Key factors of comfort pressure distribution - what we feel in sitting

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ABSTRACT

In the seating comfort research, it is known that the pressure distribution should not exceed a certain threshold from the viewpoint of tissue compression and should be widely distributed. However, its ideal distribution is not defined in past research. In this study, we focused on the pressure sensitivity of thighs and buttocks and performed an analysis assuming automotive seating. We determined the exponent of Steven's power law for seat pressure by measuring local perceived pressure load that felt the same pressure feeling at the reference load point, and the sensitivity distribution of 29 participants were measured and classified into 3 groups. The comfortable pressure distribution of 5 participants was measured using the experimental seat and converted into a perceived pressure distribution using the sensitivity distribution. The results show measured pressure distribution is not the same as perceived. Analysis of the perceived pressure distribution suggests that the comfortable perceived pressure distribution is a uniform distribution that falls within a certain range for the minimum pressure.

KEYWORDS

Seating comfort, Pressure distribution, Sensory sensitivity

Introduction

Pressure distribution is widely used in the analysis of body-chair interaction while sitting. It can be measured very easily by a commercial measuring system and is widely used in developments. Pressure distribution is very effective because it can visualize the contact state. It is known that pressure distribution that is widely dispersed and has no local concentration is good (Zemp et al., 2015), but no study showing what the optimal distribution is. In addition, although the upper limit of pressure is known from the viewpoint of blood flow inhibition due to tissue compression (Liu et al., 2020), no examples were shown about the distribution of appropriate values for comfort.

Vink et al. describe this lack of knowledge as a missing link, the effect of pressure sensitivity is linking the softness of product foam and seat, the contact area, and comfort caused by the interaction between the body and seat (Vink & Lips, 2017). It seems that individual differences, such as sensory organs, soft tissue thickness, etc., strongly affect pressure sensation. Therefore, we agreed on this model. Therefore, in this study, we focused on this pressure sensitivity.

To understand the sensory evaluation of the seating comfort, the sensitivity of thigh and buttock were measured by Hartung et al. (Hartung et al., 2004), Goossens et al. (Goossens et al., 2007), Vink et al. (Vink & Lips, 2017). No knowledge was shown about the relationship between sensitivity and pressure distribution.

In this study, we measure the pressure sensitivity distribution of the seated person. By defining this sensitivity as the conversion coefficient of the perceived pressure from the actual pressure, the purpose was to consider the perceived pressure felt by the seated person.

Sensitivity of thigh and buttock

Concept of the study

In this study, we calculate the perceived pressure felt by the seated person. Perceived pressure is obtained by multiplying the actual pressure by sensitivity.

$$Pressure_{Perceived} = Sensitivity \times Pressure_{Seat} \qquad \text{Equation (1)}$$

It is generally known that the relationship between sensation and stimulus follows Stevens' power law (Stevens, 1957). It is known that the relationship between the amount of sensation and the amount of stimulus is represented by using a power n that is unique to that sensation.

$$\emptyset = k \cdot S^n \qquad k\text{: Proportional constant} \qquad \text{Equation (2)}$$

Therefore, in this study, the reference point pressure P_1 was used as the stimulation S, and the measured pressure P_2 when a feeling of the same pressure was obtained as the sensation Ø, and the proportional constant k was defined as the sensitivity. Then, using the power law equation (2), the actual pressure is converted to the perceived pressure.

Measurement methods

Sensitivity measurement device

In this study, the sensitivity was defined by comparing the perceived pressure applied to a reference point with the pressure of the same pressure sensation at another measurement point. Figure 1 shows a pushing device for measuring sensory sensitivity. Pressurization of the thigh and buttock surfaces is performed with a contact by a rubber ball assuming pressure from the seat. The pressure was recorded using the load cell. The measurement seat shown in Figure 2 was used. The seat was cut out under the thigh area and a footrest and armrest were provided to maintain the sitting posture.

Procedure

The measurement point was defined as shown in Figure 3 using the ratio based on the femoral length L (distance between the lateral epicondyle of the femur and the greater trochanter). The sitting posture of the participant was adjusted to the same posture shown in Figure 4.

