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EFFECT OF ANTHROPOMETRIC FACTORS ON ISCHIAL AND POPLITEAL PRESSURE VARIATIONS IN DIFFERENT TYPES OF CONTOURED SEAT CUSHIONS

Gaurav Sahu
Prof. Nitin Dubey

Abstract

Introduction Sitting discomfort is major health problem among the person who spent most of the time in a seated position thus it becomes necessary to study various factors that affects the sitting pressure and prevalent conditions. So that these may be neutralize or controlled in order to increase the comfort and user sitting experience. Objective The study focuses to determine the sitting pressure in three different types of contoured seat cushions and to know whether the anthropometric factors affects this sitting pressure or not. Methodology The initial interface pressure was determined by the air-inflated digital pressure meter and the left-right popliteal region and left-right ischial region pressure readings were measured among the 10 male subjects. The subjects were instructed to sit in an upright posture. Keeping the design parameters within the anthropometric limits for the structure of Chairs, they are mounted with three different types of contoured cushions. Results It was found that weight, height, and age does not proportionally and directly affect the pressure distribution on the seat pan, but the contouring of the seat affects the pressure distribution significantly. The Results were analyzed for significance test by one-way ANOVA method. Conclusion The anthropometric factors do not have any direct effect on seat pressure distribution.

Keywords: Pressure Mapping, Seat Comfort, Seat Contour, Cushions, Pressure Distribution, Pressure Ulcers, Buttock pressure, ANOVA , Ischial Tuberosity, Popliteal region.

1. INTRODUCTION

Sitting discomfort and pressure ulcers(1,2,3) are general health problems for people who spend most of their time in a seated position. In past studies, many of the causes have been detected for the development of pressure ulcers. The application of pressure-relieving seat cushions (4) is found important in this aspect. The probability(5) of occurrence of pressure ulcers is noticeable at values above 60 mmHg of pressure, but still, there are no clear standards determined for reducing the pressure to avoid pressure ulcers. To date, there are no existing common rules and guidelines for selecting seat cushions (6,7,8) and even there is no general standard (9,10) methodology for pressure measurement. Researchers (11) in literature reviews already mentioned that many studies have done pressure mapping with subjects in one static position. The time duration of measurement ranges from less than a minute to more than half an hour. Also, researcher(11) outlined established methods of pressure measurement in seating in their review, by this, their findings set up the hypothesis that existing work in this field was done without common methodology and procedures, which resulted in vast experimental data which can be separately useful but as a single entity is very difficult to compare. Some researchers (12,13) have analyzed and compared many parameters related to cushion contact pressure, but there have been no clear findings that which material is suitable for the seat cushion. Some studies (14) have proved that a good body pressure distribution is proportional to comfort. Here, the understanding (15) is that the use of a comfortable product will increase productivity and help them to remain healthy throughout their day.

Research(16) has proven that when the curvature of the unloaded cushion changed from flat to concave accordingly the peak pressure decreases. Also, it had been noted (17) that matching the cushion to the shape of the penetrating object would result in lower interface pressure. some studies(18,19) found that polyurethane foam produces minimum peak interface pressure and offers better pressure distribution as compared to gel. The PU-foam cushion provides (20) better performance in pressure relief at an economical cost as compared to fluid-filled cushion, it also provides the advantage of air permeability and low weight. Polyurethane foam cushions that have visco-elastic and resilient properties can provide fair support to maintain the buttock's shape, thereby aiding sufficient dynamic stability(21). The general measurements (22)that are used in pressure mapping are Average Pressure, Peak Pressure, and Contact Area. Some researchers have measured pressure at different areas of the pressure map instead of looking at the whole pressure map. In this regard, they also look at the pressure points at the ischial tuberosities and the pressure around the popliteal area. Other studies (23) looked at different regions of the human-chair interface individually. Pressure mapping has been the most highly commendable measuring tool (24) for assessing comfort.

