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Positive Secular Trend in Slovak Population Urges on Updates of Functional Dimensions of Furniture

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Abstract: The presented study is focused on the evaluation of the changes in weight and height of the adult population in Slovakia to provide updated information on the secular growth trend. The main objective was to identify and quantify the pace of gradual changes in the dimensions of the Slovak adult population, which is key ergonomic information for multiple disciplines. The measurements of weights, heights and body mass indices of the current adult population of Slovakia ranging from 26 to 94 years of age that were obtained in period 1993–2017 were compared with a sample of students studying at four Slovak universities during the same years (aged 18 to 25). The increase of mean heights was app. 0.104–0.203 cm per one year (or app. 1–2 cm per decade) for males and app. 0.031–0.178 cm per one year (or app. 0.3–1.8 cm per decade) for females was statistically confirmed at different age classes covering the age structure of the whole adult population. The positive secular height trends were manifested in weight and BMI increases too. The changes in means and variation of distributions of selected variables also cause changes in quantile values. For example, the 95% quantiles of heights derived for the period 1993–2003 only cover 92–93% of the heights in the current population. This fact could have a major impact on proposals for optimal and safe arrangement of work, residential and non-residential space, including the furniture production.

Keywords: anthropometry; adults; growth; furniture; functional dimensions

1. Introduction

In the effort to invent and improve the technologies in various industrial fields, great emphasis is placed on the optimal use of specific technologies and equipment [1,2]. In the design and assessment of the spatial layout of workplaces and for production of ergonomically correct working tools, machinery and furniture, a man (his dimensions and stature) must be taken into account as a primary factor [3–5].

One of the fundamental conditions that promote worker productivity is to ensure that occupational spaces and facilities used by people are in line with the anthropometric and biomechanical characteristics of their users. Therefore, the design of an optimal workplace (furniture, working tools and etc.), is always based on the measurement of the target population of interest, usually divided into male and female categories [6]. The use of poorly designed furniture (which does not take into account the anthropometric characteristics of its users) has a negative impact on human health; References [7,8] state that improper furniture in the home and workplace (in addition to anthropometric, ergonomic and physiological deficiencies) contributes to the onset of fatigue, fatigue

syndrome, allergies, risks of somatic mutations and initiates latent diseases, and unfortunately also threatens human genetic information.

As a consequence of the growth and weight changes of the human population over time caused by a whole variety of reasons [9–11], it is necessary to perform periodical sample surveys and updates of the older population data [12,13]. According to the authors [14–17], the studies aimed at detecting the anthropometric dimensions of children and adult populations clearly show long-term changes in body dimensions. In most cases, there are positive trends in the dimensions of humans with the same physical age followed at different points in time (increases in measured parameter values) known as a secular trend. The secular trend is defined as increasing the final state of body dimensions of successive generations as compared to previous generations. This trend is interesting for a number of reasons [18–20]: (i) it is an indication of improving public health of the population; (ii) it reflects the relationship between economic growth and the standard of living; (iii) it illustrates aspects of the physiology of intergenerational relationships in growth and size.

In the period of the globalization of markets, the differences in the anthropometric characteristics of the population of the individual countries are becoming an increasingly important factor directly affecting the production and commercial strategy of companies in the furniture industry. For this reason, manufacturers' products must be based on the knowledge of the current statistical surveys and measurements of the furniture users but also be rationally based on standards for their products.

Due to an insufficient level of anthropometric research in Slovakia, furniture manufacturers are forced to rely on rather obsolete data dating back to 1981, although the positive secular trend can be expected [21]. In relation to this problem, the main objective of the present study is to evaluate the changes in the two basic anthropometric dimensions (weight and height) and body mass indices of the adult population in Slovakia in recent years and to provide updated quantified information on the secular growth trend.

The updated information will be used to reconsider the need to update standards for residential furniture of different categories: (i) laying furniture (beds and chaise lounges), (ii) multifunctional furniture (sofa beds), (iii) seating furniture (chairs, kneeling chairs, armchairs and sofas), (iv) table furniture (dining and work tables) and (v) storage cabinets (wardrobes and cabinets). Moreover, the obtained information can serve as an example of human growth trends in Central Europe that are interesting for international specialists and companies.

