Research Article

Development of Hardness Test Device for Determination of Comfort Parameters in Pillows and Experimental Study of Hardness Measurement

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(First received September 16, 2022 and in final form December 17, 2022)

Reference: Borlu, E., Furtuna Ş., Atıcı Ö., Demir R., Durmuş M., Kaya Ü., Ekinci E. Development of Hardness Test Device for Determination of Comfort Parameters in Pillows and Experimental Study of Hardness Measurement. The European Journal of Research and Development,2(4), 48-56.

Abstract

People spend a third of their lives asleep. A good night's sleep is a key to waking up pain-free, while providing an excellent opportunity to rest. Pillows are indispensable objects for a comfortable sleep. Sleeping position and personal preferences influence on the type of pillow a person need. However, there is no mutual language for the perception of comfort. This study focuses on the experimental study of the hardness measurement process to establish an objective method for evaluating pillow hardness and to examine the relationship between sensory evaluation and compression properties of pillows. In order to determine the comfort and pillow hardness parameters, studies on various fields and products were examined. A machine that measures and defines the compression amount of the pillow and the height data obtained by applying a certain force to the entire surface of the pillow has been designed. Pillows with different properties and weights were tested and the height values after applying the force were processed within the data obtained from the machine. By determining the limit and mean values, the pillows were

categorized as soft, medium-soft, medium, medium-hard and hard. As a consequence of this study, through the developed hardness measurement method, product classifications were made and the user's feeling on pillow hardness was observed.

Keywords: Pillow, Hardness, Hardness Standard, Test Device

1. Introduction

Sleep is very substantial, as it comprises the majority of human life. According to studies by Kyle et al. (2009), it is a guide for a sleep quality, a distinguished life and a healthy living. The quality of the time dissipated in sleep is crucial for the strengthening of memory and the development of cognitive ability. There are various researches such as ambient temperature, humidity and lighting, bedding and duvet cover fabric, material and type for a comfortable sleep. Nevertheless, there is a subjective evaluation that includes only the sensory evaluation of pillow comfort or hardness and not exceed tactile or physical properties.

There is no evaluation in order for human to perceive comfort in pillow selection and choose products accordingly. There are some studies in the literature have not been implemented as quality standards on home textile industry. For the comfort evaluation of buckwheat pillows, measurements were made at four different pillow heights in women aged 40 and over. As a result of subjective evaluations made by Hu et al. (2017), it was assumed that there was a negative correlation between pillow height and comfort, and it was determined that there was a direct correlation between the most preferred pillow height and shoulder width. It was found that the pillow height, which provides the most comfortable pressure distribution, is 7 cm. Once again, in a study conducted for the supine position, different pillow heights were evaluated, and the contact pressure and contact area increased with the increase of the pillow height, as a result, Li et al. (2018) pointed out that the medium-height pillows were the most comfortable.

The pillow has two critical features; hardness and temperature. In another study by Yim (2015), it was concluded that a pillow with a low temperature and not too hard would lead to a decrease in pain and increase sleep quality. Yim also emphasized that there is no relationship between the stimuli that cause awakening and the comfort of the pillow.

In another research, pillow temperature, comfort and cervical curve were measured in the supine position for 30 minutes in 20 different subjects aged 20-30 years on three different pillows (feather pillow, memory foam pillow and orthopedic pillow). Jeon et al. (2014) reported that the pillow with the highest cervical curvature is the orthopedic pillow, and accordingly, the pillow comfort is higher than the other pillows, and the temperature increase is at the lowest level. In this study, it was concluded that the orthopedic pillow is the most proper pillow on sleep quality and pillow type and shape are very important in pillow comfort.

The article includes a user feedback and a subjective evaluation of pillow comfort by determining the daily habits of the subjects and proposes a test device that provides an objective assessment of pillow comfort, comprising the identification between pillow hardness and comfort.

