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MARTIN ČUTA, PETRA URBANOVÁ, PETR BRUNECKÝ, KATEŘINA DVOULETÁ, MIROSLAV KRÁLÍK, TOMÁŠ MOŘKOVSKÝ

BODY MEASUREMENTS OF CZECH ADULT POPULATION: A BACKGROUND FOR SEATING FURNITURE FUNCTIONAL DIMENSION UPDATES

ABSTRACT: For the contemporary Czech population, the recent-most dataset available to serve as a reference to furniture designers originated in anthropometric examinations performed during the Czechoslovak spartakiad which took place in 1985. Currently valid technological design standards are based on anthropometric data collected in the 1960's. To provide background for an update of furniture functional dimensions, 37 somatic characteristics were measured in a sample of 463 adult participants. The collected data were used as a background for a design standard update proposal as a statistically significant difference was found in somatic characteristics between the current Czech population and the reference sample. Post-hoc testing was employed to verify the concept of utilizing S, M, L sizes (similarly to the clothing industry) in furniture design. For the seat height and length, the S, M, L categories for both males and females would be plausible (there is little overlap in size categories), but for seat width, armrest width and height sizes based on body height can't be defined clearly. Our results suggest that no clear recommendation can be provided to furniture designers (based on our data) in terms of creating size categories for seating furniture.

KEY WORDS: Body measurements - furniture design - S, M, L sizes - NIS project

INTRODUCTION

Sedentary behavior has been reported to cause various types of detrimental health outcomes (Chen *et al.* 2009). The disadvantages from prolonged sitting include increased intradiscal load (Nachemson 1966, Nachemson 1981) or weakened posterior lumbar structures (Beach *et al.* 2005, Corlett 2006). High

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occurrence of occupational health problems (e.g., chronic neck, upper back and lower back pain) in the present-day society has been associated with improper sitting postures and inadequate workplace (Ferrari, Russell 2003). All-day sedentary occupation at desktop computer has been proven to inflict discomfort and eventually produce health problems in the areas of the neck, shoulders and back (Straker *et al.* 1997, Ferrari, Russell 2003, Hladký 2003, Mirer, Stellman 2008). Inadequate or incorrect sitting postures produced in many instances by unfitted office furniture have been reported to cause and/or aggravate musculoskeletal disorders (Karlqvist *et al.* 2002, Norman 2005, Toomingas, Gavhed 2008). Furniture design standards originate in population-specific body measurement statistics (Hanson *et al.* 2009, Chiang *et al.* 2009, Bolstad *et al.* 2001; Hedge 2013). The standards which are not updated regularly fail to cover trends and progressive developmental changes which occur in the population naturally or are socially induced – the secular trend (Loesch *et al.* 2000, Cole 2003, Malina 2004, Myburgh *et al.* 2017). For instance, the contemporary Czech population, and in the same fashion presumably other population of the Central and Eastern Europe (Hitka *et al.* 2018, Oprişescu *et al.* 2014), continues to be under the influence of the secular trend (Grasgruber *et al.* 2014a, b). As a consequence, the adequacy of furniture design dimensions diminishes in time.

For the contemporary Czech population, the recent dataset available to serve as a reference to furniture designers or to any somatometric study for that matter originated in anthropometric examinations carried out for the purpose of the Czechoslovak spartakiad which took place in 1985. The mass sports event attended by a large number of participants of all ages created an excellent opportunity to collect a large sample of quantitative data (Bláha *et al.* 1986). Currently valid technological design standard is based on anthropometric data collected in the 1960's.

Current needs to innovate design standards gave origin to NIS project (Information System for Support Research, Innovation, Product Development and Furniture Quality, shortly Information System for Furniture Designers). The NIS project aims to provide furniture designers with a broad range of design-specific information including dimensions and related human body measurements (www 1). Improving the quality of sitting is believed to have positive influence in several problematic areas of the musculoskeletal system as well as in the overall health status and individual comfort.

To innovate design standards adequately, seating furniture fundamental design dimensions need to be taken into account. The basic ones – the seat height, seat depth, seat width, armrest height, inner inter-armrest distance, backrest height, altogether defined by 8 standard body measurements – are also included in the valid technological standards: *Fundamental measurements of the human body for the needs of technological design* (ČSN EN ISO 7250-1). The relevant somatic measurements are shown on the following *Figure 1*. The basic measurements for seating furniture include the seat height, seat depth, seat width, armrest height, inner inter-armrest distance, backrest height.

The seat height is defined by the popliteal height in sitting position. A seat with an adequate height allows the majority of body weight to rest on the ischial tuberosities, enables the back to rest on the backrest and thus provides appropriate support for the lower back.

The seat depth is defined by the length of the thigh (popliteal) in sitting position. Seat depth is important for such buttock placement which allows full use of the back-rest and for lower-limb position which eliminates compression in the popliteal area and the dorsal part of the thighs.

The width of the seat is defined by the buttocks (hip) width (seat width). In order to ensure that an acceptable percentage of users are capable of sitting down and standing up with ease and without spatial restrictions, 95th percentile of the population should be used for industrial manufacturing reference (Panero, Zelnik 1979).

The eye height is defined as the height of the lateral corner of the right eye from the plane of the seat. Adequate computer screen setting (level eyesight) and overall office layout (as oversight of the office or maintenance of eye contact between coworkers are concerned) need to be planned with understanding of this body measurement to avoid excessive load on the structures of the neck and the upper back.

The armrest height is defined by height of the flexed elbow in sitting position. Technically the armrest height is measured in the middle of the seat. Adjustable armrest height should fall into the range defined by the 5th percentile of the female population height of the flexed elbow in sitting position (lower limit) and the 95th percentile of the male population height of the flexed elbow in sitting position (upper limit) (Panero, Zelnik 1979).

