



Research on Body Pressure Distribution of Office Chair with Different BMI

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Abstract. The office chair is one of the most important sittings in the office, life and learning process. When people use uncomfortable office chairs, it can have a negative impact on people's work efficiency and health. The body pressure distribution of the office chair is one of the most common objective measures index of office chair comfort. Therefore, in order to improve the comfort of the office chair, it is necessary to study the differences in the pressure distribution and the differences in comfort evaluation of people with different BMI. The Pliance pressure test system was used to collect the seat pressure and contact area of 18 subjects with different BMI, and a subjective score for office chair of each subject was recorded. Through difference analysis, we found that the mean pressure and mean contact area of subjects with different BMI were significantly different ($P < 0.05$) and positive correlation were found for mean pressure and BMI, for mean contact area and BMI. But no correlation were found for BMI and subjective comfort scores ($p > 0.05$). According to the experimental data, the pressure distribution diagram was drawn, the pressure distribution characteristics of subjects with different BMI were summarized.

Keywords: Pressure distribution · Office chair · BMI

1 Introduction

Nowadays, working in an office chair is ubiquitous. Approximately three-quarters of all employees in industrialized countries now have jobs that require working in a sitting position. A good seat can not only properly support for hip and distribute the weight of the human body, but also improve work efficiency. An increasing amount of time is spent seated, especially in office environments, where sitting comfort are increasingly important due to the prevalence of musculoskeletal disorders [1].

At present, the methods for measuring the comfort of the office chair seat surface mainly include objective measurement and subjective evaluation. In the literature, various objective methods (e.g. pressure measurements, measurements of posture, EMG etc.) can be used to quantify the subjective comfort/discomfort of an office chair [2].

Objective methods have the advantage of being less time consuming, less dependent on a large number of subjects and less prone to measurement error [3]. The seat surface is the main interface between the user and the seat, and is an important part that affects the comfort of the user. The body pressure distribution of the office chair is one of the most common objective measures of office chair comfort [4].

However, technical methods to objectively determine sitting comfort/discomfort are always indirect and, at best, can provide only an indication of a chair user's feeling of comfort/discomfort. The comfort/discomfort of the seat is based on subjective feelings and is difficult to quantify. Subjective assessment is possible to gain an indication of the level of sitting comfort and discomfort. Vergara and Page reported that subjective evaluation is the effective way to determine changes in comfort and pain [5].

Chen Yuxia, Zhou Min, Hou Jianjun and others used the method which combined pressure distribution measurement and subjective comfort evaluation to study the relationship between objective data and subjective comfort evaluation of sofa and seat respectively. The factors affecting the comfort of sofa and chair are analyzed. Tianyi [8] also used the method which combined body pressure distribution and subjective evaluation to study the influence of sitting posture on seat comfort. This proves the effectiveness of the combination of subjective and objective evaluation.

At present, the distribution ratio of Chinese adult BMI is 1 (thin): 5 (normal): 4 (fat). The distribution of the seat surface pressure of people with different BMI is different. The pressure distribution of fat people is relatively uniform, and the highest pressure values of thin people are seen at the hip ischial tuberosity [9]. It can be seen that the individual BMI difference has an effect on the seat pressure distribution [10]. Therefore, in order to improve the comfort of the office chair, it is necessary to further study the difference in the pressure distribution of people with different BMI.

Based on the above analysis, the combined method of subjective and objective was used in this study. The pressure test system was used to measure the seat surface pressure, and the seat surface was subjectively evaluated for comfort. The experimental data was analyzed for differences. This study will provide reference and basis for the office chair seat surface design to improve the comfort of the office chair.

2 Method

2.1 Experimental Design

In this study, according to the Chinese BMI index classification criteria, 18 subjects of three types were recruited. They were divided into thin group ($BMI < 18.5$), normal group ($18.5 \leq BMI < 23.9$) and fat group ($BMI \geq 24$) respectively. The most common office chair with moderate seating hardness was selected as the experimental sample. The subjects provided their evaluation on comfort of the seat surface after sitting for 20 min. The subjective comfort experience evaluation was scored by using a 5-level comfort meter (1 point - very uncomfortable, 2 points - uncomfortable, 3 points - general, 4 points - comfortable and 5 points - very comfortable). Then, the subjects sit in the office chair in accordance with the requirements of the "reference sitting posture [11]". The reference seating posture is as follows:

- The sole of the foot placed on the floor;
- The foot forms an angle of approximately 90° with the lower leg;
- The lower leg is approximately vertical;
- The lower leg forms an angle of approximately 90° with the thigh;
- The thigh is almost horizontal;
- The thigh forms an angle of approximately 90° with the trunk;
- The trunk is erect.

