 of the body height in only three cases.

2.2   Determining perimeter dimensions

The girth dimensions were measured according to the standard, monitored for girth of chest, waist and sitting point at the levels passing through the respective somatometric points on the body, Figure 6. With octo-segmentation, the girths were measured at the levels corresponding to 5/8 of the figure height, i.e. waist height and 4/8 of figure height, i.e. height of sitting point, Figure 6. The results of measuring the girth dimensions of both variants of the waist, and sitting point and chest are shown in Figure 7.
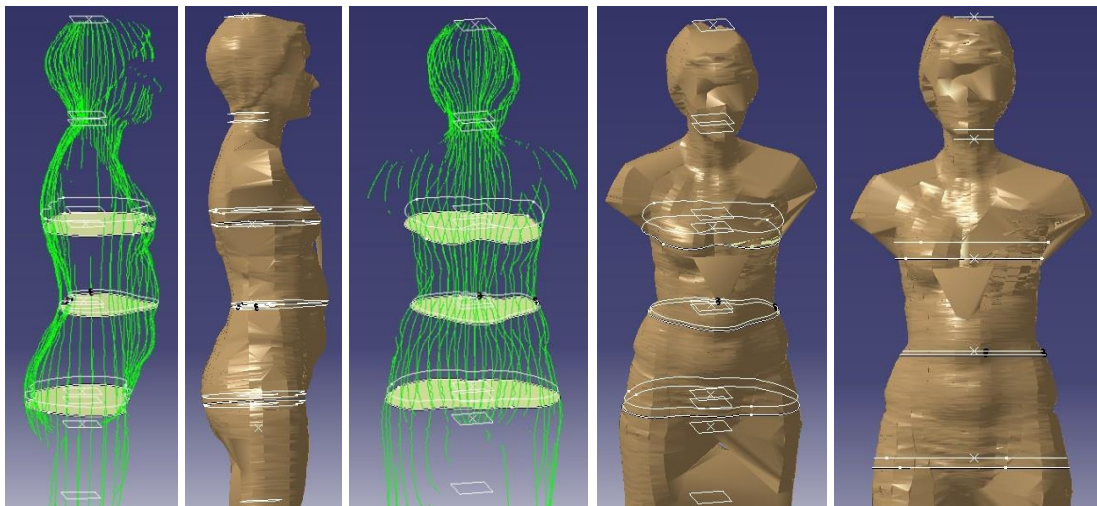
Source: Own

Fig. 6: *Image of places of girth dimensions measurements by both methods – levels passing through somatometric points are marked by a cross*
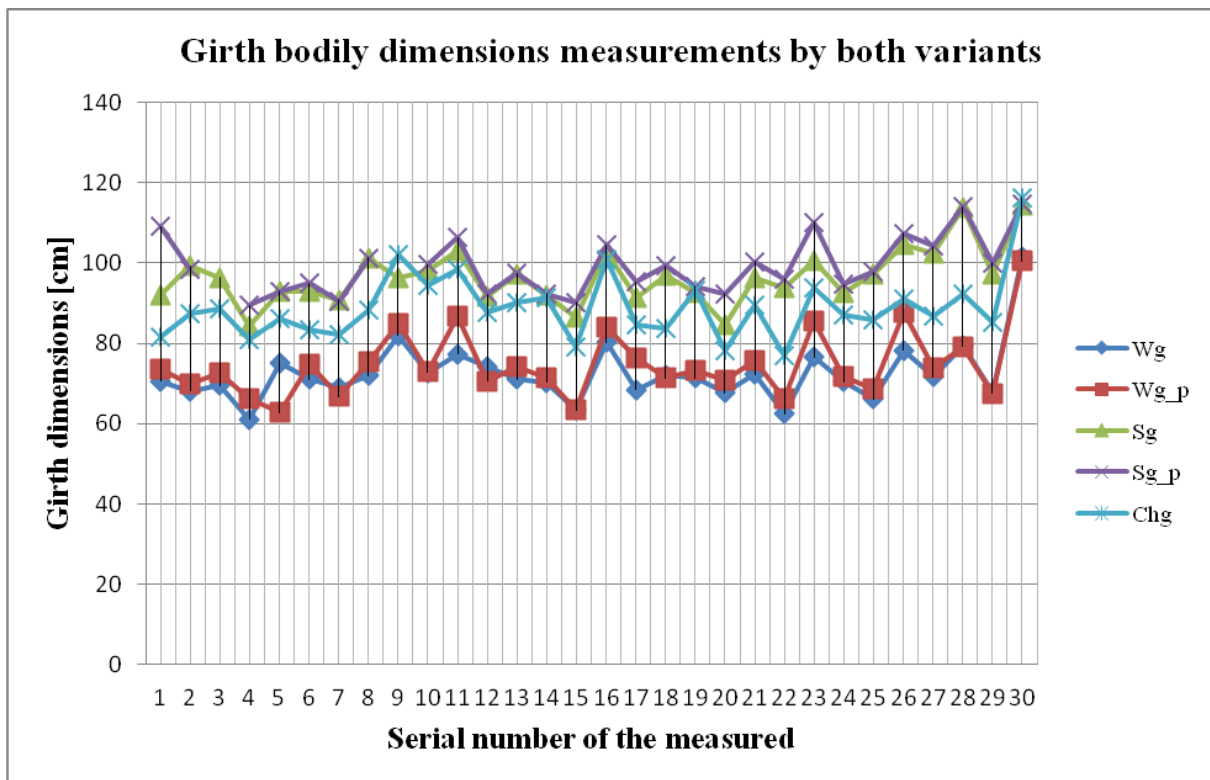
Source: Own