2. OBJECTIVE

The authors concluded (25) that chair design plays a vital role in the good pressure distribution on the seat pan, followed by participant postural effects. But here in the study, the aim is to determine that the sitting pressure in three different types of contoured seat cushions so to know whether the anthropometric factors affects this sitting pressure or not. It becomes necessary to study various factors that affects the sitting pressure, So that affects these factors may be controlled as to increase the sitting comfort and user's overall sitting experience

3. METHODOLOGY

3.1 Material selection and Pressure Reading: The three supplementary seat cushions of different contoured shapes named CC (Fig.1) ,CT (Fig.2), and BT are used in this study and they were made of Polyurethane foam of 40 density. The dimensions of these cushions were 17" x 17" with a thickness of 2". Polyurethane foam is (18,19) the best material to be used as the cushion for office chairs as it offers the best pressure distribution resulting in lower peak Pressure. The selection of 40-density polyurethane foam is based on the economical and mechanical factors as mechanical properties(26) at 40 density provide optimum effect concerning cost. The three different contoured seat cushions were mounted on the three structures of chairs of the same dimensions

Fig. 1. Graphical Model Of CC cushion

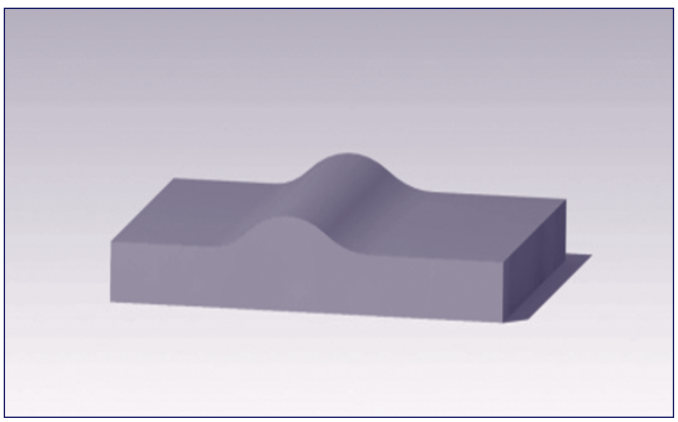
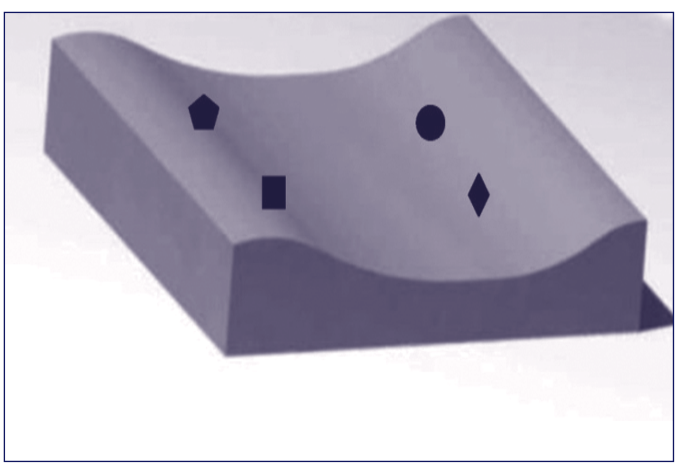


Fig. 2. Graphical Model Of CT cushion. Circle: RIT, Diamond: LIT, Pentagon :RP, Square: LP.



The air-inflated cuff-based digital pressure meter of make Dr. Morepen was used to measure the initial interface pressure between the subject and seat surface. The four specific points (27) namely two points on ischial tuberosity Region (Fig.2) and two Points on the popliteal region (Fig.2) on the subject's body were selected to measure the initial interface pressure. The subjects were asked to sit on these three chairs one by one and the pressure was measured on the specified points simultaneously, by placing the cuff at the interface, is that between the pressure point and seat surface. The four Readings were suitably marked for each subject. The average of four Pressure was named as total average pressure, which was calculated for each subject to find out the intensity of pressure in each contoured seat cushion. The readings from the above experiment were processed under one way ANOVA test to check the significance of results for $p<0.05$ (27) and the obtained results were compared with the parameters such as weight, height, and age of subjects to make the study specific.

