

# Can Pillow Height Effect the Body Pressure Distribution and Sleep Comfort: a Study of Quinquagenarian Women

Xinzhu Li<sup>1,a</sup>, Huimin Hu<sup>2,b</sup>, Su Liao<sup>1,c</sup>

<sup>1</sup> Sport Science College, Beijing Sport University  
No. 48 Information Road, Haidian District, Beijing 100084, China

<sup>2</sup> Ergonomics Laboratory, China National Institute of Standardization  
No.4 Zhi Chun Road, Haidian District, Beijing 100191, China

<sup>a</sup> E-mail: lxz0210@hotmail.com <sup>b</sup> E-mail: 82572264@qq.com <sup>c</sup> E-mail: liaosu55555@163.com

**Abstract.** A proper sleeping pillow can relax the neck muscles during sleep, yet does not impose stress on the spine or other tissues. By analyzing the different body pressure and subjective comfort evaluation of quinquagenarian women with different pillow heights (3cm, 7cm, 11cm and 15cm), this paper found that as the pillow height increased, the neck contact pressure, contact area and force increased at the same time, as well as the peak force and peak contact pressure gradually shifted from the head to the hip area. It was shown that the pillow with a height of 7cm was the most comfortable for supine positions.

## 1. Introduction

About one-third of human life time is spent during sleep, high-quality and adequate sleep is essential for people since the human body maintains the steady state, immune function and body integrity through sleep.

In the process of sleep, the pillow is an important tool to maintain the normal physiological curvature of the cervical vertebra, which supports the head [1]. The proper pillow helps to maintain the normal physiological curve of the human spine, keeping the body in a natural state and ensuring good rest and sleep. On the contrary, long-term use of inappropriate pillow may result in changes in the normal physiological curve of the cervical spine, affecting people's health [2]. Hence, choosing a comfortable pillow for sleep is a crucial issue.

In the study of bedding comfort, the comfort of the mattress has been analyzed from the perspective of the relationship between lying posture, body pressure distribution and comfort changes, yet the study on the comfort and functionality of the pillow is still limited. This study explored the effect of different height buckwheat pillows on body pressure distribution and comfort for quinquagenarian women to inquire into the relationship between pillow height and body distribution as well as sleep comfort. Therefore, it can develop options to choose the most comfortable pillows for each individual.

## 2. Experimental Process

### 2.1 Research Objects

In this experiment, a total of 19 quinquagenarian women were selected (with an average height of  $1.56 \pm 0.05$ m, weight of  $58.81 \pm 14.1$ kg, age of  $53.74 \pm 6.80$  years old and BMI of  $24.24 \pm 5.42$ ). Subjects



were recruited in nearby communities, requiring no cervical / lumbar disease and were able to complete the questionnaire independently. All of them believed that pillow height would affect sleeping comfort according to the pre- questionnaire survey.

Four pillows at different heights (3cm, 7cm, 11cm, 15cm) with the same material (buckwheat) and outward appearance (55cm×35cm) were provided for test.

## 2.2 Procedure

The subjects were asked to experience the four pillows on the mattress with a hardness of 1.56, and to complete the subjective comfort evaluation (with 5 as the full score) on the following body parts: head, shoulder, waist and hip. The body pressure distributions of supine position under four pillow-height conditions were measured by BPMS TEKscan system. Peak force value (PF), peak contact pressure value (PCP), and contact area (CA) of each subject were obtained. The three parameters were all normalized by dividing maximum data of each subject, which were presented as percentage value.

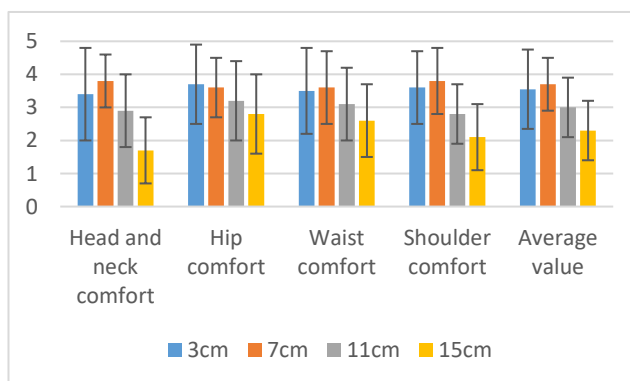
## 2.3 Data processing

In the test results, the data of the human body on the mattress was divided into the following eight zones: head area, neck area, chest area, waist area, hip area, thigh area, calf and foot area as well as the whole body. The first five body parts would be discussed especially, according to the subjective comfort evaluation.

