Article
Pressure Sensitivity of Buttock and Thigh as a Key Factor for Understanding of Sitting Comfort

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Abstract: In seating comfort research, it is known that the pressure 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. It is also known that the comfortable pressure distribution is not always constant and has individual differences. It is assumed that this is due to the influence of individual differences in body shape, such as skeletal shape and flesh of the seated person, and individual differences in sitting posture, but the mechanism has not been clarified by analyses including these factors. From the above, it is considered that the comfortable pressure distribution cannot be explained only by the mechanical state. In this study, we focused on the pressure sensitivity of thighs and buttocks and performed an analysis assuming seating in an automobile seat. 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 them into 4 types. The comfortable pressure distribution of five 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

1. Introduction

We spend about 60% of the day sitting [1], and the comfort of chairs or seats is a very important issue. In the analysis of sitting comfort, not only qualitative evaluation by subjective ratings, but also quantitative indices such as sitting posture [2], seating contour [3], electromyogram and other quantitative indicators [4] were used.

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 used in developments. Pressure distribution is very effective because it can visualize the contact state with a two-dimensional distribution. As the main findings, it is known that a distribution that is widely dispersed and has no local concentration is good [5], but there is no study showing what the optimal body pressure distribution is. Kilinscoy et al. proposed the development support system by superimposing the ratio of pressure on each of the eight blocks of seat and back according to the body map obtained in the experiments [6]. This can be said to be the ideal body pressure distribution obtained experimentally, but it is the sum of the proportions for each part and does not show a clear distribution on the seat. In addition, although the upper limit of pressure is known from the viewpoint of blood flow inhibition due to tissue compression [7], no examples show the distribution of appropriate values for comfort.
In the analysis of the determinants of the sitting posture using the musculoskeletal model, Hirao et al. showed that the musculoskeletal loads and the contact loads are involved in the determination of the comfortable sitting posture [8]. In the contact loads, the chair reaction force was used as an index, and it was shown that the reaction force concentration and the average value are involved in the posture determination. However, this can be said to be equivalent to the general knowledge of body pressure distribution.

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 [9]. Humans perceive the pressure in sitting with the sensory organs in the skin and soft tissues, and in this perception, the sensitivity of the sensory organs is affected by the density of the sensory organs and the stress distribution due to the compression of the tissue. It is considered that it seems to be perceived as comfort through the individual filter. Therefore, we can agree on the idea of Vink et al. Therefore, in this study, we focused on this pressure sensitivity.

As an example of measuring sensitivity related to the tactile sensation of the body, the two-point discrimination range and the perceptual resolution have been measured. Weinstein has examined the two-point discrimination range of the whole body part, and it is known that the thigh is about 45 mm [10]. However, the two-point discrimination range is measured by contact with a sharp object. Therefore, it is only the tactile sensitivity. Pressure pain thresholds have been measured to assess recovery from muscle fatigue and pain [11], and distribution has also been measured in the lower extremities, back, and lower back [12]. However, these only indicate the threshold value at which pressure changes to pain, and the diameter of the loader is small only for measuring local sensation.

To understand the sensory evaluation of the seat pressure distribution, Hartung et al. recorded the pressure felt at the same point loaded at the lower surface of the thigh before by memory. The recognized difference was 20 mmHg, indicating that 40 mmHg was required to feel the difference [13]. Goossens et al. [14] used 10 and 20 mm ball-shaped loaders to measure the distribution of load differences where a difference was felt at two points. Vink et al. measured the distribution of the unpleasant load on the thigh, buttocks, and back using the Advanced Force Gauge with a loader with a diameter of 20 mm. The scapula area and the knee side of the thigh were shown to be highly sensitive [9].

These studies show the sensitivity of the thigh. It does not show the relationship with the pressure distribution but is measured for use as reference data for understanding the mechanisms.

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.

2. Sensitivity of Thigh and Buttock

2.1. Concept of the Study

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

\[
\text{Pressure}_{\text{perceived}} = \text{Sensitivity} \times \text{Pressure}_{\text{Seat}},
\]

(1)

It is generally known that the relationship between sensation and stimulus follows Stevens’ power law [15]. 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.

\[
\varnothing = k \times S^n \ldots k: \text{Proportional constant},
\]

(2)

Therefore, in this study, the reference point pressure \( P_1 \) was used as the stimulation, and the measured pressure \( P_2 \) when a feeling of the same pressure was obtained as the sensation, 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.