Subjects were required to be in contact with the office chair only by buttocks and thighs, try to ensure that the rest of the body and the office chair is not in contact to reduce the influence of extraneous factors on the pressure distribution test of the seat surface. Finally, the Pliance pressure test system of German Novel Company was used to collect pressure distribution data of each subject for 30 s, and 15 s stable pressure distribution data was selected to extract mean pressure values, peak pressure values and mean contact area. One-way analysis of variance was used to compare mean pressure, peak pressure and mean contact area of people with different BMI, and the correlation between BMI and seat comfort was determined based on Spearman correlation analysis (Fig 1).

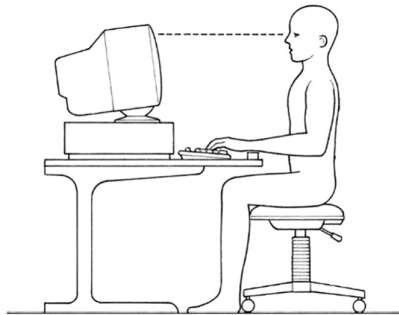


Fig. 1. The reference seating posture

2.2 Subject

In this study, according to the Chinese BMI index classification criteria, 18 subjects of three types were recruited. They were divided into thin group ($BMI < 18.5$), normal group ($18.5 \leq BMI < 23.9$) and fat group ($BMI \geq 24$) respectively. All subjects were required healthy, with no spine and hip related medical history and experimented with good physical and mental condition. All subjects provided written informed consent prior to participation in this study. Subjects' information see Table 1.

Table 1. Subjects' information

	Thin group			Normal group			Fat group		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Age (years)	20–32	23	4.1	21–32	24	3.7	23–46	32	9.2
Height (cm)	156–176.5	167.8	7.4	160–185	168.9	8.4	153.6–185	165.2	11.8
Weight (kg)	45–54.7	50.3	4.1	54–74.2	61.3	7.5	62–104	79.2	15.2
BMI	17.5–18.4	17.9	0.4	20.7–23	21.4	0.8	26.3–30.4	28.7	1.6

2.3 Main Apparatus

Pressure Test System. The body pressure distribution test was carried out by the Pliance body pressure test system (see Fig. 2) of Germany Novel. The computer software used with the system can visually display 2D and 3D color pictures of pressure distribution. And the pressure values of each sensor is contained in the picture (see Fig. 3).



Fig. 2. The main hardware of Pliance body pressure measure system

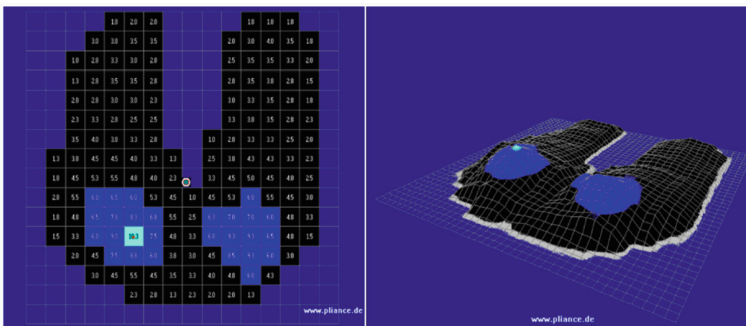


Fig. 3. 2D (left) and 3D (right) color pictures of pressure distribution. (Color figure online)

Office Chair. The seat surface hardness of 15 office chair were measured for selecting office chair by the Shore F Durometer (a device for measuring the surface hardness of soft materials such as sponges, see Fig. 4). We found that the seat surface hardness of 11 office chair is mainly concentrated between 35HD and 42HD, and the mean hardness is 40.18HD. So the office chair with 40HD and adjustable height was selected for experiment (see Fig. 5).



Fig. 4. Shore F durometer



Fig. 5. Office chair

2.4 Task and Procedure

1. Each subject was informed about the study and gave a written informed consent,
2. Before the test, the subjects were informed of experiment purpose, experiment contents and way of testing, and assistance was given to them to get familiar with the subjective comfort rating scale.

3. The gender, age, and height and weight of the subjects were record.
4. The subjects provided their evaluation on comfort of seat surface after sitting for 20 min.
5. Adjust the seat surface of the office chair to the appropriate height. The subjects sat in the office chair in accordance with the requirements of the “reference sitting posture” (see Fig. 6) while back does not contact with the backrest without using the armrest (hands on their lap).
6. Contact pressure and contact area between chair seat and buttock was measured within 30 s.