2. Material and Methods

The study is based on quantification of: (i) the secular trends in heights in calendar years 1993–2017 for each 10 year age class (generation) existing in Slovak adult population (7 classes 18–25, 26–35, 36–45, 46–55, 56–65, 66–75 and over 76 years) and (ii) the differences of basic anthropometric characteristics between two consecutive time periods 1993–2003 and 2007–2017 made to assess the impacts of identified secular trends on magnitude and variability of selected body dimensions in different time periods.

In our study, we have focused on two primary anthropometric attributes—height and weight—and one secondary attribute Body Mass Index (BMI) calculated as the weight (in kilograms) divided by the second power of height (in meters). BMI is commonly considered as a useful measure of human health, where the values from 20 to 25 indicate normal state characteristics for the fully healthy individual who did not perform any sport at the professional level.

The database available for analysis comprises the sample of the adult population (age between 26–94 years) monitored from 1993 to 2017 by the Office of Regional Healthcare of the Slovak Republic and the own data sample of the younger population (18–25 years old) acquired continuously from 1993 to 2017 by research on the students of four Slovak universities.

The first sample of the younger population consisted of 4448 men and 5078 women, students of the Technical University of Zvolen, Žilina University in Žilina, the University of Economics in Bratislava and Prešov University in Prešov. The sample of 9526 students attending various universities

situated at different locations in Slovakia naturally monitors the young population of different regions of Slovakia. The second sample was taken from the older Slovak population that are over 26 years of age and consisted of 5409 men and 3290 women of various ages detected between 1993 and 2017.

The simple linear models were used for the description of secular height trends for each age/gender class. The statistical significance of regression coefficients and overall model were tested by classic t and F tests. The slope coefficient of each linear model represents the expected change in mean height in cm per one calendar year. The statistical significance of slope coefficient and overall model can be considered as empirical proof of secular trend existence in a given period of calendar years. The models were parametrized on all available data.

Subsequently, two subsamples were formed—the measurements from 1993–2003 and 2007–2017 were extracted from the full database. The subsample for period 1993–2003 consists from 4261 males and 4799 females, the subsample period 2007–2017 contain the data of about 4797 males and 4647 females.

The values of the arithmetic mean and standard deviations for the height, weight, and BMI were calculated separately for each time period and gender. The differences in the arithmetic means and variance of the attributes between the two selected time periods were tested by Student's *t*-tests for independent samples (means) or by Fisher's F tests (variances) at the level of significance of 1% for each gender category separately.

Moreover, the quantiles of empirical height distributions important for furniture design (1, 5, 95 and 99 percentiles) were calculated for each time period. The validity of former quantiles was examined in later time periods—the calculations of percentiles in a later period corresponding to quantile values from the former period were done. All calculations were made in the Statistica 10.0 software (Statsoft Inc., 2010, Tulsa, OK, USA).

3. Results

The existence of positive secular trends in height was registered for almost every age/gender groups (Figure 1). Almost all regression coefficients and models were statistically significant, thus the existence of positive secular trends was statistically confirmed (Table 1).

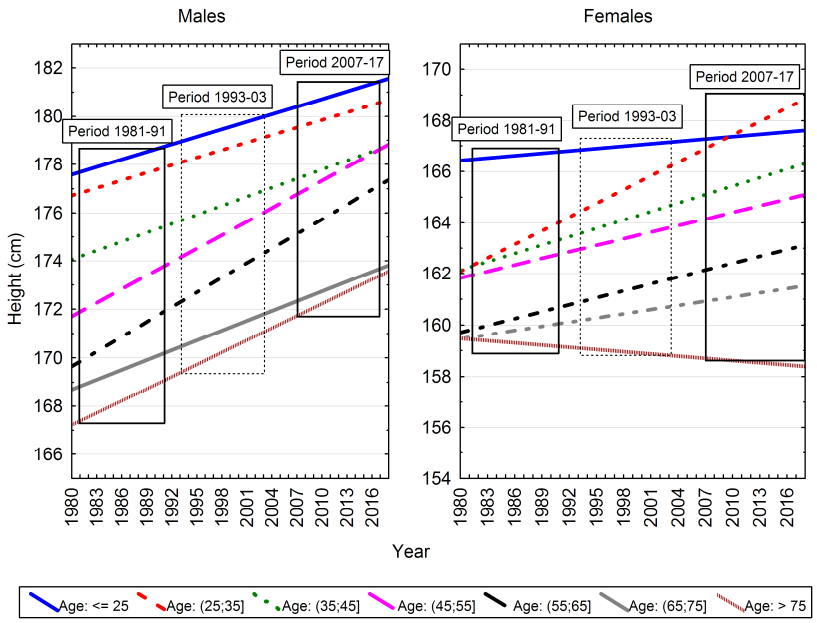

Figure 1. Secular height trends in different age categories and their impacts on height size in selected time periods (rectangles display the three compared periods—the period 1981–1991 is the period in which the furniture standards were published, the displayed trends for this period were obtained by backward extrapolation of linear models parametrized on measurements from 1993–2017).

