THE INFLUENCE OF PARTICIPANTS' SEX, MASS, HEIGHT AND BODY MASS INDEX ON PRESSURES AND COMFORT WHILE SITTING ON OFFICE CHAIRS

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ABSTRACT

This paper contains concise results of research on the subjective feeling of comfort while sitting on four different office chairs with various types of upholstered seats and its comparison with objective indicators such as pressures in relation to sex, mass, height and body mass index while sitting. The research included 69 students from the University of Zagreb, 25 of which were female and 44 male. The participants used subjective ratings to rank the chairs according to the level of comfort they provided: 1. Seat made from slabstock polyurethane foam, 2. Seat with a net, 3. Seat made from cold casted polyurethane foam and 4. Seat made from perforated cast polymer. Considering the obtained results regarding pressures and load (mass) while sitting, it can be asserted that for men the highest pressure rises depending on the increase of load on the seat. For women, the highest pressure decreases with the increase of load on the seat, while, regardless of the participant's sex, average pressure rises with the increase of mass on the seat. Bearing in mind the results regarding pressures and height while sitting, it can be concluded that for men the highest pressure rises with the increase in height. Average pressure in accordance with men's height increases on all four types of chairs, while for women, the pressure decreases as height increases. Considering the results on pressures and absolute BMI values while sitting, it can be asserted that for men the highest pressure rises with the increase of a person's body mass index, while for women it decreases.

Key words: office chair, comfort and discomfort of sitting, sex, mass, height, BMI, subjective and objective research

1. INTRODUCTION

Shifting from one chair to another, then driving in one's car, sitting on an office chair, and finally sitting down in front of the TV in the evening, is the daily routine of most people. Due to a mainly extensive workload, office chair users often do not even take notice of the time they spend sitting in an unchanged position and rarely think about the way they sit or whether that position can be deemed regular or irregular. According to scientific research, the body endures immense stress when a person sits for more than 50 minutes. After this amount of time, one should always stand up, stretch, walk and then return to work (Grbac, 2005).

Today, due to the increasing computerization of business and a larger number of so-called sitting jobs, where employees work mostly while sitting in front of a computer and where everything necessary to perform one's work tasks is available via computer, we often do not feel the need to get up from our chairs and forget to even consider the amount of time we spend in a single position. Such prolonged sitting, especially on unsuitable and poorly constructed chairs, can cause various health problems, such as neck, back and leg pain or headaches.

By researching the level of comfort provided by office chairs in relation to participants' age, sex, mass or height (Vlaović *et al*., 2006) on the basis of subjective and objective ratings of comfort/discomfort, the authors detected differences in the level of comfort of sitting on various types of seats. The authors state that "extended sitting on unsuitable chairs that insufficiently support the body causes distress and fatigue which results in discomfort of sitting." Simultaneously, the influence of certain human traits and features was placed in correlation to the feeling of comfort. According to Carcone and Keir (2007), a more extensive reading of the literature on office chairs, automobile seats and handicapped wheelchairs as well as a deeper insight into the subject of comfortable sitting on office chairs reveal that the comfort of sitting is largely based on subjective ratings – very rarely on objective ones. Despite the fact that comfort is a very important criterion for users, there is very little research that connects comfort to biomechanical variables such as pressure or the position of the lumbar part of the spine while sitting in the office.

This work elaborates the results of subjective studies on the comfort of sitting on four different types of upholstered seats and their comparison with objective indicators such as pressures and body mass (Gojak, 2010), then pressures and body mass index (BMI) (Sekovanić, 2010), and pressures and body height (Salopek, 2011), all in relation to the sex of the participant. The goal of these three works was to establish a codependency between pressures while sitting and the mass, BMI, height and sex of the participants.

2. SUBJECTS AND SAMPLES

2.1. Subjects

The study comprised a total of 69 student volunteers from the Zagreb Faculty of Forestry and Faculty of Agriculture. Twenty five subjects were female, while 44 were male. (Table 1)

Table 1. Descriptive statistics of the subjects

	Female (n=25)				**Male (n=44)**			
	Age [yrs.]	Height [cm]	Mass [kg]	BMI [kg/m^2]	Age [yrs.]	Height [cm]	Mass [kg]	BMI [kg/m^2]
Min	20	158	43,3	16,91	20	168	59,3	20,02
Max	28	177	83,8	33,49	28	191	123,3	38,46
Avg	23	167	60,9	22	23	180	83,8	25,74
SD	1,92	5,64	8,94	3,71	1,53	6,35	13,15	3,77

Due to mistakes and/or irregularities in filling out the questionnaire or measurements done by means of the measuring pad, the subjective part of the study included 65 subjects, while the objective part comprised 68 subjects. Only persons of good health took part in the study; this was determined through a pre-questionnaire in which the participants were asked to confirm that they are of good health and that they suffer from no spine, back or neck pain.

