ANALYSIS OF SELECTED ANTROPHOMETRICAL CHARACTERS DIFFERENCES OF SLOVAK AND CROATIAN ADULT POPULATION

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Abstract
The aim of this work – with the help of the selective statistic analysis – is to find out if there are significant differences in dimensions of adult population of the Slovak republic and Croatia. The subject of the research consists in 5 antrophometrical dimensions which are important especially from the point of view of ergonomy. Based on a detailed description and with the help of statistic testing the analysis of differences in the form, position, variability and derived quantiles divisions of examined characters was carried out and it was found out that in the monitored populations divided to a male and female part there are no statistically important differences in height and width body parameters but there are important differences in limbs dimensions. The statement that in both monitored countries it is not posible to use the same ergonomical norms in determination of optimum working space results from it.

The survey and obtained results indicate that in both countries there are mostly statistically significant differences in position of empirical divisions of hands and legs dimensions and this may be seen in more distinctive diversions of quantile characteristics. Practically it could be seen that dimensions of hands and legs of model figures of Croatian population (lengths of hands and legs) are at comparable height parameters systematically lower that in Slovak population part.

Key words: anthropometry, population, dimensions, variability.

Classification JEL: M 140 Corporate culture, Social responsibility

1. Introduction

The key point in a workspace, in connection with working tools or subject utilization, is a man. Largely products but also all facilities are designed and constructed for a man. That is why it is necessary to consider a human figure, especially its dimensions and power capabilities when tools and facilities are being designed and from the ergonomic point of view correct working tools, machines and furniture are being produced (Konrád, 1989). Knowing basic antrophometrical parameters of employees is a fundamental condition for determination of workplaces correct arrangement from both – optimum employees' performance point of view and work safety and hygiene point of view as well. Determination of an optimum workplace is almost always based on a comparison of found antrophometrical data of individual employees with general data of the population from which they come from. In a common situation in a properly working system we do not realize that our work environment is created in accordance with economic, social and personal goals, based on verified information resulting from the needs, possibilites and limits that a human being has.

All the parameters of work environment are recorded and codified in a system of requests and regulations and among them laws, implementing regulations, technical norms, recommendations and directions are the terminative ones. The system is built and tuned so that it suits the **needs of majority of population**. But there are also exceptions, marginal sizes, ill and disabled people, or older people and it would not be right to exclude them from social and working life. Population data are mostly found out in particular samples and in a particular moment and due to different reasons (for example the way of population nutrition, the way of life, etc.) and they may vary throughout a longer time period (Sedmák, Hitka, 2004). Apart from time changes important antrophometrical characters may also vary in space what is connected with characters of human population living in a particular living-space. In the process of designing and proposing space work places organization and also in production of ergonomically

correct working tools, machines and furniture the first factor that is to be taken in consideration is a human figure especially its dimensions and power capacities. The proposal concerning optimum workplace (furniture, working tools, facilities, etc.) always results from measurements of a target group of people which are compared with the data of the whole population living in a particular area, usually divided to men and women (Veselovský, 2006, 2007).

The aim of submitted work is – with the help of selective statistic analysis and based on a comparison of shape, position, variability and percentiles of selected antrophometrical dimensions division – to find out if there are significant differences in dimensions of adult population of the Slovak republic and Croatia. If statistically important differences of antrophometrical characters are identified, the final result will be a description of the above mentioned differences and formulation of recommendations concerning conditions under which it is possible to utilize the same ergonomic norms for both countries.

2. Material and methodology

The survey of selected antrophometrical dimensions of adult population was carried out in Slovakia and Croatia. The sample consisted of the students of Technical University in Zvolen and Faculty of Forestry in Zagreb aged from 20 – 25, it means after reaching the age of of approximated adulthood from the point of view of people growth process. Students from different regions study at both universities and so it is probable that both samples are representative enough. The Slovak sample was obtained during the years 2000 – 2010 and it is formed by measurements of 338 men and 333 women. The Croatian sample was obtained during the years 2009 and 2010 and it consists of measurements of 113 men and 44 women.

