

UTILIZATION OF ANTHROPOMETRY IN THE SPHERE OF SITTING AND BED FURNITURE

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Abstract

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Dimensions of furniture shall respond to current anthropometrical dimensions and ergonomic requirements which are recommended typological group of products. With relevance to the changes of population's height and enlargement of body proportions (according to the last measuring from 1985), it is necessary to revise the majority of dimensions of human – furniture and standards (based on updated measuring of 375 men and women). The proper furniture designing will be dependent on that.

The aim is a statistical evaluation of data from the anthropometrical measuring, acquired within the NIS grant and creating optimal dimensions of sitting and lying furniture so that they respond to the needs of current population. Graphical simulations created in ergonomic software Tecnomatix Jack are intended to illustrate the dimension requirements.

The result are processed in a form of charts which are classified XS–XL. The outputs are compared to data in professional literature and standards. According to preliminary results, the optimal dimensions were designed and those will be further specified and verified. For future, it will be necessary to state the dimensions approximatively to expected population growth.

Keywords: anthropometry, sitting furniture, bed furniture, Tecnomatix Jack

INTRODUCTION

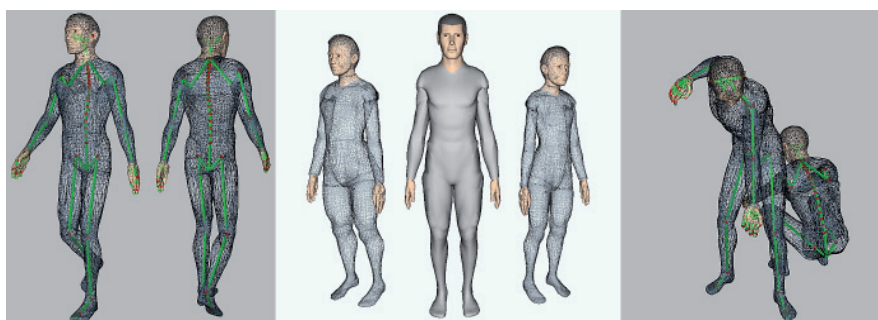
The seating furnishing is intended to brace human body while sitting. The weight of the human body is then transmitted and so the force of gravity is limited. The seating shall be designed and constructed in a way to provide comfortable sitting and maintaining the physiological processes of the human body at the same time (e.g. breathing, digestion, etc.). The sitting position allows that a substantial part of the body is carried by the ischial tuberosities (about 70–80% of body weight).

The vascular system and the nervous system in the vicinity of the projections are adjusted to carry the weight and even a long-term compression of those places does not cause any health problems. However, the lower part of thighs is not sufficiently adjusted and so compressing these parts can reduce the blood circulation, forms pressure onto muscles and muscle nerves. While sitting properly,

the ischial tuberosities should allow the weight transmitting so that there is no compression of other parts of thighs. These are the factors to take into account while dimensioning (Brunecký *et al.*, 2011).

The basic factors of quality lifestyle are sufficient sleep and relax. Human sleep approximately 1/3 of their life and so it is necessary to design the furniture intended to this activity properly.

There are phases of sleep in which the body and brain regenerate, cells renew and these are defined by extensive research. Three basic functional states of organism are represented by: REM sleep, when the brain cells are renewed; non-REM sleep (deep sleep) when the body regenerates; and awakeness. These phases of sleep interchange in regular rounds (5–6 times). If the sleep is interrupted by the increased body movements, the regeneration is not sufficient and so various sleep disorders can occur.



1: Biomechanical model of the human body in the software Tecnomatix jack

Even an inappropriate bed can cause such extra body movements (Brunecký *et al.*, 2011).

The ergonomic software such as Tecnomatix Jack can be used for simulation of human in interior, view of human relationships with the furniture or finding outreach distances. In this SW were created simulations for seating and bed furniture.

Tecnomatix Jack 3D is a simulating device intended to ergonomics, human factor and behaviour at work. The exact biomechanical model of a human is inserted into virtual environment that has 69 segments and 68 joints in total. We can maneuver these segments in 2–3 axes. In this program, there is a male model Jack and a female model – Jill. These models are able to be adjusted to random dimensions. Jack and Jill allow manipulation with the segments via the joints; the joint angles and their ranges are based on the studies of NASA.