Table 1. Secular trends in heights.

Age	Linear Regression Model				Overall Significance	
Category	**Slope**	**St.Error**	***t***	***p*-Level**	**F**	***p*-Level**
Male						
≤25	**0.105 ***	**0.016**	**6.7339**	**0.00000**	**45.346**	**0.000**
25–35	**0.104**	**0.028**	**3.7223**	**0.00021**	**13.856**	**0.000**
35–45	**0.124**	**0.030**	**4.2035**	**0.00003**	**17.670**	**0.000**
45–55	**0.187**	**0.022**	**8.4243**	**0.00000**	**70.968**	**0.000**
55–65	**0.203**	**0.040**	**5.0723**	**0.00000**	**25.729**	**0.000**
65–75	**0.135**	**0.034**	**4.0125**	**0.00007**	**16.100**	**0.000**
>75	**0.167**	**0.052**	**3.2322**	**0.00138**	**10.447**	**0.001**
Female						
≤25	**0.031**	**0.012**	**2.5645**	**0.01036**	**6.577**	**0.010**
25–35	**0.178**	**0.031**	**5.7784**	**0.00000**	**33.390**	**0.000**
35–45	**0.110**	**0.019**	**5.7333**	**0.00000**	**32.870**	**0.000**
45–55	**0.086**	**0.021**	**4.1826**	**0.00003**	**17.494**	**0.000**
55–65	**0.090**	**0.032**	**2.8168**	**0.00504**	**7.934**	**0.005**
65–75	**0.054**	**0.026**	**2.0981**	**0.03616**	**4.402**	**0.036**
>75	−0.028	0.055	−0.5140	0.60766	**0.264**	**0.608**

Source: Authors' compilation. * Bold letters denote the statistically significant regression coefficients and models at 0.01 level.

The increase of mean heights about the 0.104–0.203 cm per one year (or app. 1–2 cm per decade) and app. 0.031–0.178 cm per one year (or app. 0.3–1.8 cm per decade) can be expected for males and females. The larger and more consistent positive trends were manifested in the men category, the smaller and less consistent positive trends across the age classes were recorded for women (especially smaller positive trend at age category under 26 and reversed negative (but non-significant) trend for very old women is notable).

Still, the prevalence of rather strong positive trends in all age subpopulations is evident, thus the changes in overall height distribution properties (location, spread) in time or different generations can be expected and it is clearly demonstrated by rectangles in Figure 1. The different location and width of the rectangles in relation to y-axis indirectly demonstrate expected changes in location and variation of heights in the Slovak adult population. One very important procedure is a comparison of 1st and a 3rd rectangle that clearly shows the increase of magnitude and variation in heights between the periods where the furniture standards were issued (1981–1991) and the contemporary period 2007–2017.

More detailed and quantified information about the ongoing secular changes in the whole adult population is reported in Table 2 where the comparison of descriptive statistics of basic anthropometric dimensions between the periods 1993–2003 and 2007–2017 is provided. The selection of compared periods was driven by data availability and by an effort to ensure the same length of compared periods (11 years). Therefore, the impacts of secular trend existence in the Slovak population may be investigated not only for height but also for closely related weight and BMI.

The differences in mean ages between the periods are rather small in both gender categories (0.4–1.4 years), documenting the similarity of age structure in both subsamples. Thus the differences in means between the considered time periods are possible to interpret as a confirmation of the existence of the secular growth trends. The Slovak men and women in 2007–2017 were taller and heavier on average than men and women in 1993–2013. The increases for the app. 14 years vary between 0.5–3.9%. The differences are larger in the men category, but they are statistically significant for both gender categories. Moreover, the heights and weights of male individuals in 2007–2017 were more variable in comparison to the 1993–2003 period (differences in variation are statistically significant), whereas the variability of women's dimensions is almost unchanged and is not statistically significant.

Table 2. The changes of Slovak adult population in magnitude and variability of main anthropometric variables in periods 1993–2003 and 2007–2017.

