

# Anthropometric Variability of the Male Population as a Basis for Developing Clothing Size Systems

## Antropometrijska varijabilnost muške populacije kao osnova za razvoj sustava odjevnih veličina

*Scientific paper / Znanstveni rad*

**Ksenija Doležal\*, Renata Hrženjak**

University of Zagreb, Faculty of Textile Technology, Department of Clothing Technology, Prilaz baruna Filipovića 28a, Zagreb, Croatia

\*Correspondence: ksenija.dolezal@tff.unizg.hr

### Abstract

This study investigates the variability of anthropometric characteristics in the male population and their impact on clothing size systems. The analysis is based on a sample of 937 adult males from the Republic of Croatia, focusing on age- and region-related differences in body height and chest girth. Descriptive statistical methods were employed to assess the distribution and relationships among variables. The results indicate significant variability in body dimensions influenced by age and regional factors. Body height decreases with increasing age, while chest girth increases up to middle age, then declines slightly. The study was conducted on a sample from one region of the Republic of Croatia, and the results were compared with data for the overall male population of Croatia. Regional differences are evident across all age groups, particularly in body height. The findings confirm the limitations of existing clothing size systems, which do not fully reflect the diversity of body proportions. The results emphasise the importance of research at the subpopulation level and the need to develop more adaptable, population-specific sizing approaches. Furthermore, integrating anthropometric data into digital garment construction systems is identified as a key step towards improving garment fit and production efficiency.

**Keywords:** Anthropometry, clothing size systems, body variability, garment fit, garment construction

### Sažetak

Ovo istraživanje analizira varijabilnost antropometrijskih obilježja muške populacije i njezin utjecaj na sustave odjevnih veličina. Analiza se temelji na uzorku od 937 odraslih muškaraca iz Republike Hrvatske, s naglaskom na dobne i regionalne razlike u tjelesnoj visini i opsegu grudi. Za analizu raspodjele i međusobnih odnosa varijabli primijenjene su metode deskriptivne statistike. Rezultati ukazuju na izraženu varijabilnost tjelesnih dimenzija pod utjecajem dobi i regionalnih čimbenika. Tjelesna visina pokazuje trend smanjenja s porastom dobi, dok opseg grudi raste do srednje životne dobi, a zatim dolazi do blagog smanjenja. Istraživanje je provedeno na uzorku ispitanika jedne regije Republike Hrvatske te je napravljena usporedba s rezultatima za ukupnu mušku populaciju RH. Regionalne razlike prisutne su u svim dobnim skupinama, osobito u tjelesnoj visini. Dobiveni rezultati potvrđuju ograničenja postojećih sustava odjevnih veličina koji ne odražavaju u potpunosti raznolikost tjelesnih proporcija te je važno provoditi istraživanja i na subpopulacijskoj razini. Ističe se potreba za razvojem prilagodljivijih i populacijski specifičnih pristupa određivanju veličina, kao i integracijom antropometrijskih podataka u digitalne sustave konstrukcije odjeće.

**Ključne riječi:** Antropometrija, odjevne veličine, tjelesna varijabilnost, pristalost odjeće, konstrukcija odjeće

## 1. Introduction

In modern industrial clothing production, a key market requirement is to ensure optimal garment fit for various body shapes and proportions of users [1]. Proper garment fit directly affects functionality, aesthetic value, and user satisfaction; therefore, accurate definition of anthropometric measurements forms the foundation for pattern construction, size standardisation, and increased efficiency in production processes [1,2]. Moreover, the development of modern technologies and digital tools underscores the need for reliable and representative anthropometric data [3,4]. Anthropometric research provides detailed insight into the variability of body dimensions within a population, where age, sex, regional affiliation, and lifestyle significantly influence body proportions [1,5]. Changes in body dimensions throughout the life cycle, as well as differences between subpopulations, are important factors in developing effective clothing size systems [6]. However, traditional sizing systems

are often based on a limited number of measurements and simplified proportional relationships, which do not fully account for population variability. This approach may result in poor garment fit, increased need for alterations, and reduced user satisfaction [1,7].