Fig. 7: *Chart of non-contact method of girth body dimensions measurements by both methods – Wg, Wg_p, Sg, Sg_p and Chg*

Girths identified at levels of octo-segmentation of the body height do not pass through the places that are significant for taking measurements for clothes. It is most evident in Picture 7 showing the waist and sitting point girths.

The eighth thoracic division cannot be used to determine a plane that would go through the breast point, needed to determine the circumference of the chest.

Here we can state that proportional octo-segmentation was established many years ago and development, growth and proportions of the body are a little different today. This is caused for example by changes in lifestyle, social conditions, external influences and so on. It is known that body height is generally higher than in the days of Zeissing. This results in the differences which we observed when performing and evaluating the research.

## 3   Evaluation of measurements

The evaluation of measurement was conducted by calculating the statistical characteristics, correlation and normal (or Gaussian) probability distribution. The degree of dependence of the measured data and tightness of linear constraints between variables can be seen in Figure 8. The correlation coefficient R can take values from -1 to +1. The square of the correlation coefficient R^2 is called the coefficient of determination and takes values from 0 to +1. Normal distribution is unequivocally determined by the mean and variance, which are the parameters. Normal distribution is a single-peak distribution symmetrical about the mean, marked μ. The mean of this distribution is equal to the mode and median. The probability density has a bell shape – it reaches its maximum value in the middle. The random variable X, which is governed by this division, can take values from –A to +A. "The end" of this distribution looks as if it touches the x-axis, but it never actually does. The random variable follows a normal distribution with parameters μ and s^2, $X \sim N(\mu, s^2)$ [6]. Figures 9 to 13 show