2.2. Measurement Methods
2.2.1. 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. In a pushing device, a rubber ball was fixed on a plastic cup that directly connected to an axial type load cell. Ball, cup, and load cell are mounted on a vertical slide and can move up and down to pressurize the thigh and buttock by pushing from below.

Pressurization of the thigh and buttock surfaces is performed with contact by a rubber ball (soft tennis ball) with a diameter of the contact area of about 70 mm, assuming pressure from the seat surface when sitting on the automotive seat. The output of the load cell installed at the bottom was recorded.

For the measurement, the measurement seat shown in Figure 2 was used. The seat was cut in half, and a footrest and an armrest were provided to maintain the sitting posture. Two pushing devices were mounted on a longitudinal slide located in the undercut part of the seat cushion and were movable along the thigh, respectively.

![Figure 1. Pushing device for sensory sensitivity.](image1)

![Figure 2. Sensitivity measurement seat.](image2)
2.2.2. Procedure

In this study, the central part of the lower surface of the thigh along the femur from the buttocks to the knee was used as the measurement point. 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). Subsequent measurement sites were 0 L for the lateral epicondyle of the femur and 1 L for the greater trochanter, and the position of the measurement point was expressed as the proportional number in this paper.

![Diagram](image1)

**Figure 3.** Measurement point at thigh and buttock.

The sitting posture of the participant was adjusted to the same posture shown in Figure 4.

![Diagram](image2)

**Figure 4.** Sitting posture in the measurement.

When two types of loads, 20 N and 40 N with the contact area became a circle of $\varphi 20$ (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 1.0 L with 0.3 L as the reference point and from 0.3 to 0.8 L with 1.0 L 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 percentile (Height 177.8 cm, Weight 79.2 kg) [16].

2.2.3. Determination of Exponent of the Power Function

Figure 5 shows an example of measurement results at one measurement point. The slope of the regression line when plotting the four measured values $P_1$ and $P_2$ at each measurement point on the logarithmic axis corresponds to the power.

![Example of measured data and exponent of the power function.](image)

Based on the measured data, the exponent was calculated for the data of 29 people, excluding two people who had the result that the magnitude of the load could not be evaluated correctly and one person who had extremely poor reproducibility for two measurements.

Figure 6 shows the average value and standard deviation of the powers obtained from each measurement data. Differences are depending on the position, but no clear tendency was observed.

![The average value and standard deviation of the exponent of the power function obtained from measured data.](image)

The significant difference between the measured values at each site was calculated. Table 1 shows the significant differences between the measured values by the position of thigh and buttock. Table 1 shows the correlation coefficients of the powers obtained from the measurement data with the reference point at the ischial tuberosity or the back of the
knee. If significant differences are found, the powers cannot be regarded as equivalent to other parts of the thigh or buttock.

### Table 1. The significant differences between the measured positions.

| Reference point | Position [L] | The Exponent Average | Std. | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 |
|-----------------|--------------|-----------------------|------|-----|-----|-----|-----|-----|---|-----|-----|-----|-----|-----|-----|
|                 |              |                       |      |     |     |     |     |     |   |     |     |     |     |     |     |
| Ischium         | 0.5          | 0.85                  | 0.37 | -   | n.s. | n.s. | n.s. | ** | ** | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
|                 | 0.6          | 1.00                  | 0.44 | -   | n.s. | n.s. | n.s. | n.s. | *  | ** | n.s. | n.s. | n.s. | n.s. | n.s. |
|                 | 0.7          | 0.90                  | 0.50 | -   | n.s. | n.s. | n.s. | *  | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
|                 | 0.8          | 0.95                  | 0.35 | -   | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
|                 | 0.9          | 1.09                  | 0.49 | -   | n.s. | ** | ** | n.s. | n.s. | ** | n.s. | n.s. | n.s. | n.s. | n.s. |
|                 | 1            | 1.12                  | 0.55 | -   | ** | ** | ** | n.s. | n.s. | ** | n.s. | n.s. | n.s. | n.s. | n.s. |
| Knee            | 0.3          | 0.81                  | 0.30 | -   | n.s. | n.s. | n.s. | *  | n.s. |     |     |     |     |     |     |
|                 | 0.4          | 0.78                  | 0.26 | -   | n.s. | n.s. | n.s. | *  | n.s. |     |     |     |     |     |     |
|                 | 0.5          | 0.77                  | 0.30 | -   | n.s. | n.s. | n.s. | *  | n.s. |     |     |     |     |     |     |
|                 | 0.6          | 0.88                  | 0.42 | -   | n.s. | n.s. | n.s. | *  | n.s. |     |     |     |     |     |     |
|                 | 0.7          | 1.05                  | 0.62 | -   | n.s. | n.s. | n.s. | *  | n.s. |     |     |     |     |     |     |
|                 | 0.8          | 0.82                  | 0.30 | -   | n.s. | n.s. | n.s. | *  | n.s. |     |     |     |     |     |     |

