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Comfort Evaluation as the Example of Anthropotechnical Furniture Design

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A B S T R A C T

Human health is becoming an increasingly important issue in contemporary hectic lifestyle imposed at work and by struggle to save time and money. Sitting comfort and quality of chairs which we use for the most of our time have, thus, become essential for healthy lifestyle. Sitting discomforts arise from prolonged sitting on the inappropriate chairs, which failing to provide sufficient support to the body cause discomfort and tiring. The studies of the office chair constructions have identified differences in perception of comfort provided by different types of seats. Four seat constructions and the comfort they provide to the sitters were compared by means of subjective indicators. After a two-day sitting on each of the studied chairs the subjects scored their perception of comfort and discomfort, using the questionnaire with 17 statements. Constructional forms and materials which contributed more to the sense of comfort by minimizing fatigue and pains developed by sitting were determined.

Key words: *office chair, comfort, seat, subjective method, ergonomics*

Introduction

It is a known fact that most of us prefer sitting to standing, that sitting does not require as much muscular work as does standing[1] and that it is much easier to work while sitting because of the stabilized body posture. However, according to Grandjean (quoted by Hermaneu[2]) sitting, unlike standing, increases the pressure to intervertebral disks up to 35%. In addition, prolonged sitting can have many disadvantages, with long-term consequences to human health. Work performed at sitting, such as daily office work, requires sitting during most of the worktime, with short walking and standing intervals[2]. According to Kapica and Grbac[3] basic principle of a comfortable seat is contained in the system where the sitting bones take body weight off to the seat while the feet bear no load and the spine maintains its natural posture. Construction of upholstery and of its elements, shape and hardness of the sitting surface, degree of the seat and backrest deformity, etc. along with the product's overall construction determine sitting comfort and severity of tiring.

Whereas some believe that discomfort is the absence of comfort or that comfort is the state of subjective pleasure developed as the reaction to environment or a situation[4], the others, having performed ergonomical studies, arrived to the conclusion that comfort and discomfort are two different yet complementary extremes on the continuous scale, covering utmost discomfort, neutral (transient) state and utmost comfort[5].

Ljuljka[6] says that humans sit during travel, in the cinema and theatre and particularly throughout their academic life. For this very reason the chairs, in addition to responding to contemporary trends and beautiful design, must provide comfort above all. It is not that easy to very accurately define comfort of the furniture to sit on. Basic factor of contemporary comfort is a specific pressure to body parts. This pressure is smaller with contact surface of human body being bigger. Even the task chairs must have the rests designed so as to provide rest to the muscles of lower extremities and trunk. It is worthy of note that the characteristics of upholstery are important for comfort and proper distribution of pressure. Foamy materials are characterized by retarded re-establishment of their original shape after being unloaded. The shorter delay the quicker return to the original shape and density with full structural integrity. This is outstandingly important when changing the sitting body position.

»Striving of humans for comfort is the reason for permanent search into new constructional forms of furni-

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ture that meet users' requirements. Suitability depends mostly on the degree of their use under different conditions and on psychophysical accommodation to the users«. With these words Grbac[7] described the relation between comfort and the furniture to lie on. The same words can and must apply to the furniture to sit on.

The occurrence of cumulative trauma disorders in the office environment has increased during past few years. Branton (quoted by Fernandez et al.[8]) came to the conclusion that performing the tasks in the inappropriate sitting position should not generate any discomfort i.e. there should not be any awareness of the seat. Some of the aims of ergonomic sitting are the increased individual effectiveness, reduced tiring and establishment of the »correct« sitting posture. Improper sitting is the main cause of reduced performance during the work at sitting.