the normal distribution of heights and dimensions, while Figures 14 and 15 show the circumferential dimensions measured in two ways.
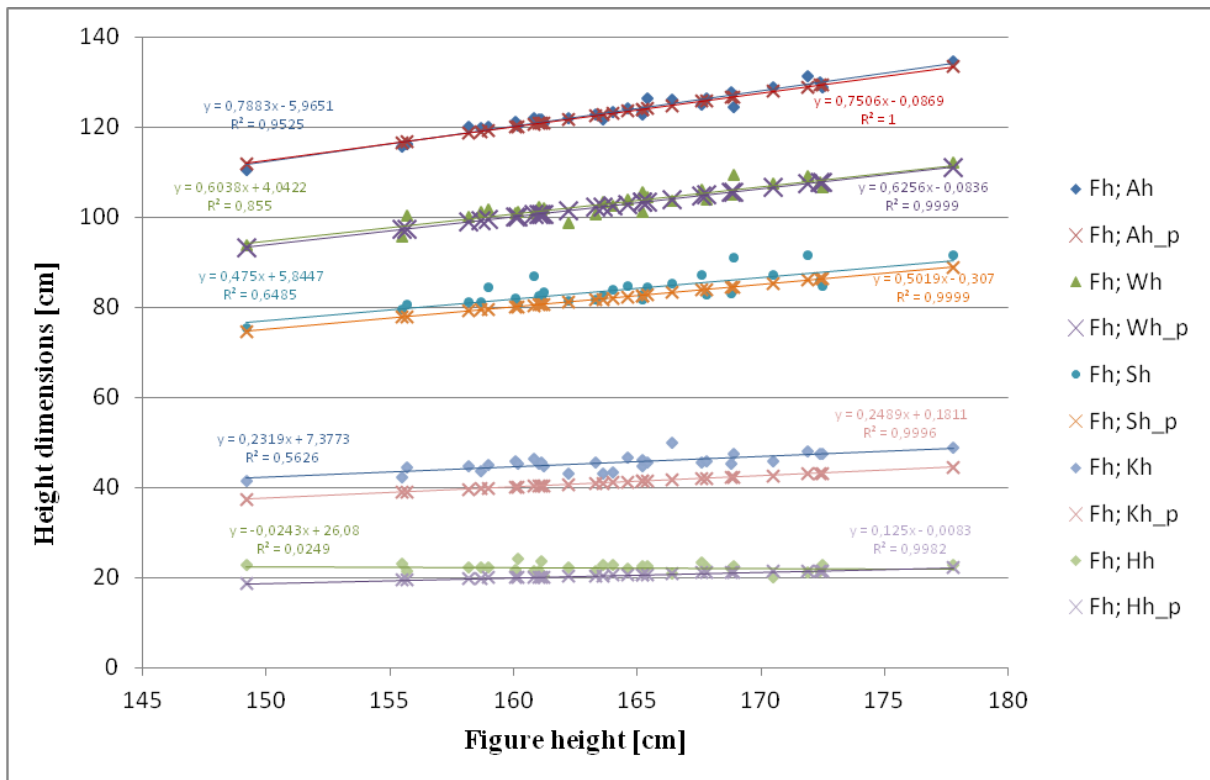