When two types of loads P_1, 20, and 40N with the contact area became a circle of Ø20 (converted to pressure, 1.59 N/cm^2), were applied to the reference point, the load P_2 that felt the same at each measurement point was measured. The measurement was performed at 6 points from 0.5 to 1.0L with 0.3 L as the reference point and from 0.3 to 0.5L with 1.0L as the reference point. The measurement was performed twice at each point.

The participants in the experiment were 32 adult males (Height 175.2 ± 4.2 cm, Weight 70.1 ± 8.9 kg) close to the American Male 50% tile.

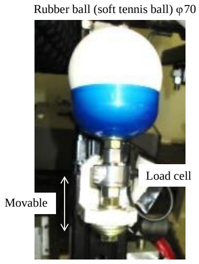


Figure 1: Pushing device

Figure 2: Sensitivity measurement seat

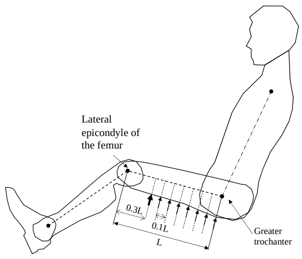


Figure 3: Measurement point at thig and buttock

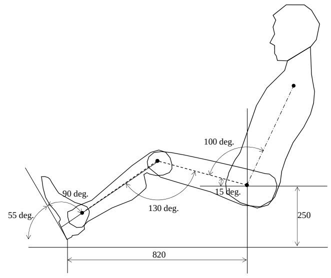


Figure 4: Sitting posture in the measurement

Determination of exponent of the power function

The slope of the regression line when plotting the four measured values P_1 and P_2 on the logarithmic axis corresponds to the exponent of the power function. The exponent was calculated for the data of 29 people, excluding 2 people who had the result that the magnitude relationship of the load could not be evaluated correctly and 1 person who had extremely poor reproducibility for two measurements.

From the results, no clear tendency was observed between the position at the thigh. The measurement points 0.9L and 1.0L at the buttock were significantly different from those of the thigh. Therefore, the exponents were determined using the average of each region as follows.

Thigh (0.3L~0.8L): 0.84 ± 0.36, Buttock (0.9L~1.0L): 1.11 ± 0.52.

Based on the above results, the sensitivity was defined as follows.

$$\text{Sensitivity } k = \frac{P_1}{P_2{}^{0.84}} \ (Thigh),\ \frac{P_1}{P_2{}^{1.11}} \ (Buttock) \qquad \text{Equation (3)}$$

The perceived pressure equation (1) becomes the equation (4).

$$Pressure_{Perceived} = k \times Pressure_{Seat}{}^{0.84} \ (Thigh), Pressure_{Seat}{}^{1.11} \ (Buttock) \quad \text{Equation (4)}$$

Sensitivity calculations

Methods

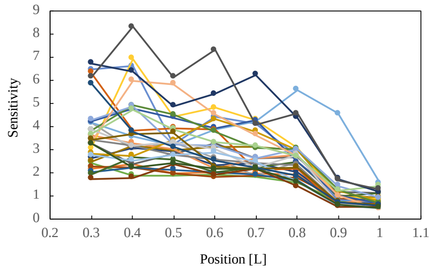
The sensitivity distribution of each participant was calculated from the same measurement data for the 29 participants. 20N (equivalent to 15.9 kPa), which is close to the seat pressure distribution value was used as the reference load. The measurement data are 6 points of 0.5 to 1.0L with 0.3L for the reference load point and 6 points of 0.3 to 0.5L with 1.0L for the reference load point. Both measured data were integrated into one distribution using calculating the value of 0.65L (midpoint of measurement area) with adjustment to fit the distribution. Then, the sensitivity distribution of each participant was calculated using equation (3).

Results

Figure 5 shows the sensitivity distribution of 29 participants.