With the ability to use the measured anthropometric dimensions, Tecnomatix Jack plays an important role in the creation of current dimensional requirements for furniture.

MATERIALS AND METHODS

Anthropometry

The current anthropometrical measuring was executed within the grant FR-TI1/050 – NIS – “Information system to support research, development, innovation and quality furniture” (2009–2012, MPO/ČR).

The grant was solved at the Department of Furniture, Design and Habitation of Mendel University in Brno. There were 375 measured probands in total, 182 of which were men and 193 women. Concerning the objectivity, it is necessary to state that the results may be interpreted as biased since potential participants, unsatisfied with their body/image were often prone to refuse to take part in measuring.

The majority of measured anthropometrical dimensions were based on the standard ČSN EN ISO 7250 The basic dimensions of human body for technological design, the additional dimensions were: height of suprasternale point, elbow height

when flexed in 90°, stylium point height and arm span.

Measuring equipment used within the anthropometrical research: anthropometer – height measurements, pelvimeter – width measurements, tape measure – circumferential measurements, personal weight (Tanita brand) – body weight.

The results were processed in the program Statistica. Then the range of average standard (25.–75. quartile/percentile) and the range of wider standard (5.–95. quartile/percentile) were set. Values of both ranges were used for the conversion of dimensions into „Dimension chart XS–XL“ – see Tab. V.

Simulation process in the ergonomic software Tecnomatix Jack

→ Analysis of dimensions of seating and bed furniture in professional literature

Software TurboCAD:

→ Compilation of models in software TurboCAD (chairs, armchairs, beds) based on the analysis and update anthropometrical measuring

Software Tecnomatix Jack:

→ “Human” → “Figure” – inserting model Jack/Jill

→ “Anthropometric Scaling” – changing model Jack/Jill according to update anthropometrical data

→ “File” → “Import” → choosing model CAD (chair, armchair, bed)

→ “Human Control / Adjust Point” – setting model Jack/Jill into desired position

→ measuring and evaluating final simulations

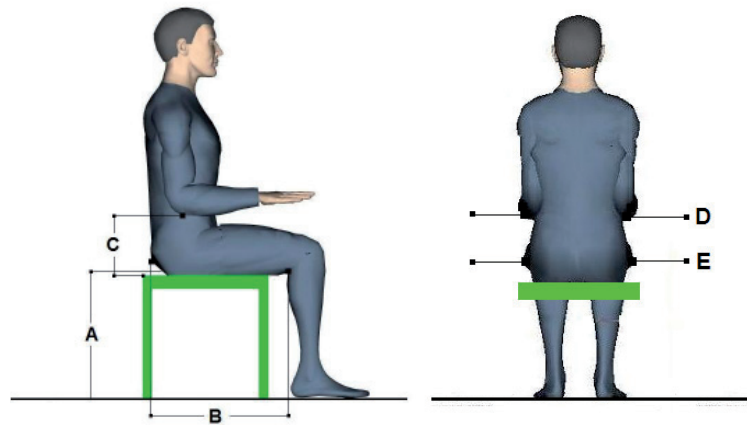
→ graphic design of final simulations.

Anthropometric dimensions and their utilization in sitting furniture dimensioning

A) popliteal height – seat height

- Vertical distance of the knee from bending popliteal region, thigh and lower leg are at right angles (measured by anthropometer).

It is an important dimension for the comfort of legs without compression of lower part of thighs which can be caused by excessively high seat. On the other hand, low seat causes raising the legs, leaning spine and compressing the lumbar area.



2: Anthropometric dimensions for sitting furniture

B) buttock-popliteal length – seat depth

- Horizontal distance from the buttocks to popliteal furrow, thigh and lower leg are at right angle (measured by upper part of anthropometer).

If the seat depth is too deep, the front edge of the seat pinches to the place right above the knee and so it reduces the blood circulation in the legs. Too shallow seat depth does not provide enough support under the thighs.