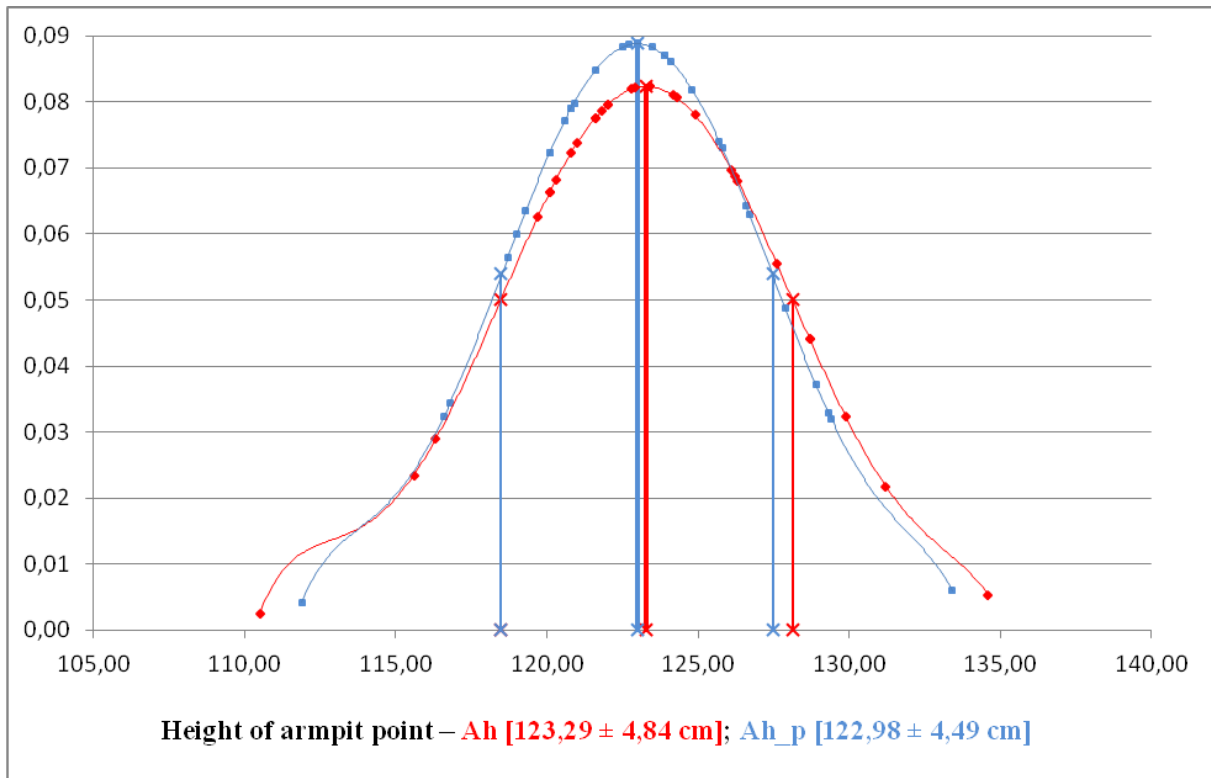
Fig. 8: *Graph of the Correlation of figure height and height dimensions - by both methods*
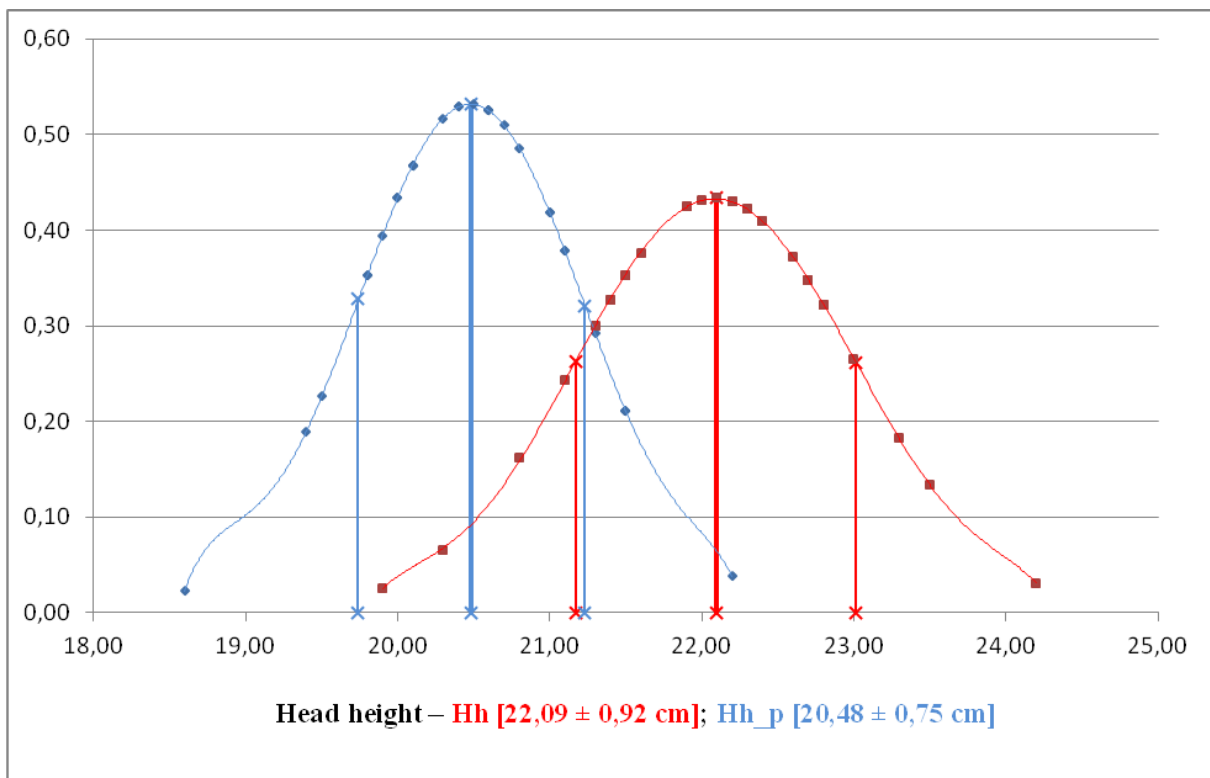