SPSS software was used for statistical analysis of the data: differences among the pressure distribution data of different pillow height were compared by using ANOVA with LSD (homogeneity of variance) and Dunnett T3 (heterogeneity of variance) respectively; spearman rank correlation analysis was used to evaluate the correlation between pillow height and comfort; stepwise regression was used to evaluate the relationship between the most comfortable pillow height and overall test indicators and subjective comfort score. All the statistical analysis set a significant level at  $p < 0.05$ .

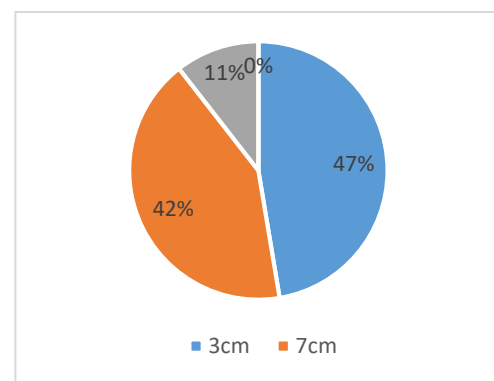
## 3. Results

### 3.1 Subjective Comfort Evaluation



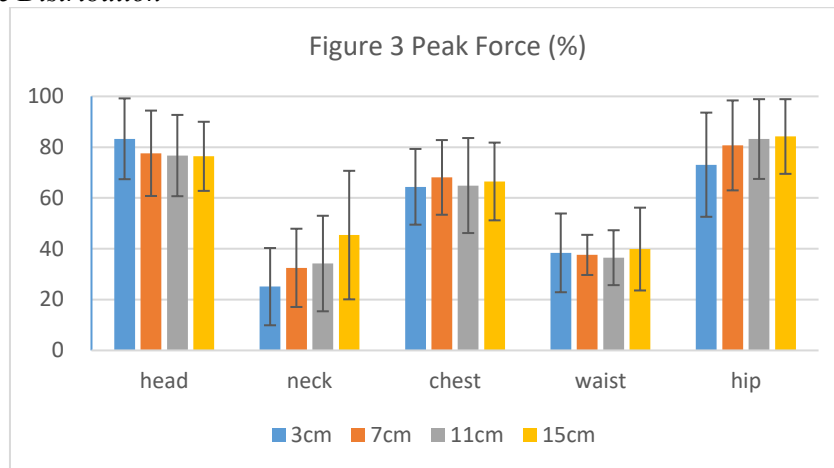
**Figure 1** Subjective Comfort Evaluation of Four Pillows (n=19)

Figure 1 showed that the 7 cm pillow got the highest average score, followed by 3 cm pillow. Most of the subjects preferred the pillow with a lower height of 3cm and 7cm.



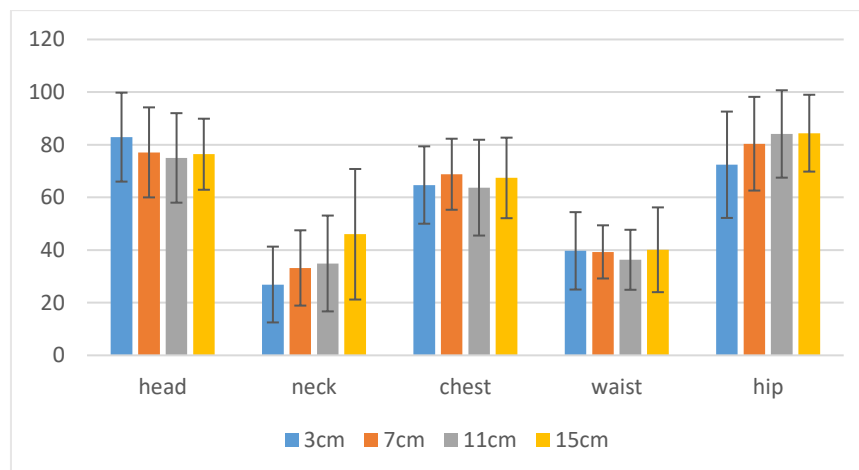
**Figure 2** Count (percentage) of the Most Comfortable Pillow (n=19)