The armrest length is defined by abdomen depth – the largest depth of the abdomen measured

horizontally from the surface of the back. The armrest length (office seating furniture) limits the distance of the backrest from the desktop. If the armrests are exceedingly long, the user cannot sit comfortably close to the table and simultaneously rest on the backrest.

The inter-armrest distance is defined by the width of the elbows. Armrests must provide comfortable rest for the upper limbs and present no limit in motion. While standing up and sitting down, the hips of the user should only slightly brush against the armrests. In chair designs, this dimension should be taken into consideration in conjunction with the armrest height.

Apart from updating the standard dimensions, a trend aimed to better adapt furniture to specific users has been proposed using the S, M, L sizing, similarly to clothing applications (Teraoka *et al.* 2005, Dvouletá, Káňová 2014). This approach allows the potential customer/user to select the appropriate-size furniture piece according to his/her body-size. Káňová and Dvouletá used an extended sizing chart (XS–XL),but based their comparison to current design standards on a UNISEX category – an average of male and female values. The size chart was based on body height quartile values for the S, M, L categories and distribution extremes for the XS and XL categories (Dvouletá, Káňová 2014). In this paper, we decided not only to test whether the current furniture design standards need updating but also if it is necessary to design size-specific furniture in the S, M, L sizes for both sexes – whether a significant overlap between size categories exists.

MATERIAL

A total of 463 participants ranging in age from 18–65 years were measured in the span of two and a quarter years (November 2009 – March 2012). The study sample comprised Czech men and women. Such individuals were included into the study sample so that compliance with the requirements of representativeness (age-, employment-, area of residence-wise) was attained: ratio of male and female participants (the final ratio 235 females and 228 males), ratio of participants from small towns (approximately 2–10 thousand inhabitants) and larger cities (Opava – approximately 70 thousand inhabitants, Brno – approximately 400 thousand inhabitants) and ratio of manual workers to predominantly sedentary occupation office employees were balanced. These two activity-types were complemented by a transitional type (including both sedentary occupation and moderate physical activity) represented mainly by students of two major universities situated in Brno (Masaryk

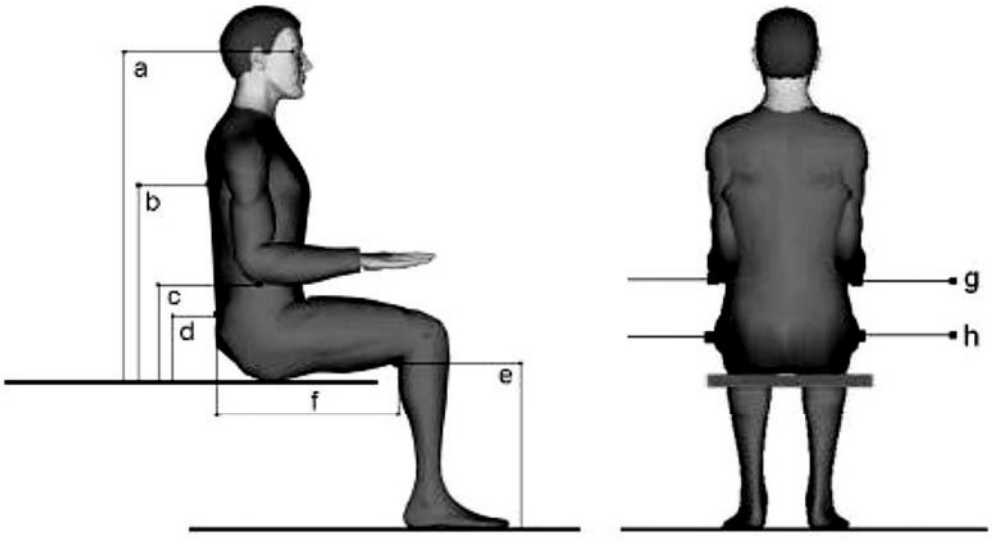

FIGURE 1: Standard body measurements used in seating furniture design: a – Height of the eyes in sitting position, b – Height of the lower angle of the scapula, c – Height of the flexed elbow in sitting position, d – Height of the buttocks above the seat, e – Popliteal height in sitting position, f – Length of the thigh (popliteal) in sitting position, g – Width of the elbows (flexed) in sitting position, h – Buttocks (hip) width (seat width).

University; Mendel University). Students of both universities generally spend part of their tuition in class lectures, part in practical courses and they have some amount of mandatory physical education. Although participants of varying backgrounds were recruited in order to maximize the representativeness of the sample, the resulting N is comparatively low in respect to the reference sample (Bláha *et al.* 1986). The reference sample is divided into age-respective categories (one-year categories from 18.00–19.99, two-year categories from 20.00–24.99, five-year categories from 25.00–29.99 and ten-year categories from 30.00–54.99). Values for respective categories were summed (and averaged) into one category (18.00–54.99) for comparison with our experimental data (18–65).

