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THE SIGNIFICANCE OF CONTACT PRESSURE DISTRIBUTION ON THE SOFT TISSUE BY MEN SITTING

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1. Introduction

The weight of the human body transfers by sitting over sitting bones (Tuber ossis ischii) and surrounded soft tissue on the chair and vice versa. The pressure by chair acts on the bulk muscular and bulk bones, so its long time activity may cause changes on the soft tissue and skeleton.

Therefore, design of the chair suitable for the human body from the ergonomic point of view becomes necessary. This is not related just with the comfort. It is connected with health carrying and avoiding of consequences connected with long time sitting. A lot of time the only relation between the chair and human body by chair designing was the magnitude and distribution of sitting pressure. Upholstery over the seat has the role to distribute the pressure under Tubera ossis ischii on the larger area and to reduce the influence of the anthropological and biomechanical properties of the individual. However, many problems today related to sitting and the seat are still inadequately solved. One of these problems is connected with long time sitting in fixed position, what in some circumstances of reduced circulation may lead to thrombosis [Stranden 2000]. Also, young drivers may loaded very often its veins in fixed condition, so they may become ill from thrombosis. Internationally accepted diagnosis for such cases calls as effort thrombosis.

Usually are complaints of aircraft pilots on the uncomforted chairs in cockpit, what is manifested by pains during middle- and long-range flights [Goossens 2000]. These pains caused by uncomfortable seat could be a reason of decreased pilot's concentration what are connected with flight safety. The pilots are seated in the chairs, which have the good possibility of geometry positioning. But, this is not enough. New solutions of the cushioning over the seat and cover from the sheepskin are designed to improve air circulation between pilot's body and aircraft cockpit's chair. Nevertheless, pilot's complaints are not eliminated by these solutions.

The main goal of this work was not just the measurement of the pressure to design new chair shape. The aim of performed measurements is also to find out the relevant values of single parameters that may good describe pressure magnitudes and its distribution by men sitting. This investigation of the pressure distribution between the skeleton and the chair should better describe its influence on the soft tissue of the human body.

2. The contact pressure measurement

2.1 Experimental set-up

The original examined chair for the measurement of the contact pressure distribution (Fig. 1) has been designed and fabricated.

Figure 1. Experimental set-up

The aim was to determinate the influence factors on the magnitude and distribution of the pressure during sitting.
Design of the chair make possible continuously displacements of its backrest through the depth from 220 to 540 mm measured from the chair front. The size of the backrest is 445 x 940 mm. It is possible to put up the backrest for 5 mm from the elastic elements. The angle of the backrest could be changed continuously from -80º to 80º related to vertical position. The chair is equipped with the armrests displaced for 200 mm from its front. The distance between armrests is equal to 485 mm. Designated height of the seat is 340 mm from the ground, but the seat height may be altered by adding of washers below the legs.

2.2 Principal of the pressure measurement

Contact pressure measurement has been performed by elastic elements deformation assessment. The elastic elements in the form of cylinders with dimensions Ø8 x 10 mm are seated on the down plate. The seat of the chair has the size of 20 x 480 x 635 mm and it consists from 20 layers beech's veneer. On the seat the mesh with 2914 square divisions with dimensions of 10±0,1 mm is attached. Each mesh division on the seat is perforated with the hole sized of Ø1 mm, where elastic elements are fastened. Under seat the measured lath is placed. Measured lath has two degrees of freedom (horizontal and vertical displacements).
Horizontal displacement *u* enables the measurement of elastic deformations of elastic elements. Vertical displacement *w* may record deformations successively line by line. Deformation of elastic elements appears during men sitting. Strain measurement is realised by erection of measured lath in the *w* direction for desired value, what could be measured by clip gauge. Moving of measured lath in the *u* direction results with contacts supplying under elastic elements and recording of measured signals. Step motors are used to manage with displacements that are measured by clip gauges, amplified and processed by PC.
One measured lath erection after another with displacement measurement enable to determinate the magnitude and distribution of the pressure by sitting. The results of the performed measurements are presented on the figures 2, 3 and 4 and tables 1, 2, 3 and 4, respectively.

2.3 The position of single person by measurement

The shin bones of individual during experiment were vertical and supported on the front edge of seat under knees. The feet were leaned on the ground for 340 mm below the upper edge of the seat. Any person tried to keep the spine in the vertical position by pressure measurement. The buttock of individual is leaned on the vertical support. Shoulder-blades and nape are supported on the top of backrest. All measurements are performed without any upholstery.