**: p < 0.01, *: p < 0.05, n.s.: no significance.

The measurement points 0.9 L and 1.0 L were significantly different from those of other parts. In addition, there were some significant differences among other measurement points.

Therefore, the exponent at the position from 0.3 to 0.8 L is the average value excluding 0.6 L based on the knee reference and 0.7 L based on the ischium reference, which is significantly different from other sites, and the exponent at 0.9 L and 1.0 L is as follows.

- **Thigh (0.3–0.8 L):** 0.84 ± 0.36
- **Buttock (0.9–1.0 L):** 1.11 ± 0.52

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

\[
\text{Sensitivity } k = \frac{P_1}{P_2^{0.84}} \text{ (Thigh)}, \frac{P_1}{P_2^{1.11}} \text{ (Buttock)},
\]  

(3)

From the above, the perceived pressure Equation (1) becomes Equation (4).

\[
\text{Pressure}_{\text{Percepted}} = k \times \text{Pressure}_{\text{Seat}}^{0.84} \text{ (Thigh)}, \text{Pressure}_{\text{Seat}}^{1.11} \text{ (Buttock)}
\]  

(4)

### 3. Sensitivity Measurements

Steven’s power law, described in the previous chapter, is the general perceptual sensory characteristic of pressure stimuli. On the other hand, each individual has a different sensitivity to final perceived pressure depending on the volume of soft tissues such as muscle and fat, the density of sensory organs, the condition of the skin, the sensitivity of nerves, tastes, and experiences. In this chapter, we calculated the sensitivity distribution for each individual.

#### 3.1. Methods

For the 29 participants in the previous chapter, the thigh sensitivity distribution of each participant was calculated from the same measurement data.

As the reference load, 20 N (equivalent to 1.59 N/cm²), which is close to the seat pressure distribution value, was used.

The measurement data are six points of 0.5 to 1.0 L with 0.3 L for the reference load point and six points of 0.3 to 0.8 L with 1.0 L for the reference load point. It is desirable to
perform measurements continuously for the one reference point, but since the measuring device has a diameter of 70 mm, the minimum distance between the reference point and the measurement point must be 70 mm. Therefore, the range of 0.3 to 1.0 L, in which pressure can be applied by the sensitivity measuring device without interfering with the lower leg, was measured by changing the reference point.

The measured data with 0.3 L and 1.0 L for the reference point were combined by the following method to obtain the sensitivity distribution.

1. Calculate the perceived pressure value of 0.65 L, which is the midpoint between 0.3 L and 1.0 L, as the average value of 0.6 L and 0.7 L, respectively.
2. The average 0.65 L value of the 0.3 L reference value and the 1.0 L reference value is set to the final value of 0.65 L.
3. Adjust the distribution of each reference point by the difference value so that 0.65 L is the final value.
4. From 0.3 L to 0.4 L, the adjusted value based on 1.0 L is used, and from 0.9 L to 1.0 L, the adjusted value based on 0.3 L is used. The average of the adjusted values was used for 0.5 L to 0.8 L.
5. For this perceived load distribution, the sensitivity distribution of each individual was calculated using the sensitivity calculation formula (2) based on the power exponent obtained in the previous chapter.

3.2. Results

Figure 7 shows the sensitivity distribution of 29 participants.

From Figure 7, 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. In addition, it can be observed that some participants with high sensitivity around the front part of the thigh are about 6 to 7 times that of the buttocks.

From the tendency of the sensitivity distribution of each participant, it was found that about half of the 29 measured subjects had low buttock and high thigh, a nearly constant type, and a type that became more sensitive around the knees. Twenty-nine participants in the experiment were classified into four types shown in Table 2 and Figure 8. The criteria for classification are as follows.

