Scientific Research Publishing

Advances in Physical Education, 2024, 14, 204-212
https://www.scirp.org/journal/ape
ISSN Online: 2164-0408
ISSN Print: 2164-0386

Pillow Material and Hardness Affects Head and Neck Pressure Distribution in Supine Position

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How to cite this paper: Takahashi, M., Bando, Y., & Fukui, T. (2024). Pillow Material and Hardness Affects Head and Neck Pressure Distribution in Supine Position. *Advances in Physical Education, 14,* 204-212.
https://doi.org/10.4236/ape.2024.144014

Received: September 12, 2024
Accepted: November 9, 2024
Published: November 12, 2024

Abstract

Objective: The aim of this study was to clarify the effects of pillow materials and hardness on the pressure distribution around the head and neck in the supine position. **Method:** Participants were 8 healthy men (33.1 ± 3.8 years). A pillow was placed on a bed with a mattress, and a sheet-type pressure distribution-measuring device was placed above it. Four types of pillows were used, in descending order of softness: polyester pillow (PEst), polyurethane water pillow (PUW), low-resilience elastic urethane pillow (LEU), and polyethylene pillow (PEth). Measurements were performed under five conditions, with the additional control condition of no pillow (None). Participants lay supine on the measuring device, and the pressure distribution throughout the body was recorded while they were relaxed. From the pressure distribution records, the contact area (%) and the load (%) of the head and neck relative to the entire body were calculated. Differences in pressure distribution due to the type of pillows were examined using one-way repeated-measures ANOVA and using multiple comparison tests with the Bonferroni method. **Results:** The contact area and load of the head and neck with respect to the entire body in None group were significantly smaller than under all pillow conditions. PEth group showed significantly lower area values than the PUW and LEU groups. Among the conditions in which a pillow was used, PEst group showed significantly lower load values than PUW, LEU, and PEth groups. **Conclusion:** This study suggested that the distribution of body pressure on the head and neck in the supine position appears to depend on the pillow material and hardness and polyurethane water pillow and low-resilience elastic urethane pillow are able to support the weight of the head and neck over a wide area, reducing strain on the neck and shoulders.

Keywords

Pillow Material, Pillow Hardness, Body Pressure Distribution, Supine

Position

1. Introduction

In a standing posture, the center of gravity will be most stable if the ears, shoulders, and hip joints are in a straight line and the spine has a gentle S-shaped curve. When sleeping, the same curvature of the spine allows for efficient recovery from fatigue and is expected to have the effect of correcting spinal distortion. In this position, the head and neck are centered, aligned with the spine from the center-upper back, and perpendicular to the shoulders, thereby minimizing biomechanical stress in these areas and maintaining muscle balance during sleep (Li et al., 2002). In contrast, insufficient support for the neck and shoulder area from a pillow may negatively affect cervical alignment and has been associated with neck pain, neck disorders, and poor sleep quality (Chen & Cai, 2012; Chun-Yiu et al., 2021; Gordon et al., 2009; Gordon et al., 2010; Gordon et al., 2011; Lei et al., 2021). Thus, pillows should support the head and neck in a neutral position to minimize biomechanical stress on cervical structures during sleep (Gordon et al., 2010).