Statistics	Period	Male					Female				
		N	Age (Year)	Weight (kg)	Height (cm)	BMI	N	Age (Year)	Weight (kg)	Height (cm)	BMI
Mean	1993–03	4261	36.8	79.4	177.2	25.3	4799	36.2	64.2	164.8	23.7
	2007–17	4797	37.2	82.5	178.7	25.8	4647	37.6	65.1	165.7	23.8
	Δ		0.44	3.10	1.48	0.53		1.41	0.98	0.84	0.13
	Δ%		1.21	**3.91 ***	**0.83**	**2.11**		**3.90**	**1.53**	**0.51**	0.53
	t		−1.18	−11.11	−9.27	−6.46		−3.72	−3.88	−6.12	−1.32
	p		0.236	**0.000**	**0.000**	**0.000**		**0.000**	**0.000**	**0.000**	0.187
St. deviation	1993–03	4261	17.60	12.68	7.20	3.88	4799	18.07	12.29	6.72	4.65
	2007–17	4797	18.06	13.77	7.88	3.98	4647	18.79	12.26	6.63	4.65
	Δ		0.45	1.08	0.68	0.10		0.72	−0.02	−0.09	0.00
	Δ%		2.58	**8.54**	**9.46**	2.46		**3.98**	−0.19	−1.39	−0.05
	F		1.052	1.178	1.198	1.050		1.081	1.004	1.028	1.001
	p		0.087	**0.000**	**0.000**	0.103		**0.007**	0.894	0.336	0.972

Source: Authors' compilation. * Bold letters denote the statistically significant differences at 0.01 level.

BMI values for both genders are enlarged in period 2007–2017, but a significant increase was registered only in the men category. Variability of BMI changed only non-significantly and virtually remained at the same level. The mean values of BMI for women are within the normality zone, but the BMI values for men are marginally beyond this zone and moreover, show a stronger tendency for an increase that is undesirable. The results obtained for BMI follows from results registered at primary variables. The lower BMI for females varying within the normal (ideal) range reflect the markedly smaller weights. Therefore, the BMI levels indicate the better predisposition of the women to be healthy in comparison to the male part of the population.

The changes in means and variations in time can be viewed as the changes in location and width of distributions of selected anthropometric dimensions. From this fact, a very interesting implication can be demonstrated (Table 3).

Table 3. The Height Percentiles (based on Normal Distribution Assumption Confirmed by Shapiro-Wilks tests).

Gender	Period	1%	5%	95%	99%
Males	1993–2003	160.45	165.36	189.04	193.94
	2007–2017	161.90	166.82	190.57	195.49
	% covered by 1993–2003 in 2007–2017	0.574	3.232	92.394	98.261
Females	1993–2003	149.17	153.75	175.85	180.43
	2007–2017	150.28	154.79	176.61	181.12
	% covered by 1993–2003 in 2007–2017	0.633	3.574	93.711	98.685

Source: Authors' compilation.

Table 2 shows the expected shift of key height quantiles between considered periods—all quantiles calculated for the later period 2007–2017 are larger, primarily in the reflection of mean increases. The quantiles derived from the 2007–2017 generation can be regarded as a reasonable estimate of the contemporary quantiles in the whole population. Let's suppose that the quantiles from 1993–2003 are quantiles of the past population incorporated in standards and norms (in fact, the quantiles from unknown more distant past population were incorporated). Subsequently, if we recalculate how large the portion of the current population is that is covered by quantiles derived from the past population, we can estimate how much population now is not be covered by the not-updated standards, especially on the upper tail of the distribution. As we can see, if the furniture is designed in order to fulfill the needs of 95% of the population, it does not cover app. 7–8% now. Similarly, if the furniture is designed to cover the 99% of the population, it is not suitable for 1.5% of oversized individuals now.

The registered shifts correspond to the 14-year time shift between the 1993–2003 and 2007–2017 periods. The actual shift between the period of standard's issue (1981–1991) and the contemporary generation of 2007–2017 is 26 years and anthropometric data used for standard's creation can be even older. Therefore, the proportions of the contemporary population not covered by furniture norms can be substantially higher. These facts are especially dangerous for the health of younger parts of the contemporary generation, because young individuals have a higher probability of being oversized than the older age classes due to the existence of secular growth trends.