3.2. Experimental design: The researchers (28) gathered information on body measurements of school students by measuring a random set of 207 individuals. By the data, a chair was designed using CATIA software. The chair was found to have a seat height of 44cm, depth of 42 cm, and breadth 42.15 cm, respectively. Furthermore, the backrest was adjustable, with a full range of motion between 95 and 105 degrees. whereas in research (29) statistics of body parts data on student at University Putra Malaysia was analyzed and the ideal measurements were stated as the seat height for students was 47.3cm, the seat depth was 44.2cm. The seat width considered with allowance was. 43.3 cm. Also the lecture notes of Cornel university Ergonomics web Mention that for adult seat depth the recommended dimension is 16.5" for fixed seats and 14-18.5" for adjustable seats. for seat width the appropriate dimension is around 20 - 22" to accommodate clothed persons. The seat height for fixed seating is 17". Here too high seating height leads to increased pressure at the popliteal region on other side low height increases weight on the ischial tuberosities. Therefore considering the above three research work, in this study the chair frame was designed in which seat height was fixed to 15". the seat Depth was kept 17" as for adult, the studies done in past recommends from 16.5" to 18.5". For seat width, considering the usability limited to computer lab chair (as the further work in our study is targeted for computer lab chair only) the width was fixed to 17". The back was made inclined to 105, with the mid back support of PU foam of flat pattern. on the above basis the three chair frame were constructed which were mounted by the CT, CC and BT cushion respectively.

3.3. Participants: Ten healthy male subjects with an average age of 36.4years (range 27-49 years), an average height of 169.8 cm (range 158 -180 cm), an average weight of 69.1 kg (range 54-83 kg, and an average BMI of 24 kg/m2 (range 18-31 kg/m2) took part in this study. For the selection of the above 10 subjects, the interviews were conducted among 20 male and 05 female subjects. Subjects without musculoskeletal disorders as well as subjects who have not received medication for a prolonged period were included in the study. All the selected subjects provided written consent to participate.

Table 1. Demographic data on the participants of the study conducted in the Department of Mechanical Engineering, OIST Bhopal, M.P.

S. no.	Subject	Subject Code. No.	Subject Age (years)	Subject Height (cm)	Subject Weight (kg)
1	Subject 1	VS 1	37(55th percentile)	168 (25th percentile)	64 (35th percentile)
2	Subject 2	US 2	27 (05th percentile)	173 (65th percentile)	73 (65th percentile)
3	Subject 3	AS 3	47 (85th percentile)	158 (05th percentile)	54 (05th percentile)
4	Subject 4	AL 4	33 (35th percentile)	170 (45th percentile)	69 (45th percentile)
5	Subject 5	RS 5	29 (15th percentile)	168 (35th percentile)	62 (25th percentile)
6	Subject 6	DU 6	38 (65th percentile)	170 (55th percentile)	70 (55th percentile)
7	Subject 7	AHK 7	49 (95th percentile)	178 (85th percentile)	75 (75th percentile)
8	Subject 8	AJ 8	32 (25th percentile)	180 (95th percentile)	79 (85th percentile)
9	Subject 9	AD 9	38 (75th percentile)	158 (15th percentile)	62 (25th percentile)
10	Subject 10	PK 10	34 (45th percentile)	175 (75th percentile)	83 (95th percentile)

4. RESULTS

4.1 Demographics: The data are consistent with a sample from a normal distribution as the points lie close to a straight line. For height (Fig.3) the mean (μ) is 169.8 (range 158 -180 cm) and the standard deviation (σ) is 7.405, for weight (Fig.4) the mean (μ) is 69.1 (range 54-83 kg)and standard deviation (σ) is 8.79962 and for age, the mean(μ) is 36.4 years (Range 27-49 years) and standard deviation (σ) is 7.12. The data continuity and variability (from 5th to 95th percentile) following the normal distribution gives the study the diversified and unique observation per subject. The chances of repeatability of any observation for age, height or weight of subject have become negligible as more than two subjects do not have the same age, height or weight.