The subject of analysis contents ***5 key antrophometrical charactes*** selected from a wider set of 25 characters which are in general important in hygienic and ergonomic practice, e.g. in determination of optimum work environment, proposal of products dimensions in a furniture industry, in construction and sizing of machines and devices in an engineering industry etc. Selected characters are the total height in a standing and sitting position, arms width, length of hand when arms are raising in a sitting position and length of leg when the leg is forward in a sitting position. These are the key parameters from the point of view of body height and width and limbs dimensions. The exact definitions of individual characters and the ways of their measurement may be found in antrophometrical literature (e.g. Strelka, 1978). All the characters have a linear length dimension and were measured with rounding off the sums to 1cm.

Statistic analysis of selected measurements was processed in the programme Statistica 7.1 (Statsoft, Inc., 2005). Empirical measurements of 5 characters for 2 populations divided to categories men and women were summarily described by means of common characteristics of position and variability of divisions – arithmetical averages $\bar{x}$ and variances s_x^2 which characterize the size and oscillation of measured values and symmetry coefficients *A* and pointing *E* describing the form of measured values division.

Apart from these common describing characteristics – ergonomically the most important quantiles – 5, 50 and 95% quantile were determined from empirical divisions. The procedure to determine empirical quantiles is as follows: measured values of monitored characters were lined up from the lowest to the highest one and by means of conjunction of number of values and required quantile strictness np the sequence number of quantile in the line of values was determined. If it is expressed as $np = j + g$, where *j* is integral part of the order and *g* is its fractional part, then empirical quantiles were calculated based on the relation:

$$x_{kv}(p) = (1-g)x_j + gx_{j+1},$$

where index *j* indicates the order of measured value x_j in the line of values arranged in order of their size. From the ergonomic point of view empirical quantiles of division (5%, 50% and 95%) and interpretation of differences of quantiles characteristics between individual populations bring the biggest practical importance. The quantiles of empirical divisions of monitored characters measured values may **differ significantly due to several reasons:**

1. The form of measured values probability division of two populations' monitored characters is not the same i.e. the probabilistic model of values occurence frequency is not the same – in these cases especially marginal quantiles may differ significantly – even in the situations where moment characteristics of particular divisions (averages, variances) do not differ from each other statistically significantly.
2. The form of measured values probability division of two populations' monitored characters is in both populations – according to statistical criteria – similar but its position and variability is not the same, i.e. the same probabilistic model has different parameters – if divisions vary significantly in a position or in both position and variability, also all the quantiles must differ, if they differ only in variability – medians do not have to differ between the populations but marginal quantiles do.

That was the reason why interpretations of differences of empirically found selected quantiles followed the tests of conformity of empirical divisions of selected characters measured values against theoretically hypothetic normal division made separately according to individual populations divided to a male and female part. The tests were carried out especially with the aim to review if the empirical divisions have the same form, i.e. if they behave according to the same probabilistic model, while by definition a model of normal division was anticipated.

If the difference of empirical divisions compared to the anticipated normal division was proved – visual graphic review of differences or conformity of the form of empirical divisions – according to individual populations quantitatively supported by comparison of coefficients of symmetry A and pointing E of displayed divisions – followed. The next step of the interpretation was the evaluation of the results of ***testing conformity*** of basic characteristics of position and variability of empirical divisions of the analysed characters (even in the situations when conformity of the divisions form was not statistically confirmed).

Conformity of the form of empirical division with normal division was verified by Shapiro-Wilk W test (Shapiro, Wilk, 1965) at a standard level of significance $\alpha = 5\%$. At the same significance level also statistical significance of differences of basic characteristics – position $\bar{x}$ and variability s_x^2 was verified. Testing was carried out with the help of standard conformity tests of 2 diameters (T-tests), respectively variances (F-tests) derived from 2 independent selections by means of procedures described in common statistical books (e.g. Scheer, 2007) or in Statistica programme manual. Final information concerning the importance of tested characteristics difference according to statistical criteria in Statistica is provided by parameter *p*-level, which is compared to the selected level $\alpha = 5\%$. In the case when *p*-level is lower than α, the null hypothezis concerning non-significance of empirically recorded difference of tested characters is refused – in the opposite case it is accepted.