Type A: Regression coefficient (the slant of regression line) > −4.35 and the maximum value < 4.0.
Type B: Regression coefficient (the slant of regression line) ≤ −4.35 and the maximum value < 5.0.
Type C: Regression coefficient (the slant of regression line) ≤ −4.35 and the maximum value ≥ 5.0.
Table 2. Types of sensitivity.

| Type | Characteristics                          | Number of Participants | Ratio of Participants |
|------|-----------------------------------------|------------------------|-----------------------|
| A    | 2 steps (Thigh, buttock)                | 14                     | 48%                   |
| B    | Increasing from buttock to thigh        | 7                      | 24%                   |
| C    | Extremely increasing from buttock to thigh | 6                    | 21%                   |
| D    | The others                              | 2                      | 7%                    |

4. Analysis of Comfortable Pressure Distribution

In the previous chapter, we measured sensory sensitivity distributions and showed that they could be classified into four types based on the characteristics of sensory sensitivity distributions. In this chapter, as an application example of the obtained sensory sensitivity distribution, we calculated the perceived pressure from the sensory sensitivity using Equation (1). The characteristics of the pressure distribution that is perceived comfortably are examined.

4.1. Pressure Measurements

Comfort pressure distribution was measured under the sitting posture shown in Figure 3 by adjusting the best seat cushion shape for 5 adult males (Height $176.2 \pm 5.1$ cm, Weight $69.6 \pm 9.6$ kg) selected from sensitivity participants type A to C. An experimental seat with a variable shape in the two-dimensional sagittal plane [17] shown in Figure 9 was used. The experimental seat was composed of eight units fixed on the seat cushion frame, and 14 units fixed on the angle adjustable seat back frame. Each unit had a supporting surface that freely rotated to fit the body that was electrically adjustable perpendicular to the frame by using a remote controller.

The sensitivity distribution of five participants is shown in Figure 10.

The pressure distribution at the seat cushion was measured by the pressure distribution sensor (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 1.0 L on the femur axis line was extracted as shown in Figure 11.

Figure 9. Experimental seat.

Figure 10. Sensitivity distribution of the participants.

Figure 11. Lateral sum of comfort measured pressure.
4.2. Calculation of Perceived Pressure

The comfortable pressure distributions of the five participants shown in Figure 11 were converted into perceived pressure distributions as shown in Figure 12 using the sensitivity distribution.

![Figure 12. Perceived pressure distribution.](image)

5. Discussion

5.1. Exponent of Power Function for Pressure Sensation

The exponent of power function obtained in this study was 0.84 for the thigh and 1.11 for the buttocks. Since both are powers that should be close to 1.0, there is no significant tendency, but the thighs are sensitive to small pressure stimuli and less sensitive to large pressure stimuli. Additionally, the buttocks tended to be the opposite.

Stevens investigated powers for various sensory stimuli and showed pressure on the palm for 1.1 [18]. It was suggested that there is not much difference in the body part for the pressure sensation, although the numerical values are slightly different.

5.2. Sensitivity Distribution

As shown in Table 2 and Figure 8, the sensitivity distribution was less sensitive on the buttocks than on the thighs. About half of the subjects were Type A, and the thighs had almost constant sensitivity, while the remaining about half were more sensitive on the knee side in the thighs. It is suggested that this difference in sensitivity distribution affects the perception of body pressure distribution during seating and is a factor in individual differences in seating posture and comfort pressure distribution.

Two-point discrimination thresholds were measured for 29 participants in the sensory sensitivity experiment at buttock (1.0 L) and knee (0.3 L) using calipers. Table 3 shows the mean and standard deviation for each type except Type D (the others).

| Type | Buttock (mm) | Knee (mm) |
|------|--------------|-----------|
| A    | 47.0 ± 13.6  | 46.6 ± 10.9 |
| B    | 45.5 ± 16.6  | 49.5 ± 5.3  |
| C    | 35.0 ± 10.5  | 32.4 ± 10.3 |

There was no clear relationship between the type of sensitivity distribution and the two-point discrimination threshold. In other words, the two-point discrimination threshold, which is relatively easy to measure, cannot be used instead of pressure sensitivity. However, the two-point discrimination threshold of Type C was smaller than that of Type A and B, and the sensitivity trends were consistent with those of Type A and B.
5.3. Perceived Pressure Distribution

The sensitivity distribution of the five participants shown in Figure 10 was A type 3 (Participant A1, A2, A3) and B and C type 1 each (Participant B1, C1) in the classification described above.