Evaluation and scoring are the two commonest methods for evaluation of ergonomic office task chairs. The questionnaire with comfort and discomfort scales is valuable for determining whether comfort and discomfort estimates are in bipolar continuum[9]. The factors of biomechanical discomfort increase as a function of daytime, while design turns to be unimportant. Potter et al.[9] have shown that accurate evaluation of a chair takes several hours. Proper ergonomic evaluation and identification of a chair comfort during 8-hour workday requires at least three hours[10]. In the view of the fact that majority of discomfort descriptors are time-dependent, it is not easy to recommend the measurement procedure. There is, however, consistency in the attitude that in one single day at a certain standard time (e.g. between 9 am and 11 am) only one chair must be evaluated. It has been shown that comfort and discomfort can be quantified independently and that the scales developed for the Chair Evaluation Checklist provide consistent results, suitable for practical evaluation of chairs comfort and discomfort[11].

The main goal of the paper is to find connection between different seat designs of office chairs and their comfort/discomfort to the user by subjective evaluation with questionnaire.

Material and Methods

Chair samples

The samples were those available at the market for the end users and in accordance with relevant European norms[12]. The selected ones had the construction which provided natural and appropriate sitting posture and comfort achieved primarily by their mechanism, seat and backrest shape and quality, and by adjustable armrests[13]. Study design included 16 chairs divided in 4 groups of four seemingly equal chairs but with differently constructed seats. Each group comprised [1] chairs with the PU foam seat filament (PU-foam), [2] chairs with the filament of cold-casted PU foam, (PU-ccf), [3] chairs with the

a) Model A *b) Model B* *c) Model C* *d) Model D*

Fig. 1. Chair models used in the study.

TABLE 1
CHARACTERISTICS OF THE CHAIR SEATS

Model	Model A PU-foam	Model A PU-ccf	Model A springs	Model B PU-foam	Model B PU-ccf
PU density	40 kg/m^3	40 kg/m^3	40 kg/m^3 (thickness 15.0 mm)	32 kg/m^3	55 kg/m^3
total thickness	49.5 mm	49.1 mm	56.2 mm	48.8 mm	62.2 mm
microsprings	–	–	Ø45 mm/40 mm Ø1.6 mm	–	–
seat base	PET	PET	PET	plywood	plywood
	Seat thickness of the model C and model D was not measured because it was made of the framed elastic net				

PU – Polyurethan, PET – Polyethylene, PU-foam – chairs with the PU foam seat filament, PU-ccf – chairs with the filament of cold-casted PU foam

combination of the pocketed micro springs and the layer of cold-casted PU foam and [4] chairs with the seat having a framed net. All chairs were coded. The models are shown on Figure 1.

Subjects

The study included 36 subjects (18 female and 18 male) from 22 to 60 years of age. They had been performing office jobs within the time-span of 3 months to 27 years which require mostly sitting position.

TABLE 2
CLASSIFICATION OF THE SUBJECTS BY AGE

Age	Up to 30 y.	31 to 40 y.	Over 40 y.	Σ
Females	8	5	5	18
Males	6	9	3	18
Σ	14	14	8	36

TABLE 3
STATISTICAL DATA ABOUT THE SUBJECTS

	Age (years)	Height (cm)	Weight (kg)
Arithmetical mean	35.1	173.6	71.9
Standard deviation	9.7	8.6	12.8
Minimum	22	156	48
Maximum	60	187	103

The subjects were grouped in nine (9) syndicates of four.

Methods

According to the opinion and perception of the subjects having used the office task chairs, the method for their comfort evaluation was based on the questionnaire[14]. Every subject tested four chairs, each over two working days according to the preset scheme. On day 1 the subjects adjusted the correct chair position and started using a chair. On day 2 after three hours of sitting they had to complete the questionnaire. Then they changed the chair and repeated a two-day cycle. They were also introduced to the study aim and to different seat filaments. Relevant to the chair groups the seats were more or less of different design (chair groups 1 and 3 were more homogeneous).

The questionnaire contained 17 statements about comfort and discomfort (defined by relevant parameters). Answering order was not strict, but the answers had to be provided between 11.00 a.m. and noon.

Each of 17 questions comprised a statement e.g. *I have sore muscles* and the scale from 1 to 9 (Figure 2). To answer, the subjects had to mark with »*X*« any place on the scale.