Fig. 3. Normal Probability Plot of Height

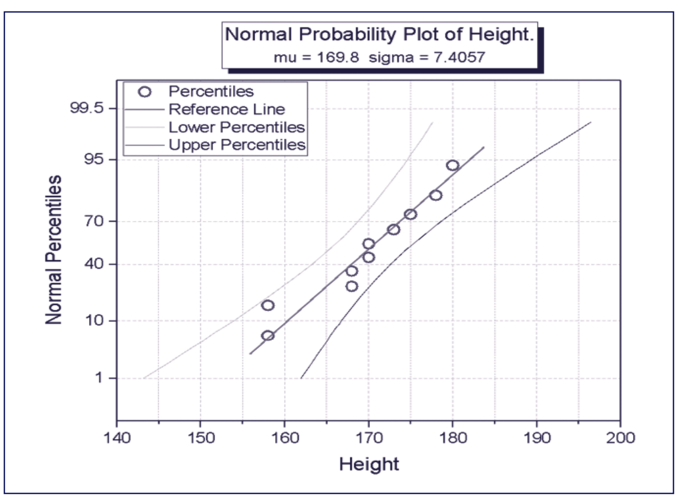
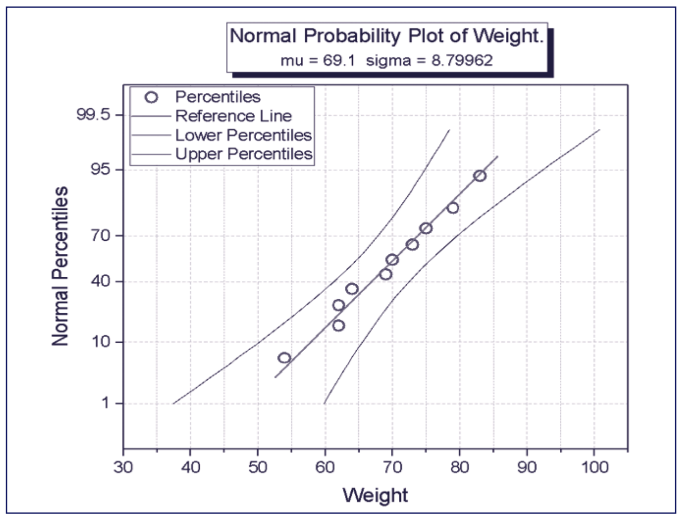
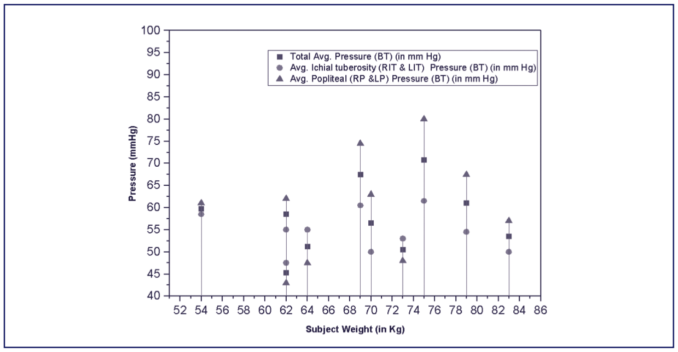


Fig. 4. Normal Probability Plot of Weight.



4.2 Pressure variation with respect to the weight of a subject: The ten subjects with an average weight of 69.1 kg and average BMI of 24 were made to sit on CT, CC and BT cushions simultaneously and the pressure was noted at ischial tuberosity and popliteal region for the left and right side of the body. For cushion BT (Fig.5) the highest total Average pressure value is 70.75 mmHg (95th percentile), here the mean (μ) is 57.45 and the standard deviation (σ) is 7.81. On observation of all types of average pressure variations, it is found that they are not proportional to the weight of subjects as it is clear from the fig, that the pressure is not simultaneously increasing or decreasing with weight. Here the pressure variation is random with respect to weight. Moreover, for 3 subjects, the average ischial tuberosity pressure is high and for the remaining subjects the average popliteal pressure is high thus the pressure is not distributed evenly in a particular direction. The pressure is randomly distributed over the seat pan irrective of any direction or subject included in the study.

Fig. 5. Pressure variation on chair BT with respect to the weight of a subject



For cushion CC (Fig.6) the Highest total Average pressure value is 56.75 mm Hg (95th percentile) , here the mean (μ) is 43.4 and the standard deviation (σ) is 7.85. On observation of all types of average pressure variations, it is found that they are not proportional to the weight of subjects as it is clear from the fig, that the pressure is not simultaneously increasing or decreasing with weight. The pressure variation is random with respect to weight. Moreover, for 5 subjects the average ischial tuberosity pressure is high and for the remaining 5 subjects the average popliteal pressure is high thus the pressure is not distributed on the seat pan, evenly in a particular direction.