C) elbow height above the seat in a sitting position – armrests height

- Vertical distance from the olecranon point on the tip of bent elbow to the seat surface (measured by anthropometer).

The height of armrests is dependent on the position of elbow, table top thickness, and height of the thigh and the broad of armrests. The height of armrests is in relation to the width of the seat and the broad of armrests and it is a complicated relation that needs further and more detailed solution.

D) elbow-to-elbow breadth in a sitting position – inner distance between armrests

- Direct distance between the outer sides of elbows, arms at right angle (measured by the upper part of anthropometer).

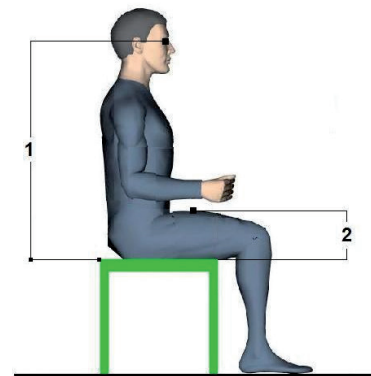
The armrests must provide a comfortable support for arms without any limitations. When standing up or sitting down, hips should only slightly touch them. This dimension shall be considered altogether with the height of armrests.

E) hip breadth in a sitting position – seat width

- The greatest horizontal distance of soft parts of gluteal region (measured by the upper part of anthropometer).

The width of seat should exceed the width of gluteal region since the legs are open in a sitting position. There should be a certain reserve for movement and clothing on each side.

Functional anthropometric dimensions and their utilization in sitting furniture



3: Functional anthropometric dimensions for sitting furniture

1) eye height in the sitting position

- Vertical distance of the outer corner of the right eye from the floor (measured by anthropometer).

These dimensions provide comfortable visual contact without an excessive neck and upper spine strain.

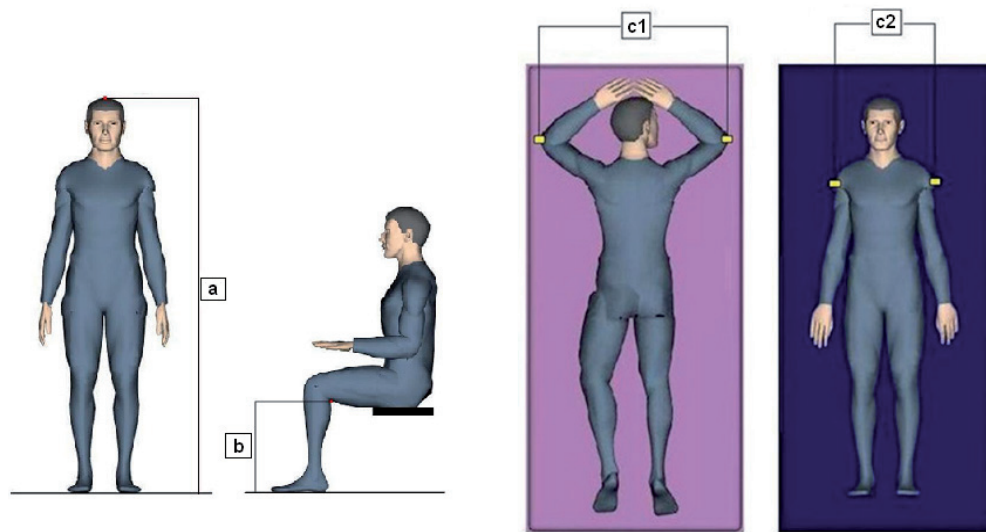
2) height of thighs above the seat

- Vertical distance of the thigh top to the seat surface (measured by anthropometer).

This dimension sets the distance between the seat surface and the lower part of the table.

Anthropometric dimensions and their utilization for dimensioning of bed furniture

For dimensioning of bed furniture, the following anthropometrical dimensions are very important – the stature (a), the popliteal height in a sitting position (b), the width of elbows (c1) and the width of shoulders (c2).



4: Anthropometric dimensions for bed furniture

a) stature – length of lying area

- Vertical distance from the highest point of the head (vertex) to the surface (measured by anthropometer).