3. The results with measurement analysis

The measurements were performed on the sample of 37 male and 33 female persons. Some characteristics of samples are given in the tables 1 and 2. Sport type of constitution with larger muscle mass produces also larger pressures, but smaller than very thin constitution. Thick persons have the smallest pressure variation. Extra thick persons (especially older woman) have the same pressures that are a little bit changed with different sitting conditions. Thin individuals have smaller areas under thigh bones and front edges are displaced toward Tuber ossis ischii. Also on the back side the edge of sitting is displaced toward Tuber ossis ischii. The width of sitting is changing relatively a little. It is important to explore all relevant factors that may influence on the magnitude and distribution of sitting pressure. Because of that, anthropological and biomechanical analyses of sitting were performed.

3.1 Biomechanical aspect of sitting

It was observed that even small shifting of the head, trunk or any extremity has substantial change of the pressure field as a consequence. As an example of such behaviour, the head turning for ~ 90^o in the left side is presented on the Fig. 2 (pressure measurement was performed without backrest). From the Fig. 2 is obviously that weight of body is transferred on the right side. Maximal right side pressure is 60% greater than left side pressure. One can conclude from this picture that individual position drastically influences the measurement results. If the sitting plane is so low that legs may touch the ground, the greatest pressures appear under Tuber ossis ischii. Here the region below the thigh is unloaded what is the case also by sitting on the leading part of the seat. If the sitting plane is too high and feet don’t touch the ground, the pressure is transferred through the large field under thighs and maximal pressure appears on the edge under knee. Twisting of the backrest turns the gravity centre of the upper part of body to back, so the contact surface is displaced also to back. Maximal pressures under Tuber ossis ischii are then displaced for 1 to 2 cm and back edge of the contact surface for 3 to 5 cm.

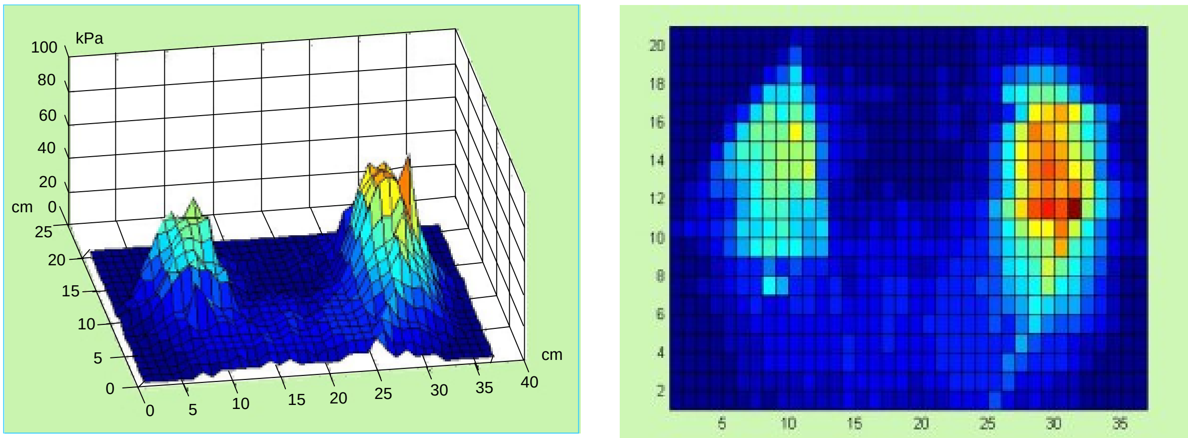

Figure 2. Graphical example of measured pressure by sitting

3.2 Biomechanical principal of the sitting

Radiographic studies all confirm that the pelvis rotates backwards and the lumbar spine flattens when sitting [Andersson 1986]. When moving from a standing to an unsupported sitting position, lumbar lordosis decreased by an average of 38°. This mainly occurred by backward rotation of the pelvis (average 28°). The remaining 10° were changes in the vertebral body angles of the two lower lumbar segments. Akerblom, Keegan, Schoberth and others that flattening of the lumbar lordosis in sitting can be prevented by the use of well-designed low-back support. Andersson et al studied in what way different types of lumbar supports placed at different levels of lumbar spine influenced a number of angles, including the lumbar lordosis angle, as well as the influence of changes including the lumbar lordosis angle, as well as the influence of changes in backrest inclination on those angles. Groups of muscles on the buttock have influence on the lumbar vertebrae configuration and pelvis. They are connecting thigh and knee cap. The rotation of kneecap to back brings to flatten of lumbar vertebrae and to changing of magnitude and distribution of pressure.