Figure 13 shows the measured pressure distribution and perceived pressure distribution using the obtained sensitivity distribution for the conversion. Since the sensitivity distribution obtained in this study is only on the femoral axis, the sensitivity distribution in the anterior-posterior direction was applied over the entire lateral direction.

![Figure 13. Measured comfort pressure distribution and perceived pressure distribution.](image)

The perceived pressure distribution is significantly different from that measured and more complicated and larger.

Participants of all types tended to perceive relatively high pressure around the buttocks, which has low sensory sensitivity. The buttocks are supported by the ischial tuberosity of the pelvis, and pressure is concentrated, but the low sensitivity of the buttocks may prevent discomfort even if the perceived pressure is high.

Participants in Type B and C, whose sensitivity increased as it approached the knee, showed greater perceived pressure, but tended to have lower perceived pressure near the knee, where the sensitivity was highest. In other words, the participants preferred to avoid the highly sensitive areas, but seems to have obtained a sense of support by supporting the anterior thighs.

5.4. Perceptual Mechanism of Body Pressure Distribution

The optimal pressure distribution of the five participants is shown in Figure 11. The thighs are close to uniform and the buttocks have high-pressure values for four out of five participants, and two of them tend to have particularly high pressure in the buttocks. In addition, one participant 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 optimal body pressure distribution shown in Figure 11 was converted to the perceived pressure distribution shown in Figure 12.

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/cm² was observed, except for one participant (A3) with a large value at the thigh.

In general, it is said that the pressure distribution is related to the feeling of fitness by feeling the continuity of pressure [19]. Therefore, the perceived pressure ratio is shown in Figure 14, a ratio to the minimum value of perceived pressure was calculated as an index of continuity.

![Figure 14. The perceived pressure ratio distribution.](image1)

Figure 14. The perceived pressure ratio distribution.

Figure 15 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 A3. It means the pressure distribution was close to flat. In other words, it was found that perceived pressure distribution that is within the range of about two times of the minimum value may be preferred.

![Figure 15. The average and standard deviation of the perceived pressure ratio.](image2)

Figure 15. The average and standard deviation of the perceived pressure ratio.

5.5. Reflection in Seat Design

As mentioned above, the sensitivity distribution of the thigh and buttock can be roughly classified into three types. Additionally, 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 this
sensitivity distribution. In addition, since the sensitivity tends to increase, the seat should be made so that high pressure is not applied to around the backside of the knee.

5.6. Limitation of the Study

In this study, we assume that sensory sensitivity is inherent to the human body and does not change. However, we have not confirmed changes in sensitivity that may be caused by changes in muscle characteristics due to postural maintaining or changes in the state of blood circulation in soft tissues due to continuous pressure in prolonged seating. It shall be confirmed in a future study.

For the sensitivity measurements, a car seat was cut and the support pressure was reproduced with a rubber ball to simulate the pressure caused by the seat. This is not the same as the actual seat support condition.

The analysis of the perceived mechanism of pressure distribution was limited only for seat cushion in the two-dimensional sagittal plane with five participants. Therefore, it will be necessary to increase the number of participants and analyze the mechanism in detail.

In the future, expansion to the backrest area and a three-dimensional analysis are also desired.

6. Conclusions

In this study, we determined the exponent of Steven’s power law for seat pressure, 0.84 for thigh, and 1.11 for buttock.

The sensory sensitivity distribution of 29 people was measured and classified into three types and the others.

As an application example, the comfortable pressure distribution was measured using five 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.