The statements (in a random order) were the following ones: (1) I feel tired, (2) The chair looks nice, (3) I feel restless, (4) I have sore muscles, (5) I like the chair, (6) I feel pain induced by seating, (7) I feel stiff, (8) The seat feels soft, (9) I feel uneven pressure on thighs and buttocks, (10) I feel relaxed, (11) I feel cramped, (12) The seat is big enough (13) I have heavy legs, (14) I feel restful, (15) I feel numb, (16) I feel calm and (17) I feel comfortable.

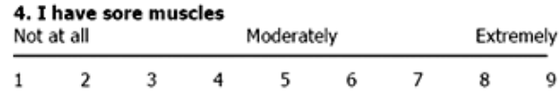

Fig. 2. An example of the question from the questionnaire.

The statements numbered with 2, 5, 8, 10, 12, 14, 16 and 17, presents statements on comfort scale, and those numbered with 1, 3, 4, 6, 7, 9, 11, 13 and 15 presents statements on discomfort scale.

Results

Subjective evaluation of chairs comfort/discomfort

The data were processed by statistical software SPSS 10.0.7. Subjective evaluation of the statements from the questionnaire made by the subjects was compiled on the level of a statement and divided by total number of subjects (36) in order to get average result for a specific statement evaluation. The results are shown in Figure 3.

Figure 4 shows differences in evaluation of the chairs made by the statements which showed that the differences were statistically significant. The significance was tested by t-test for relevant samples used to check the difference in arithmetical means of evaluation by the statements for each respective chair.

Testing of reliability and validity of the comfort and discomfort scales

The »I feel comfortable« statement of this research is treated as a criterion variable, so the results of the examinees on the scales of comfort and discomfort correlate with this statement. The correlation testing between the results on the comfort scale, the results on the discomfort scale and the statement »I feel comfortable« Pearson *r* correlation coefficient was used, and the results obtained are shown in Table 4.

In further illustrations, the correlations of the comfort and discomfort scales with the criterion variable »I feel comfortable« are shown. Average values of the statements were used in the charts on the scales of comfort/discomfort (axis x) and average value of the »I feel comfortable« results (axis y).

Based on the correlations obtained, the following can be concluded: (i) between the comfort and discomfort scales there is a significant negative correlation of medium height ($r=-0.55$; $p<0.01$), which is in accordance with a hypothetical discomfort model and the comfort suggested by Zhang and the associates (1996). Namely,

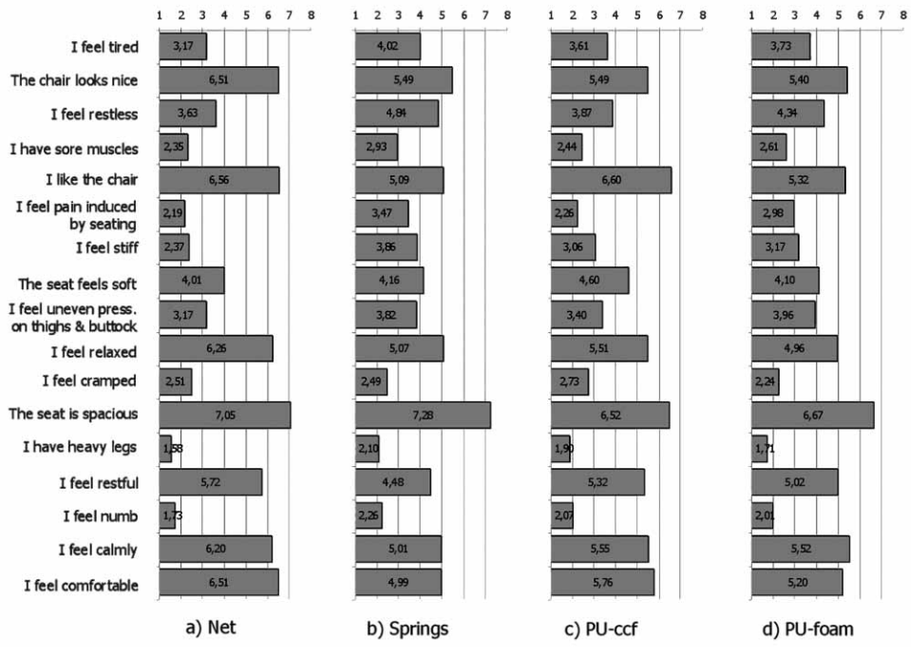

Fig. 3. The results of each statement evaluation.