The base dimension for lying area is the body height including a definite allowance (space for stretching feet, resting the head on arms, etc.)

b) popliteal height in the sitting position – height of lying area

- Vertical distance from the popliteal region to the surface, the thigh and lower leg are at right angle (measure by anthropometer).

Choosing the proper height of the lying area is based on the popliteal height in the sitting position due to sitting down/standing up from the bed. Elderly people should have higher height of lying area (similarly to the sitting furniture and the height of the seat and armrests).

c1) width of elbows – width of lying area

- Simulation in Tecnomatix Jack according to literature (Dlabal *et al.*, 1970).

The width of lying area is determined by the dimension of the width of human body and the area which is necessary for various positions and

movements while sleeping. The maximal width can be defined as when lying on the back with arms in a relaxed position. This dimension is based on the width of elbows in the maximal span enlarged by 20–25%.

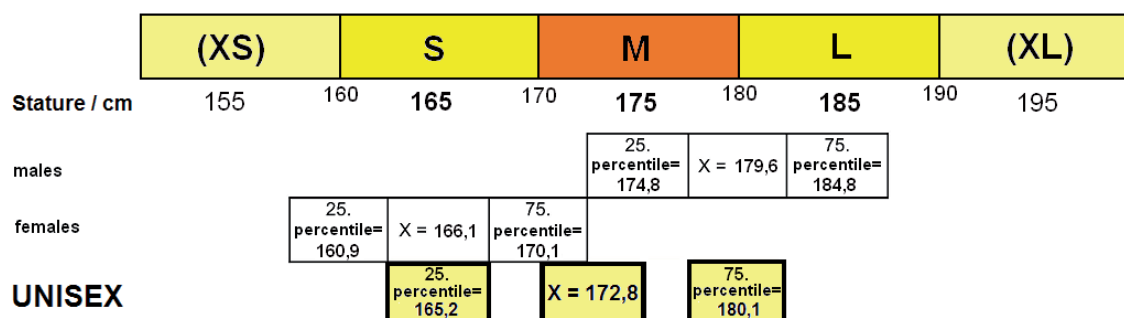
c2) shoulder breadth – width of lying area

- Direct distance of the right and left deltoid areas (measured the upper part of anthropometer).

The second width is based on the bideltoid width of shoulders which is enlarged by 38.2 cm.

Dimension chart construction

The dimensions of furniture should respond to anthropometrical dimensions and ergonomic requirements given for each typological group of product. With relevance to changes in the height of population and enlargement of body proportions (according to the last measurement in 1985), the populations is in the positive secular trend and so it will be necessary to revise the majority of dimensions human – furniture, dimension standards and specifications. For easier orientation, we can implement the traditional classification from the clothing industry (XS, S, M, L, XL) which will be appreciated especially by the customers.



5: Dimension chart XS–XL

The difference of body height between the male and female population is 13 centimeters, however we can find „diffusion“ of male and female heights quite often and due to this fact, there was created a complex set (unisex – 375 probands) – see Tab. V.

RESULTS AND DISCUSSION

All measured anthropometric data were processed in the software Statistica. In Tab. I–III – are selected anthropometric dimensions related to sitting and bed furniture.

Selected simulations in software Tecnomatix Jack – sitting furniture

The results of anthropometrical measuring are processed via software Tecnomatix Jack and they are compared to data in professional literature and standards. According to preliminary results, the optimal dimensions were designed and those will be further specified and verified.

The classification „M“ in the dimension chart shows the average of adult population. The dimensions of classifications „S“ and „L“ are set in the range of average standards (25.–75. quartile/percentile), the range of wider standards (5.–95. quartile/percentile) are represented by „XS“ and „XL.“ The minimal and maximal dimensions of