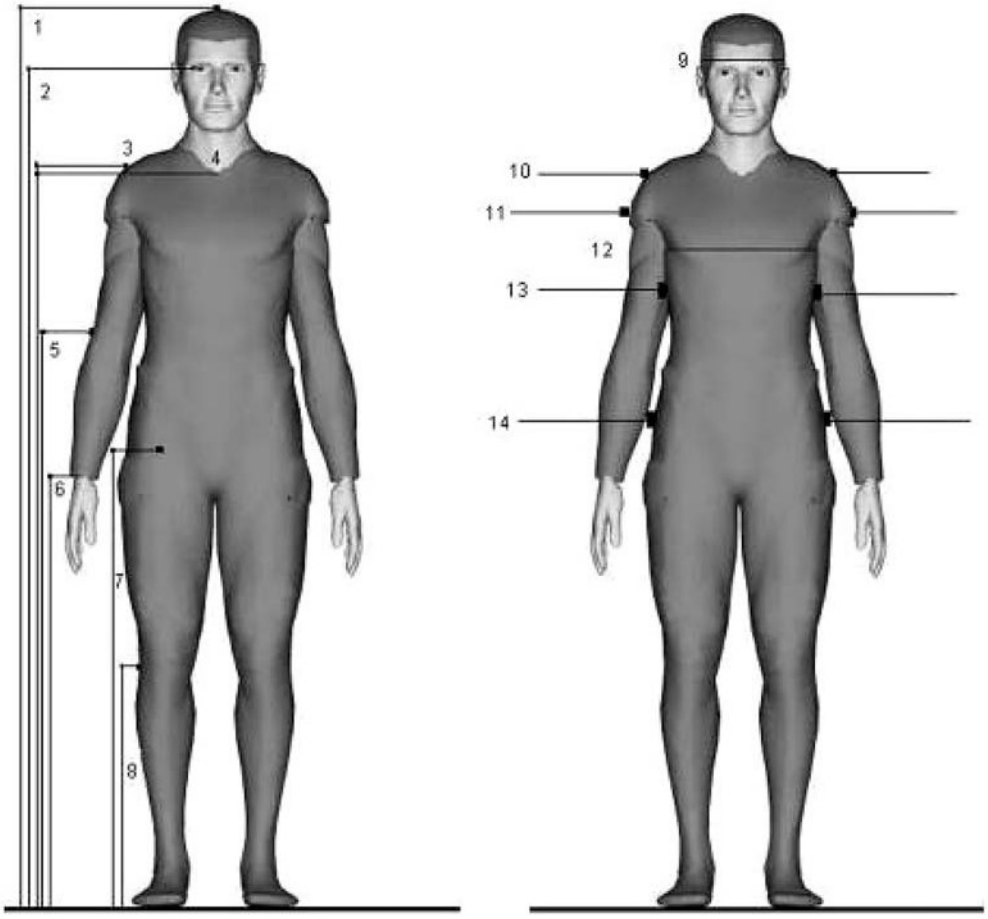

FIGURE 2: Body measurements overview: 1 – Body height – height of the Vertex landmark, 2 – Eye height (lateral angle of the right eye height), 3 – Height of the Acromiale landmark (shoulder height), 4 – Height of the Suprasternale landmark, 5 – Height of the Radiale landmark (elbow height), 6 – Height of the Stylion landmark (height of the wrist), 7 – Height of the Iliospinale landmark (height of the pelvis), 8 – Height of the Tibiale landmark (knee height), 9 – Head circumference, 10 – Shoulder breadth (distance between right and left Acromiale landmarks), 11 – Bideltoid breadth (horizontal distance between two distant-most points in the deltoid region), 12 – Chest circumference (at the height of the Mesosternale landmark in girls, Thelion in boys), 13 – Transversal chest diameter (horizontal distance between two distant-most points of the chest, in frontal plane), 14 – Pelvic breadth (distance between right and left Iliocristale landmarks). Note: not pictured – Height of the flexed elbow (measured on the Olecranon), Sagittal chest diameter (horizontal distance of the middle part of the Sternum and the corresponding thoracic vertebra spinous process), Arm span (distance of right and left Daktylion landmarks, arms raised in horizontal position), Arm reach – length of the outstretched arm – horizontal distance from the wall to the axis of the hand grip (holding a measuring prop peg 20 mm in diameter), Forearm reach – horizontal distance from the elbow (Olecranon) to the axis of the hand grip (holding a measuring prop peg 20 mm in diameter), Body weight.

METHOD

The examination was carried out under conditions which guarantee privacy and anonymity of the participants. Each person was examined upon signing an informed consent form and participation was voluntary.

Prior to measurement the following information was noted about each participant: code number, sex, birthdate, occupation, measurement date and time.

Males were measured by a male researcher, females by a female researcher in order to ensure correctness and to meet the ethical principles of anthropological examination.

The measurements were carried out with certified anthropometric instruments. During the measurement the participants of the study were clad in their underwear, measurements were taken in the standard anatomical position (in case of sitting measurements the participants were seated in an actively upright straightened position, thighs parallel in a horizontal position, lower legs at a right angle, head oriented in the Frankfurt horizontal plane, the seat was a standard – horizontal board, even and level in all parts). All bilateral measurements were taken on the right side.

Body weight was measured using a digital personal scale, circumferences using a measuring tape, height, length and some width measurements using an anthropometer. Most width measurements were measured using a pelvimeter.

The measured parameters are illustrated on the following Figure 2 and Figure 3 (created in the ergonomic SW package Tecnomatix Jack by Siemens) with short descriptions. Detailed definitions will be provided on request by authors (for reasons of limited space) or can be found in the handbook (Knussmann *et al.* 1980).