The supine position enables body pressure to be distributed over the entire back, which allows for good body fluid circulation. In addition, this sleeping position is less likely to cause muscle stiffness but is greatly affected by the pillow height and material. The optimal pillow height for regular-shaped pillows has been reported to be 10 - 12 cm (Kim et al., 2015; Sacco et al., 2015; Soal et al., 2019). If the pillow is too high, the cervical vertebrae lean forward. This places the weight of the head on the neck and shoulders, which can cause headaches and stiff shoulders due to blood flow disturbances in the head and neck. Additionally, it may aggravate snoring and increase the likelihood of hypoxia (Cazan et al., 2017; Karabag & Iplikcioglu., 2022). However, if the pillow is too low, the cervical vertebrae will bend backwards, placing a load on the shoulder joints, which can cause numbness and pain in the arms. Regarding pillow materials, rubber and spring pillows have a positive effect on chronic neck pain and sleep satisfaction, roll pillows and water-based pillows restore cervical lordosis, and latex pillows control awakening headaches and shoulder blade/arm pain (Gordon et al., 2010; Setokawa et al., 2007). However, cervical spine alignment has been reported to be affected by the height and shape of the pillow rather than its material while other researchers found contradictory results, with alignment affected by the pillow material rather than the shape (Chun-Yiu et al., 2021; Gordon et al., 2011). Therefore, there is no consensus on the appropriate pillow design (i.e., shape, height, material), and the criteria for the appropriate selection of the optimal pillow for an individual are unclear. While research into ergonomic pillow design has progressed (Cai & Chen, 2016; Lei et al., 2021), the optimal pillow height may not necessarily correlate with individual anthropometric dimensions such as the length and width of the head-shoulder region (Erfanian et al., 2004). It is difficult to clarify whether

the influence of pillow height on cervical spine alignment is good or bad due to individual differences in head weight and spinal column alignment, as well as pillow material and hardness. In addition, subjective evaluations may be influenced by participants' social background and mental and health states.

One objective indicator for evaluating the suitability of a pillow for a body is to measure pressure distribution (Li et al., 2017; Ren et al., 2016). However, there have been no reports to date that have verified the type of pillow based on the pressure distribution in the head and neck relative to the pressure distribution in the whole body. The aim of this study was to clarify the effects of pillow materials and hardness on the pressure distribution around the head and neck in the supine position. The null hypothesis was that there is no difference in body pressure distribution in the head and neck in the supine position according to pillow type.

2. Materials and Methods

2.1. Ethical Approval of Studies and Informed Consent

This study was conducted in accordance with the Declaration of Helsinki and with the approval of the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (approval no. ECNG-R-294). The details of the study were fully explained to all participants, and written informed consent was obtained from all participants prior to their participation.

This study was conducted in accordance with the PRILE 2021 guidelines (Nagendrababu et al., 2021) (**Figure 1**).

2.2. Participants

Participants were 8 healthy men (age 33.1 ± 3.8 years). Exclusion criteria were sleep disorders, spinal cord injuries, or spine-related musculoskeletal disorders (e.g., neck pain, lumbar spine disease, spinal symptoms, or treatments thereof) (Cai & Chen., 2016; Kim et al., 2015; Li et al., 2021; Ren et al., 2016; Sacco et al., 2015).

2.3. Measurement of Body Pressure Distribution

A pillow was placed on a bed with a mattress, and a sheet-type pressure distribution-measuring device (X3 Pro Electronics; XSENSOR, Alberta, Canada) was placed above it. This device has built-in pressure sensors consisting of 160 × 64 sensors spaced at 1.27 cm intervals. Four types of pillows were used, in descending order of softness: polyester pillow (PEst), polyurethane water pillow (PUW), low-resilience elastic urethane pillow (LEU), and polyethylene pillow (PEth) (**Figure 2**). Measurements were performed under five conditions, with the additional control condition of no pillow (None). Participants lay supine on the measuring device, and the pressure distribution throughout the body was recorded while they were relaxed. From the pressure distribution records, the contact area (%) and the load (%) of the head and neck relative to the entire body were calculated.