I: Anthropometric dimensions for the design of sitting furniture

Anthropometric measurements and their use for the design of seating furniture										
Variable	Descriptive statistics (measurements) – the whole file / UNISEX									
	N valid	Average	Median	Minimum	Maximum	5. percentile	25. percentile	75. percentile	95. percentile	Standard deviation
Elbow rest height	374	24.1928	24.2	16.3	35.5	20	22.5	25.7	28.8	2.66164
Popliteal height	375	41.8963	41.7	34.9	50.1	37.5	40	44	46.4	2.73961
Elbow-to-elbow breadth	375	61.1813	60.1	32.1	86.5	46.8	54.3	68.1	77.9	9.56193
Hip breadth	375	40.2107	39.8	32.1	53.5	34.5	37.9	42.3	47	3.67009
Buttock-popliteal length	375	49.0715	48.9	41.5	57.2	44.5	46.8	51.1	53.9	2.9073

II: Functional anthropometric dimensions of sitting furniture

Functional anthropometric dimensions related to the seating furniture										
Variable	Descriptive statistics (measurements) – the whole file / UNISEX									
	N valid	Average	Median	Minimum	Maximum	5. percentile	25. percentile	75. percentile	95. percentile	Standard deviation
Eye height sitting	375	79.1604	78.8	68	93	72.4	76.1	82.1	86.8	4.29131
Thigh clearance	375	14.9296	14.8	11.2	20	12.7	13.8	16	17.8	1.55412

III: Anthropometric dimensions for the design of bed furniture

Anthropometric measurements and their use for the design of bed furniture										
Variable	Descriptive statistics (measurements) – the whole file / UNISEX									
	N valid	Average	Median	Minimum	Maximum	5. percentile	25. percentile	75. percentile	95. percentile	Standard deviation
Stature	375	172.8008	171.7	152.2	200.1	158.4	165.2	180.1	188.5	9.54364
Shoulder breadth	373	45.6086	45.6	37.4	58.5	39.9	42.3	48.2	52.5	3.99185
Popliteal height	375	41.8963	41.7	34.9	50.1	37.5	40	44	46.4	2.73961

population were not included since they are the extremes of measured samples.

Dimensions in the chart are rounded to integers. The depth of the seat (B) is recalculated from the 3.percentile UNISEX, and the enumeration is based on the source: PANERO, J. – ZELNIK, M. *Human dimension & interior space: a source book of design reference standards*, 1979.

The comparison of actual dimensional requirements for seating furniture – universal interior chair (for work and eating) with the standard ČSN 91 0611:

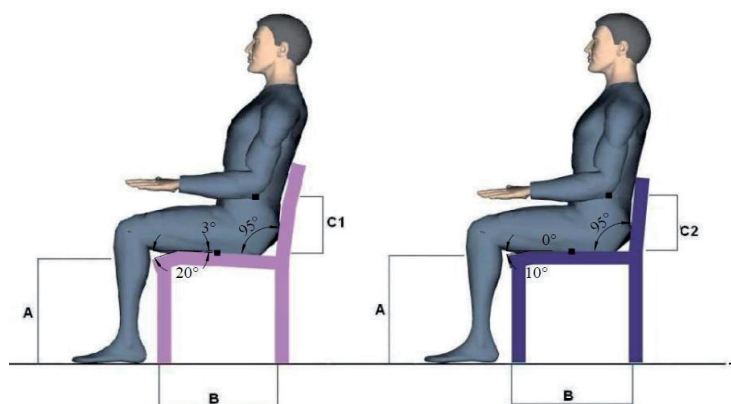
- seat height is insufficient for classification „XS“ and „S“;
- minimal seat depth is insufficient for classification „XS“–„XL“;

- height of armrests is suitable for classification „XS“–„XL“;
- minimal seat width is suitable for classification „XS“–„XL“;
- minimal armrest spacing is insufficient for classification „XS“–„XL“.

The dimensions in the chart are rounded to integers. For comfortable sitting, it is convenient to lower the height of the seat about 2 cm maximally. Lowering the seat more than 2 cm is unsuitable with relevance to other changes after the deformation of upholstery. There are 10 cm included in the width of the seat and this addition is based on ČSN 91 0611.