3. Results

The table one provides the review of basic descriptive characteristics and the results of descriptive characteristics testing and the form of selected characters divisions according to individual countries for a male part of population. The form of frequencies divisions is depicted in the figure 1A – E. The Table 2 brings the same results for a female part of population and is depicted in the picture 2A – E.

The tests of conformity of empirical divisions of 5 verified characters in a male part of population showed in 6 out of 10 cases (combination character x country) a difference from assumed normality (Table 1). Diversion from normality is mostly caused by assymetry of divisions while approximately equal it may be left-sided or right-sided assymetry (Figure 1A – E).

Table 1: Basic descriptive statistics and tests – Slovak and Croatian male sample

Variable	Popul.	Mean	T-test	Varian.	F-test	Skewness	Kurtosis	W-test	Quantiles		
			p-level		p-level	A	E	p-level	5%	50%	95%
Body	Slovak	181.8		41.6		0.235	0.258	**0.035**	172.0	182.0	193.0
height	Croatia	182.6	0.253	39.3	0.925	-0.182	-0.296	0.440	171.0	183.0	193.0
Arm	Slovak	48.5		19.6		**1.184**[2]	**2.866**	**0.000**	43.0	48.0	57.0
width	Croatia	48.1	0.318	16.2	0.773	**0.647**	0.128	**0.001**	43.0	47.0	55.0
Sitting	Slovak	94.3		20.4		**-0.308**	0.410	**0.002**	86.0	95.0	101.0
height	Croatia	94.6	0.492	19.0	0.639	-0.051	0.730	0.148	88.0	95.0	101.0
Leg	Slovak	109.6		51.2		-0.135	0.376	0.095	98.0	110.0	122.0
length	Croatia	108.9	0.353	52.4	0.386	**0.403**	-0.410	**0.013**	100.0	108.0	121.0
Hand	Slovak	86.6		31.6		-0.092	-0.119	0.102	78.0	86.0	96.0
range	Croatia	84.8	**0.005**[1]	37.1	0.873	**-0.582**	0.485	**0.012**	74.0	86.0	95.0

Source: own study

In general the tests of variances of position and variability moment characteristics showed only small differences between the monitored populations, since the populations differ statistically significantly only in a variability of a hand range in a sitting position which is significantly lower in Croatian population due to our findings. It results from the above mentioned facts that the differences of quantile characteristics are mostly caused by a dissimilar form of frequencies divisions and not by differences in their position or variability. If we look at the situation in details **it can be seen that:**

1. As to body height the form of Slovak and Croatian measurements empirical divisions is not the same. Slovak male population differs significantly from normality due to the existence of a moderate left-side asymmetry combined with positive pointing. Division of heights of Croatian male population does not differ significantly from normality even if coefficients A and E indicate that there is a moderate tendency to a right-side asymmetry and bigger flatness and they are opposite tendencies than in Slovak population (Table 1). Differences in forms of both populations heights are not visually very distinctive (Figure 1A), because the diversion from a normal form and pointing is in both divisions relatively moderate (in 1 case it is even not statistically confirmed). Moment characteristics of both populations do not differ significantly, size and variability of male heights in Slovakia and Croatia is – also according to relatively strict statistic criteria given by a big sample size – comparable. Quantile characteristics of both populations heights rounded to 1cm differ minimally among each other. In Croatian population we register lower 5% quantile due to bigger flatness and right-side asymmetry of division and we also register a bigger median what is probably

[1] Levels of significance which are bold indicate statistically significant differences of tested characteristics against the selected level of significance 5%

[2] Values A and E bold – significantly differ from zero at the level of significance 5%

caused by a moderate statistically non-confirmed movement of position of the whole division to the right direction.