Fig. 6. Pressure variation on chair CC with respect to the weight of a subject.

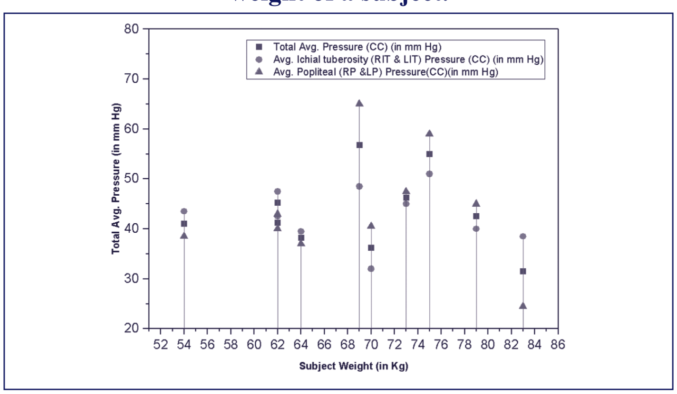
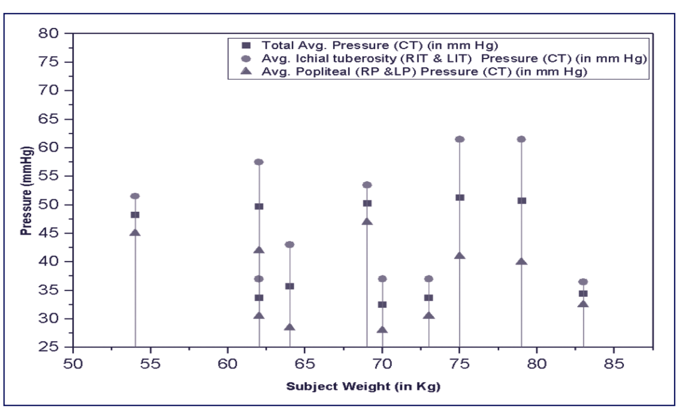


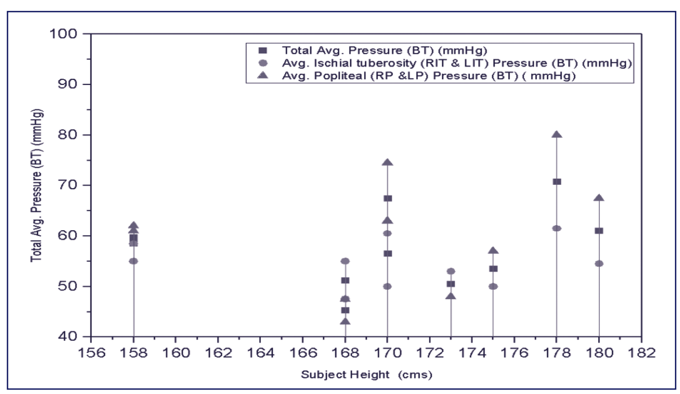
Fig. 7. Pressure variation on chair CT with respect to the weight of a subject.



For cushion CT (Fig.7) the Highest total Average pressure value is 51.25 mmHg (95th percentile) , here the mean (μ) is 42.05 and the standard deviation (σ) is 8.504. On observation of all types of average pressure variations, it is found that they are not proportional to the weight of subjects as it is clear from the fig.7, that the pressure is not simultaneously increasing or decreasing with weight. The pressure variation in CT is random with respect to weight. Moreover, for all 10 subjects, the average ischial tuberosity pressure is high and for none of the subjects, the average popliteal pressure is high thus here the pressure is centered more towards the ischial tuberosity region on the seat pan, but it varies from subject to subject irrespective of weight.

