

COMPARATIVE ANALYSIS OF OFFICE CHAIRS WITH DIFFERENT POSTURES

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Abstract:

This paper presents a comparative study of five, highly rated office chairs considering the ergonomic, structural construction, functionality, body pressure distribution aspects. During the investigation adjustability to the users dimensions, the physiological advantages of the postures the chairs provide, the comfort of sitting, the quality of execution were considered also. The compared chairs provided diverse sitting postures focusing on certain comfort aspects from elastic support (Aeron) to active seating (Spinalis), from balancing structure (Thatsit) to upright seating position (Salli) and posture monitoring (Axia Smart). The structural analysis of the chairs revealed the significant differences in adjustability, there were chairs with very complex structure, multiple adjustable parts, while others showed a simple but efficient construction. The results of the body pressure distribution analysis demonstrated the differences in peak pressures, contact areas between chair types, seating postures and subjects' body build.

Key words: body pressure distribution; office chairs, ergonomic, seating posture, intelligent solution.

INTRODUCTION

The increasing sedentary life-style of people could lead to back pain, cardiovascular problems and several musculoskeletal disorders. In order to prevent all these disadvantages of sitting, office chair developers continuously look after new solutions to diminish the negative consequences of prolonged sitting and to increase the comfort consequently. Users' high comfort sensation is linked to well-being, safety feeling and healthy sensation. However, the mentioned subjective evaluation criteria can be fulfilled mainly by objective design specifications. Between these, we find geometry (dimensions, angles), the quality of the embedded materials, the selected structure and other design factors like manufacturability, easy of assembly, sustainability requirements, etc. The support of the lumbar region, adjustability of seat height, arms, the characteristics of the upholstery materials are critical since influence the body pressure distribution, a directly linked effect to comfort. This pressure is smaller when the contact surface of the human body is larger (Ergić 2002, Grbac and Ivelić 2005).

A highly rated office chair by its ergonomic design and many adjustable parts offers to the users a high comfort and efficient work. Treaster and Marras (1987) revealed that beside an adequate support in the work chair, sufficient room must be provided to the users in order to preserve the user's health and comfort feeling. The various work tasks make the work more diverse and force the workers body in different body postures (Adams 1986; Babski-Reeves 2005; Commissaris and Reijneveld 2005; Dowell 2001; Ellegast 2007; Van Dieën 2001). By posture changes the pressure exerted by body on the seat and the backrest are changing continuously therefore the comfort level of various postures is altering also. Since people have different body mass indexes (BMI) they press differently the chairs with same body parts and on the same spot resulting in deviations of the pressure surface and pressure intensity. For an optimal pressure map depicting one of the most important comfort components of a chair, the high pressure values are located

under the ischium tuberosity, the lumbar section of the back, and around the shoulder blades. Consequently, a suitable body pressure distribution is essential to a healthy and comfortable seat (Grandjean 1973). According to Zemp *et al.* (2015) pressure distribution measurements of the seat pan and the backrest are one of the most common objective methods to analyze or compare different sitting postures, for this reason the pressure mapping is an accepted method used by researches to evaluate pressure redistribution on chairs. Chair developers and manufacturers focus not just on designing high comfort cushions, but on assuring body postures different from the well-known straight or 90° seating. The kneeling chair, the saddle chair, the dynamic chair are the results of these efforts.

OBJECTIVE

The main objective of this article was to compare five modern office chairs with different seating postures from ergonomic, structural, technological and comfort points of view. For comparisons and analysis the visual inspection, reverse engineering methodology, standard strength and durability tests, body pressure distribution measurement were used as comparison methods.

MATERIAL, METHOD, EQUIPMENT

For this comparative study five work chairs were selected each of them showing some special characteristics as follows (Fig. 1):

- **Aeron Remastered** is the second generation of the famous Aeron chair designed by Bill Stumpf and Don Chadwick in 1994, and redesigned by the latter in 2016. Produced by Herman Miller the Aeron chair is considered „the Dot-Com Throne”
- The Norwegian industrial designer Peter Opsvik, known as the foremost designer of unconventional seating solutions, designed **Thatsit Balance** chair in 1991. Thatsit, the adjustable kneeling chair creates balance in all postures, and offers support for seat, shin and back simultaneously.
- **Spinalis** chair offers an active sitting, using a spring as active element. The chair replicate the sitting on a therapy ball, where the user constantly use the muscles to adjust to the seat's slight movements.
- **Salli** saddle chair has a two-part seat and offers a body posture similar to horse riding. The upright position of the pelvis supported by the sitting bones assure a good back posture and free movements of limbs and back.
- **Axia Smart** office chair developed by BMA Ergonomics teaches the users to sit better. The pressure sensors built in the seat and back monitor the user's sitting habits, and warn the users in case of unhealthy postures.