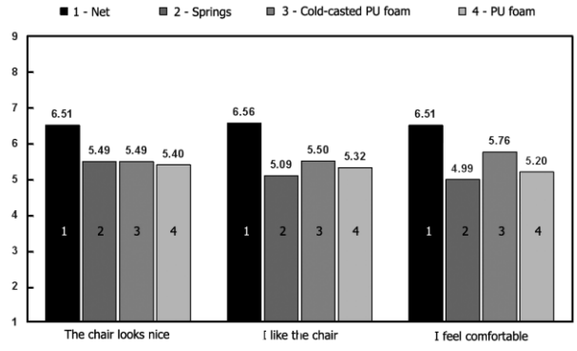

Fig. 4. The statements showing statistically significant difference in evaluation.

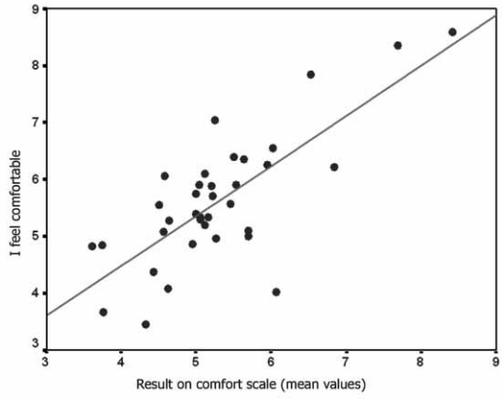

Fig. 5. The correlation of the average result on the comfort scale and the statement »I feel comfortable«.

the aforementioned authors believe that comfort and discomfort are two relatively independent entities; (ii) the correlation, i.e. the connection between the comfort scale and the statement »I feel comfortable« is statistically significant and high ($r=0.76$; $p<0.01$) and it has expectedly positive unary operator; (iii) the correlation of the discomfort scale and the statement »I feel comfortable« is statistically significant, of middle height and negative unary operator ($r=–0.56$; $p<0.01$).

TABLE 4
THE CORRELATION OF THE COMFORT AND DISCOMFORT SCALES AND THE »I FEEL COMFORTABLE« STATEMENT

	Scales/question	Discomfort scale	Comfort scale	I feel comfortable
A.	Discomfort scale	1.00	–0.55*	–0.56*
B.	Comfort scale	–0.55*	1.00	0.76*
C.	I feel comfortable	–0.56*	0.76*	1.00

*Correlations are statistically significant in the 1% level

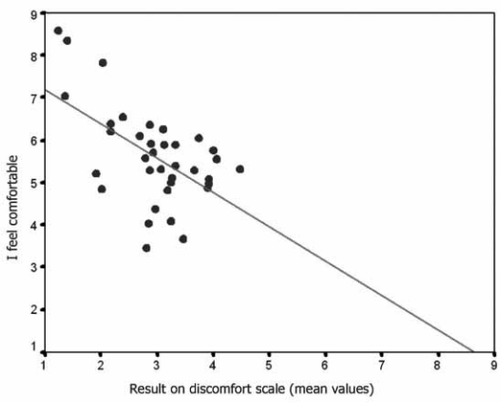

Fig. 6. The correlation of the average result on the discomfort scale and the statement »I feel comfortable«.

The results of the reliability of comfort and discomfort scales and the validity of the measurement checked by means of the correlation with the statement »I feel comfortable«, confirmed the so far obtained results and enables the usage of these scales while checking the influence of different constructions of seats of the office chairs to a subjective experience of comfort with the examinees.