2. As to arms width the form of measured values empirical divisions statistically significantly differs from the normal division in both populations, whereby in both populations the diversion is caused by the left-side assymetry combined with a higher pointing (table 1). Provided tendencies are significant in Slovak population specially – Croatian population differs from the Slovak one by a lower almost normal pointing (Figure 1B). The tests of moment characteristics of arms width did not prove significant differences in divisions´ position and variability. Comparable form and small differences could be consequently seen at low differences of empirical quantile characteristics and a distinctive difference equal to 2cm is registered at 95% quantile. By means of detailed analysis, however, it was found out that the above mentioned difference is caused by an empirical way of quantile determination and accidental existence of 1 extreme value in Slovak population than substantial differences in the form, position and variability of the whole divisions.
3. As to the heights in a sitting position – the division of heights in Slovak population proves to be statistically different from the normal division but this fact was not confirmed in Croatian population (Table 1). Both divisions show the tendency towards the right-side asymmetry and a higher pointing but in Croatian population these tendencies are so weak that they are not strong enough to show statistically significant diversion from normality. Both divisions are visually similar (Figure 1C), but the Croatian division is in contrast to the Slovak one almost ideal symmetrical and moderately more pointed. Moment characteristics of both divisions' position and variability do not significantly differ with each other. Small differences in the form, position and variability of the height of men in a sitting position in both coutries are seen in small quantiles differences – they differ with each other only of 5% of a quantile. Similarly as for arms widths the registered difference is probably caused by the empirical way of quantiles determination combined with the occurence of 1 extremly small height in Slovak population.
4. As to the leg lengths in a forward sitting position it can be stated that in Croatian population there is a significant diversion from normality caused by a moderate left-side asymmetry and a flatter form. Slovak population has almost a normal form and in contrast to Croatian population there is a non-significant tendency towards the right-side asymmetry and a higher pointing (Table 1). Visual differences between both populations and compared with the normal division may be seen quite well (Figure 1D). The tests of differences of moment characteristics prove that in position and variability of divisions between populations there are no siginificant differences. Consequently also differences of quantile characteristics are not high and do not exceed 2cm in an absolute expression. Differences of quantile characteristics are not of systematic character (5% of quantiles are higher for Croats and 50 and 95 is moderately higher for Slovaks) and this is caused especially by differences in a form supposed that the differences of moment characteristics are negligible. We can notice that a more distinctive left-side asymmetry of Croatian division is seen in a smaller median although arithmetic averages are comparable.
5. As to forward hand lengths in a sitting position the Slovak male population do not show statistically significant diversion from the normal division (in spite of moderate visual tendency towards the left-side asymmetry and higher flatness), in Croatian male population exists significant diversion from normality especially do due to the existence of the right-side asymmetry (Table 1, Figure 1E). The tests of moment characteristics did not prove statistically significant difference in divisions' variability but the tests of arithmetic averages differences significance of hand range showed that the Slovak division is significantly moved to the right i.e. that the average forward hand reach in a sitting position is significantly higher than in Croatian population. Differences in a position were consequently seen in quantile characteristics – upper and lower quantile are smaller in Croatian than in Slovak population. In spite of statistically confirmed difference the medians do not differ and probably it is caused by the right-side

asymmetry of Croatian population. The Table 2 contains the survey of characteristics and tests of antrophometrical dimensions of Slovakia and Croatia female population. The form of divisions of frequency of female population is visually presented in a set of figures 2A – E.