Fig. 1.
The selected office chairs.

An ergonomic analysis was performed as a first step of this study, where the comfort of the chairs, adjustability to the human dimensions, possible body postures during the use were investigated. The examination of chairs structure, built-in materials, connections, joints, quality of manufacturing, function carrier parts followed thereafter. Reverse engineering methodology was used for this, i.e. each chair was disassembled in parts and examined separately.

The comfort analysis of chairs was performed using the Tekscan's Body Pressure Measurement System TM (BPMSTM) was used. The pressure sensitive foils' size was 488 × 427mm, containing 2016 pressure points with a pressure range of 0-350mmHg, and accuracy of + / - 3.5mmHg. Before using the BPMS measuring system the pressure sensitive foils were calibrated with the help of a vacuum pump. The pressure maps were collected and analyzed with the software delivered with the system (BPMS Research 7.20) in the form of image (.fsx or .jpg) or short (0-200 s long) video files. A female and a male subject with normal and overweight body mass indexes (Table 1.) provided the pressure maps.

Table 1

The subjects' body built characteristics

Gender	Height, cm	Weight, kg	BMI, kg/m2	WHO Class	Sitting weight, kg
female	172	67	22,6	N	50
male	177	92	28,1	PO	68

RESULTS AND DISCUSSION

Ergonomic study

All five chairs were examined from dimensional, body postures, fitting to the human body and comfort aspects. The newly developed elastomeric suspension used in Aeron, the 8Z Pellicle eliminates the circulation-restricting pressure point by introducing zones (8) with different elasticities. The PostureFit SL support with its individual pads stabilize the sacrum and support the lumbar region of the spine to mimic the healthful standing position. The Varier ThatSit Balans chair is a kneeling chair which keeps the spine in an upright, dynamic posture, tilts forward the pelvis when leaning forward. The higher open angle between upper and lower body improves the oxygen supply and blood circulation. The active sitting offered by Spinalis chair is a sitting that activates the back and abdominal muscles. The constant movement of the pelvis is very important because the correct position of the pelvis and spine affect breathing and digestion, strengthen muscles while encouraging proper posture and body balance. The correct posture on Salli chair is achieved on a two-part saddle chair that has a dynamic seat. This is the chair which offers a 135 degree angle between spine and femour, the neutral and healthiest posture for joints. Axia Smart chair warns the users if they sit in a wrong posture using a vibrational signal in the seat cushion as a direct feedback.

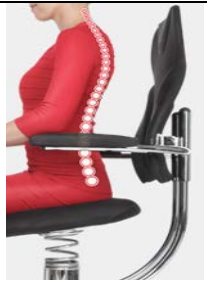
Aeron Remastered	Thatsit Balance	Spinalis	Salli	Axia Smart
				
www.hermanmiller.com/research/	www.corporateseating.com	www.spinalis.com	http://www.dms-medical.co.za/	www.bma-ergonomics.com/en

Fig. 2.

Characteristic postures assured by the selected chairs.

Structural analysis

Each chair was disassembled to the last independent part and analyzed from functional, feasibility, manufacturability, sustainability points of view. The Aeron chair shows a very complex, high quality structure, with many adjustable parts, and well-thought-out details. Laminated and molded wooden elements dominates in the case of Thatsit chair where the knee pads, seat depth and back height are adjustable. The active sitting in the case of the Spinalis chair is assured by a spiral spring which let the users to continuously swing on the seat. The back height is adjustable beside the seat height. Salli chair has a gas spring with longer piston rod to assure a higher seat height. The two part seat is adaptable to user preferences and can be chosen with tilt or swing mechanism.

Aeron Remastered	Thatsit Balance	Spinalis	Salli	Axia Smart
				

Fig. 3.