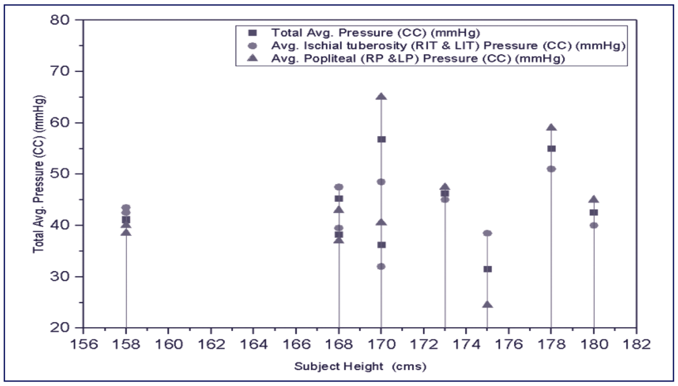
4.3 Pressure variation with respect to the height of a subject: The ten subjects with an average height of 169.8 cm and average BMI of 24 were made to sit on CT, CC and BT cushions simultaneously and the pressure was noted at ischial tuberosity and popliteal region for the left and right side of the body. For cushion BT (Fig.8) the highest total Average pressure value (Table 3) is 70.75 mmHg (95th percentile), here the mean (μ) is 57.45 and the standard deviation (σ) is 7.81. On observation of all types of average pressure variations, it is found that they are not proportional to the height of subjects as it is clear from the fig, that the pressure is not gradually increasing or decreasing with height. Here the pressure variation is random with respect to height. The two subjects having the same height do not show any similarity in average pressure distribution, their average differs in all respects. Moreover, for 3 subjects the average ischial tuberosity pressure is high and for the remaining 7 subjects the average popliteal pressure is high thus the pressure is not distributed on the seat pan, evenly in a particular direction, and the distribution varies from subject to subject irrespective of height..

Fig. 8. Pressure variation on chair BT with respect to the height of a subject.



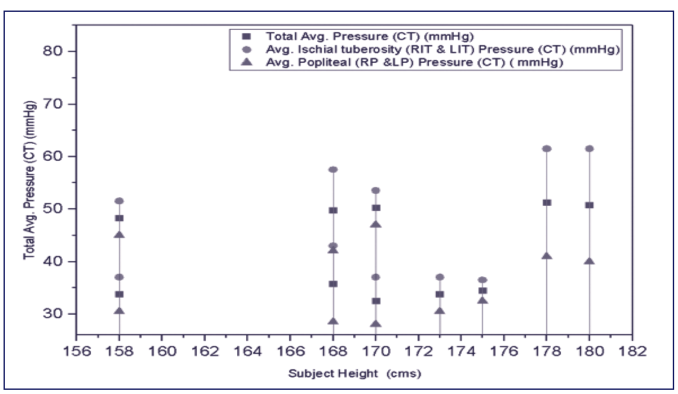
For cushion CC (Fig.9) the highest total Average pressure value is 56.75 mmHg (95th percentile) , here the mean (μ) is 43.4 and the standard deviation (σ) is 7.85. On observation of all types of average pressure variations, it is found that they are not proportional to the height of subjects as it is clear from the fig, that the pressure is not gradually increasing or decreasing with height. Here the pressure variation is random with respect to height. The two subjects having the same height do not show any similarity in average pressure distribution here also and their average differs in all respects. Moreover, for 5 subjects the average ischial tuberosity pressure is high and for the remaining 5 subjects the average popliteal pressure is high thus the pressure is not distributed on the seat pan, evenly in a particular direction, distribution varies from subject to subject irrespective of Height.

Fig. 9. Pressure variation on chair CC with respect to the height of a subject.



For cushion CT (Fig.10) the Highest total Average pressure value is 51.25 mmHg (95th percentile), here the mean (μ) is 42.05 and the standard deviation (σ) is 8.504. On observation of all types of average pressure variations, it is found that they are not proportional to the height of subjects as it is clear from the fig, that the pressure is not gradually increasing or decreasing with height. Here the pressure variation is random with respect to height. The two subjects having the same height do not show any similarity in average pressure distribution, their average differs in all respects. Moreover, for all 10 subjects, the average ischial tuberosity pressure is high as compared to the Average Popliteal pressure thus the pressure is centered in a particular direction on the seat pan, but again this distribution varies from subject to subject irrespective of Height.

Fig. 10. Pressure variation on chair CT with respect to the height of a subject.



4.4 One way ANOVA test for contoured seat cushion: The one-way analysis of variance (ANOVA) is used to determine whether there are any statistically significant differences between the means of three or more independent groups. Here in the study the three groups are considered which were the Total Average Pressure (Table 3) of Chair CT (group 1), CC (group 2) and BT (group 3). Each Group consists the Total Average Pressure of 10 Subjects. The results were find to be statically Significant at p <0.05. with $F(2,27) = 11.19$, $p = 0.00028$.