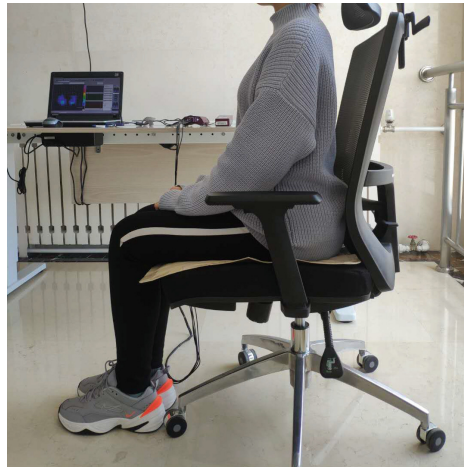


Fig. 6. The experimental scene. The subject kept the “reference sitting posture” while back does not contact with the backrest without using the armrest (hands on their lap) for 30 s. Measure the pressure distribution during this period.

2.5 Data Analysis

Subjective scores of different BMI subjects were counted. Peak pressure values, mean pressure values and mean contact area of the sensors during the measurements were extracted from the Novel software. One-way analysis of variance was used to determine whether there was a difference between pressure distribution and BMI. Spearman correlation analysis was used to determine correlation between subjective comfort scores and BMI, mean pressure and BMI, peak pressure and BMI, mean contact area and BMI. The significance was determined at a 0.05 level.

3 Results

Significant differences were found for mean pressure and mean contact area of people with different BMI ($p < 0.05$). See Table 2 for significant results. Positive correlations were found for mean pressure and BMI, for Mean contact area and BMI (see Table 3).

Table 2. Pressure and contact area of different group and difference results.

	Group	N	Mean	SD	Sig.
Mean pressure (kPa)	Thin group	6	4.02	0.34	0.004
	Normal group	6	4.71	0.48	
	Fat group	6	5.20	0.45	
Peak pressure (kPa)	Thin group	6	12.96	3.80	0.568
	Normal group	6	11.58	2.89	
	Fat group	6	11.17	2.03	
Mean contact area (cm ²)	Thin group	6	922.38	37.52	0.000
	Normal group	6	1011.42	36.16	
	Fat group	6	1164.48	112.74	

Table 3. Correlation between subjective comfort scores and BMI, mean pressure and BMI, peak pressure and BMI, mean contact area and BMI.

		Mean pressure	Peak pressure	Mean contact area	Subjective scores
Spearman's rho	Correlation coefficient (R)	0.893*	-0.133	0.828*	0.026
	Sig.	0.000	0.598	0.000	0.919
	N	18	18	18	18

*Correlation is significant at the 0.01 level. $R > 0.8$ means strongly correlated.

3.1 Mean Pressure

Mean pressure of thin group was the lowest (4.02 kPa). Mean pressure of fat group was the highest (5.20 kPa). Mean pressure of normal group was somewhere between the two (4.71 kPa). And positive correlations were found for mean pressure and BMI ($R > 0.8$, $p < 0.05$). In Fig. 7, the distribution of mean pressure is shown. And the trend of mean pressure with BMI can be seen from the dotted line in the figure. So, mean pressure increases with increasing BMI.

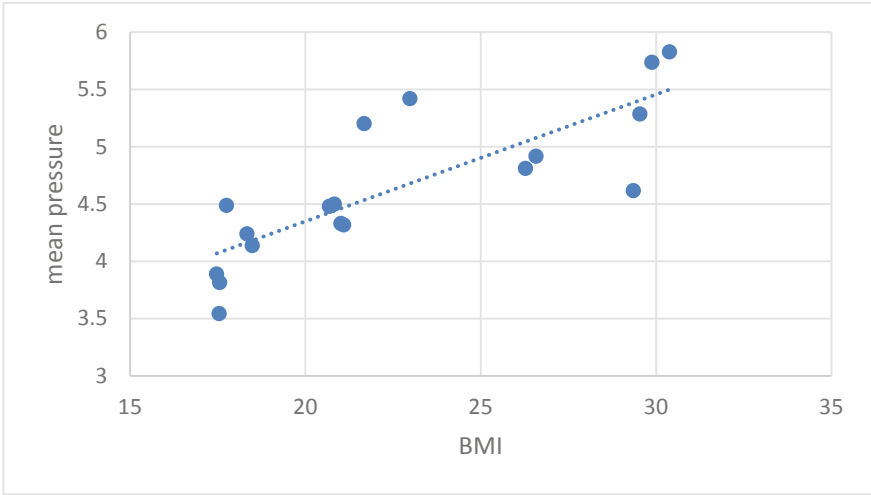


Fig. 7. Mean pressure scatter diagram of 18 subjects. And the dotted line represents the trend line of mean pressure with BMI

3.2 Peak Pressure

No significant differences were found for peak pressure of people with different BMI ($p > 0.05$). And no correlations were found for peak pressure and BMI ($p > 0.05$). It can be seen from Fig. 8 that with the increase of BMI, there is no obvious change trend of peak pressure.