Structural characteristics of the investigated chairs.

Body pressure distribution analysis

The influence of subjects' body built on seat and back pressure distribution was investigated using a sensing foil measurement system. From the pressure maps the contact area and peak pressure values were determined. Figure 4. contains the pressure maps of both subjects for chairs with straight sitting postures. Due to the lower body mass index of the female subject, the contact areas both on seat and back were lower than of male subject who fall into the overweight class. The peak pressure values show similarity between the subjects, however the female subject press the Axia Smart chair with the lowest pressure. Even though the peak pressure values are comparable, the high pressure zones for the male subject are considerably larger.

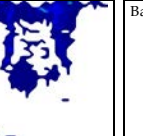
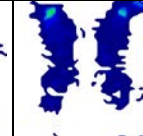
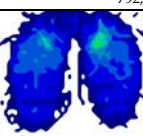
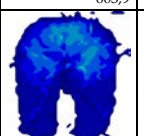
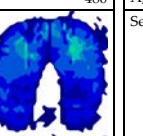
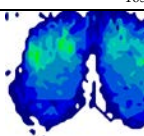
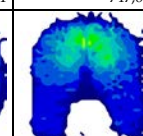
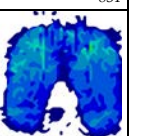
Female				Male			
	Aeron Remastered	Axia Smart	Spinalis		Aeron Remastered	Axia Smart	Spinalis
Back				Back			
P_{max} , N/cm ²	0,92	0,44	0,72	P_{max} , N/cm ²	0,76	1,74	0,91
A , cm ²	792,8	603,9	480	A , cm ²	1058,1	747,6	831
Seat				Seat			
P_{max} , N/cm ²	1,89	1,15	1,61	P_{max} , N/cm ²	1,76	1,89	1,53
A , cm ²	1196,4	1322,3	1284,1	A , cm ²	1351,2	1407	1337

Fig. 4.
The influence of chair type on pressure distribution maps.

Figure 5 represent the pressure maps for chairs with unconventional sitting postures. In the second column of the matrix the pressure maps of the Aeron chair remained for comparison purposes. The backs of Salli and Thatsit chairs are smaller resulting in a visible lower contact areas and higher pressure values consequently. The saddle chair's pressure maps shows very high peak pressures under the ischial tuberosity highlighting the wrongly adjusted two-seat panes. The back contact areas for Salli and Thatsit chairs are half of the Aeron Chair's similar value. The higher pressure on the lumbar zone for Thatsit chair can be also observed. The male subject expose more pressure on seat when sits on Aeron chair and press more the back of the Thatsit chair. The shape of the contact area on seat varies but the size of the area is comparable in the case of female subject.

The effect of leaning forward on the pressure maps are represented in Figure 6 and 7. In the case of Thatsit chair the female subject slightly attach the back while the male subject does not attach at all. On the seat there are no considerable changes in area and peak pressure. By leaning forward the chair tilts ahead and the female user press the knee pads with 2,59 N/cm² which is almost double of the original value. Leaning forward does not have considerable effect on the contact area of seat pane but the peak pressure decreased slightly.

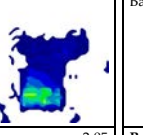
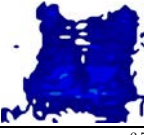
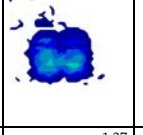
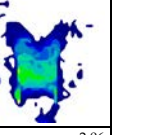
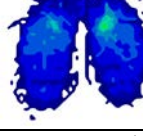
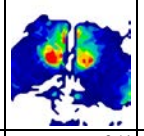
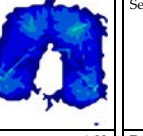
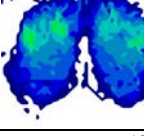
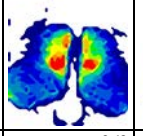
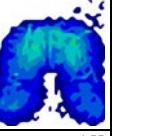
Female				Male			
	Aeron Remastered	Sally	Thatsit		Aeron Remastered	Sally	Thatsit
Back				Back			
P_{max} , N/cm ²	0,92	1,04	2,05	P_{max} , N/cm ²	0,76	1,37	2,06
A , cm ²	792,8	488,3	584,3	A , cm ²	1058,1	473,8	672
Seat				Seat			
P_{max} , N/cm ²	1,89	3,46	1,32	P_{max} , N/cm ²	1,76	3,63	1,55
A , cm ²	1196,4	1118	1186,1	A , cm ²	1351,2	11171,6	1057

Fig. 5.
The influence of posture on pressure distribution maps.