The aim of this study is to analyse the variability of body height and chest girth in the male population and to assess their implications for existing clothing size systems. The research is based on a sample of subjects from the Republic of Croatia, with particular emphasis on the influence of age and regional factors on the observed anthropometric variables. Based on the collected data and selected body dimensions, categories were defined according to height ranges and chest girth, in accordance with relevant standards (ISO 8559-1, EN 13402), enabling comparison with existing sizing systems [8,9].

The results provide a basis for improving existing clothing size systems and developing more adaptable, population-specific models that better

reflect the actual body characteristics of users [10,11]. This also opens the possibility of applying the results in digital garment construction systems, including CAD technologies, contributing to the optimisation of design and production processes, reduction of errors, and improvement of the quality and competitiveness of clothing products in the market [4,12]. Although a wider range of anthropometric measurements is typically used to define clothing size systems, body height and chest girth were chosen as the basic parameters, that is, the main primary body measurements in existing standardised sizing systems, because of their significant influence on garment construction. This also represents a limitation of the study, which should be addressed in future research.

## 2. Experimental part

### 2.1. Materials and Methods

The measurements required for this study are part of a cross-sectional study conducted in the Republic of Croatia from 2005 to 2007, during which 30,866 participants were measured. For this research, a subsample of 937 adult males from the Goransko-Primorska region was selected. As height categories and chest girth classes had already been defined based on measurements of all adult males included in the study, the aim was to further investigate and determine differences at the subpopulation level [13]. Measurements were carried out using conventional methods in accordance with ISO 8559-1 and EN 13402 standards, employing anthropometric instruments: an anthropometer for determining body height and a flexible anthropometric tape for measuring chest girth. The subjects were divided into age groups, and the analysis was conducted at the regional level (Goransko-Primorska region). Data on body height and chest girth were collected as primary anthropometric measurements relevant to garment construction. For comparison, reference data for the overall male population of the Republic of Croatia were used. Descriptive statistical methods were applied for data analysis, including arithmetic mean, standard deviation, and coefficient of variation [14,15]. Differences between age groups and regions were analysed using graphical and tabular representations.

## 3. Results and Discussion

Estimates of the basic statistical parameters of body height distribution by age group in the Goransko-Primorska region are presented in Table 1.

The results show that the mean body height of the subjects is 175.4 cm, with a standard deviation of 8.2 cm. The coefficient of variation is 4.7%, indicating a relatively homogeneous distribution of body height within the observed population. The 95% confidence interval ranges from 174.8 cm to 175.9 cm, suggesting high precision in the mean estimate.

The minimum recorded body height is 148 cm, while the maximum is 196 cm, confirming the presence of variability within the sample despite the relatively low coefficient of variation.

**Table 1.** Basic parameters of body height distribution of men (cm) in the Goransko-Primorska region by age group

Region	Age	N	Mean (cm)	SD
Goransko-Primorska	20-29	250	178.6	6.9
	30-39	128	178.3	7.5
	40-49	125	176.6	7.4
	50-59	108	175.2	7.1
	60-69	117	172.6	8.3
	70-79	111	171.9	9.2
	80-85	98	169.2	7.2
	<b>Total</b>	<b>937</b>	<b>175.4</b>	<b>8.2</b>

N – sample size; Mean – arithmetic mean; SD – standard deviation

Table 1(continued)

Region	CV (%)	95%CI		Range	
		h1	h2	Min	Max
Goransko-Primorska	3.9	177.7	179.4	161.0	195.0
	4.2	177.0	179.6	158.0	196.0
	4.2	175.3	177.9	150.0	196.0
	4.1	173.9	176.6	154.0	191.5
	4.8	171.1	174.1	151.5	195.0
	5.3	170.2	173.6	148.0	190.0
	4.3	167.7	170.6	156.0	188.0
	4.7	174.8	175.9	148.0	196.0