2.2. Samples

Four models of office chairs (Figure 1) were chosen for the study. They were marked with the following codes: S-01, S-02, S-03 and S-04. They differed in design and structure, while the main difference lay in the construction of the seating surface. The S-01 chair had a seat filled with slabstock polyurethane foam; chair S-02 had a framed seat with a net stretched in order to cover the seating part; the S-03 chair had a seat filled with cold casted polyurethane foam, while the S-04 chair had a seat made from perforated cast polymer.

a) S-01 b) S-02 c) S-03 d) S-04

Figure 1. Chair models

An overview of characteristics for each model is contained in Table 2, while detailed descriptions of the chairs can be found in the authors' original works (Gojak, 2010; Sekovanić, 2010; Salopek, 2011).

Table 2. Basic technical characteristics of the models (dimensions set according to HRN EN 1335-1)

Chair model:	S-01	S-02	S-03	S-04
	(mm)			
seat height	420-520	380-540	400-520	390-508
seat depth	400	445	440	450
seat width	475	518	494	500
backrest height	510	505	690	660
backrest width	480	550	486	469
armrest height	190-290	145-250	228-290	177-279
armrest width	50-80	95	95	120

3. RESEARCH METHODS

The study was based on two methods. The subjective method was based on the participants' opinion about the feeling of discomfort while sitting on office chairs during a given period of time. Considering that the ratings focused on the seat of the chair, and not the entire chair, the participants were asked to fill out the questionnaire having in mind only the seat and its influence on their body, buttocks and thighs.

Each participant sat on four various seats for 10 minutes, after which they filled out a questionnaire about the level of comfort they experienced. The questionnaire (*Category Partitioning Scale CP-50*) (Shen and Parsons, 1997) consisted of 6 rating categories which asked the participants to answer the following: *Evaluate the intensity of pressure and level of*

discomfort while sitting, next to which were numerical values that had to be circled by the participant. The offered categories were: *No pressure/no discomfort (0), Very low pressure/low discomfort (1-10), Low pressure/low discomfort (11-20), Medium pressure/discomfort (21-30), High pressure/great discomfort (31-40), Very high pressure/great discomfort (41-50).*

The chairs were set for every individual participant in order to achieve "proper sitting". This was done by adjusting the height of the seat in a manner which enabled both feet to fully touch the ground with knees placed in an angle greater than 90°. The angle of the backrest was set to 95° in relation to the floor and remained unchanged for all participants. The height of the armrest was also fitted specially for each participant so that their lower-arms, when resting on the armrests, formed an angle of 90° with their upper-arms.

The objective research method included anthropometric measurements and measuring the pressures between the seat and the participant by means of the *ErgoCheck©Chair* measuring pad (ECC). The remaining equipment comprised digital weighing scales, various measuring tapes, digital photo cameras with tripods and stool. The anthropometric measurements engulfed measuring the mass and height from which the body mass index (BMI) was determined. After the anthropometric measuring, each participant sat on one of the chairs, all of which were covered with a measuring pad. Then, the distributions and values of the pressure, mass and surface was recorded for two typical seating positions: upright sitting leaned back against the backrest with arms placed on the armrests; and body leaned forward with arms placed on knees. During the first part of the recording, the participants sat still for about 30 seconds, after which the same process was done in the other, working sitting position without the possibility of standing up from the chair. The same process of recording was done on all four chair models. Due to the limitedness of the space, only the results of the working position are included.

4. RESULTS AND DISCUSSION

Due to the large number of results, not all could be included in this work. Therefore, we chose depictions that demonstrate certain observed values and indicate some of their correlations.

4.1. Subjective rating results

The results of the subjective ratings of chairs are shown in Figure 2. The rating decreases as a chair is rated more comfortable.