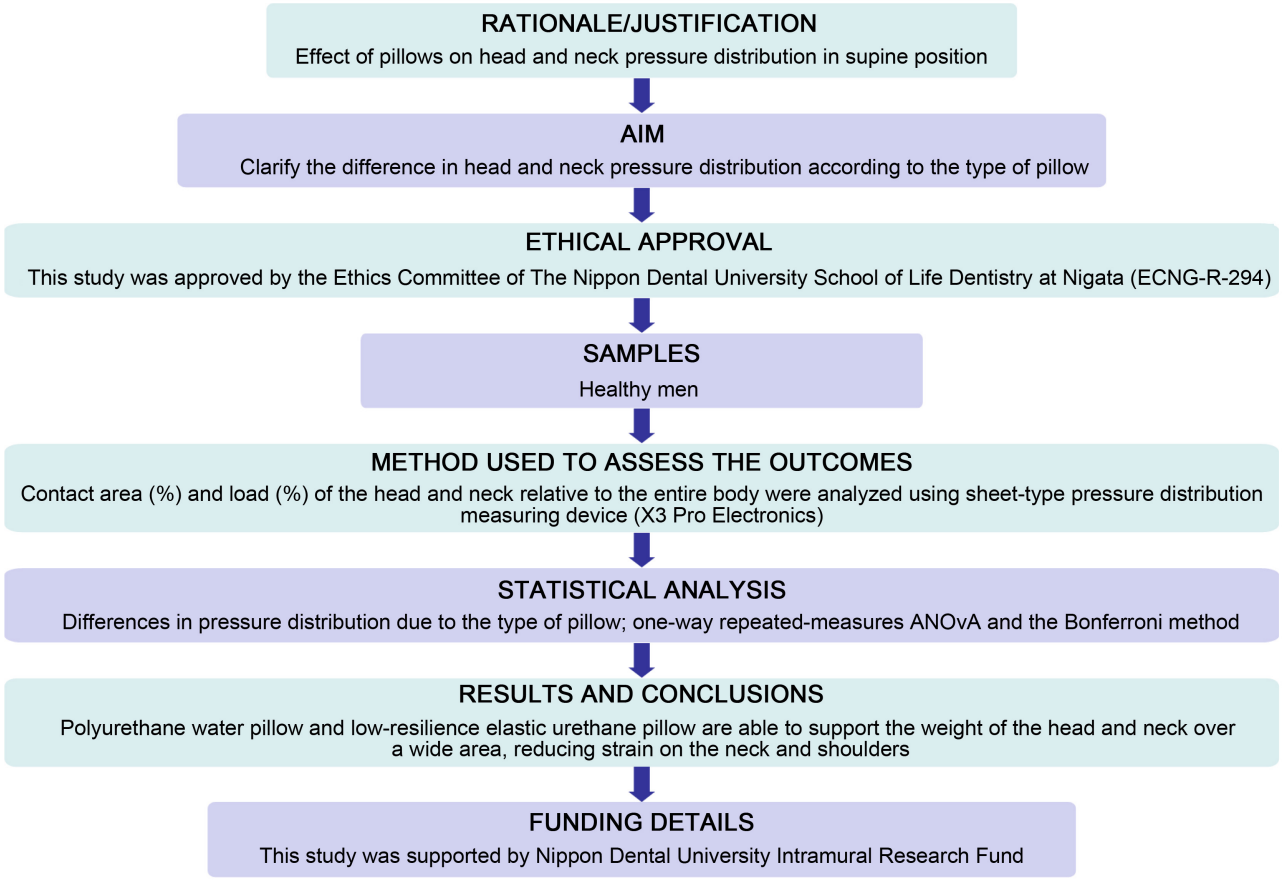

Figure 1. Research design flowchart.

	Soft ⟵ Hard			
Material	Polyester pillow (PEst)	Polvurethane water pillow (PUW)	Low-resilience elastic urethane pillow (LEU)	Polyethvlene pillow (PEth)
Dimensions width × depth × height (cm)	60 × 40 × 15	51 × 35.5 × water volume	50 × 31 × 11.5	56 × 30 × 8
Shape				

Figure 2. Pillow type (material, dimensions, and shape).

2.4. Statistical Analysis

Statistical analysis was performed using SPSS 17.0 software (SPSS Japan Inc., Tokyo, Japan) and the level of significance was set at $P < 0.05$. The Shapiro-Wilk test was used for normality testing. Normality was confirmed at each level. Differences in pressure distribution due to the type of pillow were examined using one-way

repeated-measures analysis of variance and using multiple comparison tests with the Bonferroni method.