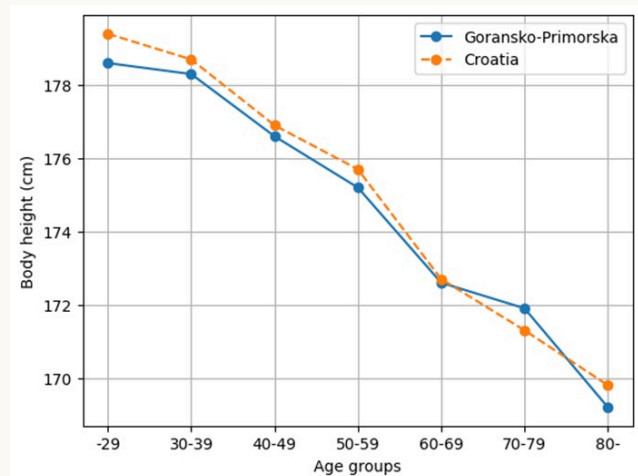
CV – coefficient of variation (%); 95% CI – 95% confidence interval; h1 and h2 – lower and upper confidence limits; Min and Max – minimum and maximum values

**Table 2.** Basic parameters of body height distribution for men (cm) in the Republic of Croatia by age group

Region	Age	N	Mean (cm)	SD	CV (%)
Republic of Croatia	20-29	1085	179.4	7.1	3.9
	30-39	575	178.7	7.1	4.0
	40-49	535	176.9	6.7	3.8
	50-59	515	175.7	7.1	4.6
	60-69	490	172.7	7.8	4.5
	70-79	469	171.3	7.9	4.6
	80-85	444	169.8	8.0	4.8
	<b>Total</b>	<b>4113</b>	<b>174.9</b>	<b>7.4</b>	<b>4.6</b>

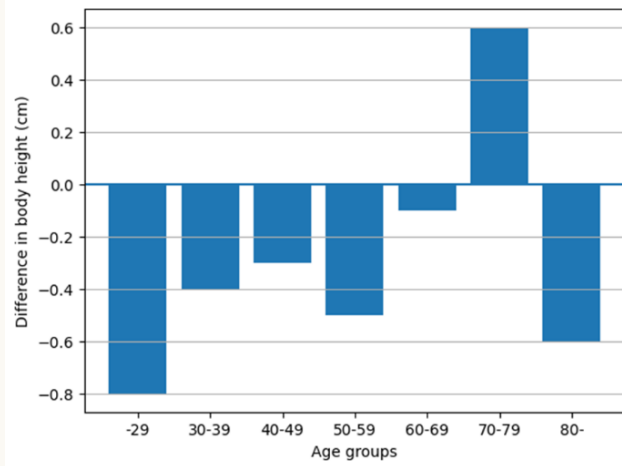
N – sample size; Mean – arithmetic mean; SD – standard deviation; CV – coefficient of variation (%)

Table 2 presents the basic statistical indicators of body height for men in the Republic of Croatia by age group. A clear trend of gradual decrease in average body height with increasing age is observed – from 179.4 cm in the youngest group (20–29 years) to 169.8 cm in the oldest group (80–85 years). The standard deviation ranges from 6.7 to 8 cm, indicating moderate variability within all age groups. The coefficient of variation (3.8–4.8%) confirms a relatively homogeneous distribution of body height in the population. The overall average body height is 174.9 cm, which serves as a reference value for the observed population.



**Figure 1.** Changes in average male body height by age group in the Goransko-Primorska region and the Republic of Croatia overall

The graph in Figure 1 shows the change in average body height across age groups for the Goransko–Primorska region and the overall population of the Republic of Croatia. In both groups, a clear trend of decreasing body height with increasing age is evident. The highest values are found in the youngest age groups, with a gradual decline continuing through the older categories. Differences between the region and the overall population are minimal across all age groups, indicating a high level of agreement and similarity in body height.