The differences in evaluation of comfort/discomfort with respect to constructional design and material of the seat

Significance of differences in subjective evaluation of comfort and discomfort was checked by MANOVA, multivariate analysis of variance with repetitive measuring of two factors – evaluation and chair. Given the fact that evaluation factor referred to comfort and discomfort, i.e. varied at two levels whereas the chairs factor varied at four levels (net, springs, PU foam and cold-casted PU foam), eight variables were created to check the effect of each chair on evaluation of comfort i.e. discomfort. The table below shows arithmetical means and standard deviations in evaluation of each chair's comfort and discomfort.

TABLE 5
ARITHMETICAL MEANS AND STANDARD DEVIATIONS OF COMFORT AND DISCOMFORT

Variables	Arithmetical mean	Standard deviation
Comfort – Net	5.88	1.27
Comfort – Springs	4.88	1.46
Comfort – PU-ccf	5.33	1.16
Comfort – PU-foam	5.05	1.22
Discomfort – Net	2.52	0.92
Discomfort – Springs	3.41	1.42
Discomfort – PU-ccf	2.83	1.03
Discomfort – PU-foam	3.06	1.17

TABLE 6
MANOVA – SIGNIFICANCE OF THE TESTED DIFFERENCES

	F	p (significance of differences)
Scales	79.202	0.00
Chairs	2.531	0.12
Scales * Chairs	5.259	0.03

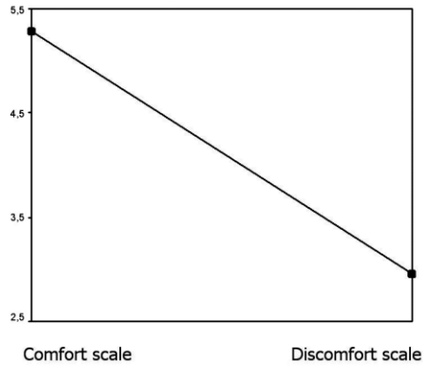

Fig. 7. Main effect of the scales.

In evaluation of all studied chairs, the scores for comfort on the respective scale were statistically significantly higher than those for discomfort on the respective scale. This means that the subjects scored all chairs as more comfortable than uncomfortable.

Evaluation interaction on the scales and of the chairs was statistically significant. In order to determine on which scale the evaluation of individual chairs differed significantly, a *post hoc* analysis with t-test for dependent samples was carried out. T-test results are given below (the differences are statistically significant, accounting for 5%):

- In the test of differences evaluation between the chairs with a net and springs, the former ones have shown to be significantly more comfortable (t=3.58; p=0.00).
- In the test of differences evaluation between the chairs with a net and cold-casted PU foam, the former ones have shown to be significantly more comfortable (t= 2.61; p=0.01).
- In the test of differences evaluation between the chairs with a net and PU foam, the former ones have shown to be significantly more comfortable (t=3.14; p=0.00).
- In the test of differences evaluation between the chairs with springs and cold-casted PU foam, the latter ones have shown to be significantly more comfortable (t= –2.11; p=0.04).
- In the test of differences evaluation between the chairs with a net and springs, the latter ones have shown to be significantly more uncomfortable (t=–3.66; p=0.00).
- In the test of differences evaluation between the chairs with a net and PU foam, the latter ones have shown to be significantly more uncomfortable (t=–2.24; p=0.03).

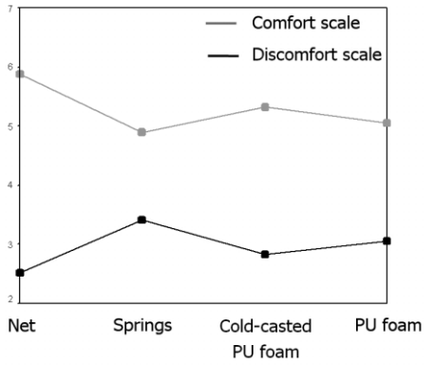

Fig. 8. Scales-chairs interaction.