3. Results

An example of the body pressure distribution results is shown in Figure 3. In the None and PEth, pressure was concentrated on the back of the head, and the head was supported by a narrow area. In the None and PEst, the neck was not supported by a pillow, and pressure was concentrated on the shoulders. In contrast, the PUW and LEU supported the head and neck over a wide area, and the pressure distribution in this area was similar to that in the whole body.

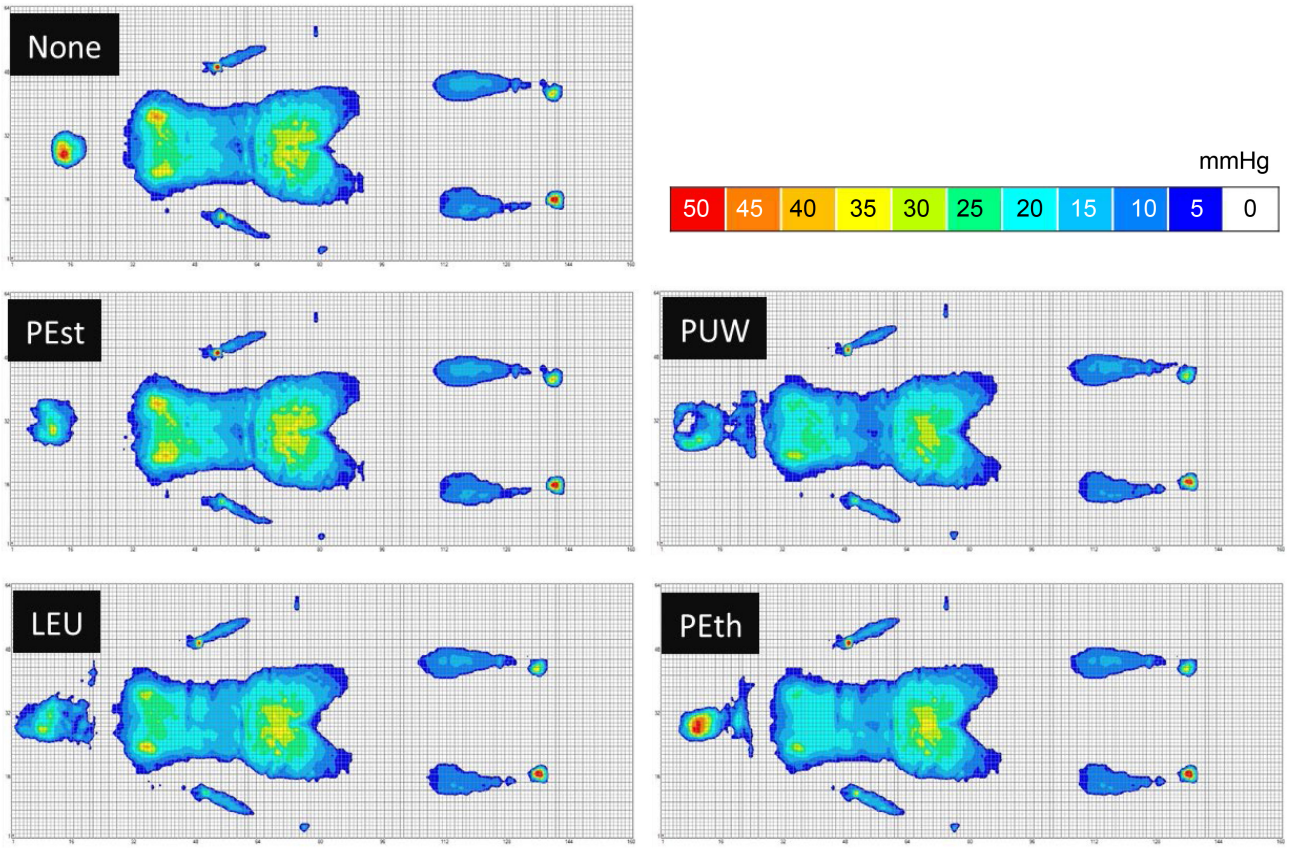

Figure 3. Representative example of the measurement result of body pressure distribution.