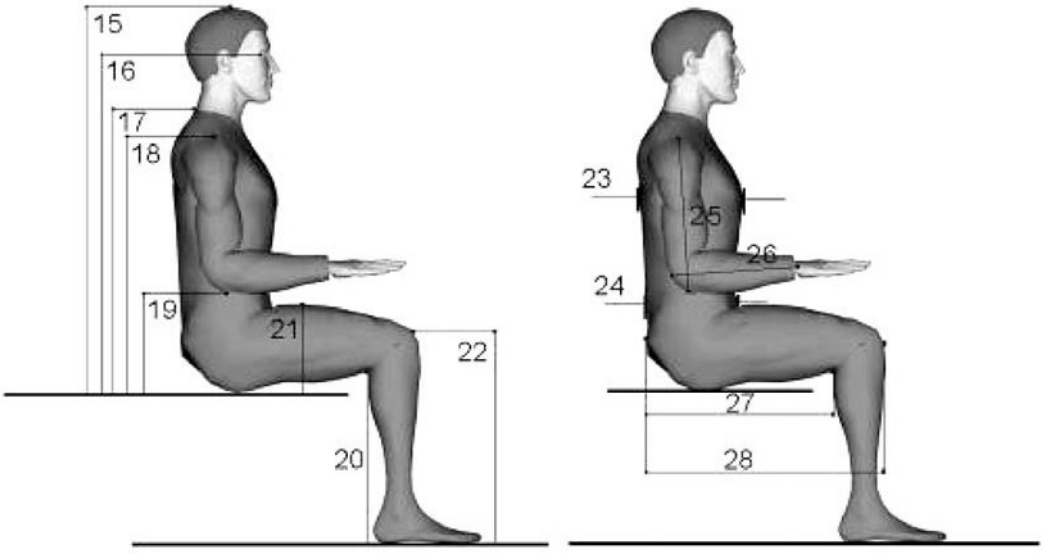

FIGURE 3: Body measurements in sitting position overview: 15 – Sitting body height – Vertex landmark distance from the seat, 16 – Eye height – sitting – (lateral angle of the right eye distance from the seat), 17 – Height of the Cervicale landmark (distance of the C7 spinous process prominence from the seat), 18 – Shoulder height (distance of the Acromiale landmark from the seat), 19 – Height of the flexed elbow (distance of the Olecranon from the seat), 20 – Popliteal height (distance of the flexed knee – flexion line in the popliteal crease) from the ground, 21 – Vertical thigh thickness, 22 – Knee height (distance of the Patella upper margin on the flexed knee from the ground), 23 – Chest depth, 24 – Abdomen depth, 25 – Upper arm length – distance of the Acromiale landmark and the Olecranon (elbow is flexed), 26 – Forearm length – distance from the Olecranon (elbow is flexed) to the Stylion landmark, 27 – Length of the thigh (popliteal) – horizontal distance from the dorsal surface of the buttocks to the popliteal crease (knee is flexed), 28 – Length of the thigh (patellar) – horizontal distance from the dorsal surface of the buttocks to the front surface of patella (knee is flexed).
Note: not pictured here – Width of the elbows (flexed) – direct horizontal distance between lateral-most points on the elbows in individually comfortable position (see *Figure* 1g).
Buttocks (hip) width (seat width) – the largest horizontal distance between two distant-most points on the soft tissue in the gluteal – hip region (see *Figure* 1h). Height of the Radiale anthropometric landmark (height of the elbow) – distance from the seat.

All overview statistics listed below were carried out in the IBM SPSS Statistics package version 20. Normality of the distribution was tested using a one-sample Kolmogorov Smirnov test, statistical significance of differences (study sample versus reference values by Bláha *et al.* 1986) was tested using a one sample t-test. To test whether the S, M, L sizes/categories in males and females overlap, we performed ANOVA with the unequal N HSD post-hoc test in Statistica 13 SW. The proposed size categories are based on body height percentiles; the post-hoc analyses were carried out for furniture-specific dimensions: Elbow width, Hip width, Length of the thigh (popliteal, sitting), Length of the thigh (patellar, sitting), Knee height (sitting), Popliteal height (sitting), Elbow height (sitting), Height of the radiale (sitting).

The S, M, L sizes were constructed using the body height percentile values for males and females separately. To keep the analysis results informative, we omitted the XS and XL categories – as used by Dvouletá and Káňová (2014). The S category was defined by the 10^{th} (lower limit) and 25^{th} percentile (upper limit) of body height. The M category was defined by the 25^{th} percentile (precisely, percentile 25,1; lower limit) and 75^{th} percentile (upper limit) and the L category was defined by the 75^{th} percentile (precisely, percentile 75,1; lower limit) and 90^{th} percentile (upper limit) of body height.

RESULTS

In the following tables, descriptive statistics of acquired data are presented for women and men separately. In case of variables for which adequate reference data (Bláha *et al.* 1986) was available, t-tests were performed to compare population means. Only those parameters were included in the tables for which a comparison reference was available in Bláha's sample with the addition of those parameters which are considered crucial for seating furniture design. Prior to testing, normality of the distribution was verified using a one-sample KS test. In men, all tested variables proved to have normal distribution; in women, body weight, chest circumference and sagittal diameter of the chest did not have normal distribution. Non-parametric testing (one-sample Wilcoxon signed rank test) was performed for these variables.

The results show that in comparison with the recent-most reference dataset available (Bláha *et al.* 1986) the current Czech population is significantly larger in the majority of the body measurements except for head circumference (both in men and women).

The nation-wide reference dataset does not contain many of the measurements from our protocol as they are ergonomics-specific and therefore we could not compare them with the reference sample. The aim of the project was to create a background for design standard updates; some authors (Teraoka *et al.* 2005, Dvouletá, Káňová 2014) suggest including sizing categories (S, M, L) based on body height for easier customer orientation into the standards to individualize furniture sizes. For sexually dimorphic somatic characteristics, biological variation in males and females in general overlaps to some extent. The results are visualized in the tables 3–10. To summarize, individual categories overlap (i.e. there is no statistical difference between categories) to a higher extent in width characteristics (*Table 3 and 4*). Understandably, as the categories are defined by body height, characteristics which correlate with body height will overlap to a lesser extent – most values for individual sizes/categories are significantly different for knee height and thigh length (*Tables 5–8*).

DISCUSSION

Comparisons with available reference samples

Comparison of the acquired data was performed using an adequate, recent-most available reference sample of the Czech population. Although the reference is constructed upon anthropometric population-wide examinations carried out in the 1980's (Bláha *et al.* 1986), it is the only representative reference sample for anthropometric comparisons. Except for head circumference, the contemporary Czech population differed significantly – being larger than the 1980's population-wide reference – in all parameters where comparison was possible. The majority of ergonomic-specific measurements was not included in the population-wide reference sample and are not included in the analysis/overview (these measurements were collected as they have informative value for furniture design). Another comparison option for measurements not included in the basic set is to use the official technological design standard as reference (ČSN 91 0620 *Chairs. Function dimensions and methods of measurement*). It is still currently valid (although said standard became effective in 1982 and originates in anthropometric examinations performed in the 1960's) (www 1). The standard only establishes the upper and lower limits which define the range of accepted

TABLE 1: Anthropometric measurements (selection) – women. ***stand for very highly statistically significant difference on the level of p<0,001; ** stand for highly statistically significant difference on the level of p<0,01. N/A is abbreviated from Not Applicable; these measurements were not included in the reference sample. [a] stands for very high statistically significant difference – tested non-parametrically using Wilcoxon signed rank test.