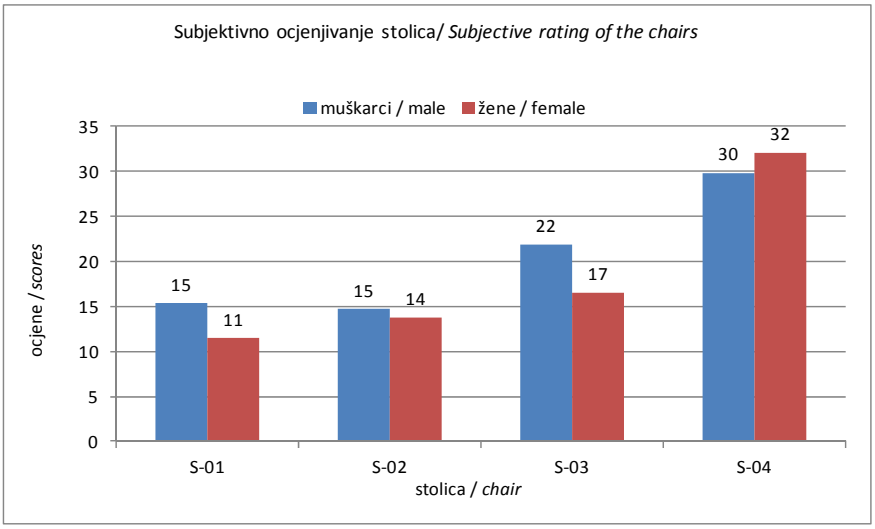

Figure 2. Results of the subjective ratings of chairs

The results of the subjective ratings of chairs in relation to female BMI are depicted in Figure 3. The rating decreases as a chair is rated more comfortable.

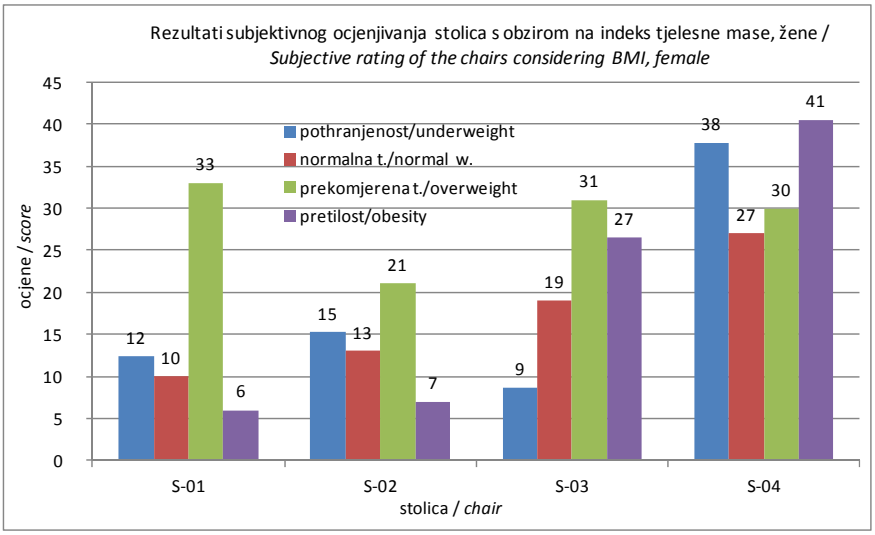

Figure 3. The results of subjective ratings of chairs in relation to female BMI

Figure 4 portrays results of subjective ratings of chairs in relation to male height categories.

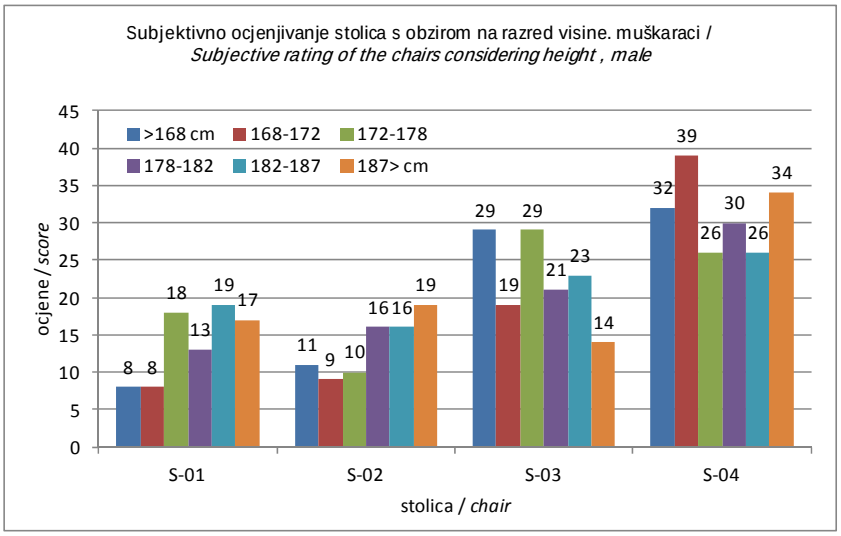

Figure 4. Results of subjective ratings of the chairs in relation to male height categories