Figure 4 shows a comparison of the contact area of the head and neck with respect to the entire body. In the None, the area of the head and neck in the whole body was significantly smaller than under all pillow conditions ($P < 0.01$). Among the conditions in which a pillow was used, the PEth showed significantly lower area values than the PUW and LEU ($P < 0.01$). In addition, the PUW showed significantly higher area values than the PEst ($P < 0.05$).

The loads of the head and neck with respect to the entire body are compared in Figure 5. In the None, the loads of the head and neck in the whole body were significantly smaller than under all pillow conditions ($P < 0.01$ and $P < 0.05$).

Among the conditions in which a pillow was used, the PEst showed significantly lower load values than the PUW, LEU, and PEth ($P < 0.01$).

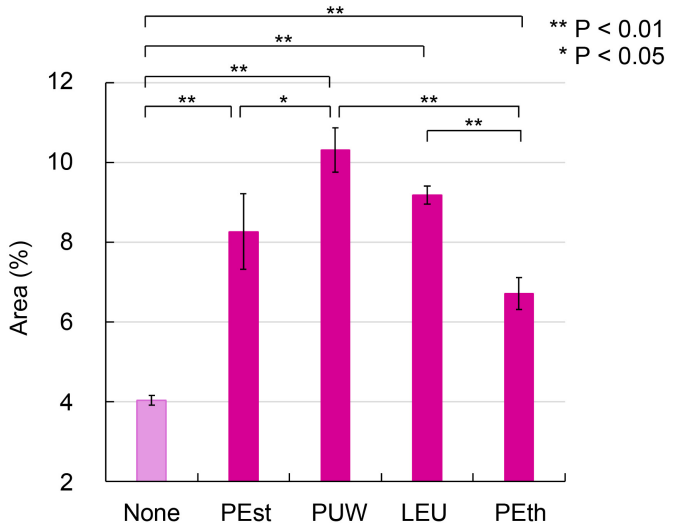

Figure 4. Contact area of the head and neck relative to the whole body. Measurements are expressed as means ± SD. Error bar indicates standard error of the mean. $^{**}P < 0.01$, $^{*}P < 0.05$: denotes statistically significant difference.

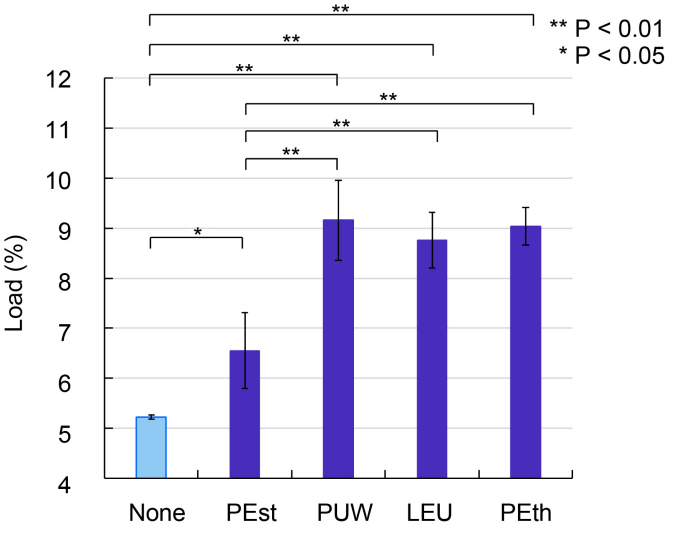

Figure 5. Head and neck loads relative to the whole body. Measurements are expressed as means ± SD. Error bar indicates standard error of the mean. $^{**}P < 0.01$, $^{*}P < 0.05$: denotes statistically significant difference.