Anthropometric measurements women	N	Average	Median	SD	t value	p value
Body weight	235	67.3	64.5	12.75	N/A	0.000[a]
Body height	235	166.6	166.1	6.34	6.32	0.000***
Head circumference	235	55.2	55.1	1.41	1.80	0.072
Chest circumference	235	91.5	89.9	8.26	N/A	0.000[a]
Height of the Acromiale	235	136.8	136.3	5.63	5.66	0.000***
Height of the Suprasternale	235	135.5	135.2	5.50	5.53	0.000***
Height of the Radiale	235	106.3	106.5	4.73	7.15	0.000***
Height of the flexed elbow	235	103.5	103.3	4.47	N/A	N/A
Height of the Iliospinale	235	93.9	93.9	5.23	5.18	0.000***
Height of the Tibiale	235	46.1	45.9	2.67	12.98	0.000***
Height of the Stylion	235	83.1	83.0	3.73	8.64	0.000***
Sagittal chest diameter	235	19.1	18.8	2.69	N/A	0.000[a]
Transversal chest diameter	235	29.3	29.4	2.89	18.91	0.000***
Pelvic breadth	235	28.6	28.2	3.13	3.56	0.000***
Shoulder breadth	235	37.3	37.2	1.90	9.63	0.000***
Height of the Radiale (sitting)	235	26.3	26.4	2.84	N/A	N/A
Height of the flexed elbow (sitting)	235	23.7	23.8	2.68	N/A	N/A
Popliteal height (sitting)	235	40.3	40.1	2.12	N/A	N/A
Knee height (sitting)	235	50.6	50.6	2.55	N/A	N/A
Width of elbows (sitting)	235	60.4	59.9	10.75	N/A	N/A
Buttocks (hip) width (sitting)	235	41.3	41.0	3.59	N/A	N/A
Length of the thigh (popliteal, sitting)	235	48,1	48.05	2.71	N/A	N/A
Length of the thigh (patellar, sitting)	235	58.6	58.5	3.18	N/A	N/A

furniture design dimensions therefore the informative value of this comparison option is quite low. A different kind of approach was introduced (Teraoka *et al.* 2005, Dvouletá, Káňová 2014) – the S, M, L sizing chart.

S, M, L sizes in furniture design

When individually adjustable seating furniture is not an option, it was suggested that a sizing concept similar to sizing used in clothing industry (S, M, L) be used to implement partial individualization (Teraoka *et al.* 2005, Dvouletá, Káňová 2014). Using this concept, customers would be offered furniture in small, medium and large sizes (Dvouletá and Káňová also include XS and XL) sizes based on body height. The customer would be able to select an appropriate furniture size according to his/her body height. Using our data, we tested whether this approach is reasonable for the somatic dimensions which are most relevant for seating furniture design. Our results suggest (although the sample size might be a limiting factor) that overall the

TABLE 2: Anthropometric measurements (selection) – men. ***stand for very highly statistically significant difference on the level of p<0,001; ** stand for highly statistically significant difference on the level of p<0,01; * stand for statistically significant difference on the level of p<0,05. N/A is abbreviated from Not Applicable; these measurements were not included in the reference sample.

Summary statistics men	N	Average	Median	SD	t value	p value
Body weight	227	81.0	79.2	14.10	4.96	0.000***
Body height	228	179.7	180.1	7.10	5.90	0.000***
Head circumference	228	57.1	57.2	1.80	-0.83	0.405
Chest circumference	228	98.9	98.3	10.05	3.92	0.000***
Height of the	228	148.0	147.9	6.42	4.77	0.000***
Height of the	228	146.8	146.9	6.43	5.53	0.000***
Height of the Radiale	228	114.6	114.4	5.34	5.37	0.000***
Height of the flexed	228	111.6	111.4	5.19	N/A	N/A
Height of the	228	102.2	101.9	5.61	6.51	0.000***
Height of the Tibiale	228	50.7	50.8	3.04	13.9	0.000***
Height of the Stylion	228	88.9	88.8	4.39	5.75	0.000***
Sagittal chest diameter	228	23.0	22.5	3.07	10.6	0.000***
Transversal chest	228	33.0	33.0	3.05	17.81	0.000***
Pelvic breadth	228	31.2	30.8	3.28	12.04	0.000***
Shoulder breadth	228	40.6	40.4	2.65	2.26	0.024*
Height of the Radiale	228	27.2	27.2	3.08	N/A	N/A
Height of the flexed	227	23.9	23.9	2.84	N/A	N/A
Popliteal height	228	43.7	43.9	2.29	N/A	N/A
Knee height (sitting)	228	54.9	54.8	2.79	N/A	N/A
Width of elbows	228	62.2	61.4	9.36	N/A	N/A
Buttocks (hip) width	228	38.0	38.1	3.44	N/A	N/A
Length of the thigh	228	49.6	49.5	2.70	N/A	N/A
Length of the thigh	228	61.2	61.1	2,87	N/A	N/A

concept of S, M, L sizes in seating furniture may not be practical. For some dimensions of seating furniture (seat length, seat height) defined by lengths of the lower extremity, it would be advisable to create three sizes (S, M, L) for each sex (with some minor reduction) as the overlap between categories is minimal. This phenomenon was expected as extremity lengths are correlated with body height (Hauser *et al.* 2005, Duyar, Pelin 2003, Ozaslan *et al.* 2003, Han, Lean 1996, Chumlea *et al.* 1994, Agarwal *et al.* 2015, Fredriks *et al.* 2005). Regarding the other parameters, the categories overlapped, including Width of elbows (which defines armrest distance), where there was a complete overlap between all the categories. This parameter is dependent on individual perception of comfortable position and is highly individually variable. Elbow height and Height of the radiale (which define armrest height) also presented almost complete overlap between categories as these parameters depend on individually variable proportions of the upper body and arm length. Hip

TABLE 3: Width of elbows (sitting) – S, M, L category overlap.