4. Discussion

4.1. Human Growth Trends in Slovakia and Other Countries

Secular trends were documented in many countries since the 19th century [22–25]. Height increases were registered in southern Europe [26]. Hauspie et al. [27] found secular trends in Europe during the last decades of the 20th century ranging from 3 mm/decade in Scandinavia to 30 mm/decade in parts of Southern and Eastern Europe.

Although height in the Netherlands [19] and Scandinavia appears to be close to a plateau, the increase is likely to continue for some decades to come in Southern Europe [20]. The existence of secular trends can be considered as a global phenomenon [17,20,28–30].

In this regard, our research complements a number of other studies carried out in the recent past in Slovakia and different neighboring countries. Comparing the results of our research with the results of other researches is difficult for a variety of reasons, such as the different sample sizes, specific measurement methods, demographic coverage, ethnic mix or health status of the participants.

Despite this, References [31–33] independently studied the basic anthropometric measurements on the territory of Slovakia and they confirmed the existence of a positive secular trend of the physical dimensions of the population of Slovakia. The results of anthropometric research on the territory of the Czech and Slovak Republic realized by Reference [34] clearly show that in the Czech population, as well as in the Slovak population, there was a significant increase in the body dimensions, namely body height, and weight. According to Kovařík [34], the body height and weight do not grow at an equal pace. The weight of the Czech population grows more rapidly than the height of the body, especially among men. On the contrary, according to the results of our research, as well as the results of the Kotradyová [31] research project, there is a decline in the weight of the Slovak population. Both studies showed a significant decrease in body weight, especially in females.

Regarding the Czech population, Reference [17] confirmed an acceleration in the growth of the average body height and weight from 1955 in young men aged 18–25, and this trend has been slowing down since the 1980s. Vignerová et al. [14] registered the mean height of 13-year-old Czech boys has increased by 19.4 cm, and the mean height of Czech girls has increased by 18.3 cm, since 1895.

Very interesting results regarding the secular trends in heights, weights, and BMI in young Romanian students aged 18–24 years were reported by Ioana et al. [35]. The authors registered secular growth stagnation for males and females in heights accompanied by a significant increase in BMI values in accordance to overall European trends.

Similarly, to Slovakia and Czechia, the results of other research from other geographical areas confirm the existence of a secular trend in different parts of the world: (i) the US and North America [36–41]; (ii) northern Europe [42,43]; (iii) south and south-eastern Europe [44–48]; (iv) western Europe [11,19,27,49] or (v) Asia [12,50–52]. Also, some globally oriented reviews support the idea of secular growth trends in the heights of the human population during the 20th century [53].

Although some indications about the contemporary slowdown or stagnation of secular trends in heights (similar to the mentioned Romanian study) were reported for some regions and populations [28,54–56], the positive secular trend in central and eastern Europe probably still prevails.

Several possible explanations of the positive secular trend in Slovakia are possible. First of all, the current generation is affected by the events that have taken place over the last three decades in Slovakia

(the fundamental change of political regime, entry of Slovakia to the European Union). The economic prosperity of the population resulting from economic and political changes (the purchasing power more than doubled compared to 1989), the influence, availability and quality of diet, adherence to healthy lifestyle or availability of vitamins and medicines all could also have an impact. Also, the positive change in healthcare greatly impacts such trends [57].

Grashuber et al. [15,16] in their worldwide reviews found that the most important factors affecting the heights in human populations is consumption of protein-rich food and the human development index (as the measure of society wealth) which are most strongly associated with tall statures. Both factors were increased or improved in Slovakia, especially after the country's entry into EU, due to favorable economic development.

Moreover, the social status and the achieved education—one of the factors influencing the development of body physical dimensions of the human population—were improved for many families in Slovakia [58].

4.2. Implications for the Furniture Industry

Anthropometric information can be used to inform the design of tools, equipment, workstations, and others. Appropriate use of anthropometry in design may improve well-being, health, comfort, and safety [59]. The anthropological and ergonomic requirements are crucial in many ways in terms of the shape and dimensions of various consumer products [21,60,61]. Innovations have an impact on the products produced by the furniture industry [62]. Due to the existence of a positive secular trend in Slovak adult population, it is necessary to reassess the correctness of the current ergonomic, hygienic and design standards. Since the secular trend is not only registered in our country, a similar necessity to review outdated global standards may potentially arise in other parts of Europe [43,63].