2. Materials and Methods

2.1. Subjective Evaluations

The experiment was carried out to measure the sensation of the pillows during sleep, alias the sensory evaluation, in order to measure the comfort that people seek in the pillow. Subjects shared general characteristics such as height, weight, age, and gender. In this experiment, 100 healthy individuals (50 men - 50 women) aged 25-45 years were selected. Individuals had no known history of disease and were identified from nearby societies. The general characteristics of the individuals subjected to the experiment are given in Table 1.

Table 1: Characteristics of Individuals

	Sex	Age	Weight	Height
Men	50 male	35,47 years	78,4 kg	176,2 cm
Women	50 female	34,33 years	62,2 kg	164,4 cm

Various pillows were provided for the experiment in 50*70 dimensions between 550 gr and 1150 gr produced from different filling materials (cotton, fiber, wool etc.). The sample pillow in the figure below has been on the market for several years. The pillow is made of goose down, it is one of the products designed to support the body shape and keep the spine in the best position.

Figure 1: Sample pillow (Manufacturer: Yataş Group, Turkey)

Various pillows were inspected by the participants and experienced their comfort. After the experiment was completed, a questionnaire was completed in for based user feedback and subjective evaluations. Supine or side sleeping position is recommended as the ideal sleeping position, but a good sleep varies person's matter of opinion. It was asked which sleeping position participants most prefer. While no gender-related change was observed in the sleeping position, the preferred positions according to age are given in Figure 2. Side sleeping position was chosen as the most common by the participants. Participants in both age ranges made similar preferences in sleeping positions.

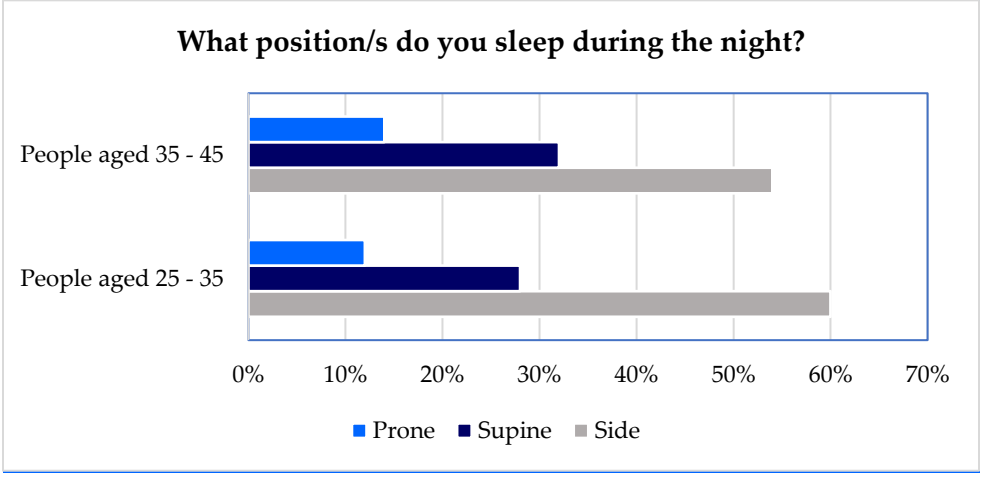

Figure 2: The most common sleeping position/s

According to the advice of health and sleep experts, the same pillow should not be slept for more than 10 years. In the questions addressed to subjects, the majority of people said they used a pillow for at least 5 years, and some of them perseverate over 10 years.

