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Body Pressure Distribution Measurement for Comfort Evaluation of a Coccyx Seating Mat

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Abstract. This study evaluates the seating mat comfort based on the measurement results of body pressure. A specially designed sitting mat for decubitus patients features its alleviated pressure on the coccyx, while maintaining well distributed body pressure force which may give more comfort to its users. For validation, a series of pressure measurement scheme is planned for a variety of conditions comprising the floor conditions (a flat floor, an office chair, and a car seat) and the mat options. For a quantitative evaluation, some comfort indices including the seat pressure distribution (SPD) and segmental pressure ratio are employed. The test results support that the proposed cushion mat effectively alleviates the pressure near coccyx maintaining less overall body pressure over the mat.

Keywords: decubitus mat, body pressure measurement, seat pressure distribution, pressure ratio, comfort, ischium.

1 Introduction

The body pressure distribution acting on the seating devices such as the seating mats, office chairs, and car seats is considered to be a very important factor that affects the human comfort. For all seat makers ranging from homes and offices, cars, trains and airplanes pursue better conditions that satisfy human comfort requirements, body pressure information has been used extensively by many investigators [1-5]. Earlier in the 1990s in Korea, Park et al. [1] emphasized the importance of the pressure distribution between the body and the seat surface on the seat comfort and developed their own pressure measurement system [2] . However, the discussion was limited to those on the effect of body pressure distribution on physiological effects mostly and did not provide any quantitative description out of pressure distribution data. Lee et al. [3] proposed a comfort evaluation method based on the correlation study between the subjective and objective approaches, in which they considered the hip pressure ratio as an important parameter. According to their results, the higher hip pressure ratio is associated with lower overall ratings. Lee et al.[4] used the body pressure

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measurement data to replicate the passenger's motion during the ingress and egress periods. Naturally, recently designs are focused on pressure distribution for improved ride comfort qualities of vehicle seats [5].

Other than general seating situations as in offices, homes, and in cars, special needs for right pressure distribution arise from patients who suffer from decubitus. The present study evaluates the comfort indices in an objective manner for the seating mat for decubitus patients (named 'coccyx seating mat') which are directly associated with the decubitus patients' feel of comfort. The desired features are assumed to be reduced pressure that might not irritate the patients' affected area and mild pressure gradient to give a better sitting comfort.

2 Methods of Approach

2.1 Body Pressure Mat

In order to evaluate the desired feature, the Xsensor X3 PX100:48:48 sensor [6] is used to measure the due body pressure, which measures the local pressure on the equally spaced 48x48 measurement points. The measurement pressure range is from 0.14 (N/cm^2) to 2.7 (N/cm^2).

2.2 Affecting Parameters to Seating Comfort

Xsensor body pressure mat provides information such as mean pressure, maximum pressure, the location of the center of pressure (COP) and the contact area. In the present study, two more relevant comfort indices that can be reduced from the measured local pressure are considered, which are both known to reflect the subjective evaluation well [2]:

(1) Seat pressure distribution (SPD, %):

$$\mathrm{SPD}(\%) = \frac{\sum_{i=1}^{n}(p_i - p_m)^2}{np_m^2} \times 100 \quad (\mathbf{1})$$

The seat pressure distribution (SPD) is widely accepted in automotive seat comfort evaluation and represents the capacity of a mat to distribute the pressure. The lower SPD, the more uniformly distributed the pressure.

(2) Ischium pressure ratio (Pr, %):

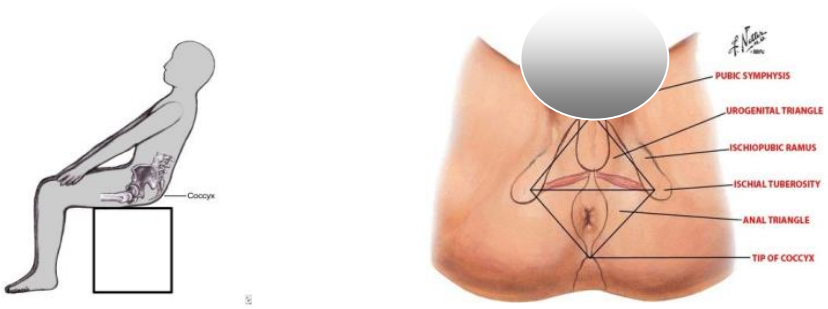
$$\mathrm{Pr}(\%) = \frac{\sum_{interested\ area} p_i}{\sum_{total\ area} p_i} \times 100 \quad (\mathbf{2})$$

The pressure ratio (Pr) is defined as the ratio of the pressure force on the interested area with respect to the total pressure force acting on the mat. In the present study, we defined the interested local area as the 38.1cm x 12.7cm (15”x5”) rectangular area near ischium that covers the mostly hip contact surface.