3.3 Anthropometrics

The measurement results are shown in the tables 1 and 2, where the ratio of individual height h and body mass m are given. The average values of maximal pressure p_{max} and area A were calculated. Average value of maximal sitting pressure produced by men body is 16,77% greater than one produced by women. But, average value of sitting area by woman is for 20,8% greater than by men. The magnitude and distribution of the pressure is individual characteristic, what can be seen from the measurement results (fig. 3, 4, 5 and 6). The constitution of the single person has significant influence on the pressure field. As muscles are stronger, the pressures are greater. The people, who spend long time in the sitting postures or are not exploded to physical efforts, show lower pressures. From anthropometric results index of prettily and muscles index are calculated, but their values by statistical analysis give not accepted results. Body mass index only gives acceptable results (tables 3 and 4). Except this, it has been trying to replace complex pressure measurement with single anthropometrical measurements, what is depicted on the fig. 5 and 6. The pressure is lower when the contact surface of human body by supporting is greater (fig. 3 and 4). The seat could be adjusted to the shape of body, what is valid for the resting body only. Changing of the sitting postures should not influence on the comfort of sitting. Suhova shown that a man during 5-hours sitting changes its posture for 1000 times.

Table 1. Statistical values of measured parameters for male

	h cm	m kg	Age years	$\frac{h}{m}$	$\ln\frac{h}{m}$	p_{max} kPa	p_{ave} kPa	A cm^2
Average value	180,3	82,1	35,5	2,248	0,798	42,88	17,85	452
Standard deviation	6,63	13,6	15	0,355	0,158	1,58	2,416	89
Minimal value	170	61	18	1,59	0,464	31	14,06	284
Maximal value	196	118	58	3,015	1,104	59,5	22,45	607

Table 2. Statistical values of measured parameters for female

	h cm	m kg	Age years	$\frac{h}{m}$	$\ln\frac{h}{m}$	p_{max} kPa	p_{ave} kPa	A cm^2
Average value	165,6	66,1	31,6	2,605	0,941	36,7	12,1	546
Standard deviation	7,21	14,2	11,3	0,439	0,188	7,30	2,37	176
Minimal value	148	49	19	1,398	0,335	26	8,34	337
Maximal value	179	120,2	54	3,237	1,174	55,5	19,5	1215

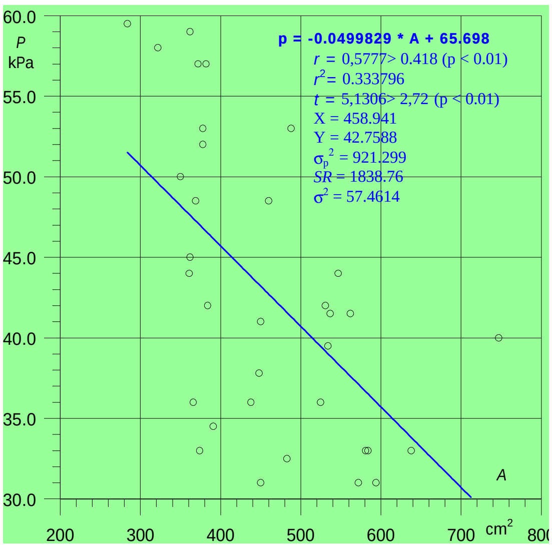

Figure 3. Maximal pressures by sitting depending on sitting's surface (for men)

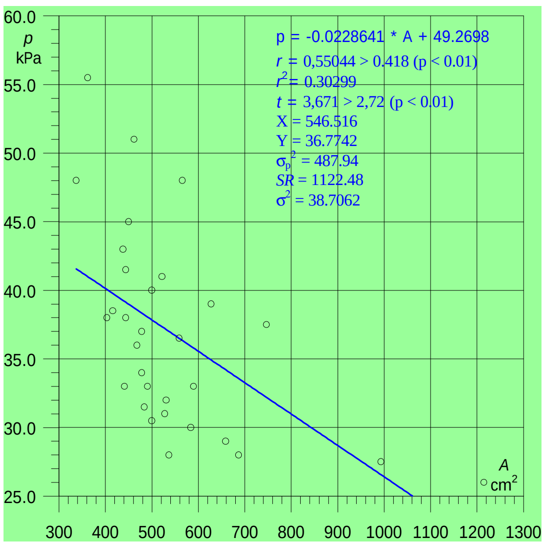

Figure 4. Maximal pressures by sitting depending on sitting's surface (for women)

Table 3. Statistical values of anthropometrical values - women

	O_1 cm	O_2 cm	O_3 cm	O_4 cm	O_5 cm	O_6 cm	M_{index}	$I_{prettily}$	$\frac{m}{h^2}$
Average value	31,12	29,5	80,01	78,72	101,6	88,8	5,57	0,763	24,15
Standard deviation	5,21	4,99	13,57	14,27	10,95	8,17	2,59	0,070	5,28
Minimal value	23	22	64,6	61,5	88	78,7	1,72	0,672	17,86
Maximal value	47,5	46	115	119,5	137	111	12,5	0,934	42,59

O_1 – circumference of the upper arm in flexion and by fist contraction, O_2 – circumference of the upper arm of relaxed fist, O_3 – circumference of abdomen on the level of umbilicus in the horizontal line, O_4 – circumference of abdomen 2-3 fingers over umbilicus in the horizontal line, O_5 – circumference over hips, O_6 – circumference over breasts.