**Figure 2.** Differences in average male body height between the Goransko–Primorska region and the Republic of Croatia by age group

The graph (Figure 2) of body height differences shows deviations between the Goransko–Primorska region and the overall population of the Republic of Croatia by age group. The differences are very small and fall within a narrow range, without a pronounced systematic trend. In most age groups, the values are slightly negative, indicating a somewhat lower average body height in the region, while in some groups minimal positive deviations are observed. Overall, the results indicate a high level of similarity in body height. Furthermore, the t-test results showed that the differences in mean body height between the Goransko–Primorska region and the overall population of the Republic of Croatia are not statistically significant ( $p > 0.05$ ).

Table 3 presents the basic parameters of chest girth distribution for men in the Goransko–Primorska region by age group, while Table 4 shows the basic parameters of chest girth distribution for men in the Republic of Croatia.

**Table 3.** Basic parameters of chest girth distribution for men (cm) in the Goransko–Primorska region by age group

Region	Age	N	Mean (cm)	SD
Goransko-Primorska	20-29	250	95.7	8.5
	30-39	128	103.4	9.5
	40-49	125	105.9	8.7
	50-59	108	105.5	8.3
	60-69	117	104.9	8.8
	70-79	111	105.7	8.9
	80-85	98	105.3	7.0
	<b>Total</b>	<b>937</b>	<b>102.6</b>	<b>9.5</b>

N – sample size; Mean – arithmetic mean; SD – standard deviation

Table 3 (continued)

Region	CV (%)	95%CI		Range	
		h1	h2	Min	Max
Goransko-Primorska	8.9	94.6	96.7	75	120.5
	9.2	101.8	105.1	80	134.0
	8.2	104.4	107.5	82	128.5
	7.8	104.0	107.1	88	132.0
	8.4	103.3	106.5	78	122.0
	8.4	104.0	107.4	85	128.0
	6.6	103.9	106.7	82	119.0
	9.3	102.0	103.2	75	134.0

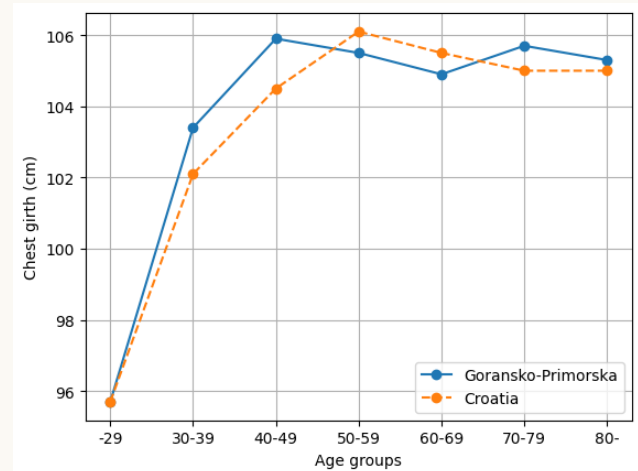
CV – coefficient of variation (%); 95% CI – 95% confidence interval; h1 and h2 – lower and upper confidence limits; Min and Max – minimum and maximum values

**Table 4.** Basic parameters of chest girth distribution for men (cm) in the Republic of Croatia by age group

Region	Age	N	Mean (cm)	SD	CV (%)
Republic of Croatia	20-29	1085	95.7	8.1	8.5
	30-39	575	102.1	8.5	8.3
	40-49	535	104.5	8.8	8.4
	50-59	515	106.1	9.0	8.4
	60-69	490	105.5	8.4	8.0
	70-79	469	105	9.0	8.6
	80-85	444	105	8.7	8.3
<b>Total</b>	<b>4113</b>	<b>103.4</b>	<b>8.6</b>	<b>8.4</b>	