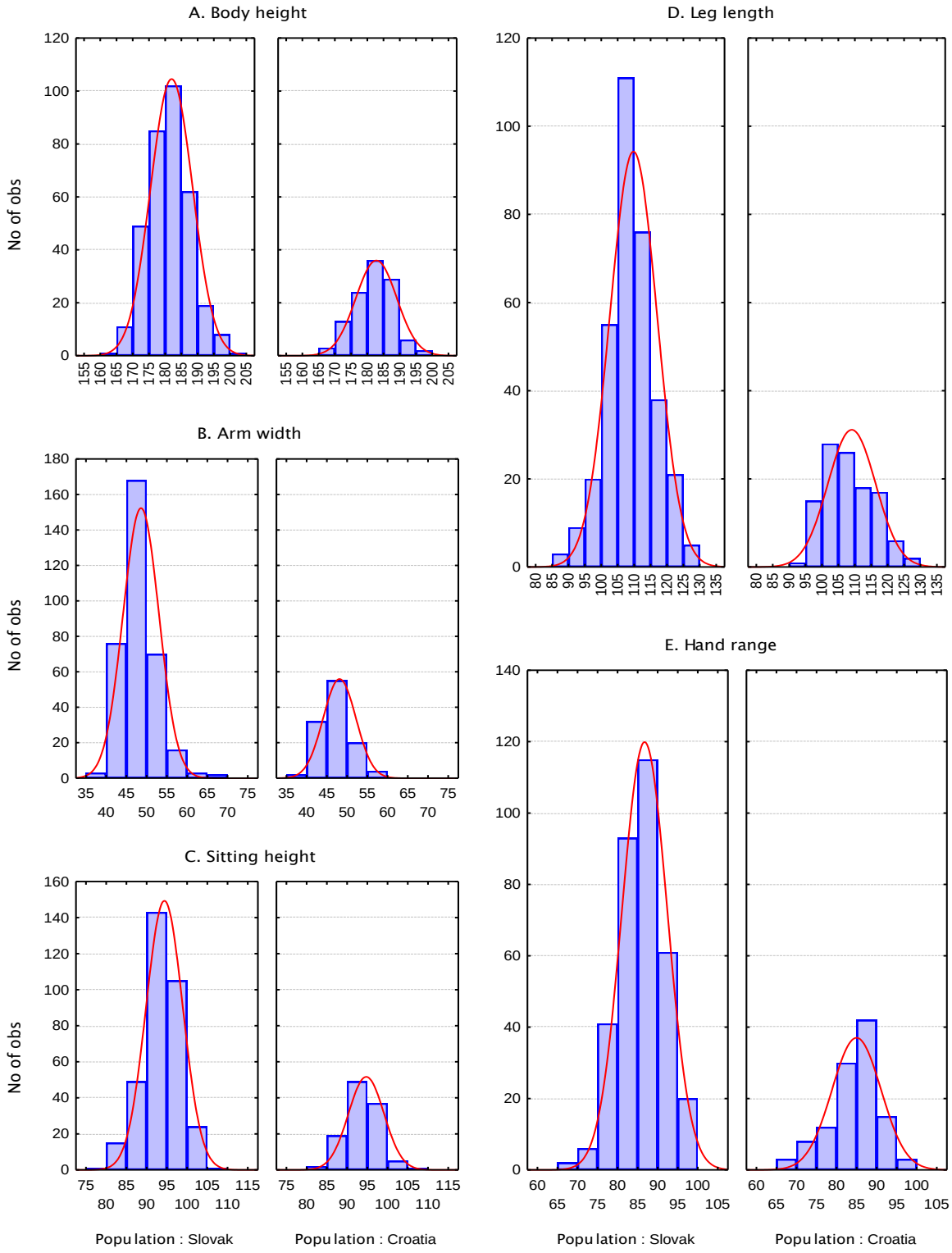

Figure 1: Forms of selected antrophometrical dimensions measured values divisions – male part of population

Source: own study

Table 2: Basic descriptive statistics and tests - Slovak and Croatian female sample