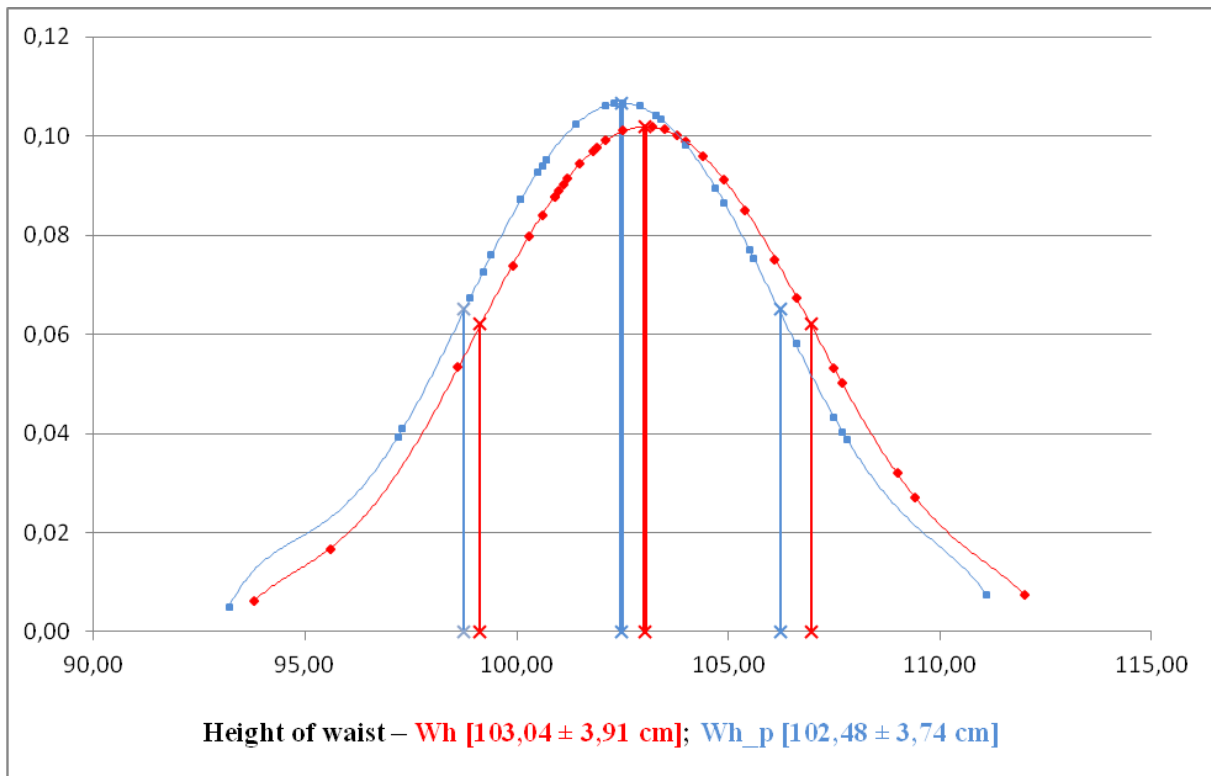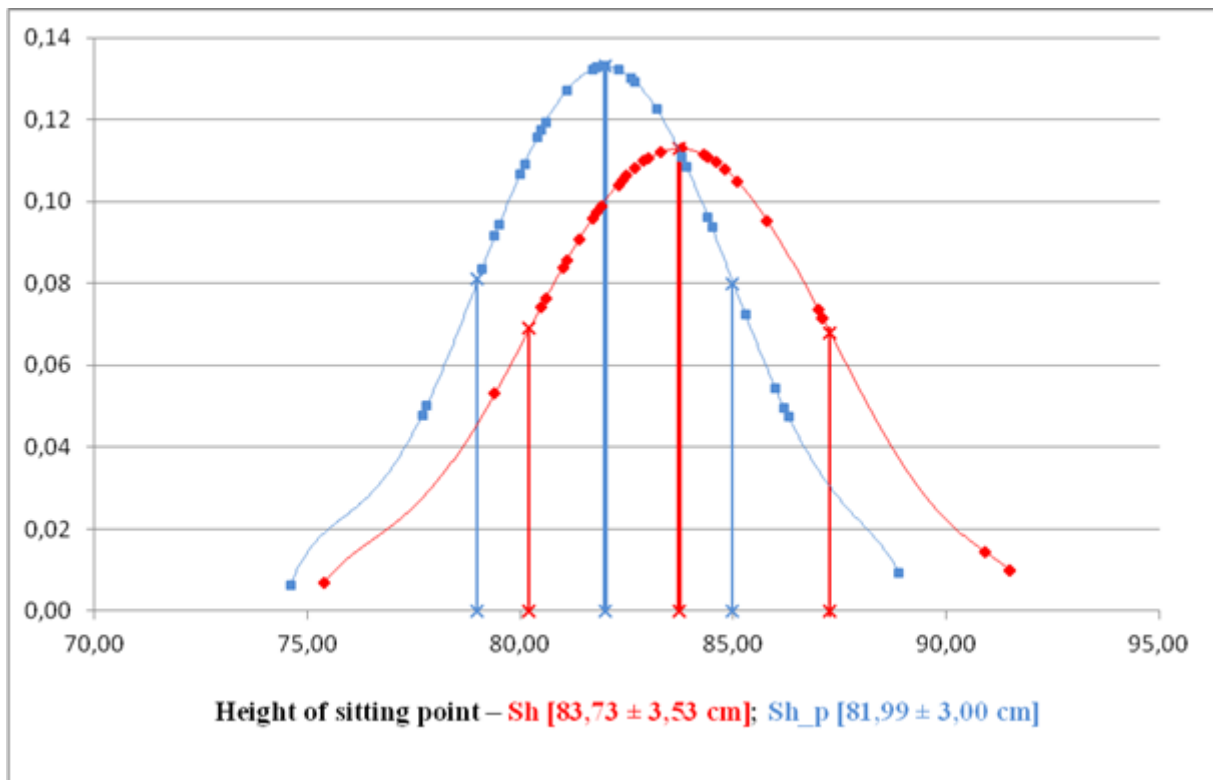**Fig. 9:** *Graph of the normal division for Head height – Hh, Hh_p*