Width of elbows	Female S	Male S	Female M	Male M	Female L	Male L
Female S		Overlap	Overlap	Overlap	Overlap	Overlap
Male S	Overlap		Overlap	Overlap	Overlap	Overlap
Female M	Overlap	Overlap		Overlap	Overlap	Overlap
Male M	Overlap	Overlap	Overlap		Overlap	Overlap
Female L	Overlap	Overlap	Overlap	Overlap		Overlap
Male L	Overlap	Overlap	Overlap	Overlap	Overlap	

TABLE 4: Hip width – S, M, L category overlap.

Hip width	Female S	Male S	Female M	Male M	Female L	Male L
Female S		**No overlap**	Overlap	**No overlap**	Overlap	Overlap
Male S	**No overlap**		**No overlap**	Overlap	**No overlap**	**No overlap**
Female M	Overlap	**No overlap**		**No overlap**	Overlap	Overlap
Male M	**No overlap**	Overlap	**No overlap**		**No overlap**	Overlap
Female L	Overlap	**No overlap**	Overlap	**No overlap**		**No overlap**
Male L	Overlap	**No overlap**	Overlap	Overlap	**No overlap**	

TABLE 5: Length of the thigh (popliteal, sitting) – S, M, L category overlap.

Popliteal length	Female S	Male S	Female M	Male M	Female L	Male L
Female S		Overlap	**No overlap**	**No overlap**	**No overlap**	**No overlap**
Male S	Overlap		Overlap	**No overlap**	**No overlap**	**No overlap**
Female M	**No overlap**	Overlap		**No overlap**	**No overlap**	**No overlap**
Male M	**No overlap**	**No overlap**	**No overlap**		Overlap	**No overlap**
Female L	**No overlap**	**No overlap**	**No overlap**	Overlap		**No overlap**
Male L	**No overlap**	**No overlap**	**No overlap**	**No overlap**	**No overlap**	

TABLE 6: Length of the thigh (patellar, sitting) – S, M, L category overlap.

Patellar length	Female S	Male S	Female M	Male M	Female L	Male L
Female S		**No overlap**	Overlap	**No overlap**	**No overlap**	**No overlap**
Male S	**No overlap**		Overlap	**No overlap**	Overlap	**No overlap**
Female M	Overlap	Overlap		**No overlap**	**No overlap**	**No overlap**
Male M	**No overlap**	**No overlap**	**No overlap**		Overlap	**No overlap**
Female L	**No overlap**	Overlap	**No overlap**	Overlap		**No overlap**
Male L	**No overlap**	**No overlap**	**No overlap**	**No overlap**	**No overlap**	

TABLE 7: Knee height (sitting) – S, M, L category overlap.

Knee height	Female S	Male S	Female M	Male M	Female L	Male L
Female S		**No overlap**	**No overlap**	**No overlap**	**No overlap**	**No overlap**
Male S	**No overlap**		**No overlap**	**No overlap**	Overlap	**No overlap**
Female M	**No overlap**	**No overlap**		**No overlap**	**No overlap**	**No overlap**
Male M	**No overlap**	**No overlap**	**No overlap**		**No overlap**	**No overlap**
Female L	**No overlap**	Overlap	**No overlap**	**No overlap**		**No overlap**
Male L	**No overlap**	**No overlap**	**No overlap**	**No overlap**	**No overlap**	

TABLE 8: Popliteal height (sitting) – S, M, L category overlap.

Popliteal height	Female S	Male S	Female M	Male M	Female L	Male L
Female S		**No overlap**	Overlap	**No overlap**	**No overlap**	**No overlap**
Male S	**No overlap**		**No overlap**	**No overlap**	Overlap	**No overlap**
Female M	Overlap	**No overlap**		**No overlap**	**No overlap**	**No overlap**
Male M	**No overlap**	**No overlap**	**No overlap**		**No overlap**	**No overlap**
Female L	**No overlap**	Overlap	**No overlap**	**No overlap**		**No overlap**
Male L	**No overlap**	**No overlap**	**No overlap**	**No overlap**	**No overlap**	

TABLE 9: Elbow height (sitting) – S, M, L category overlap.

Elbow height	Female S	Male S	Female M	Male M	Female L	Male L
Female S		Overlap	Overlap	Overlap	Overlap	**No overlap**
Male S	Overlap		Overlap	Overlap	Overlap	**No overlap**
Female M	Overlap	Overlap		Overlap	Overlap	Overlap
Male M	Overlap	Overlap	Overlap		Overlap	**No overlap**
Female L	Overlap	Overlap	Overlap	Overlap		Overlap
Male L	**No overlap**	**No overlap**	Overlap	**No overlap**	Overlap	

TABLE 10: Height of the radiale (sitting) – S, M, L category overlap.

Radiale height	Female S	Male S	Female M	Male M	Female L	Male L
Female S		Overlap	Overlap	Overlap	Overlap	**No overlap**
Male S	Overlap		Overlap	Overlap	Overlap	**No overlap**
Female M	Overlap	Overlap		Overlap	Overlap	**No overlap**
Male M	Overlap	Overlap	Overlap		Overlap	Overlap
Female L	Overlap	Overlap	Overlap	Overlap		**No overlap**
Male L	**No overlap**	**No overlap**	**No overlap**	Overlap	**No overlap**	

width (which defines seat width) presented approximately a half of overlapping categories.