- In the test of differences evaluation between the chairs with springs and cold-casted PU foam, the latter ones have shown to be significantly more uncomfortable ($t=2.62$; $p=0.01$).

The rest of tested differences were not statistically significant.

Discussion and Conclusions

The differences in evaluation of the chairs expressed by the statements (Figure 4): *The chair looks nice; I like the chair* and *I feel comfortable* are statistically significant. In all three statements the chair with a net is scored significantly higher than all other chairs.

T-test for dependent samples has shown that the chair with a net is statistically significantly more comfortable than other chairs. The chair with cold-casted PU foam is significantly more comfortable than the chair with springs, but statistically it does not differ significantly from the chair with PU foam.

Scoring of the studied seat constructions by comfort:

1. a seat with a net
2. a seat with cold-casted PU foam / seat with PU foam
3. a seat with springs

Also, statistically significant differences have been obtained by evaluation on a discomfort scale. Significant differences appear in evaluation of the chairs with a net, with springs and with PU foam. The difference in evaluated discomfort of the chair with a net and the chair with cold-casted PU foam is not statistically significant. Significant is the difference between the evaluated discomfort of the chair with springs and the chair with cold-casted PU foam where the former one is scored on the discomfort scale significantly higher.

Scoring of the studied seat construction by discomfort:

1. a seat with springs
2. a seat with PU foam
3. a seat with cold-casted PU foam / a seat with a net

The intention to reduce the differences in chairs as much as possible by their design has been achieved partially. The difficulties have shown the models with a net because of their limited choice, which prevented their visual comparison with other models. To some extent that problem was marked, but because the design does not affect scoring, these differences have not been the matter of further consideration.

It is worthy of note that the subjects showed more preference for the statements about aesthetic characteristics of the chairs that were closely related to the comfort scale, rather than to discomfort scale. This is very obvious in Figure 3a-3d showing generally higher scores for these statements.

It has been concluded that the chair with a net got higher scores, which might be attributed to its frame construction and the absence of a hard seat base under the sitting surface. This fact along with good elasticity of the net enables uniform and good pressure distribution.

From discussions with the subjects it can be concluded that some were quite unaware of the possibility and need to adjust the office task chairs. Unfortunately, they were using the chairs as left by their previous users or as bought.

Unquestionably, support must be given to further research into materials and constructions which are inherently different from the top scored netted model in this study and which provide significantly less differences in perception of comfort than do the available ones.

Special consideration and future research should also be focused and coordinated in cooperation with various medical professionals (physiatrists, orthopaedists, rheumatologists, etc.) and experts who work on new materials. Their joint consideration related to the furniture used for the most of our day- and nighttime must be the design that provides comfort and prevents various disorders of the spine, joints, blood circulation, allergies, etc.

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PROCJENA UDOBNOSTI KAO PRIMJER ANTROPOTEHNIČKOG DIZAJNA NAMJEŠTAJA

S A Ž E T A K

Zdravlje čovjeka biva sve važnija karika u lancu koji se sve više napinje u današnjem poslovanju i borbi za svaku uštedu vremena i kapitala. Udobnost sjedenja i kvaliteta stolica na kojima se provodi sve više vremena tako postaje preduvjet zdravom življenju. Problem neudobnosti javlja se pri dugotrajnom sjedenju na neprikladnim stolicama koje nedovoljno podržavaju tijelo i izazivaju nelagodu i umor. Istraživanjem konstrukcija uredskih stolica utvrđene su razlike u osjećaju udobnosti sjedenja na različitim vrstama sjedala. Uspoređene su četiri konstrukcije sjedala i njihove udobnosti prema korisniku pomoću subjektivnih pokazatelja. Ispitanici su nakon dvodnevnog sjedenja na stolici ocjenjivali osjećaje udobnosti i neudobnosti pomoću upitnika sa 17 tvrdnji. Određeni su konstrukcijski oblik i uporabljeni materijali koji bolje utječu na osjećaj udobnosti time što minimaliziraju osjećaj zamora i pojavu bolova pri sjedenju.