4. Discussion

The present results showed that the contact area and load of the head and neck with respect to the whole body when in the supine position depended on whether or not a pillow was used and on the type of pillow. Therefore, the null hypothesis,

specifically that there is no difference in body pressure distribution in the head and neck in the supine position by pillow type, was rejected.

Generally, soft pillows sink under the weight of the head, making it difficult for them to support the head. In contrast, hard pillows tend to concentrate the weight of the head on one point, facilitating the development of blood flow disorders. A high pillow has been reported to cause the cervical spine to tilt forward, shifting the peak contact pressure to the hip joint area (Li et al., 2017). It is therefore presumed that the pillow that best fits the body is the one that supports the head and neck over a wide area and has little difference in pressure distribution from the rest of the body; in other words, it is of a height and hardness that does not require other parts of the body to compensate for the load on the head (about 8% - 13% of body weight). The pillows compared in this study differed in material and height. The PEst was filled with polyester microfiber cotton and had a height of 15 cm, the PUW allowed the height to be adjusted as desired, the LEU was 11.5 cm high, and the PEth was a three-dimensional structure made of polyethylene and was 8 cm high. The hardest pillow was the PEth, followed, in order, by LEU, PUW, and PEst.

The results of this study showed that the contact area of the head and neck with respect to the whole body was the largest with PUW, followed by LEU. Because PUW is water-filled pillows made of polyurethane, a flexible material, the water pressure easily changes to match the shape of the head and neck, and it is presumed that this allows the head and neck to be supported over a wide area, regardless of the participant's body shape. In addition, because LEU is made of low-resilience elastic urethane and their wavy shape closely fits the head and neck, they may have been able to support the head and neck over a wide area, similar to PUW. If the area over which the head bears pressure is small, it can concentrate pressure around the shoulders or pelvis. The contact area of the head was smaller under the None condition than under the other conditions in which a pillow was used. The PEth had the next smallest contact area and, because it was a hard pillow, the pressure may have been placed on the anteriorly tilted neck.

In terms of head and neck load relative to the entire body, it is desirable for the pillow to be able to support the weight of an average head (i.e., about 8% - 13% of body weight). The results of this study showed that the head and neck load percentages were high for PUW, LEU, and PEth, at about 9.2%, 8.8%, and 9.0%, respectively. These three conditions indicate that the pillow was able to support the weight of the head. However, the pillow also needs to support the head and neck over a wide area. If this area is small, pressure is concentrated in a small area, which is undesirable. As shown in the head pressure values in **Figure 1**, the PEth and None had an overpressure area in the head exceeding 50 mmHg and the contact area of the head was small compared with the other conditions. In other words, judging from the contact area and load of the head and neck in relation to the whole body, the results suggest that, under the conditions of this study, the PUW and LEU support the weight of the head and neck over a wide area and place

little strain on the neck and shoulders. Therefore, when selecting the optimal pillow for the body, it is necessary to consider the contact area in addition to pressure distribution. It is important to note that, although hard pillows can support the weight of the head, a small contact area can easily cause overpressure in one spot at the back of the head.

This study has two main limitations. The first is that the sample size is small. We plan to increase the sample size and re-evaluate in the future, and also verify the results in the lateral position. Second, because posture changes occur repeatedly during sleep, this study alone cannot evaluate sleep quality. In order to verify this, it is necessary to evaluate the pillow after using it for a certain period of time, and it is desirable to perform a comprehensive verification based on subjective and objective evaluations.

5. Conclusion

In the measurement environment of this study, it was suggested that the distribution of body pressure on the head and neck in the supine position appears to depend on the pillow material and hardness and polyurethane water pillow and low-resilience elastic urethane pillow are able to support the weight of the head and neck over a wide area, reducing strain on the neck and shoulders.

Acknowledgements

This study was supported by Nippon Dental University Intramural Research Fund.

Conflicts of Interest

The authors have no conflicts of interest relevant to this article.

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