IV: Legend to figures – sitting furniture

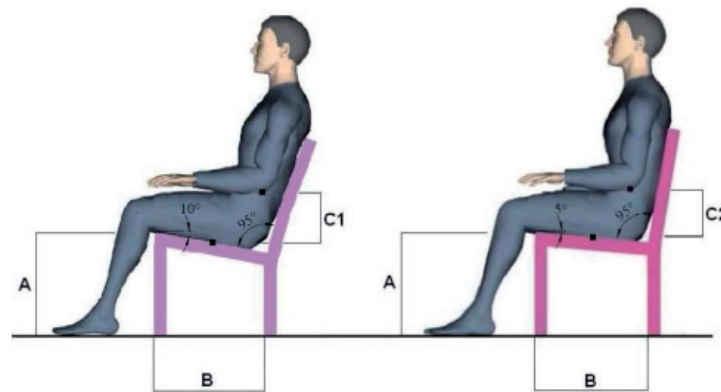
Dimensions were defined by:	
A	Anthropometric dimension – Popliteal height
B	Anthropometric dimension – Buttock-popliteal length
C1, C2	ČSN 91 0620 – (upper plane of armrest – functional center of the seat surface)
Seat width	Anthropometric dimension – Hip breadth
Armrest spacing	Anthropometric dimension – Elbow-to-elbow breadth



6: Universal interior chair – optimum dimensions

V: Universal interior chair – table XS–XL UNISEX

Universal interior chair (for work and eating)					
Size	XS	S	M	L	XL
Stature +/- 5 cm	(155 cm)	165 cm	175 cm	185 cm	(195 cm)
A	32.0 cm	40.0 cm	42.0 cm	45.0 cm	47.0 cm
B	40.0 cm	40.0 cm	45.0 cm	45.0 cm	50.0 cm
C1	19.0 cm	20.0 cm	21.0 cm	22.0 cm	23.0 cm
C2	18.0 cm	19.0 cm	20.0 cm	21.0 cm	22.0 cm
Seat width	35.0 cm	40.0 cm	40.0 cm	45.0 cm	45.0 cm
Armrest spacing	55.0 cm	60.0 cm	60.0 cm	65.0 cm	70.0 cm
Angle of tilt of seat surface	0°–3°				
Angle of backrest	95°				
Angle of the front edge of the seat surface	10°–20°				



7: Armchair – optimum dimensions

VI: Armchair – table XS–XL UNISEX

Armchair					
Size	XS	S	M	L	XL
Stature +/- 5cm	(155 cm)	165 cm	175 cm	185 cm	(195 cm)
A	30.0–32.0 cm	38.0–40.0 cm	40.0–42.0 cm	43.0–45.0 cm	45.0–47.0 cm
B	45.0 cm	45.0 cm	50.0 cm	50.0 cm	55.0 cm
C1	17.0 cm	18.0 cm	19.0 cm	20.0 cm	21.0 cm
C2	13.0 cm	14.0 cm	15.0 cm	16.0 cm	17.0 cm
Seat width	50.0 cm	50.0 cm	50.0 cm	55.0 cm	60.0 cm
Armrest spacing	55.0 cm	60.0 cm	60.0 cm	65.0 cm	70.0 cm
Angle of tilt of seat surface	5°–10°				
Angle of backrest	95°				

The comparison of actual dimensional requirements for seating furniture – armchair with the standard ČSN 91 0620:

- minimal seat height is insufficient for classification „XS“;
- minimal seat depth is insufficient for classification „XS“–„XL“;
- maximal height of armrests is insufficient for classification „XS“–„XL“;
- minimal seat width is suitable for classification „XS“–„XL“;
- minimal armrest spacing is insufficient for classification „XS“–„XL“.