4.2. Results of measurements by ECC measuring pad

Figures 5 and 6 portray amounts of mean values for the highest (p-max) and average (p-avg) pressure while sitting in the working position for both sexes.

The highest amount of the highest pressure in the working position was observed in both sexes on the chair with a polymer seat (S-04), while the chair with slabstock polyurethane foam (S-01) and the chair with cold casted polyurethane foam (S-03) exhibited minor differences in pressures among the two sexes. If the sitting position changes from the working into the leaned back, the highest pressure decreases significantly.

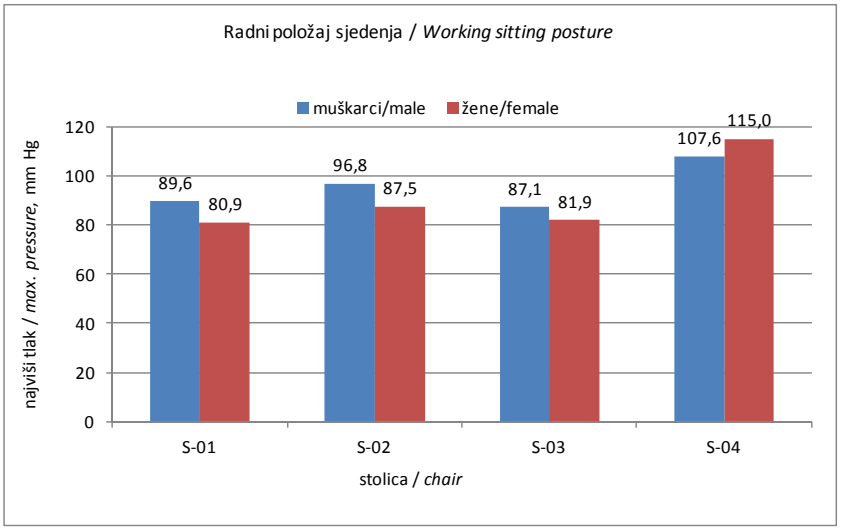

Figure 5. The correlation between the highest pressure and sitting in the working position

The comparisons of the dependency between the highest pressure and load show that, on almost all chairs, this pressure increases for men in the working position, except for the chair with the polymer seat (S-04), while for women the highest pressure decreases on all chairs except the one with slabstock polyurethane foam (S-01). Probably the greatest influence on the highest pressure comes from a person's physique. Due to a larger percentage of fat in the gluteal area and thighs, women demonstrate a decrease of the highest pressure as mass increases. This is most probably not due to the larger concentrated pressure of sit bones on the several sensors located in the narrow area where this pressure may appear. The seat surface of the chair with a polymer seat (S-04) has a mild indentation where the sit bones are usually located and that is why the area beneath the thighs probably takes over the load from the sit bones. Persons of smaller mass that possess less fat cause these points to demonstrate higher pressure because their sit bones press the measuring sensors more directly.

The average pressure on chairs in the working sitting position is largest on the chair with a net on the seat (S-04) for both sexes, while other chairs demonstrate smaller variations in pressures. Changing the sitting position causes only a smaller change in the amounts of pressures – a mere 5 mmHg.