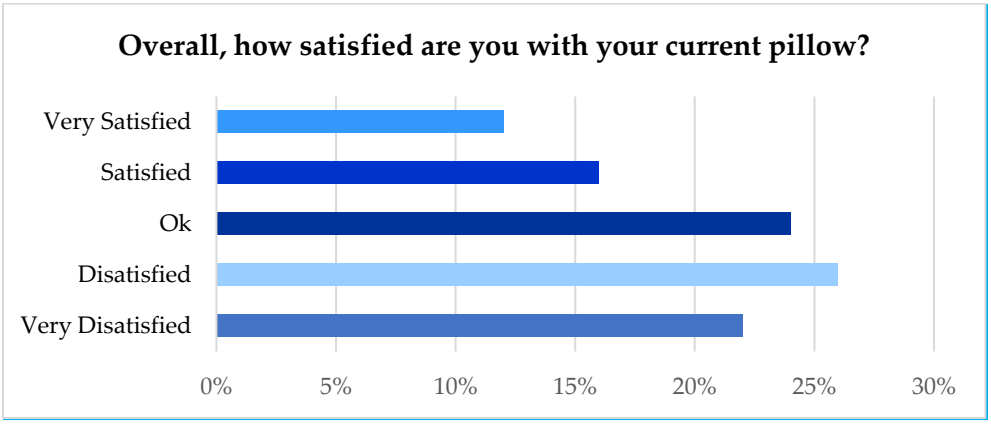

Figure 3: Satisfaction rate with the current pillow

Even the highest quality pillows are likely to result in loss of support and comfort during extended use. For hygiene purposes, using the pillows for so long causes bacteria and germs to accumulate. Pillow life or usability is directly proportional to the satisfaction of the person with the existing pillow and also cause or increase the sleep problems. As given in Figure 3, 22% stated that subjects were not at all satisfied with their pillows.

2.2. Objective Evaluations

It is a device intended to measure hardness of the pillow. The purpose is to create hardness ranges especially for the evaluation of comfort. Hardness is assigned as a specific value as a definition and it is to apply a certain method in order to define hardness rather than trial-and-error definitions for products produced in quality and R&D processes. Since there is no criterion when the end user wants a hard or soft pillow, the products are grouped as soft, medium-soft, medium, medium-hard and hard with the data obtained with this device. This device is a pioneer in offering products that meet customer demand. With the same method, it allows to measure all materials that require comfort measurement such as sitting group, cushion, pillow, mattress, automotive seat, etc.