Table 2. One-way analysis of variance for 10 subjects on three different types of contoured cushion.

Source	*SS*	*df*	*MS*	
Between-treatments	1454.6167	2	727.3083	F(2,27) = 11.19
Within-treatments	1754.725	27	64.9898	
Total	3209.3417	29		

Table 3, Total Average Pressure Distribution on seat pan for chair CT,CC and BT.

Subject Code.No.	Total Average Pressure (mmHg) (CT)	Total Average Pressure (mmHg) (CC)	Total Average Pressure (mmHg) (BT)
VS 1	35.75	38.25	51.25
US 2	33.75	46.25	50.5
AS 3	48.25	41	59.75
AL 4	50.25	56.75	67.5
RS 5	49.75	45.25	45.25
DU 6	32.5	36.25	56.5
AHK 7	51.25	55	70.75
AJ 8	50.75	42.5	61
AD 9	33.75	41.25	58.5
PK 10	34.5	31.5	53.5

5. DISCUSSION

5.1 Deviation of Pressure distribution on Seat pan: A study on 10 male subjects (table 1) of variable and continuous Weight (fig), Height (fig), and Age was conducted in which the ischial and popliteal region pressure (27) were noted, the results show that the pressure at these points are not proportional to Age, Weight, and Height but they are random as compare to specified parameters. It is also clear from the observation that in all kinds of cushions the RIT, LIT, RP, and LP pressure are not the same for a particular subject. The Pressure is not uniformly distributed in all direction rather than that is distributed unevenly, which causes the deviation in pressure from the mean pressure value of a particular subject. The pressure deviation on the seat pan in BT ranges from 1.707 (Subject: AS 3) to 13.744 (Subject: AHK 7), in CC ranges from 2.217 (Subject: US 2) to 10.750 (Subject: AL 4), and in CT ranges from 2.645 (Subject: PK 10) to 15.326 (Subject: AHK-7).Here the subject (AHK-7) show maximum deviation for seat BT and CT, but for minimum deviation there is no such kind of repetition among the subjects .Moreover the weight percentile of AHK-7 is less than two subjects, height Percentile is less than one subjects and Age is maximum among all ten subject, so AHK-7 doesn't hold any particular parameter to justify the highest deviation value in the BT and CT. Thus it is clear that the height, weight and age doesn't have any significant effect on Pressure distribution deviation on seat pan. The fact (25) is that the posture affect the pressure distribution more. On the other hand posture may be affected by the Anthropometric factors if the seat of suitable dimension is not selected.

Table 4 . Pressure deviation on seat pan of three different types of contoured cushion

Chair Type	Min. Deviation	Max. Deviation	Mean Deviation
BT	1.707	13.744	7.725± 6.018
CC	2.217	10.750	6.483±4.266
CT	2.645	15.326	8.985±6.340

5.2 Variation of Pressure distribution on Seat pan: The pressure at the interface was not proportional to Age, Weight and Height for BT, CT, and CC but they are random as compared to specified parameters as it is already discussed in results. The four interface pressure points namely RIT, LIT, RP, and LP, measured for chair BT (Table 5), chair CC (Table 6), and chair CT (Table 7) bears almost different readings for a particular individuals on same chairs as well as a particular individual shows different readings of specified pressure points on different chairs and also there is a significant pressure difference between popliteal and ischial tuberosity region for all the subjects too. For any of the cushion types, the popliteal and ischial tuberosity pressure reading is not the same. In cushion BT (Table 5) , for 3 subjects the average ischial tuberosity pressure is high and for the remaining 7 subjects, the average popliteal pressure is high. In CC (Table 6), for 5 subjects, the average ischial tuberosity pressure is high and for the remaining 5 subjects, the average popliteal pressure is high. In CT (Table 7) for all 10 subjects, the average ischial tuberosity pressure is high and for none of the subjects, the average popliteal pressure is high. The RIT and LIT pressure is not the same for any subject for BT and CT chair as well as RP and LP pressure are also not the same for any subject for BT and CT chair. Only two subjects show this equal distribution of Pressure for CC chair only. Thus it is clear, that in any case the pressure at ischial and popliteal region is not same whereas only for one subject the left and right ischial tuberosity is same (AJ-8) and for only one subject the left and right popliteal is same (AD-9) that too for chair CC.