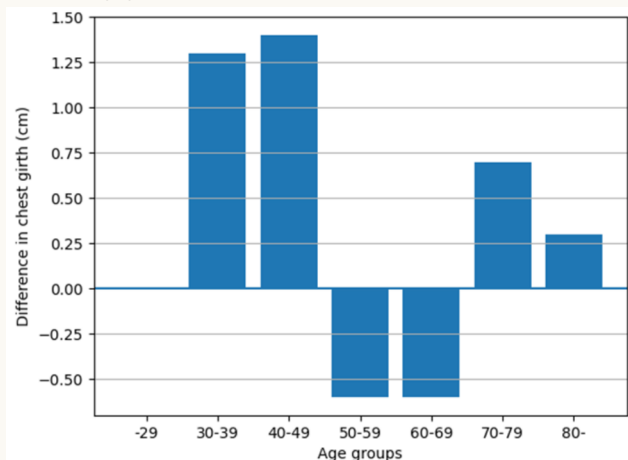
N – sample size; Mean – arithmetic mean; SD – standard deviation; CV – coefficient of variation (%)

Table 3 presents the basic statistical indicators of chest girth in men in the Republic of Croatia by age group. There is a trend of increasing average chest girth from the youngest group (95.7 cm) to middle age (106.1 cm), followed by stabilisation and a slight decrease in older age groups. The standard deviation ranges from 8.1 to 9 cm, indicating moderate variability within the population. The coefficient of variation (approximately 8–8.6%) indicates a relatively uniform distribution of chest girth. The overall average value is 103.4 cm, serving as a reference value for the observed population.



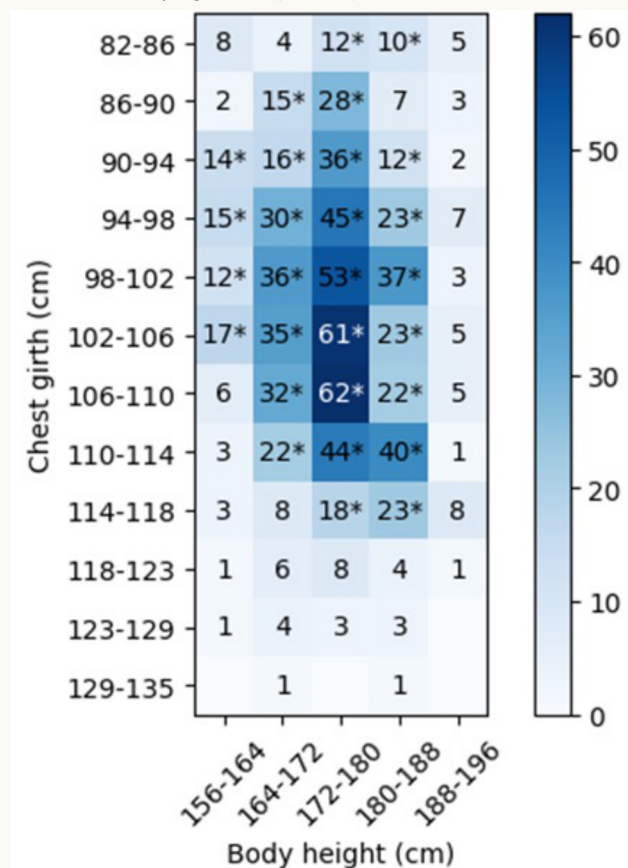
**Figure 3.** Changes in average chest girth of men by age group in the Goransko–Primorska region and in the Republic of Croatia overall

The graph shows the change in average chest girth across age groups for the Goransko–Primorska region and the overall population of the Republic of Croatia. Chest girth increases up to middle age, then stabilises or slightly decreases in older age groups. The values for both groups are very similar, with minor deviations in certain age groups, confirming the consistency of body proportions between the region and the overall population.