Our results suggest that no clear recommendation can be provided to furniture designers (based on our data) in terms of creating size categories for seating furniture, which would allow an easy orientation to the consumer based on his/her body height. For the seat height and length, the S, M, L categories for both males and females would be plausible, but for seat width, armrest width and height sizes based on body height can't be defined clearly. It is up for discussion whether and how to reduce the categories - possibly into UNISEX categories following the suggestion of Dvouletá and Káňová (2014).

CONCLUSION

During an anthropometric examination performed within the NIS project 463 participants were measured. The collected raw anthropometric data was subjected to a statistical overview and basic comparison using t-tests (or a non-parametric equivalent). In the majority of the selected body measurements the current Czech population differed significantly from what is assumed to be the current state-of-the-art standard resource for furniture designers. Our data was used as a background for a design standard update proposal (as one of the primary outputs of the NIS project). We also tested the plausibility of S, M, L sizing in seating furniture design, however no clear recommendation can be formulated based on our data. It seems that in terms of seat length and width, creating S, M, L sizes would be plausible based on users' body height, for seat width and armrest width and height the S, M and L sizes can't be clearly defined based on body height.

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REFERENCES

AGARWAL, S., SYED HYDER, H. S., AGARWAL, S. K., 2015: Correlation of body height by foot length and knee height measurements in population of North India. *International Journal of Anatomy and Research* 3, 3: 1225-1229. DOI: http://dx.doi.org/10.16965/ijar.2015.197

BEACH, T. A., PARKINSON, R. J., STOTHART, J. P., CALLAGHAN, J. P., 2005: Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine. *Spine Journal* 5, 2:145-154. DOI: 10.1016/j.spinee.2004.07.036

BLÁHA, P., ŠEDIVÝ, V., ČECHOVSKÝ, K., KOSOVÁ, A., 1986: *Anthropometric studies of the Czechoslovak population from 6 to 55 years (Czechoslovak spartakiade 1985)* (in Czech - *Antropometrie československé populace od 6 do 55 let (Československá spartakiáda 1985))*, ÚNV VS Praha.

BOLSTAD, G., BENUM, B., ROKNE, A., 2001: Anthropometry of Norwegian light industry and office workers. *Applied Ergonomics* 32, 239-246. DOI: 10.1016/s0003-6870(00)00067-3

COLE, T. J., 2003: The secular trend in human physical growth: A biological view. *Economics and Human Biology* 1, 161-168. DOI: 10.1016/S1570-677X(02)00033-3

CORLETT, E. N., 2006: Background to sitting at work: research-based requirements for the design of work seats. *Ergonomics* 49, 14:1538-1546. DOI: 10.1080/00140130600766261

DUYAR, I., PELIN, C.: 2003: Body height estimation based on tibia length in different stature groups. *American Journal of Physical Anthropology* 122: 23-27. DOI: 10.1002/ajpa.10257

DVOULETÁ, K., KÁŇOVÁ, D., 2014: Utilization of anthropometry in the sphere of sitting and bed furniture. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 62: 81-90. DOI: http://dx.doi.org/10.11118/actaun201462010081

FERRARI, R., RUSSELL, A. S., 2003: Neck pain. *Best Practice & Research Clinical Rheumatology* 17, 1: 57-70. DOI:10.1053/yberh.2003.269

FREDRIKS, A. M., VAN BUUREN, S., VAN HEEL, W. J., DIJKMAN-NEERINCX, R. H., VERLOOVE-VANHORICK, S. P., WIT, J. M., 2005: Nationwide age references for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. *Archives of Disease in Childhood* 90, 8: 807-812. DOI: 10.1136/adc.2004.050799

GRASGRUBER P., SEDLÁČEK J., MICHÁLEK J., 2014: Antropometrické charakteristiky české populace (Anthropometric Characteristics of Czech Population). *Studia Sportiva* 3: 85-134.

GRASGRUBER, P., CACEK, J., KALINA, T., SEBERA, M., 2014: The role of nutrition and genetics as key determinants of the positive height trend. *Economics and Human Biology* 15: 81-100. DOI: 10.1016/j.ehb.2014.07.002.

HÁLA, B., BRUNECKÝ, P., KOVAŘÍK, M., JIČÍNSKÝ, M., 2010: *Furniture Information System "NIS" Part I - Content and structure of the system*. Brno.

HAN, T. S., LEAN, M. E. J., 1996: Lower leg length as an index of stature in adults. *International Journal of Obesity* 20: 21-27.

HANSON, L., SPERLING, L., GARD, G., IPSEN, S., VERGARA, C.O., 2009: Swedish anthropometrics for product and workplace design. *Applied Ergonomics* 40, 797–806. DOI: 10.1016/j.apergo.2008.08.007.

HAUSER, R., SMOLINSKI, J., GOS, T., 2005: The estimation of stature on the basis of measurements of the femur. *Forensic Science International* 147(1–2): 185–190. DOI: 10.1016/j.forsciint.2004.09.070.

HEGDE, A., 2013: *Anthropometry and Workspace Design.* Cornell University: Ithaca, NY, USA.

HITKA, M., SEDMÁK, R., JOŠČÁK, P., LIŽBETINOVÁ, L., 2018: Positive secular trend in Slovak population urges on updates of functional dimensions of furniture. *Sustainability*, 10: 3474. DOI: https://doi.org/10.3390/su10103474.

HLADKÝ, A., 2003: Ergonomic risk factors in health problems related to work at computer monitors. Part II - Locomotor system problems (in Czech - Ergonomické rizikové faktory zdravotních problémů u počítačových obrazovek. Část II. potíže pohybové soustavy). *České pracovní lékařstv,* 2: 60–66.

CHEN, S. M., LIU, M. F., COOK, J., BASS, S., SING, K. L., 2009: Sedentary lifestyle as a risk factor for low back pain: a systematic review. *International Archives of Occupational and Environmental Health* 82, 7: 797–806. DOI: 10.1007/s00420-009-0410-0.