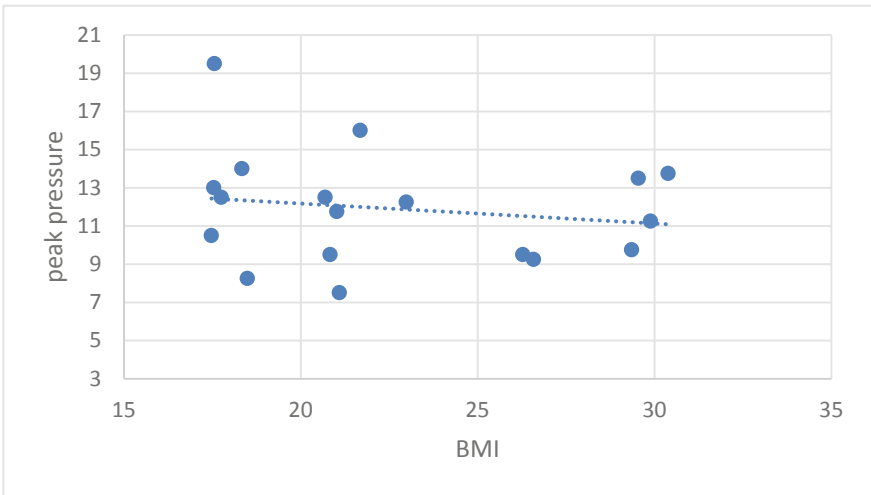


Fig. 8. Peak pressure scatter diagram of 18 subjects. And the dotted line represents the trend line of peak pressure with BMI

3.3 Mean Contact Area

The mean contact area of the fat group was the largest (1164.48 cm²). The mean contact area of the thin group was the smallest (922.38 cm²), and the mean contact area of the normal group was between the two (1011.42 cm²). Positive correlations were found for mean contact area and BMI ($R > 0.8$, $p < 0.05$). It can be seen from Fig. 9 that as the BMI increases, the mean contact area has a significant increase trend. The higher the BMI is, the larger the volume of the subject is. So the contact area between the hip and the office chair is larger.

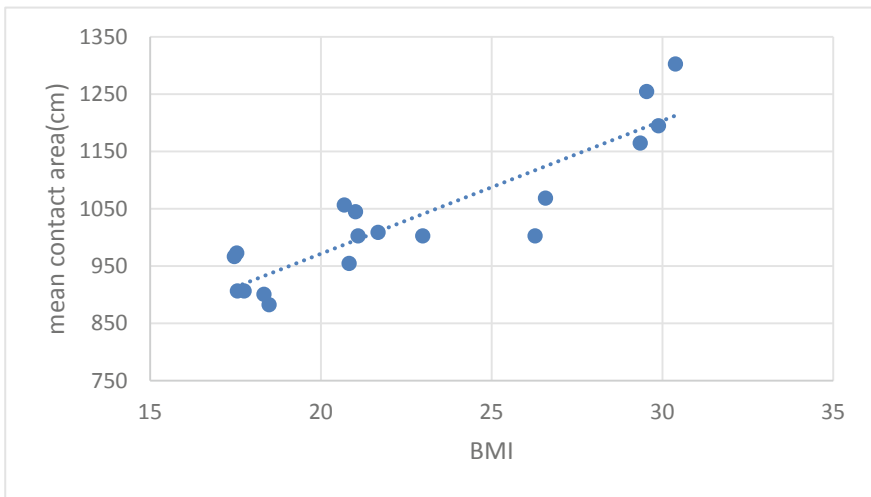


Fig. 9. Mean contact area scatter diagram of 18 subjects. And the dotted line represents the trend line of mean contact area with BMI

3.4 Subjective Score

No significant correlations were found for subjective scores and BMI ($p > 0.05$). At present, only one office chair with moderate hardness is selected in the experiment. It is possible that this office chair has met the comfort requirements of all the subjects. And López-Torres [12] reported comfort is an extremely complex concept that involves the absence of discomfort and the presence of a series of positive perceptions. Some participants in the experience said that this office chair did not cause discomfort, so they thought that this office chair is comfortable, which may lead to no difference in subjective scores, or there was indeed no significant correlation between subjective score and BMI. Studies have shown that subjective comfort evaluation may take at least 1 h to distinguish the change of comfort [13], and the experience of this experiment is only 20 min, which may not be enough to get an effective subjective score in a short time. Therefore, it is necessary to carry out experiments with longer experience in the future, so as to obtain accurate subjective scores.

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