Variab.	Popul.	Mean	T-test	Varian.	F-test	Skewness	Kurtosis	W-test	Quantiles		
			p-level		p-level	A	E	p-level	5%	50%	95%
Body	Slovak	168.8		36.1		-0.109	-0.081	0.256	160.0	169.0	178.0
height	Croatia	167.3	0.130	45.6	0.560	0.427	-0.187	0.166	156.0	166.0	178.0
Arm	Slovak	41.3		9.3		0.214	0.182	**0.001**	36.0	41.0	47.0
width	Croatia	41.1	0.678	8.4	0.920	0.584	-0.122	0.051	37.0	41.0	46.0
Sitting	Slovak	88.3		18.8		**-0.456**[2]	**0.724**	**0.000**	81.0	89.0	95.0
height	Croatia	88.6	0.643	15.5	0.609	0.148	-0.522	0.772	83.0	88.0	95.0
Leg	Slovak	101.3		37.0		0.021	**1.236**	**0.001**	92.0	101.0	111.0
length	Croatia	98.4	**0.003**[1]	42.7	0.505	0.606	0.357	0.180	90.0	97.0	111.0
Hand	Slovak	77.8		28.7		-0.147	**0.916**	**0.007**	70.0	78.0	86.0
range	Croatia	76.3	0.065	10.6	**0.001**	-0.477	0.153	0.113	70.0	77.0	80.0

Source: own study

[1, 2] *See Table 1*

The tests of form conformity of empirical divisions compared with expected normal division in the female part of samples of Slovak and Croatian population showed that divisions of female part approach to normality more than in the male part. In the female part Shapir-Wilk´s test showed the conformity with normality in 6 out of 10 cases and this is exactly opposite proportion than in the male sample (Table 2). Moreover only 1 out of 4 cases with the proved diversion from normality may be evaluated as statistically highly significant. The next difference is the fact that in the female part of population the diversion from normality was more frequently caused by the tendency to a higher pointing than by the asymmetry of divisions' form (Figure 2C-E).

The tests of differences significance of moment characterisitcs of position and variability of monitored characters empirical divisions showed similarly as in the male part of population that most divisions of both countries differ significantly neither in position nor in variability. But there are 2 exceptions where it was shown that there is statistically significant difference in positions of legs length and in variability of hands reaches in both verified countries (Table 2).

The **detailed analysis** of individual characters in the female part of Slovak and Croatian inhabitants showed that:

1. As to body height in a standing position – empirical divisions do not differ statistically significantly from a normal division although in Croatian population we can register a moderate tendency towards the right-side asymmetry (Figure 2A). The tests of moment characteristics did not show significant difference in position and variability of divisons (Table 2) also we can notice that Slovak population at higher arithmetical average shows a lower variance of heights and the situation in Croatian population is opposite. The combination of statistically non-significant right-side asymmetry and of the same non-significant lower average height and higher variance of heights became evident in relatively big differences in quantile characteristics when the lower quantiles differ by 4cm and medians by 3cm not in favour of Croatian population.
2. As to arms width there is a statistically significant diversion from normality in the female part of population (Table 2) which is caused by the combination of the left-side asymmetry and higher pointing – in Croatian part diversion from normality is not confirmed although both divisions are very similar (Figure 2B). The tests of moment characteristics did not show any significant

differences neither in position nor in variability of divisions in both countries and so there are no serious differences in quantile characteristics.