(3) Average pressure around the coccyx:

$$p_{avg,coccyx} = \frac{\sum_{no.of\ \ nodes} p_{i,j}}{no.of\ \ nodes} \quad (3)$$

The average pressure around the coccyx is an important factor that affects the comfort of decubitus patients. To evaluate the acting pressure level the average pressure is monitored for a certain area that contains the coccyx. For the tip of coccyx is located at the rear apex of the anal triangle, rectangular area of 6.4cm x 8.9cm (2.5”x3.5”) rearward from the ischium tuberosity (Fig. 2(b)) is selected for the evaluation of the local average pressure.



(a) Sitting posture with coccyx (b) Anal triangle

Fig. 1. Illustrations showing (a) a sitting posture and (b) the anal triangle [7]

(4) Local maximum pressure gradient :

High level of pressure gradient on the body suggests uneven load on the body skin and unnatural circulation of body fluids under the skin. Therefore lower level of pressure gradient is the desired feature of comfortable sitting. In the present study, this pressure gradient is defined as :

$$\text{Maximum pressure gradient} = \max\left(\left(\frac{\Delta p}{\Delta x}\right)_{i,j} + \left(\frac{\Delta p}{\Delta y}\right)_{i,j} \right) \quad (4)$$

(5) Location of the center of pressure (x):

The location of the center of pressure is measured based on the distance x from the center of pressure point and the line that connects the centers of ischium tuberosity marks (Fig. 3). The measured distance between the ischium tuberosity marks in Fig. 3

was found to be around 10~13 cm.

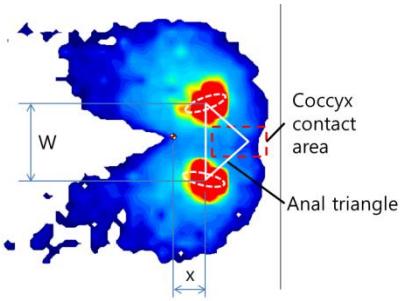


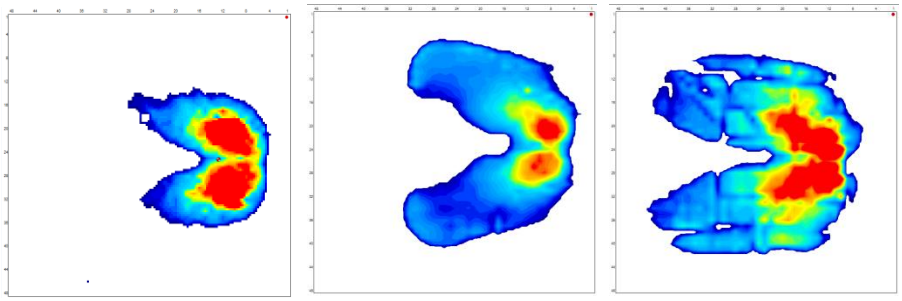
Fig. 2. Illustrations showing (a) a sitting posture and (b) the anal triangle

2.3 Test Conditions and Procedures

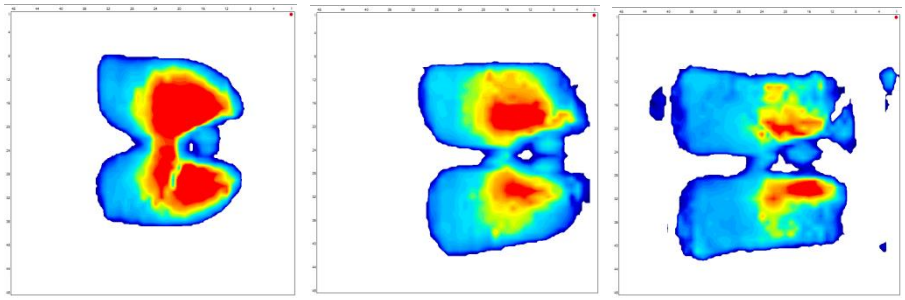
The measurements are conducted for the three cases which comprise of (a) bare floor, (b) an office chair, and (c) a car seat with and without a coccyx mat.