Height of armpit point – Ah [123,29 ± 4,84 cm]; Ah_p [122,98 ± 4,49 cm]

Fig. 10: *Graph of the normal division for Height of armpit point – Ah, Ah_p*

Height of waist – Wh [103,04 ± 3,91 cm]; Wh_p [102,48 ± 3,74 cm]

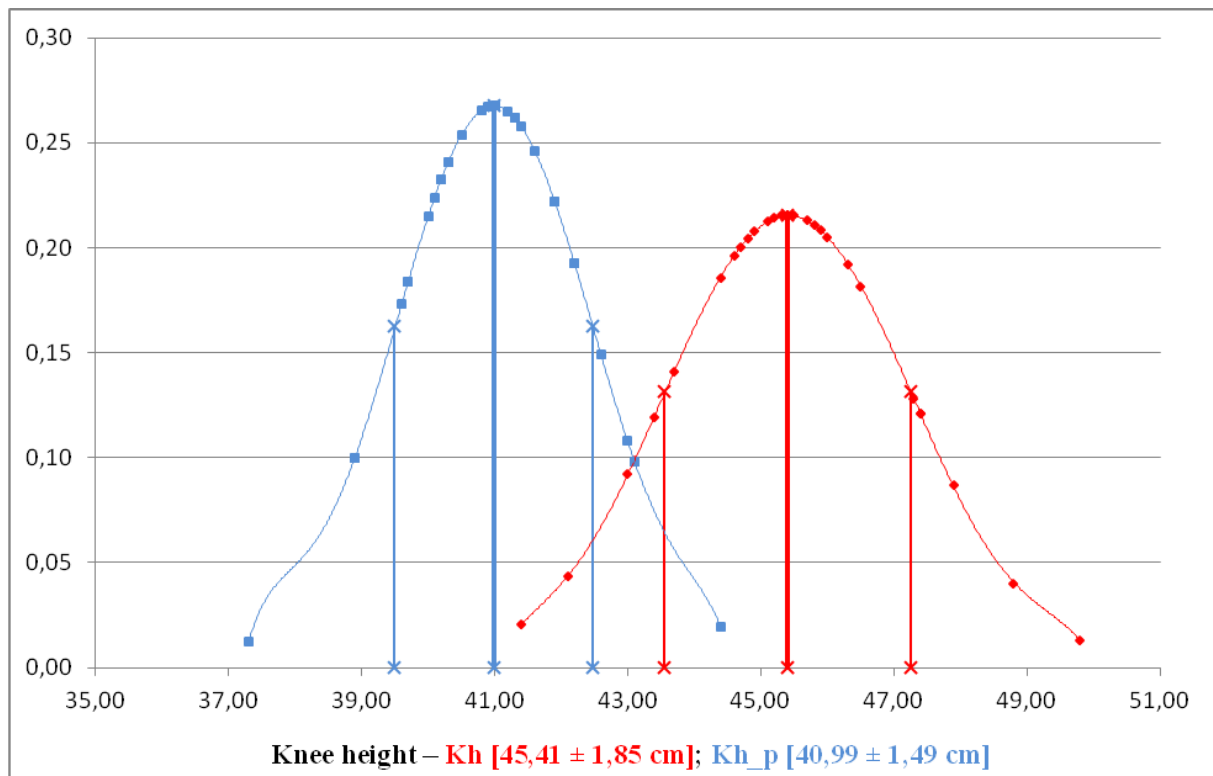**Fig. 11:** *Graph of the normal division for Height of waist – Wh, Wh_p*