Table 4. Statistical values of anthropometrical values - men

	O_1 cm	O_2 cm	O_3 cm	O_4 cm	O_5 cm	O_6 cm	M_{index}	$I_{prettily}$	$\frac{m}{h^2}$
Average value	33,2	30,8	90,5	88,6	101,9	98,76	7,81	0,863	25,29
Standard deviation	4,6	4,21	12,2	12,96	7,33	9,21	3,56	0,086	4,11
Minimal value	25,8	23,5	69	65	90	78	1,54	0,722	16,92
Maximal value	43,5	41	118	121	121,7	118,5	15,99	1,152	34,94

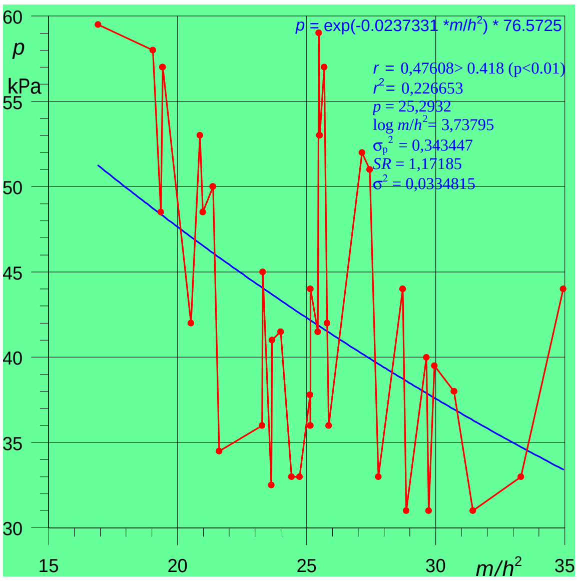

Figure 5. Maximal pressures by sitting depending on Body mass index – by men

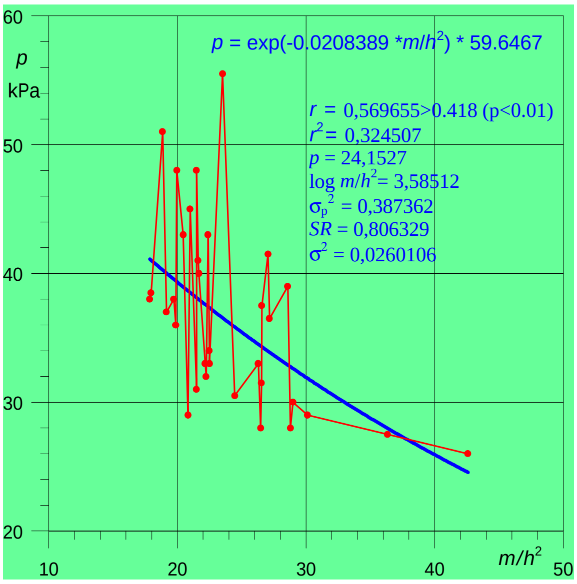

Figure 6. Maximal pressures by sitting depending on Body mass index – by women

3.4 The pressures on the blood vessels

Many studies are shown that inadequate designed chair has unfavourable influence on blood vessels as direct consequence. Akerblom and Schoberth proved that pressure on the edge of the chair do not stop circulation even in the arteries with smallest pressure. Landis study describes 4,3 kPa as maximal pressure that soft tissue of the men could tolerate without any problems. This level of pressure dominates on the border between arterioles and capillary. This value is not applicable by sitting [Jürgen 1997] from simple reason. Namely, when the weight of the body divides by sitting area, then average value is greater than Landis value. Such sitting is not physiologically acceptable for the men. Therefore, Jürgen proposed that pressure appearing during sitting on the chair with upholstery should not overcomes 10 kPa under Tuber ossis ischii.

4. Conclusions

On the basis of performed measurements and biomechanical and anthropometrical analysis may be concluded that magnitude and distribution of sitting pressure is individual characteristic of any person. For the same age and sex of the person with the same ratio of height and body mass different pressure fields were obtained. Individual characteristics of magnitude and distribution pressure are related to:

- ratio of the soft tissue and skeleton,
- ratio of the muscles and fat tissue,
- thickness and distribution of the fat tissue,
- shape and size of bones (spine and pelvis shape) etc.

There is no analytical law for maximal pressures. Also, maximal pressure is not only dominant value for the chair design. If that were the case, air or water bag would be an appropriate solution. Much important role by chair design plays the distribution of the pressure. Therefore, optimal chair design would be achieved with individual approach to any single person. The goal of designers today should be to realise chair shape with such magnitude and distribution of pressure, which will ensure legs muscles and human body relaxation by sitting. This will provide long time sitting without any health consequences.

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