Fig. 3. Illustrated view of the tested coccyx mat prepared for testing

3 Results and Discussions



(a) Bare floor w/o mat (b) Office chair w/o mat (c) Car seat w/o mat



(d) Bare floor with mat (e) Office chair with mat (f) Car seat with mat

Fig. 4. Pressure distribution of subject B in different seating conditions

The analyzed test results are summarized in Table 1, in which the important comfort parameters defined in Sec. 2 are shown for the three prescribed seating conditions with and without a mat, respectively. According to the results in Table 1 which is the results for subject B (male in his 30s), the important observation are as follows:

(1) SPDs with mat decrease in all cases by 7%~41% which provides more even pressure distribution over the seating area.

(2) The average pressures around the coccyx significantly decreased by 74%, 58%, and 82% with mat cases on a hard floor, an office chair, and a car seat, respectively, which is a desired feature of coccyx mats.

Table 1. Reduced data from the measurements for different seating conditions

Description	Unit	Hard floor		Office chair		Car seat	
Subject	B	w/o mat	with mat	w/o mat	with mat	w/o mat	With mat
Mean pressure	N/cm^2	0.93	0.80	0.62	0.71	0.59	0.61
Max. pressure	N/cm^2	3.41*	3.41*	1.68	1.53	1.58	1.41
Contact area	cm^2	597	929	1168	1231	1423	1316
SPD	%	100	59	48	38	44	37
Ischium Pres. ratio	%	81	71	58	62	51	52
$P_{avg,\ coccyx}$	N/cm^2	0.87	0.23	0.88	0.37	0.72	0.13
Max. press. grad.	$(N/cm^2)/cm$	1.42	1.47	0.44	0.41	0.48	0.43

*data saturated

**the distance of the center of pressure point from ischium tuberosity mark line

4 Conclusions

The body pressure measurement results on the seating mat (a coccyx mat) for ischium patients are analyzed by introducing some comfort parameters used in automotive industry such as the SPD and the pressure ratio as well as the default information provided by the pressure mat manufacturers. These objective measures can provide more direct evaluation of the comfort level as needed in its application fields.
Through the present study, the comfort index values could be obtained to be compared for the two cases with and without a coccyx mat, which clearly identified the benefit of lowering local pressure around the affected area.
Further efforts to be done for better evaluation of seating comfort include the followings:

(1) the use of time averaged measurement data for the analysis to improve reliability
(2) to seek better ways to define the body location in the measured pressure distribution data.

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References

1. Park, S., Lee, N., Lee, S., An Investigation of the Relationship between Subjective Comfort Evaluation and Body Pressure Distribution of Vehicle Seats, Journal of the Ergonomics Society of Korea, Vo. 12, No. 1, pp. 3-15 (1993)
2. S. Park, N. Lee, C. Kim, S. Lee, Development of a Body Pressure Distribution Measuring Equipment for an Automotive Seat, Journal of Korean Institute of Industrial Engineers, Vol. 19, No. 3, pp. 113-121 (1993)
3. Lee, H., Park, H., Na, H., Kim, J., Cho, H., Jeon, O., A Study on the Comfort Evaluation Method for Automotive Seat, Proceedings of KSAE Spring-Fall Annual Conference, pp. 1412-1426 (2007)
4. Lee, K., Kim, J., Kim, Y., Choi, D., Lee, Y., Study on Reenactment Appraisal of Motion for Boarding and Alighting using Body-Pressure Analysis within Vehicle Seat, Proceedings of the Korean Society of Automotive Engineers Spring Conference, pp. 1043-1047 (2015)
5. Leon, L. Z., Characterization of Vehicle Seat Structural Dynamics and Effects on Ride Comfort, RMIT ME thesis (2012)
6. XSENSOR Test and Measurement Product Catalog
7. Google Image, http://www.google.co.kr/search under ‘coccyx’