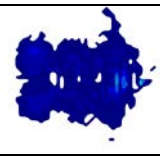
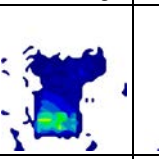
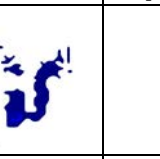
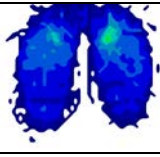
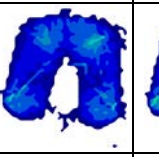
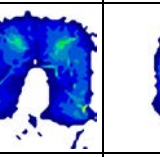
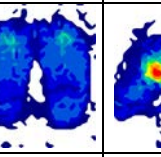
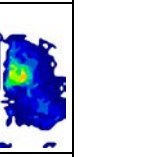
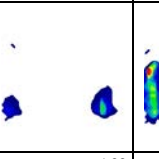
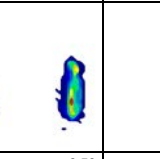
Female					
	Aeron Remastered	Thatsit straight	Thatsit forward	Spinalis forward	Salli forward
Back					
P_{max} , N/cm ²	0,92	2,05	0,45		
A , cm ²	792,8	584,3	219,9		
Seat					
P_{max} , N/cm ²	1,89	1,32	1,42	1,38	2,49
A , cm ²	1196,4	1186,1	1129,3	1244,90	1048,8
Knee					
P_{max} , N/cm ²		1,38	2,59		
A , cm ²		102,2	314,8		

Fig. 6.

The influence of leaning on pressure distribution maps for the female subject.

Figure 7 shows the pressure distribution maps for the male subject when he lean forward in chair just like in the case of typewriting. The knee pad contact area is more than three times higher and the peak pressure is almost double. As a consequence, the back pressure is converted on knee pressure but with lower contact area. In the case of the Salli chair, the red zone indicating a higher pressure increased. Contrary to conventional office chairs the pressure did not increase in the front edge zone when subjects lean forward due to the tilting of whole Thatsit chair and due to the bending of seat pane of the Spinalis chair.

CONCLUSIONS

The results obtained within the present study demonstrated that office chairs providing diverse seating postures focus on some certain ergonomic and comfort aspect. Ones highlight the importance of lumbar support, others put accent on active or upright seating, some others emphasis the significance of body support in each posture. The body pressure distribution analysis revealed that considerable pressure is exerted on knee pads when subject tilt forward, the peak pressure values do not increase in the front zone when the seat panes are flexible.

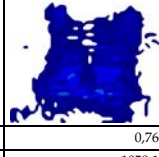
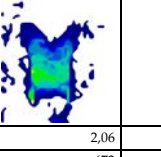
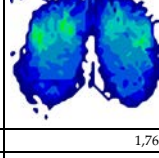
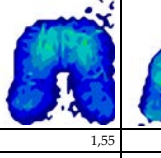
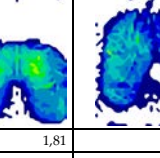
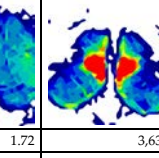
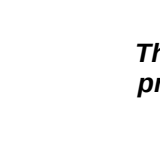
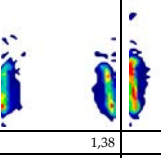
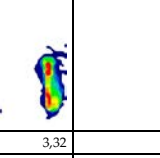
Male					
	Aeron Remastered	Thatsit straight	Thatsit forward	Spinalis forward	Salli forward
Back					
P_{max} , N/cm ²	0,76	2,06			
A , cm ²	1058,1	672			
Seat					
P_{max} , N/cm ²	1,76	1,55	1,81	1,72	3,63
A , cm ²	1351,2	1057	954,8	1387,4	1015,7
Knee					
P_{max} , N/cm ²		1,38	3,32		
A , cm ²		102,2	362,3		

Fig. 7.

The influence of posture on pressure distribution maps of the male subject.

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