Analysis of comfortable pressure distribution

Comfort pressure measurements



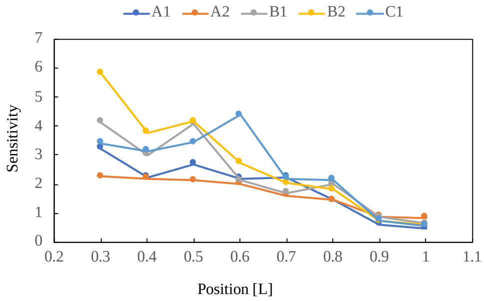


Figure 5: Sensitivity of participants   Figure 6: Sensitivity of the comfort test participants

Comfort pressure distribution was measured under the sitting posture shown in Figure 3 by adjusting the best seat shape for 5 adult males (Height 176.2 ± 5.1 cm, Weight 69.6 ± 9.6 kg). An experimental seat with variable shape in the two-dimensional sagittal plane (Hirao et al., 2006) was used. The sensitivity distribution of 5 participants was shown in Figure 6.

The pressure distribution at the seat cushion was measured by the pressure sensing mat (X-Sensor), and the skeletal coordinates of the femur were measured by the three-dimensional digitizer (FAROARM). From this comfortable pressure distribution, the sum of the pressure values in the lateral direction of the seat cushion from 0.3 L to 1.0L on the femur axis line was extracted as shown in Figure 7.

Calculation of perceived pressure

The comfortable pressure distributions of the five participants shown in Figure 7 were converted into perceived pressure distributions as shown in Figure 8 using the sensitivity distribution. Examples of measured and perceived comfortable pressure distribution were shown in Figure 9. There were the differences that measured one was relatively flat at the thigh but perceived one was more complex and sharper.

Discussion

Sensitivity distribution

From Figure 5, it was found that in most participants, the sensitivity of the buttocks was low in the range of 1 to 2, and the thigh was highly sensitive to the buttocks. From the tendency of the sensitivity distribution of each participant, 29 participants in the experiment were classified into