Fig. 12: *Graph of normal division for Height of sitting point – Sh, Sh_p*

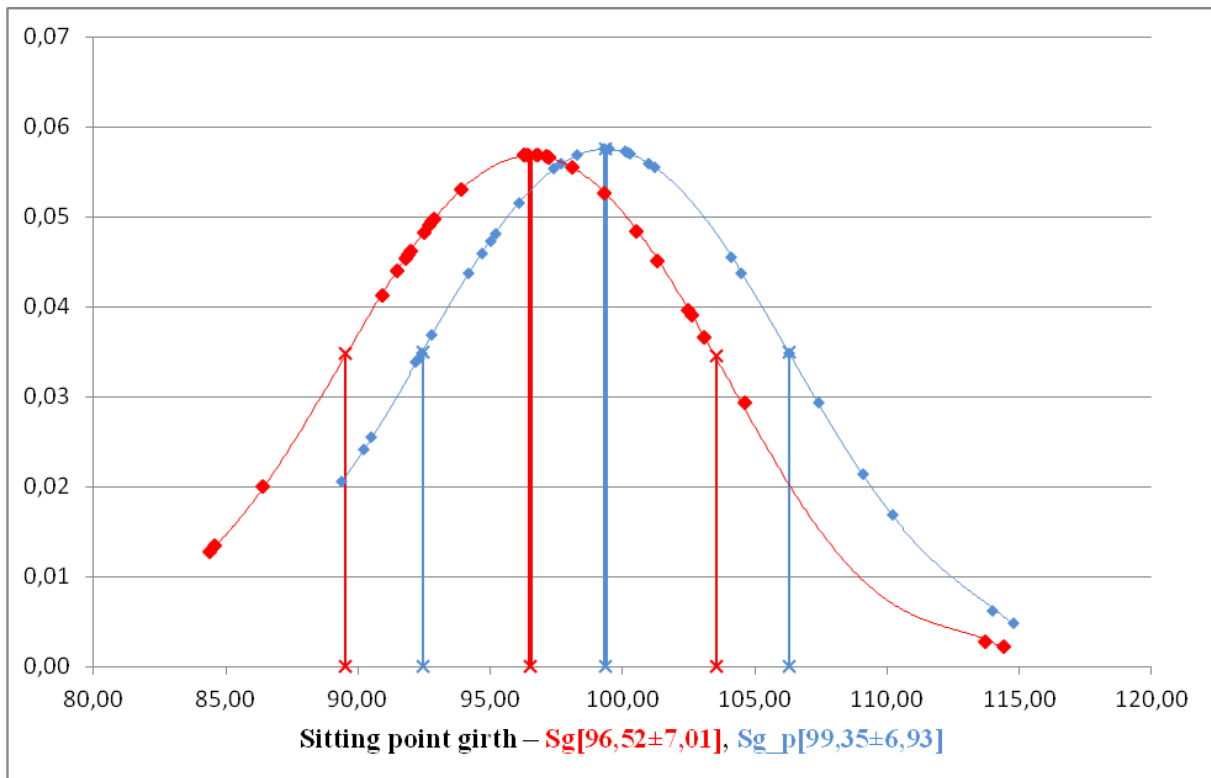**Fig. 13:** *Graph of the normal division for Knee height – Kh, Kh_p*
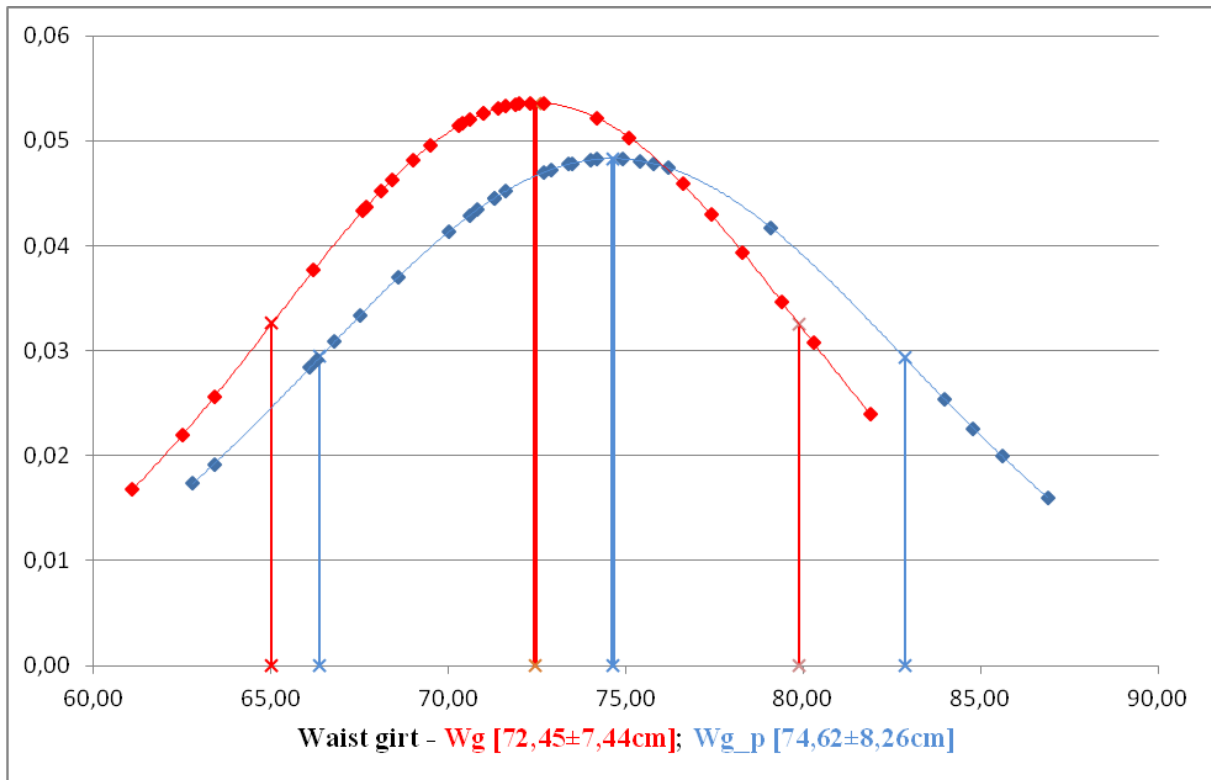
Fig. 14: *Graph of the normal division for Waist girth – Wg, Wg_p*

Fig. 15: *Graph of the normal division for Sitting point girth – Sg, Sg_p*

The normal division for height – Fh [163.97 ± 5.99 cm]; the normal division for Chest girth – Chg [88.92 ± 8.07 cm].

The proportions are used for assessing the size and arrangement of the figure.