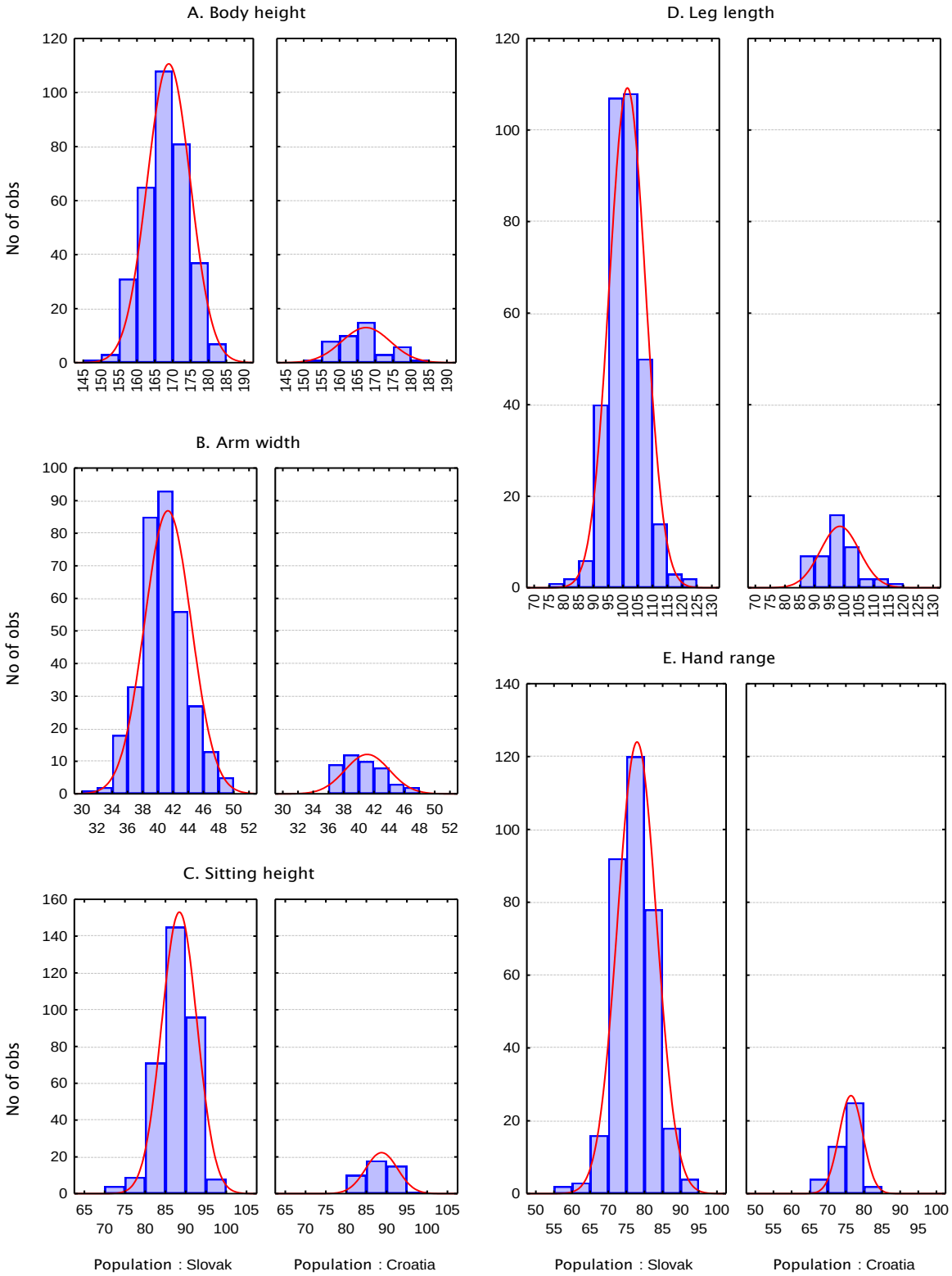

Figure 2: Forms of selected antrophometrical dimensions measured values divisions – female part of population