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References
1. Oka, K.; Sugiyama, T.; Inoue, S.; Shibata, A.; Ishii, K.; Neville, O. Science of sedentary behavior: Application of the behavioral epidemiology framework. J. Jpn. Soc. Health Educ. Promot. 2013, 21, 142–153. (In Japanese) [CrossRef]
2. Katsuraki, M.; Hanai, T.; Takatsui, K.; Suwa, A.; Nagashima, H. Development of the New Generation Ergonomic Seat Based on Occupant Posture Analysis; SAE Technical Paper 950140; SAE International: Warrendale, PA, USA, 1995; pp. 1–10. [CrossRef]
3. Yamazaki, N. Analysis of sitting comfortability of driver’s seat by contact shape. Ergonomics 1992, 35, 677–692. [CrossRef] [PubMed]
4. Hirao, A.; Kato, K.; Kitazaki, S.; Yamazaki, N. Evaluations of physical fatigue during long-term driving with a new driving posture. SAE Trans. J. Passeng. Cars Mech. Syst. 2008, V116-6, 69–76. [CrossRef]
5. Zemp, R.; Taylor, W.R.; Lorenzetti, S. Are pressure measurements effective in the assessment of office chair comfort/discomfort? A review. Appl. Ergon. 2015, 48, 273–282. [CrossRef] [PubMed]
6. Kilincsoy, U.; Wagner, A.; Vink, P.; Bubb, H. Application of ideal pressure distribution in development process of automobile seats. Work 2016, 54, 895–904. [CrossRef] [PubMed]

7. Liu, Z.; Cascioli, V.; McCarthy, P.W. Review of Measuring Microenvironmental Changes at the Body-Seat Interface and the Relationship between Object Measurement and Subjective Evaluation. Sensors 2020, 20, 6715. [CrossRef] [PubMed]

8. Hirao, A.; Matsuoka, Y.; Yamazaki, N. Biomechanical Determinants of Sitting Posture. In Proceedings of the Second International Comfort Congress, Delft, The Netherlands, 29–30 August 2019; Volume 5A-5, pp. 1–8. Available online: http://icc.tudelft.nl/ICC2019/ICC2019_5A5.pdf (accessed on 21 July 2022).

9. Vink, P.; Lips, D. Sensitivity of the human back and buttocks: The missing link in comfort seat design. Appl. Ergon. 2017, 58, 287–292. [CrossRef] [PubMed]

10. Myles, K.; Binseel, M.S. The Tactile Modality: A Review of Tactile Sensitivity and Human Tactile Interfaces, Army Research Laboratory, ARL-TR-4115. 2007. Available online: https://apps.dtic.mil/sti/citations/ADA468389 (accessed on 21 July 2022).

11. Alburquerque-Sendín, F.; Madeleine, P.; Fernández-de-Las-Peñas, C.; Camargo, P.R.; Salvini, T.F. Spotlight on topographical pressure pain sensitivity maps: A review. J. Pain Res. 2018, 11, 215–225. [CrossRef] [PubMed]

12. Binderup, A.T.; Arendt-Nielsen, L.; Madeleine, P. Pressure Pain Sensitivity Maps of the Neck-Shoulder and the Low Back Regions in Men and Women. BMC Musculoskelet. Disord. 2010, 11, 234. Available online: https://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/1471-2474-11-234 (accessed on 21 July 2022). [CrossRef] [PubMed]

13. Hartung, J.; Schlicht, T.; Bubb, H. Sensitivity of Human Pressure Feelings While Sitting; SAE Technical Paper 2004-01-2140; SAE International: Warrendale, PA, USA, 2004; pp. 1–5. [CrossRef]

14. Goossens, R.H.M.; Teew, R.; Snijders, C.J. Sensitivity for pressure difference on the ischial tuberosity. Ergonomics 2007, 48, 895–902. [CrossRef] [PubMed]

15. Stevens, S.S. On The Psychophysical Law. Psychol. Rev. 1957, 64, 153–181. [CrossRef] [PubMed]

16. SAE International. Civilian American and European Surface Anthropometry Resource (CAESAR) North American Database; SAE International: Warrendale, PA, USA, 2002.

17. Hirao, A.; Kitazaki, S.; Yamazaki, N. Development of a New Driving Posture Focused on Biomechanical Loads; SAE Technical Paper 2006-01-1302; SAE International: Warrendale, PA, USA, 2006; pp. 1–8. [CrossRef]

18. Stevens, S.S. The Psychophysics of Sensory Function. Am. Sci. 1960, 48, 226–253. Available online: http://www.jstor.org/stable/27827540 (accessed on 21 July 2022).

19. Matsuoka, Y. Design Factor of Design Factor of Automotive Seat—The Design Method of Seat (1). Bull. Jpn. Soc. Sci. Des. 1994, 41, 41–48. [CrossRef]