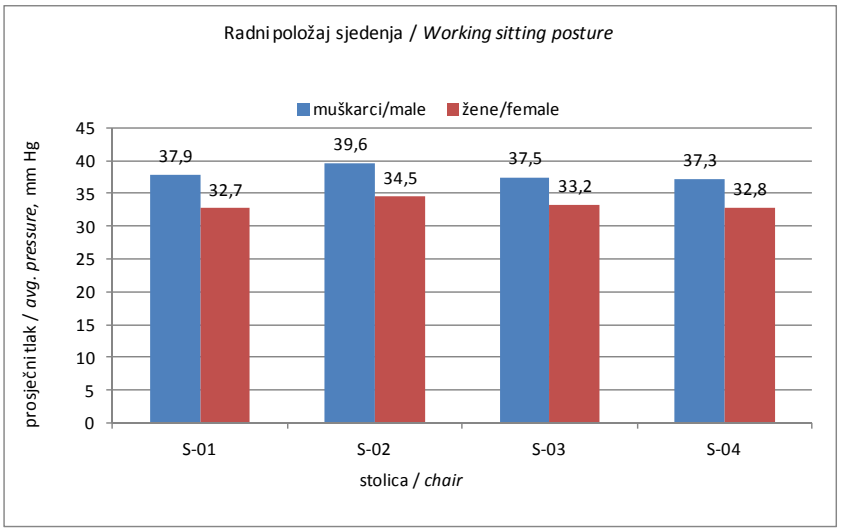

Figure 6. The dependency of average pressure on sitting in the working position

From the results of comparisons between average pressures and load, we notice an ascending trend on all chairs for both sexes in the working position of sitting, i.e. the increase of load causes the average pressure to grow. The same happens in the leaned back position of sitting.

The presumption that the highest pressure indicates the appearance of discomfort, while better distribution of average pressure indicates comfort, has not been proven by this study. The highest pressure value is not reliable for assessing comfort because this type of pressure is the consequence of pressure on only one or perhaps several sensors located beneath the sit bones. On the other hand, the average pressure value is an insufficient indicator of the level of comfort a seat provides. With the increase of mass, the trend of the average pressure (p-avg) should decrease and that is why average pressure should indicate comfort, but that has not been demonstrated in this study. In both sexes on all chairs and in both sitting positions, the trend of the average pressure increases because the highest pressure value has been integrated in its final value.

Figure 7 depicts the dependency of mean load values on sitting in the working position for both sexes.

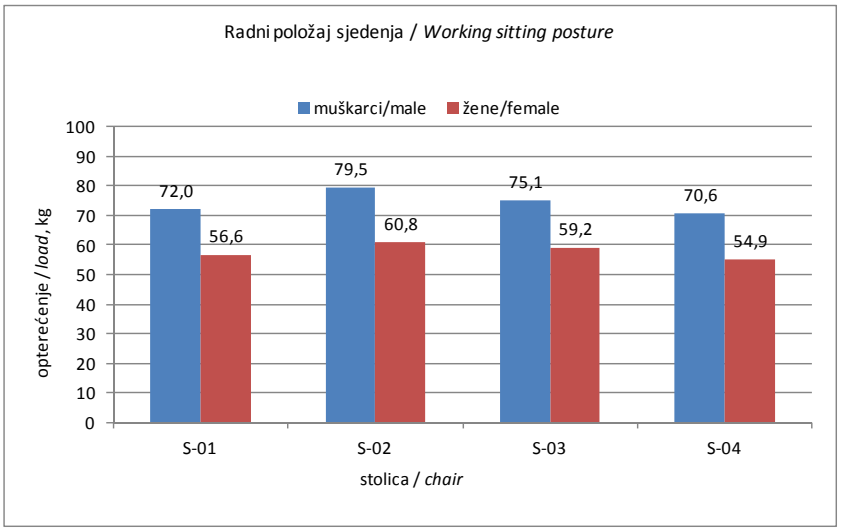

Figure 7. The dependency of load (mass) on sitting in the working position

The load (mass) on the chairs in both positions and for both sexes is rather similar, although the working position demonstrates a slightly higher load. However, if we consider the distribution of load on the chairs, it is evident that the chair with a net (S-02) shows the greatest load, while the chair with the polymer seat (S-04) demonstrates the least. Changing positions from the leaned back into the working causes an increase of load, but causes no change in the ratings of the chairs.

Figure 8 portrays mean highest pressure values on the S-04 chair in regards to the body mass index categories: underweight (BMI<20 kg/m^2), normal weight (20≤BMI<25 kg/m^2), overweight (25≤BMI<30 kg/m^2) and obese (30≤BMI<40 kg/m^2) in the working position of sitting for both sexes.