For the knowledge to be used effectively, they should be implemented already within the framework of teaching in schools and universities dealing with the development, design, and creation of furniture [64]. Updating measurements (e.g., every 10 years) and then updating the dimensions for the current generation is needed as part of the implementation. Sustainability—the development that meets the needs of the present without compromising the ability of future generations to meet their own needs—includes attention to natural and physical resources ('planet'), but also attention to human and social resources ('people'), in combination with economic sustainability ('profit') [65,66]. In this way, we will achieve the sustainability of standards and their timeliness.

Regarding the furniture sector, the relationship between man, furniture and objects are expressed by the functional dimensions of the furniture that are important when designing it. There are these dimensions contained in standards and in various manuals [67–69]. The furniture industry should be interested in updating the furniture production standards. Based on the fact that the European labor force is getting older, the proportion of older people in the population is rising, too. For this reason, it is necessary to adapt the relevance of furniture, IT equipment, and services designed and tailored to the characteristics of the population [70].

Therefore, the first main strategic direction is to strengthen the demand for high-quality human factors/ergonomics by increasing awareness among powerful stakeholders of the value of high-quality by communicating with stakeholders, by building partnerships and by educating stakeholders. The second main strategic direction is to strengthen the application of high-quality ergonomics factors by promoting the education of specialists, by ensuring high-quality standards of applications and specialists, and by promoting research excellence at universities and other organizations [71].

However, the country-specific standards are a priority. Based on an analysis of valid standards in Slovakia and containing functional dimensions for residential furniture, it is clear that these Slovak technical norms (STN) standards cover only bed mattresses in the case of laying furniture [72], chairs [73], armchairs and sofas [74] as seating furniture, cabinets as storage furniture [75], sofa beds as part of multifunctional furniture [76], and machines [77]. These standards were issued 26 to 36 years ago. There are also several invalid standards of home furniture for beds, kitchen chairs,

dining and writing tables, kitchen furniture and shoe cabinets. The European standards, adopted into the system of Slovak standards, determine the requirements for office and laboratory furniture.

Due to the increase in the height of both men and women and its relatively strong well-known correlation with many other body dimensions [78], it is probably necessary to adjust some functional dimensions and construction parameters of all basic types of furniture [79,80]. The necessary modifications for bedding (bed, lounge and sofa bed) are mainly in the length but also in the width of the lying area and its height above the floor. The adjustment should be based on the height and other needed dimensions of the male population.

In connection with the findings of the secular trend of growth in the adult population, furniture manufacturers should adjust cost/pricing practices in those areas where the causal relationship between the costs incurred and the respective outputs is expressed [4]. This is important for predicting the financial situation of these enterprises [11]. This means that there is also a need to define a price adjustment for products that require a change in functional dimensions (bedding, multifunctional furniture, sitting furniture, door height, etc.).

Increase in production costs of about 10–15% was preliminarily estimated by Reference [81]. Later works revealed that the price increase can be from 5% (with the increase of door openings) to 40% (bed furniture), independent of the demand for production. Such calculations can be further predicted based on results obtained in our study.

5. Conclusions

The persistent positive secular trend in the height of the adult population over the last two decades in Slovakia was confirmed by empirical anthropometric survey. There is a strong need to adjust (furniture) standards. If producers and economists do not address the problem in the future, serious economic consequences and damage to the health of the population could occur.

Modification of standard dimensions requires interdisciplinary collaboration between designers, developers, anthropologists, ergonomists and health professionals. Only such a multidisciplinary approach can deliver results in the production of health-conscious consumer products. For this reason, we see further potential in the next research direction:

- to analyze (in detail) the functional parameters of selected types of furniture (beds, chaise lounges, bed sofas, chairs, sofas, dining, and work desks and cabinets) and their relationship to anthropometric measurements,
- to prepare documents for the processing of norms of the functional dimensions of basic types of home furniture,
- to assess the justifiability of the use of European standards in Slovakia, or prepare documentation for the processing of the national amendment,
- to examine the suitability of labeling of furniture according to the classification used by the clothing industry (XS, S, M, L, XL) and to prepare background material for this marking.

Moreover, knowledge of the basic anthropometric measurements of employees is also important for creating the right workplace layout in terms of optimal performance of employees as well as the safety and hygiene of work. The comparison of the anthropometric data of the employees with the general data of the population is the basis for creating the optimal construction of machines, designing tools, and daily consumption items. Therefore, it is necessary to periodically update and monitor the data on population anthropometric characteristics in the future.

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