### 3.2 Body Pressure Distribution



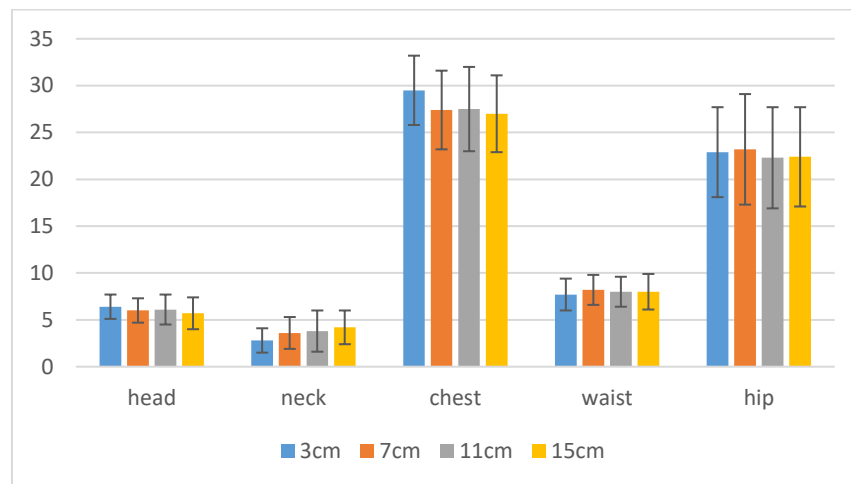
**Figure 3** Peak Force (%), n=19)

As the pillow height increased, the peak force of neck and hip area tended to increase. When the pillow height was under 7cm, the whole body peak force appeared in the head area, when the pillow height was higher than 7cm, the whole body peak force appeared in the hip area.



**Figure 4** Peak Contact Pressure (%), n=19)

From Figure 4, it can be concluded that with the increase of the pillow height, the PCP neck increased, the PCP head tended to decrease and the PCP hip tended to increase. When the pillow was under 7cm, the peak contact pressure appeared in the head area, when the pillow was higher than 7cm, the peak contact pressure appeared in the hip area.



**Figure 5** Contact Area (% , n=19)

As can be seen from Figure 5, as the pillow height increased, the contact area of neck increased while the contact area of chest decreased.

### 3.3 Correlations

**Table 1** Correlations of Pillow Height and Comfort (n = 19)

Pillow height	Correlation coefficient r
Head comfort	-0.494*
Hip comfort	-0.284*
Waist comfort	-0.304*
Shoulder comfort	-0.517*

\*. The correlation is significant at a confidence level (double test) of 0.05.

As shown in Table 1, the correlation coefficient between pillow height and shoulder comfort was the highest, which was -0.517, followed by head and neck comfort, the correlation coefficient was -0.494.

The regression equation was:

The most comfortable pillow height =  $6.594 + 0.521 \text{ PF hip} + 0.032 \text{ CA neck} - 2.037 \text{ Hip comfort}$  ( $R = 0.919$ )

### 4. Analysis

According to the subjective evaluation of pillow comfort and ergonomics, the pillow with a height of 7cm achieved the highest score, followed by the pillow with a height of 3cm, which was consistent with previous studies on the most comfortable pillow in supine position [3,4].

The average subjective score of pillow comfort and waist comfort score were the closest. Liu [5] conducted an epidemiological survey, which showed that sleeping on high pillow is the risky factors of low back pain for young people. Sleeping pillow height change not only affects the cervical thoracic spine curvature, but also has impact on the lumbosacral spine curvature. Xiong's research [6] confirmed that different height of the pillow can affect the cervical and cervical spine sagittal curvature parameters, and the ideal balance of the sagittal spinal column can keep each component of vertebra in good balance. If the balance is damaged, it may accelerate the degeneration of the spine, causing neck pain, back pain, headache or radiating pain of limbs.