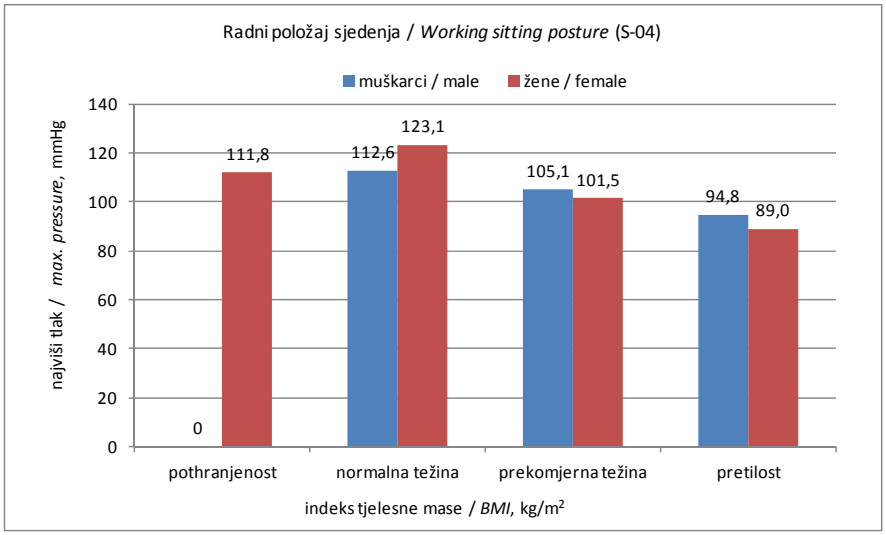

Figure 8. The highest pressure values in the working position of sitting according to BMI category

Comparisons of the dependence of the highest pressure in the working position and absolute values of the body mass index reveal that, for men, the chair with slabstock polyurethane foam (S-01) and the chair with cold casted polyurethane foam demonstrate no trend; the chair with the net (S-02) shows an increasing trend, while the chair with a polymer seat (S-04) demonstrates a decreasing trend. As was mentioned previously, the chair with a polymer seat (S-04) has a mild indentation where the sit bones are located, which causes the area beneath the thighs to take over the load from the sit bones. Persons of smaller mass that possess less fat cause these points to demonstrate higher pressure because their sit bones press the measuring sensors more directly. The pressures for women with a lower body mass index are higher than for women with a higher body mass index. Probably the greatest influence on the highest pressure comes from a person's physique. Due to a larger percentage of fat in the gluteal area and thighs, women demonstrate a decrease of the highest pressure as mass increases. This is most probably not due to the larger concentrated pressure of sit bones on the several sensors located in the narrow area where this pressure may appear.

Figure 9 depicts mean average pressure values on the S-02 chair in regards to body mass index categories for sitting in the working position for both sexes.

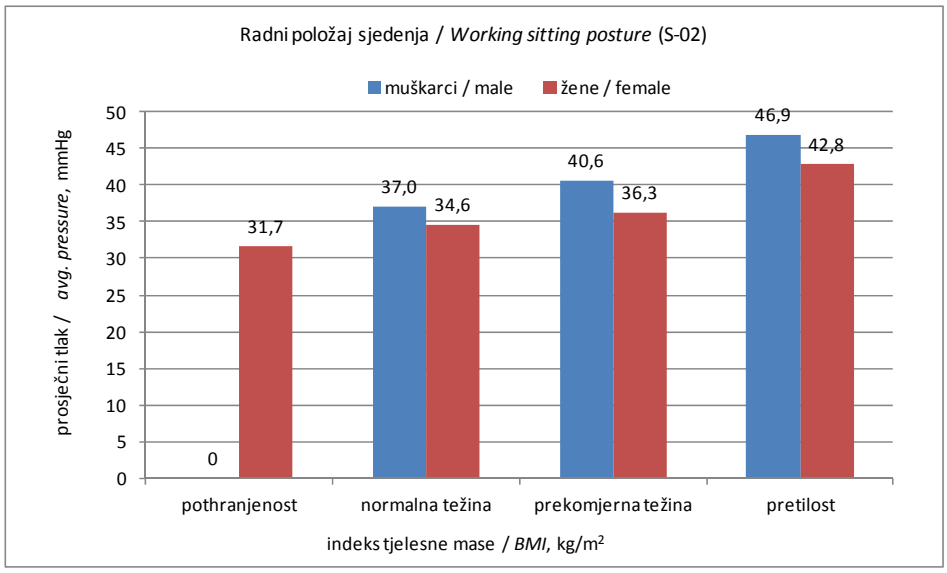

Figure 9. Average pressure values in the working position in relation to BMI categories

The results of this comparison reveal that for both men and women in the working position of sitting the increase of BMI causes the increase of the average pressure, just as in the case of the leaned back position of sitting.