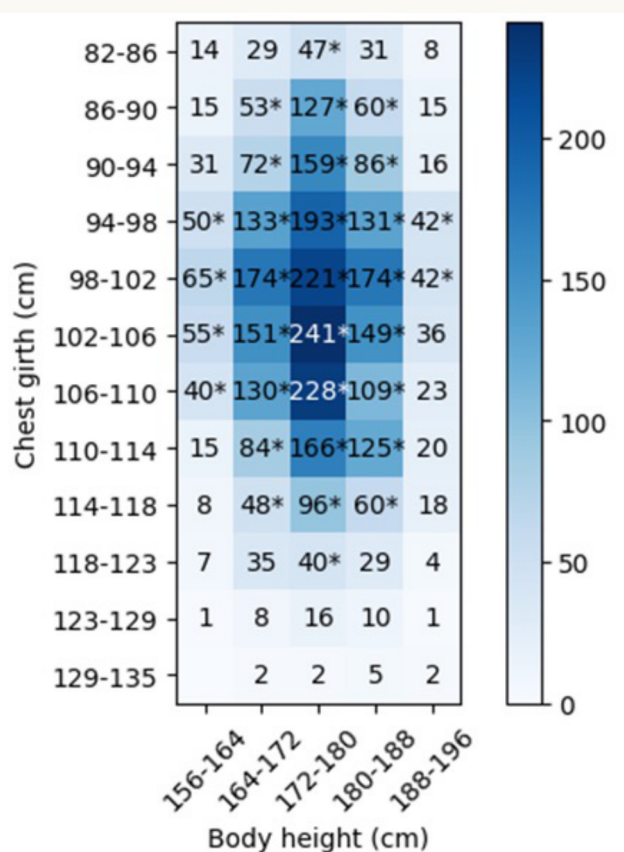


**Figure 4.** Differences in average chest girth of men between the Goransko–Primorska region and the Republic of Croatia by age group

The graph of chest girth differences shows minor deviations between the Goransko–Primorska region and the overall population across all age groups. The differences are mostly within  $\pm 1.5$  cm, with no clear pattern of increase or decrease with age. In some age groups, the region shows slightly higher values, while in others the values are lower compared to the overall population. These results confirm the relative uniformity of chest girth between the observed groups, as also supported by the t-test results, since the differences in mean chest girth between the Goransko-Primorska region and the overall population of the Republic of Croatia are not statistically significant ( $p > 0.05$ ).



**Figure 5.** Distribution of subjects by combinations of body height and chest girth in the Goransko–Primorska region



**Figure 6.** Distribution of subjects by combinations of body height and chest girth in the Republic of Croatia

The graphs show the distribution of subjects according to combinations of body height and chest girth, allowing a detailed analysis of the relationship between these two key anthropometric dimensions. In both representations, it is evident that the highest concentration of subjects occurs in the middle categories of body height (172–180 cm) and chest girth (98–110 cm), indicating the dominant presence of average body proportions in the population. The main difference is the higher representation of subjects from the Republic of Croatia in the body height category 188–196 cm and chest girth ranges of 94–98 cm and 98–102 cm.

Values exceeding 1% are additionally marked to facilitate the identification of more significant groups, while the most pronounced frequencies are visually emphasised by lightening the numerical labels. This enables quicker identification of areas with the highest data density. Conversely, marginal categories, that is, extreme values of body height and chest girth, are significantly less represented, confirming the lower frequency of such body characteristics within the observed population. Comparison of the two graphs shows a similar distribution pattern, with differences in absolute frequencies; the larger sample produces a more pronounced and stable distribution. The results confirm the importance of using detailed anthropometric distributions when defining clothing size systems, as they allow more precise adjustment of construction parameters to the actual body dimensions of the population.

The distribution of respondents by combinations of body height and chest girth provides a basis for defining a preliminary clothing size system. Each combination of body height and chest girth intervals can be considered a separate size category, with the dominant categories identified by the highest frequencies within the distribution.