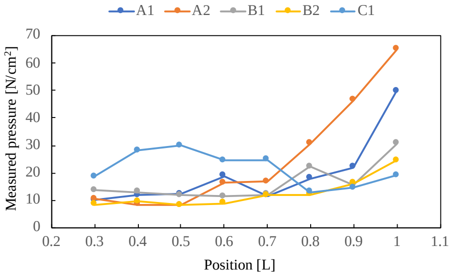


Figure 7: Measured comfort pressure

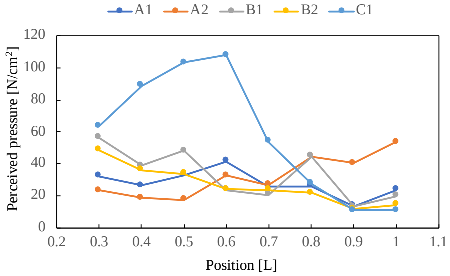


Figure 8: Perceived comfort pressure

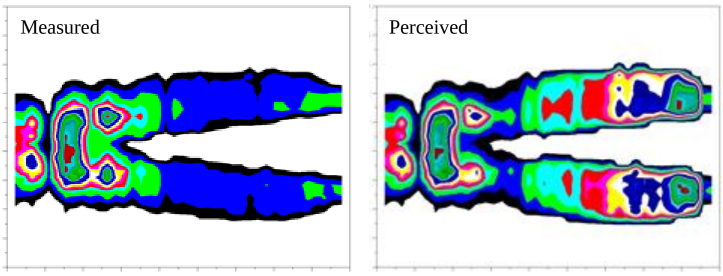


Figure 9: Example of measured and perceived pressure distribution

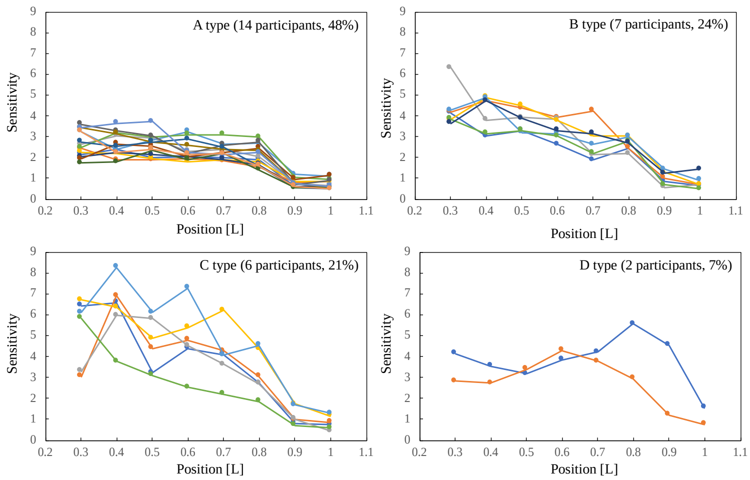


Figure 10: Four types of the sensitivity distribution

four types shown in Figure 10.

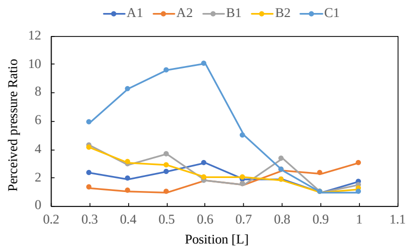
Perceptual mechanism of body pressure distribution

The sensitivity distribution shown in Figure 6 was A type 2 (Participant A1, A2) and B type 2 (B1, B2) and C type 1 (C1) in the classification described above.

The comfortable pressure distribution of the 5 participants was shown in Figure 7. The thighs are close to uniform and the buttocks have high-pressure values for 4 out of 5 participants and 2 of them tend to have particularly high pressure in the buttocks (A1, A2). In addition, one participant (C1) was significantly different, and the pressure in the thigh tended to be relatively high. In other words, two types were observed according to the tendency of the thigh and buttock respectively. Therefore, it is found that the optimal pressure distribution is not constant for all, which is consistent with the fact that no findings for optimal distribution have been shown.

The comfortable pressure distribution was converted to the perceived pressure distribution shown in Figure 8. In the perceived pressure distribution, the common tendency that a small value distribution from the thigh to the buttock within the range from 10 to 60 N/cm^2 was observed except for one participant (C1) with a large value at the thigh.

It is said that the pressure distribution is related to the feeling of fitness by feeling the continuity of pressure (Matsuoka, 1994). The perceived pressure ratio shown in Figure 11, a ratio to the minimum value of perceived pressure, was calculated as an index of continuity. Figure 12 shows the average and standard deviation of the perceived pressure ratio of each participant. It was found that the pressure distribution ratio was in the range of 1.8 to 2.5 ± 0.5 to 1.2, excluding participant C1. It means the pressure distribution was close to flat. In other words, it was found that perceived



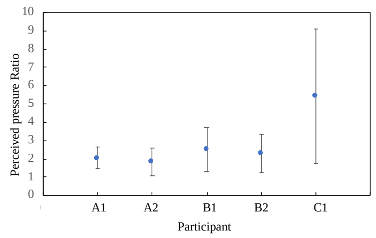


Figure 11: Perceived pressure ratio distribution   Figure 12: Average of the perceived pressure ratio

pressure distribution is within the range of about 2 times the minimum value may be preferred.

Reflection in seat design

As mentioned above, the sensitivity distribution can be roughly classified into 3 types. And the comfortable state may be two types of perceived pressure ratio distribution. Therefore, it is desirable to have a seat cushion shape or hardness adjustment mechanism that can absorb individual differences. In addition, since the sensitivity tends to increase, the seat should be made so that high pressure is not applied around the backside of the knee.

Conclusion

In this study, we determined the exponent of Steven's power law for seat pressure, and the sensory sensitivity distribution of 29 people was measured and classified into 3 groups.

The comfortable pressure distribution was measured using 5 participants and converted into a perceptual pressure distribution using the sensory sensitivity distribution. Analysis of the perceived pressure distribution suggests that the comfortable perceived pressure distribution is a uniform distribution that falls within a certain range for the minimum pressure.

The analysis of this study was limited only to the seat cushion. More detailed study and expansion to the backrest area and a three-dimensional analysis are also desired in the future.

In conducting all the experiments of this research, informed consent was obtained from the participants and Nissan's Human Subjects Research Ethics Committee approved the experiments.

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