Ideal proportions correspond to the mean values of individual body parts obtained using the statistical method. The creators of the objects can follow the above-mentioned range of normal distribution with parameters μ and s^2 resulting from both methods of non-contact measurement of body size. Octo-segmentation of the human body is especially useful in the creation of art. Circumferential dimensions cannot be measured in the planes of octo-segmentation for clothing purposes. These are located above or below:

- the anatomic waist on the body,

- the most prominent point of the seat,

and the 6/8 plane does not pass through the anatomic point necessary for measuring chest girth, but through the height of the armpit point. The 7/8 plane is, in most cases, higher than the lowest point of the chin (gnathion). Octo-segmentation can therefore be used as a rough guide for the creation of technical drawings and models of clothing and their components and the creation of the design documentation of clothes with the aim of approximating the ideal proportions of the human body, and consequently optically extend, shorten, broaden, narrow this figure and its parts.

Conclusion

The advantages of digitally displaying the measured figure are that it allows the viewing of a figure from various angles and it allows an easy return to a 3D picture of the measured figure with the possibility to amend the measurement with new dimensions. Additionally, it reveals the posture and body proportions, which the designer can project into data for clothes making clothes. Thanks to the digital picture gained via the non-contact method, all variations in the proportions and the body posture can be found. These findings can be used to influence the design, modelling and segmentation of clothes, leading to the right choice of textile material and its colour and pattern, so that any variation or deviation found can be visually corrected and the desired proportions and outline of the clothes achieved.

Literature

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3D OBRAZ A PROPORCIONALITA LIDSKÉHO TĚLA

Cílem článku je poukázat na principy proporcionality a posouzení proporcionality lidského těla na základě 3D digitálního obrazu získaného scanováním povrchu lidského těla. Měření prováděné na postavě v digitální podobě vychází z principů uplatňovaných v normě ČSN 80 0090 a z osminového členění výšky postavy. Výsledky měření uskutečněné na souboru 30 mladých žen vyjadřují statistické charakteristiky, korelace a normální Gaussovo rozdělení doplněné grafickým vyobrazením. Výzkum ukázal, že osminové členění lze použít pro oděvní účely spíše orientačně. V rovinách osminového členění není možné měřit obvodové rozměry, neboť anatomicky neodpovídají místům na těle a jejich výsledky by ovlivnily standardizaci a rozměrovou typologii postav. Mohou však být orientací pro tvorbu oděvu s ideálními proporcemi lidského těla, ale i umělce, designéry a specialisty.

3D-BILD UND PROPORTIONALITÄT DES MENSCHLICHEN KÖRPERS

Der Artikel beschäftigt sich mit den Prinzipien der Proportionalität und der Bewertung der Proportionalität des menschlichen Körpers auf Grundlage eines 3D-Bildes, das durch Scannen der Oberfläche des menschlichen Körpers entstand. Die in digitaler Form an einer Figur durchgeführte Messung geht von den in der Norm ČSN 80 0090 angewandten Prinzipien und der Achtelgliederung der Körperhöhe aus. Die Ergebnisse der an 30 jungen Frauen durchgeführten Messungen geben Auskunft über die statistische Charakteristiken, die Zusammenhänge und die normale Gaußsche Gliederung, ergänzt um graphische Abbildungen. Die Forschung zeigte, dass die Achtelgliederung für Bekleidungszwecke eher orientierungsmäßig angewendet werden kann. Es nicht möglich, die Umfangmaße in den Ebenen der Achtelgliederung zu messen, da sie anatomisch nicht den Stellen am Körper entsprechen und ihre Ergebnisse die standardisierte Typologie der Figuren beeinflussen würden. Sie können jedoch eine Orientierung für die Bekleidungsfertigung mit idealen Proportionen des menschlichen Körpers sowie für Künstler, Designer und Spezialisten sein.

OBRAZ 3D A PROPORCJONALNOŚĆ LUDZKIEGO CIAŁA

Celem artykułu jest zwrócenie uwagi na zasady pproporcjonalności i analizy proporcji ludzkiego ciała na podstawie cyfrowego obrazu 3D, uzyskanego w wyniku skanowania powierzchni ludzkiego ciała. Pomiary sylwetki przeprowadzane cyfrowo opierają się o zasady podane w normie ČSN 80 0090 oraz podział wysokościowy na 8 części. Wyniki pomiarów przeprowadzonych na grupie 30 młodych kobiet wyrażają charakterystyki statystyczne, korelacje i normalny rozkład Gaussa, uzupełnione wyobrażeniem graficznym. Badania pokazały, że podziału na 8 części można użyć do celów odzieżowych raczej orientacyjnie. W płaszczyznach podziału ósemkowego nie można mierzyć rozmiarów obwodowych, ponieważ anatomicznie nie odpowiadają miejscom na ciele a ich wyniki wpłynęłyby na standaryzowaną typologię sylwetek. Mogą jednak służyć jako orientacyjne do tworzenia odzieży z idealnymi proporcjami ciała ludzkiego, oraz dla artystów, designerów i specjalistów.