CHIANG, J., PARKINSON, M. B., STEPHENS, A., 2009: *Anthropometry for a North American Manufacturing.* In: Proceedings of the 12th SAE Digital Human Modeling for Design and Engineering Conference, Göteborg, Sweden, 9–11 June 2009.

CHUMLEA, W. C., GUO, S. S., STEINBAUGH, M. L., 1994: Prediction of stature from knee height for black and white adults and children with application to mobility-impaired or handicapped persons. *Journal of the American Dietetic Association* 94, 12: 1385–1391. DOI: https://doi.org/10.1016/0002-8223(94)92540-2.

KARLQVIST, L., WIGAEUS TORNQVIST, E., HAGBERG, M., HAGMAN, M., TOOMINGAS, A., 2002: Self-reported working conditions of VDU operators and associations with musculoskeletal symptoms: a cross-sectional study focussing on gender differences. *International Journal of Industrial Ergonomics* 30: 277–294. DOI: 10.1016/S0169-8141(02)00131-2.

KNUSSMANN, R., SCHWIDETZKI, I., JÜRGENS, H. W., ZIEGELMAYER, G., 1988: *Anthropologie. Handbuch Der Vergleichenden Biologie Des Menschen I/1: Band I: Wesen Und Methoden Der Anthropologie. 1. Teil: Wissenschaftstheorie, Geschichte, Morphologische Methoden (German edition).* Gustav Fischer Verlag, Stuttgart, New York.

LOESCH, D. Z., STOKES, K., HUGGINS, P. M, 2000: Secular trend in height and weight of Australian children and adolescents. *American Journal of Physical Anthropology* 111, 545–556. DOI: https://doi.org/10.1002/(SICI)1096-8644(200004)111:4<545::AID-AJPA9>3.0.CO;2-X

MALINA, R. M., 2004: Secular trends in growth, maturation and physical performance: A review. *Anthropological Review* 67, 3–31.

MIRER, F. E., STELLMAN, J. M., 2008: Occupational safety and health protections. In: H. K. Heggenhougen (Ed.): *International Encyclopedia of Public Health.* Pp. 658–668. Academic Press, Oxford.

MYBURGH, J., STAUB, K., RUHLI, F. J., SMITH, J. R., STEYN, M., 2017: Secular trend in stature of late 20th century white South Africans and two European populations. *HOMO – Journal of Comparative Human Biology* 68, 433–439. DOI: 10.1016/j.jchb.2017.10.001.

NACHEMSON, A., 1966: The load on lumbar disks in different positions of the body. *Clinical Orthopaedics and Related Research* 45: 107–122.

NACHEMSON, A. L., 1981: Disc pressure measurements. *Spine* 6: 93–97. DOI: 10.1097/00007632-198101000-00020.

NORMAN, K., 2005: *Call centre work-characteristics, physical and psychosocial exposure, and health related outcomes.* Dissertation, Department of Mechanical Engineering, Linköping University. Arbete och Hälsa. National Institute for Working Life, Stockholm.

OPRIŞESCU, I., GHERGHEL, C. L., MINCULESCU, C., 2014: Secular trend of growth in height, weight and Body Mass Index in young Romanians aged 18-24 years. *Procedia - Social and Behavioral Sciences* 117: 622–626.

OZASLAN, A., ISCAN M. Y., OZASLAN, I., TUGCU, H., KOC, S., 2003: Estimation of stature from body parts. *Forensic Science International* 132,1: 40–45. DOI: 10.1016/s0379-0738(02)00425-5.

PANERO, J., ZELNIK, M., 1979: *Human dimension & interior space: a source book of design reference standards.* New York.

STRAKER, L. M., POLLOCK, C. M., MANGHARAM, J. E., 1997. The effect of shoulder posture on performance, discomfort and muscle fatigue whilst working on a visual display unit. *International Journal of Industrial Ergonomics* 20, 1: 1–10. DOI: https://doi.org/10.1016/S0169-8141(96)00027-3.

TERAOKA, T., MITSUYA, R., NORO, K., 2005: Comfort in furniture at home. In: Vink, P. (Ed.): *Comfort and design. Principles and good practice.* CRC Press, USA.

TOOMINGAS, A., GAVHED, D., 2008: Workstation layout and work postures at call centres in Sweden in relation to national law, EU-directives and ISO-standards, and to operators' comfort and symptoms. *International Journal of Industrial Ergonomics* 38, 11–12: 1051–1061. DOI: 10.1016/j.ergon.2008.02.010.

VIGNEROVÁ. J., RIEDLOVÁ, J., BLÁHA, P., KOBZOVÁ, J., KREJČOVSKÝ, L., BRABEC, M., HRUŠKOVÁ, M., 2006: *6th Nation-wide Anthropological Survey of Children and Adolescents 2001, Czech Republic. Summary results.* Faculty of Science, Charles University and The National Institute of Public Health, Prague.

ELECTRONIC SOURCES

www 1: Department of Furniture, Design and Habitat, Faculty of Forestry and Wood Technology, Mendel University in Brno, 2013. Information system for furniture designers (in Czech – Nábytkářský informační systém). http://www.n-i-s.cz/cz/rozmery/page/55/. Retrieved March 3rd, 2014.

Martin Čuta*
Petra Urbanová
Miroslav Králík
Tomáš Mořkovský
Masaryk University, Faculty of Science
Department of Anthropology
Kotlářská 2, Brno
Czech Republic
E-mail: cuta@sci.muni.cz
E-mail: urbanova@sci.muni.cz
E-mail: kralik@sci.muni.cz
E-mail: tmorkovsky@email.cz

Petr Brunecký
Kateřina Dvouletá
Mendel University in Brno, Faculty of Forestry and Wood Technology
Department of Furniture
Zemědělská 3, Brno
Czech Republic
E-mail: petr.brunecky@gmail.com
E-mail: katerina.dvouleta@centrum.cz

*Corresponding author.