According to the standardized data, as the pillow height increased, contact area, pick force and pick contact pressure of neck all increased, indicating that the force imposed on the neck increased obviously, which had more effective support for the neck, yet it may also cause discomfort to the neck. As the pillow height increased, chest contact area decreased, but waist contact area tended to increase, indicating that the occipital height adjusted the posture of the spine, making the waist fit the mattress

better and got more support. As the pillow height increased, peak force and peak contact pressure gradually shifted from the head to the hip area, it was possible that the higher pillow height raised the upper body (chest area), while the hip and lower body area can prevent the body from slipping.

When the pillow height was less than 7cm, the peak force and peak contact pressure appeared in the head. According to the head comfort and hip comfort score of pillow with a height of 3cm and 7cm, hip comfort decreased with pillow height increasing, which was relevant with the increase of force and contact pressure, hence 7cm should be the most comfortable pressure distribution pillow height.

There was a significant negative correlation between comfort subjective score and occipital height in line with the trend of mean, in which the occipital height had the greatest impact on shoulder and head comfort.

Comfort was significantly correlated with pillow height, which was the normal result of the experiment; and its significant correlation with hardness, elasticity and contact might change on subjective experience due to increased filler and pillow weight, despite the length, width, material, fabric and some ergonomic indicators of these four pillows were exactly the same, which was in good agreement with the evaluation of the pillow hardness, height and comfort found by the Japanese scholar Yokura[7]. This was also consistent with the finding by Korean scholar Park [8] that the evaluation of pillow comfort rules can be based on the conclusion of the relationship between pillow height, nature and stiffness.

Xu et al. [9] conducted an experiment by measuring the human shoulder and zygomatic distance and shoulder width size and the relationship between the occipital height, which concluded that the best pillow height =  $0.167 \times \text{shoulder width} + 4.6\text{cm}$ . This paper obtained a regression equation which showed that the most comfortable pillow height could be calculated through hip peak force, neck contact area and hip comfort score.

## 5. Conclusion

It can be concluded that increasing pillow height led to an increasing body pressure. In the experiment, as the pillow height increased, neck peak contact pressure, contact area and peak force increased, which had more effective support for the neck, yet it may also cause discomfort to the neck. However, it has shown that 7cm pillow height was more comfortable for supine position compared to the rest heights in this study.

## Reference:

- [1] Gordon, S.J., Grimmer-Somers, K.A., T. Your Pillow May Not Guarantee a Good Night's Sleep or Symptom-Free Waking.[J]. *Physiotherapy Canada*, 2011, 63(2):183-90.
- [2] Nancy A, Joanne C, Sydney L, et al. A comparison of three types of neck support in fibromyalgia patients[J]. *Arthritis Care & Research the Official Journal of the Arthritis Health Professions Association*, 1998, 11(5):405-410.
- [3] Minezaki F, Murakami S, Shinmura R, et al. Ergonomic Studies on Pillow (Part 1):The Height of Pillow[J]. *Journal of Home Economics of Japan*, 1969, 20.
- [4] Hou, Shen. Effect of Sleeping Pillow Height on Supine Sleep Comfort[J]. *Furniture*, 2013, Vol. 34, No. 1
- [5] Liu, Liu. Epidemiological investigation of low back pain in middle school students[J]. *Chinese Public Health* 1998, Volume 14, Number 6
- [6] Xiong, Ke, Effect of different pillow height on curvature parameters of cervical and thoracic sagittal[J]. *Chinese Journal of Bone and Joint Injury* September, Vol.31, No.9
- [7] Yokura H. Using the compression properties of pillows to estimate sleeping comfort[J]. *International Journal of Clothing Science & Technology*, 1999, 11(2/3):160-169.
- [8] Park S J, Lee. Development of Selection System of Comfort Pillow[J]. *Human Factors & Ergonomics Society Annual Meeting Proceedings*, 2003, 47(5):816-820.
- [9] Xu, Chen, Zhang, et al. Measurement of 68 Adults' Shoulder Width and Proper Pillow-related Parameters[J]. *Chinese Journal of Rehabilitation*, Oct 2009, Vol.24 No.5.