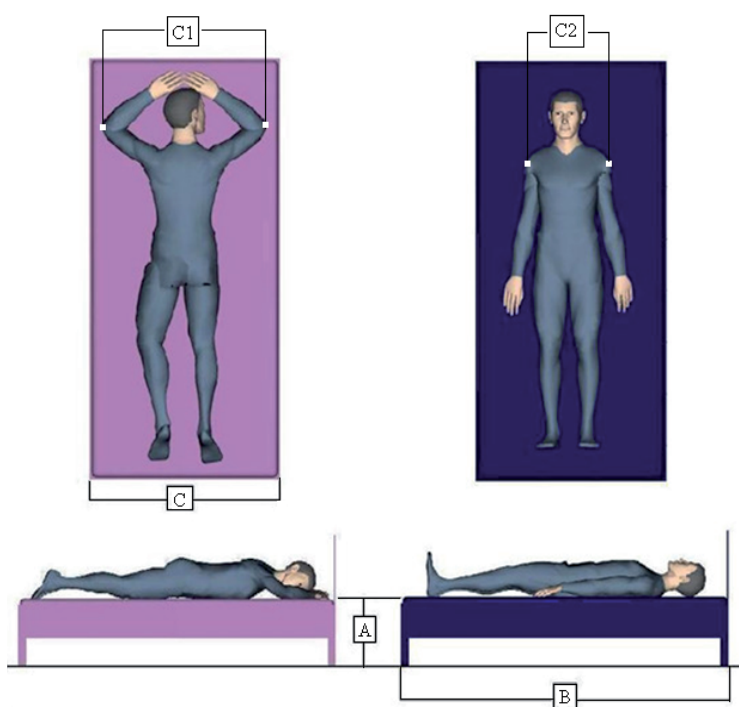
Selected simulations in software Tecnomatix Jack – bed furniture

With relevance to the fact that anthropometrical measuring can record only dimensions of bodies, it was essential to set the allowance of the dimension of lying area. These dimensions are specified in professional literature (Panero, Zelnik, 1979; Dlabal *et al.*, 1970) see Tab. VII. Dimensions B and C were averaged and used to set appropriate allowance and optimal dimension – see Fig. 8. Anthropometrical data are indicated in an ideal situation – after the load of average weight of the human body (size M-UNISEX).

The bodies are figured to illustrate the space that human body needs in relation to the surface of bed. The designs are only of informative character.

VII: Legend to figures – bed furniture

Dimensions were defined by:	
A	Anthropometric dimension – Popliteal height
B	According to Dlabal <i>et al.</i> , 1970 = Stature + 25.5 cm
	According to Panero and Zelnik, 1979 = Stature + 28.1 cm
C	According to Dlabal <i>et al.</i> , 1970 = Elbow-to-elbow breadth in the maximum span (C1) + 20–25%
	According to Panero and Zelnik, 1979 = Shoulder breadth (C2) + 38.2 cm
C1	Anthropometric dimension – Elbow-to-elbow breadth in the maximum span
C2	Anthropometric dimension – Bideltoid shoulder breadth (at the largest expansion of the deltoid muscle)



8: Single bed – optimum dimensions

VIII: Single bed – table XS–XL UNISEX

Single bed					
Size	XS	S	M	L	XL
Stature +/- 5cm	(155 cm)	165 cm	175 cm	185 cm	(195 cm)
A	31.5 cm	40.0 cm	42.0 cm	45.0 cm	47.0 cm
B	185.0 cm	195.0 cm	205.0 cm	215.0 cm	225.0 cm
C	85.0 cm	90.0 cm	90.0 cm	95.0 cm	100.0 cm

Positions, in which a body can occur while sleeping, can require more space in reality.

The comparison of actual dimensional requirements for bed furniture – single bed with the standard ČSN 91 1010:

- height of lying surface is insufficient for classification „XS“ and „S“;
- length of lying surface is insufficient for classification „XL“;
- minimal width of lying surface is insufficient for classification „XS“–„XL“.

Dimensions B (the length of lying area) and C (the width of lying area) in charts are rounded onto integers.