Figure 10 depicts the amount of the sitting surface, measured by means of the measuring pad and in relation to the working position.

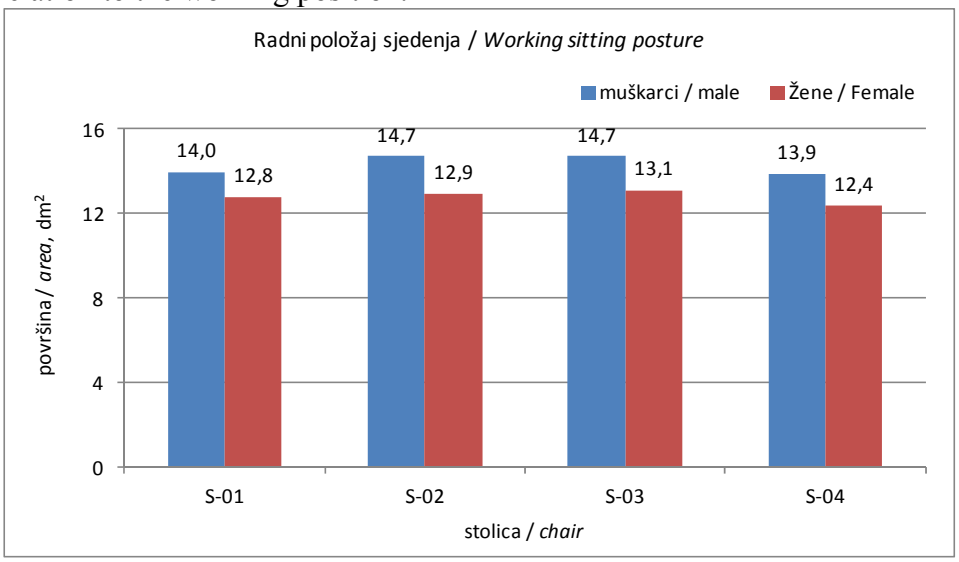

Figure 10. Sitting surface in the working position on all four chairs

The sitting surface on chairs is very similar for both sexes. The largest sitting surface appears in both positions of sitting on the chair with the net (S-02) and the chair with cold casted polyurethane foam (S-03), while for the chair with the slabstock polyurethane foam (S-01) and the chair with the polymer seat (S-04) this value is somewhat lower. The difference between the leaned back and working position while sitting is minimal and does not go over 0.5 dm^2, which comes as no surprise because the mass of the participants does not change during sitting on various chairs – the minimal changes occur due to the differences in chair structures and the sensitivity of the measuring pad sensors. We should also mention that the change from the leaned back into the working position of sitting was determined by the unchanged placement of the buttocks on the sitting surface when leaning forward.

5. CONCLUSION

5.1. Subjective research

- Considering the sex, both women and men rated the chairs with the slabstock polyurethane foam and the net as the most comfortable. The least comfortable chair for both sexes was subjectively the chair with the polymer seat. Such a rating is most probably the consequence of the fact that this chair had no upholstered layer, except of course for the relatively elastic perforated surface.
- In the discomfort assessment for all BMI categories, both men and women rated the polymer seat chair as the least comfortable.
- Generally, regardless of the sex and bearing in mind the subjective ratings of the level of discomfort, the chairs can be ranked as follows: [1] Polymer seat chair (S-04) (least comfortable); [2] The cold casted polyurethane foam chair (S-03); [3] The chair with the net (S-02) and [4] The slabstock polyurethane foam chair (S-01).

5.2. Objective research

Considering the results obtained within this study, the following can be concluded:

- Regardless of the sitting position for men, the highest pressure grows with the increase of load (mass) on the seat, while for women the highest pressure decreases with the increase of load on the seat.
- Regardless of the sitting position and regardless of the sex, the average pressure grows with the increase of load (mass) on the seat.
- Regardless of the sitting position for men and in relation to the body mass index, the highest pressure grows with the increase of the body mass index, while for women it decreases.
- Regardless of the sitting position and regardless of the sex, the average pressure increases with the increase of the body mass index.
- Regardless of the sitting position, both sexes demonstrated that the highest pressure on the seat increases with height.
- Regardless of the sitting position for women, the average pressure decreases with the increase in height, while for men this trend is reversed.
- Regardless of the sitting position for men, the increase of height causes an increase of load, while for women it decreases.

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