Source: own study

3. As to body heights in a sitting position we register a significant diversion from normality in the Slovak sample while in the Croatian part there is almost an ideal normality (Table 2). Slovak division is characterized by the significant right-side asymmetry and a higher pointing in comparison to normality (Figure 2C). The tests of moment characteristics showed that arithmetical averages and diversions of the heights in a sittting position differ only accidentally between the countries what became evident (in spite of more distinctive differences in a form of divisions) also in small differences of selected quantiles.
4. As to legs lengths in a forward position we again register more significant diversion from normality only in the Slovak sample, in this case the diversion is caused exclusively by a higher pointing because the form is almost ideal symetrical (Table 2, Figure 2D). Visually in the Croatian part there is a tendency towards the left-side asymmetry but it was not statistically quantitatively proved. The tests of divisions' characteristics of position and variability showed statistically significant differences in divisions' position but not in their variability (Table 2). The Croatian female population has significantly lower length of forward leg in a sitting position and the stated fact became evident in lower values of a low 5% quatile and median. The upper 95% quantiles are similar and it is probably the reflection of a higher pointing of Slovak and left-side asymmetry of Croatian values division.
5. As to forward hands reaches in a sitting position we can see almost ideal symmetry and pointing of Slovak division and the tendency of right-side asymmetry and higher pointing in Croatian female population (Figure 2E). The diversion from normality in the Croatian sample is statistically significant (Table 2). The tests of position and variability characteristics of the Slovak and Croatian population showed evident, statistically highly significant difference of hands reaches variability which is much lower in the Croatian sample. The differences in position of hands reaches divisions were not proved according to statistic criteria although similarly as to legs lengths the average hands reach in Slovak population is bigger that in the Croatian sample. The differences in variability and partially in position of divisions became evident also in quantile characteristics when a relatively small statistically non-confirmed difference in position may be seen apart from arithmetical averages also in values of medians and distinctive statistically significant difference in variabilities is well seen in 6cm difference of upper 95% quantiles not in favour of the Croatian sample.

4. Conclusion

Detailed analysis of differences of 5 antrophometrical dimensions of Slovakia and Croatia inhabitants defining the dimensions of an adult person brought the following facts and **generalizations in the male part of population:**

a) Differences of verified characters quantile characteristics are minimal; almost all of them – regardless of a verified character – may intrude into the absolute frame ± 2cm. The only exception is the forward hand reach in a sitting position where the results indicate that Croatian population's hand reach is in average smaller which may be seen in a systematic shift of quantiles to the left in the direction towards lower values. Similar tendency was registered also for forward leg length in a sitting position but it was not confirmed by means of statistical tests.
b) Low differences of quantiles mostly result from non-significant differences in position and variability of empirical values of analyzed characters values and from the practical point of view it indicates that most differences of verified measures of position and variability of monitored divisions is so low that it is not possible to distinguish it from statistical discrepancy resulting from representation.

c) Apart from that the differences in the form and pointing of divisions of verified characters frequency in the male population part are also very low. Most empirical divisions of verified characters in both populations statistically significantly differ from a standard division where diversions from normality are caused especially by divisions' asymmetry but on the other side the direction of diversion from normality (right-side or left-side asymmetry) is positive conformable with it (1 exception concerning forward leg length in a sitting position).

In the **female part of population** of the compared coutries the following facts were registered:

a) The differences of verified characters quantile characteristics are a little bit higher even if almost all of them may intrude into the absolute frame +/- 4cm. But for women more distinctive systematic trends towards lower quatile values appear in Croatian population, they especially concern hands and legs dimensions but also total body height in a standing position.

b) The above mentioned fact is caused especially by more distinctive differences in a position of compared divisions; less distinctive are differences in their variability. Divisions of the analyzed characters in both monitored countries – in contrast to a male population – approach normality better and due to it both monitored populations have very similar form and pointing of divisions.

In general it results from presented findings and facts that height and width parameters of model figures of male and female population in both countries are comparable and quantile characteristics of body heights and arms width utilized for determination of ergonomic, hygienic and constructive norms in different areas of human activities are very similar in both countries. Selected samples of both countries may be combined and the combined sample may be used to check actual valid legal regulations in both countries.

As to dimensions and quantile characteristics of model figures hands and legs we recommend higher reserve and exclusion of samples combination. The survey and obtained results indicate that in both countries there are mostly statistically significant differences in position of empirical divisions of hands and legs dimensions and this may be seen in more distinctive diversions of quantile characteristics. Practically it could be seen that dimensions of hands and legs of model figures of Croatian population (lengths of hands and legs) are at comparable height parameters systematically lower that in Slovak population part. In determination of norms and regulations for antrophometrical dimensions concerning the dimensions of hands and legs we recommend to proceed independently.

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