## 4. Conclusion

The study confirmed significant variability in the anthropometric characteristics of the male population, with age and regional affiliation exerting a notable influence on body height and chest girth. A clear trend of decreasing body height with increasing age was observed, while chest girth increases up to middle age, then stabilises or slightly declines. Comparison of results from the Goransko–Primorska region with the overall population of the Republic of Croatia showed a high level of agreement, with relatively small deviations across all age groups. However, even these minor differences confirm the existence of regional specificities that should be considered when defining clothing size systems. Analysis of the distribution of combinations of body height and chest girth indicates a dominant presence of middle categories, while extreme values are significantly less frequent.

These findings highlight the limitations of existing standardised clothing size systems, which do not fully reflect the diversity of body proportions. There is a clear need to develop more flexible and population-specific sizing systems based on detailed anthropometric data. Integration of such data into digital tools and CAD systems enables more precise garment construction, reduction of production errors, and improvement of garment fit and user satisfaction. The results provide a relevant basis for further research on developing advanced, data-driven approaches in clothing design and production. Based on the obtained results, preliminary size categories can be defined according to combinations of body height and chest girth, in accordance with the EN 13402 standard. These categories can serve as a basis for the further development of optimised clothing size systems.

## Literatura

- [1] Ujević D., Doležal K.: Croatian anthropometric system in theory and practice. *Theoretical Aspects and Application of Croatian Anthropometric System*. Zagreb: Zrinski, 2010, pp. 1-6
- [2] Ashdown S. P.: *Anthropometry, apparel sizing and design*. Woodhead Publishing, 2007
- [3] Bogusławska-Bączek, M.: Analysis of the contemporary problem of garment sizes. In *Proceedings of the 7<sup>th</sup> Textile Science Conference*; Liberec, Czech Republic, 2013.
- [4] Istook C. L., & Hwang S. J.: 3D body scanning systems with application to the apparel industry. *Journal of Fashion Marketing and Management*, **5** (2001) 2, 120–132.
- [5] Gupta D., & Gangadhar B. (2004). A statistical model for developing body size charts for garments. *International Journal of Clothing Science and Technology*, **16**(5), 458–469.
- [6] Doležal K., Hrženjak R., Ujević D.: Determination of a System of Women's Clothing Sizes in the Goransko-primorska County of the Republic of Croatia. *Fibres & textiles in Eastern Europe*, **24** (2016), 6 (120); 26-31. doi: 10.5604/12303666.1221733
- [7] Gupta D.: *Anthropometry, Apparel Sizing and Design*, Woodhead Publishing Series in Textiles, 34-66, 2014
- [8] European Committee for Standardization. EN 13402: Size designation of clothes. CEN, 2001
- [9] International Organization for Standardization. ISO 8559-1: Size designation of clothes – Anthropometric definitions. ISO, 2017
- [10] Balach M., Lesiakowska-Jablonska M., Frydrych I.: Anthropometry and Size Groups in the Clothing Industry. *Autex Research Journal* **20** (2019) 1, 1-7 DOI:10.2478/aut-2019-0001
- [11] Ashdown S.P.: *Sizing in clothing: developing effective sizing systems for ready-to-wear clothing*. Woodhead Publishing, 2019
- [12] Simmons K. P. & Istook C. L.: Body measurement techniques: Comparing 3D body-scanning and anthropometric methods. *Journal of Fashion Marketing and Management*, **7** (2003) 3, 306–332
- [13] Doležal K.: Investigation of the influence of regional characteristics of physical dimensions on garment construction and fit; Doctoral Dissertation, University of Zagreb, Croatia, 2012.
- [14] Horvat J.: *Statistics by SPSS/PC+*. Osijek: Faculty of Economics, J. J. Strossmayer University, 1995
- [15] Pallant J.: *SPSS survival manual: A step-by-step guide to data analysis using SPSS*. Belgrade: Mikro Knjiga, 2011

## Acknowledgement

The publication of the work is a result of the implementation of the institutional research project "Development of Sustainable Clothing With Added Value", RoDv, TTF-IIP-05, funded by the European Union - NextGenerationEU.