Table 5 . Pressure Distribution on seat pan for chair BT

Subject Code.No.	RIT (mm Hg)	LIT (mm Hg)	RP (mm Hg)	LP (mm Hg)	Avg. Ischial tuberosity (RIT & LIT) Pressure (mm Hg)	Avg. Popliteal (RP &LP) Pressure (mm Hg)
VS 1	53	57	42	53	55	47.5
US 2	54	52	51	45	53	48
AS 3	59	58	60	62	58.5	61
AL 4	60	61	70	79	60.5	74.5
RS 5	49	46	47	39	47.5	43
DU 6	51	49	64	62	50	63
AHK 7	65	58	70	90	61.5	80
AJ 8	55	54	66	69	54.5	67.5
AD 9	56	54	63	61	55	62
PK 10	51	49	56	58	50	57

Table 6. Pressure Distribution on seat pan for chair CC

Subject Code.No.	RIT (mm Hg)	LIT (mm Hg)	RP (mm Hg)	LP (mm Hg)	Avg. Ischial tuberosity (RIT & LIT) Pressure (mm Hg)	Avg. Popliteal (RP &LP) Pressure (mm Hg)
VS 1	36	43	34	40	39.5	37
US 2	43	47	48	47	45	47.5
AS 3	42	45	40	37	43.5	38.5
AL 4	52	45	60	70	48.5	65
RS 5	49	46	47	39	47.5	43
DU 6	26	38	40	41	32	40.5
AHK 7	42	60	65	53	51	59
AJ 8	40	40	44	46	40	45
AD 9	40	45	40	40	42.5	40
PK 10	34	43	27	22	38.5	24.5

Table 7. Pressure Distribution on seat pan for chair CT

Subject Code.No.	RIT (mm Hg)	LIT (mm Hg)	RP (mm Hg)	LP (mm Hg)	Avg. Ischial tuberosity (RIT & LIT) Pressure (mm Hg)	Avg. Popliteal (RP &LP) Pressure (mm Hg)
VS 1	40	46	25	32	43	28.5
US 2	34	40	30	31	37	30.5
AS 3	51	52	45	45	51.5	45
AL 4	59	48	42	52	53.5	47
RS 5	57	58	46	38	57.5	42
DU 6	34	40	32	24	37	28
AHK 7	68	55	31	51	61.5	41
AJ 8	58	65	43	37	61.5	40
AD 9	34	40	30	31	37	30.5
PK 10	37	36	34	31	36.5	32.5

6. CONCLUSION

Polyurethane foam (18,19) is the best material to be used as the cushion for office chairs as it offers the best pressure distribution resulting in lower peak Pressure regardless of other materials. Here all three cushions were made of PU foam. In Cushion BT the mean Pressure value is 57.45 mmHg whereas in CT is 42.05 mmHg and in CC is 43.4 mmHg. Thus the magnitude of pressure is lower in CT. The mean deviation in pressure on the seat pan is more in CT followed by BT and CC (table. 4), more the pressure deviation from the mean reflects that the difference in RIT, LIT, RP, and LP pressure is more. Here for every chair type, the pressure distribution on the interface varies significantly (table 2) on the seat pan with respect to a particular subject ($p<0.05$). Thus it is clear that the pressure is not equally distributed on the seat pan for any kind of chair type. Moreover, it is clear from all observations that the weight, height, and age of the subject do not proportionally affect the pressure distribution on the seat pan. The anthropometric factors do not have any direct effect on seat pressure distribution. But the variation of total average pressure shown in CT, CC, and BT mark that contouring of the seat affects the pressure distribution, and ANOVA Analysis of the results states that the results are significant for $p<0.05$.

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AUTHORS

Gaurav Sahu, Research Scholar, Madhyanchal Professional University, Bhadbhada Road, Ratibad, Bhopal – 462 044(MP), India
Email: gtech_gaurav@yahoo.com

Prof. Nitin Dubey, Associate Professor, Madhyanchal Professional University, Bhadbhada Road, Ratibad, Bhopal – 462 044(MP), India
Email: nitindub@gmail.com