The comparison of actual dimensional requirements for bed furniture – double bed with the standard ČSN 91 1010:

- height of lying surface is insufficient for classification „XS“ and „S“;
- length of lying surface is insufficient for classification „XL“;

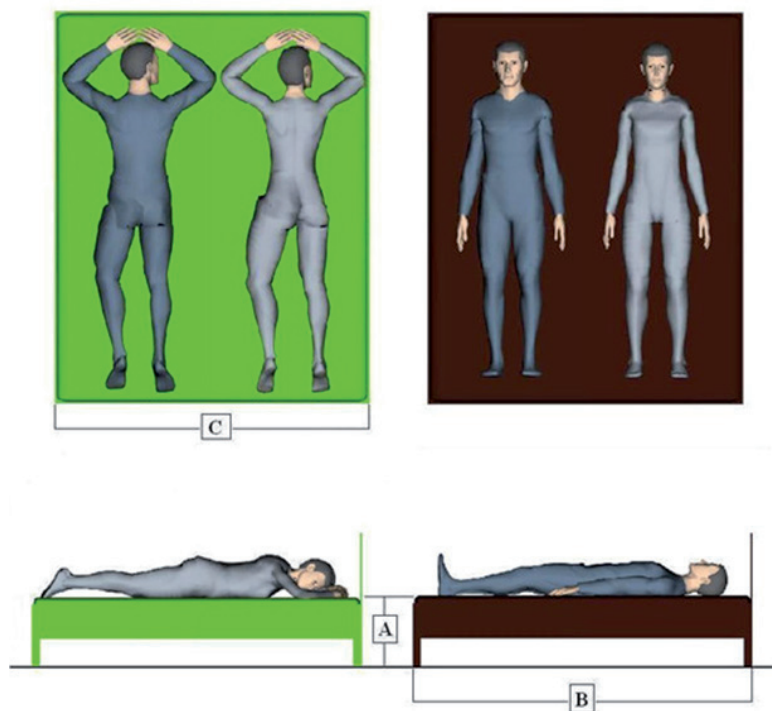
- width of lying surface is suitable for classification „XS“–„XL“.

CONCLUSION

Increasing body size of the adult population (the confirmation of secular trend) which was measured reflects the dimensional requirements of seating and bed furniture. Therefore it is appropriate to review and revise them.

By comparing the current dimensional requirements for seating and bed furniture with existing standards (ČSN 91 0611, ČSN 91 0620, ČSN 91 1010) was found that most of the dimensions of seating and bed furniture can no longer comply with current adult population, which is still in the positive secular trend.

All comparison of current dimensional requirements with standards and publications are published on the website www.n-i-s.cz (NIS Furniture Information System).



9: Double bed – optimum dimensions

IX: Double bed – table XS–XL UNISEX

Double bed					
Size	XS	S	M	L	XL
Stature +/- 5cm	(155 cm)	165 cm	175 cm	185 cm	(195 cm)
A	31.5 cm	40.0 cm	42.0 cm	45.0 cm	47.0 cm
B	185.0 cm	195.0 cm	205.0 cm	215.0 cm	225.0 cm
C	150.0 cm	150.0 cm	160.0 cm	170.0 cm	180.0 cm

SUMMARY

The main aim was to update the dimension requirements, dimension standards and specifications. In this particular case it was for the sitting and bed furniture.

Owing to the project FR-TI1/050 - NIS – „Information system for the support of research, development, innovation and quality of furniture“ (2009–2012, MPO/ČR), the anthropometrical measuring of adult population could be processed. The data were collected by professionals, under the leading of Mgr. Martin Čuta, Ph.D. There were 375 measured probands in total, 182 of which were men and 193 women.

It was necessary to compare the data with the last anthropometrical measuring, which was executed in 1985. The enlargement of body proportions affirmed the positive secular trend in adult population and it is directly reflective in the dimension requirements for sitting and bed furniture.

The difference of body height between the male and female population is 13 centimetres, however we can find „diffusion“ of male and female heights quite often and due to this fact, there was created a complex set (unisex – 375 probands).

The results were processed in the programme Statistica. The range of average standard, range of wider standard and the average value were used to recalculate the dimensions into the „Dimension Chart XS–XL“ which is intended to ease the orientation of clients in the furniture sphere.

Dimension simulations of sitting and bed furniture were created in ergonomic software Tecnomatix Jack. It is a 3D simulation tool focused on ergonomics. There is an exact biomechanical model of a human (Jack/Jill) which can be operated and set to exact required position.

According to preliminary results, we have created optimal dimensions for sitting and bed furniture and implemented them into the „Dimension Chart“. These dimensions will be specified and verified.

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