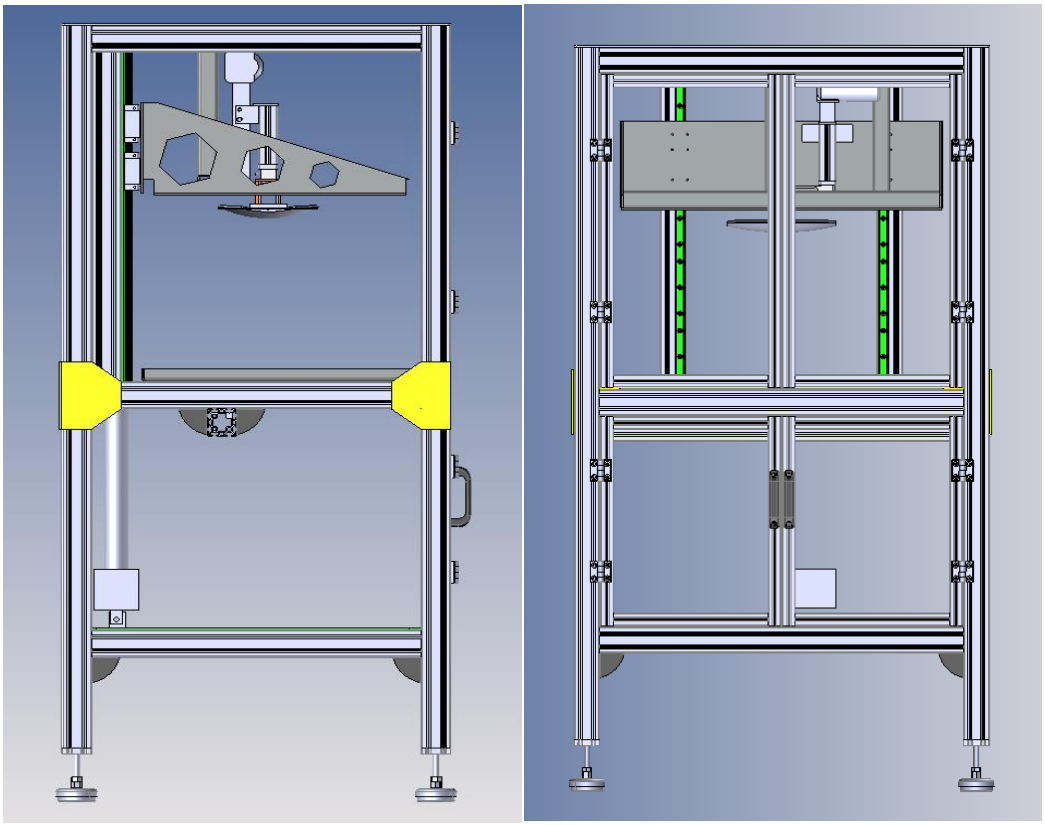

Figure 4: Hardness Measurement Test Device

With the developed test device, a force will be applied with a certain pressure to the entire surface of the pillow and the head area while the products are in the test phase. Under the force generated, it will cause a certain displacement in the pillows. As a result of the force applied by the plate designed to cover the entire cushion surface, the fibers that will disperse at any point of the pillow will be stabilized. Then, with the model simulating the human head, force is applied to the actual area of the pillow. A screen is designed to indicate the compression amount and post-pressure height of the pillow. Depending on the compression of the pillow as a result of the applied force, the height from the ground is also measured by the aid of the appliance. Inversely proportionally, the higher the pillow height, the harder it is.

The test process in the pillow hardness device is carried out in two stages. First, the plate applies a force of any value between 0.5 kg - 5 kg on the pillow so that it prevents the pillow from moving. After this process, as a second process, the model simulating the human head applies a force equal to the average human head weight (based on the data obtained from the literature). A similar method is performed with three different plates that will simulate side sleeping, supine sleeping and prone sleeping positions.

Figure 5: Head models simulates the side, supine and prone sleeping positions

Three different methods are used for three different sleeping positions. With this method, the pillow usage area, head weight, neck contact point and sleep triangle are simulated correctly and data is obtained from each point of the pillow used. The distribution of the applied force load depending on the surface area is provided, and the reaction force obtained is interpreted linearly with the data obtained from this area. Since there are different surface areas for each sleeping direction, different head models are available as given in Figure 5.

3. Results

The values obtained after applying force to the pillows in different weights and filling materials are given in Table 2. The measurements are recurring twice in 19 different samples. The mean values for these two measurements were obtained. By comparing these values with a software, the correlation between weight and filling was determined.

Table 2: Test values of different type of pillows

Sample	Description	Slump Value – 1 (mm)	Slump Value – 2 (mm)	Mean Value (mm)	Fill Amount
1	Fiber Pillow	87	84	85,5	550 gr
2	Goose Down Pillow	88	86	87	800 gr
3	Bead Fiber Pillow	94	92	93	580 gr
4	Polyester Fiber Pillow	98	96	97	750 gr
5	Goose Down Pillow	102	98	100	1000 gr
6	Fiber Pillow	102	101	101,5	600 gr
7	Goose Down Pillow	109	106	107,5	1150 gr
8	Siliconized Fiber Pillow	114	112	113	650 gr
9	Siliconized Fiber Pillow	118	116	117	580 gr
10	Bead Fiber Pillow	122	121	121,5	750 gr
11	Siliconized Fiber Pillow	91	89	90	550 gr
12	Siliconized Fiber Pillow	126	125	125,5	650 gr
13	Bead Fiber Pillow	130	135	132,5	580 gr
14	Bamboo Pillow	131	129	130	800 gr
15	Cotton Pillow	136	136	136	1000 gr
16	Micro Fiber Pillow	137	140	138,5	1050 gr
17	PES Pillow	139	138	138,5	750 gr
18	Siliconized Fiber Pillow	145	145	145	700 gr
19	Wool Pillow	164	162	163	1000 gr

As a result of the correlation, pillows were classified as soft, medium-soft, medium, medium-hard and hard according to the minimum, average and maximum values.

Table 3: Pillow classification table

Min		Mid		Max
Soft	**Medium-Soft**	**Medium**	**Medium-Hard**	**Hard**
86	105	125	144	163

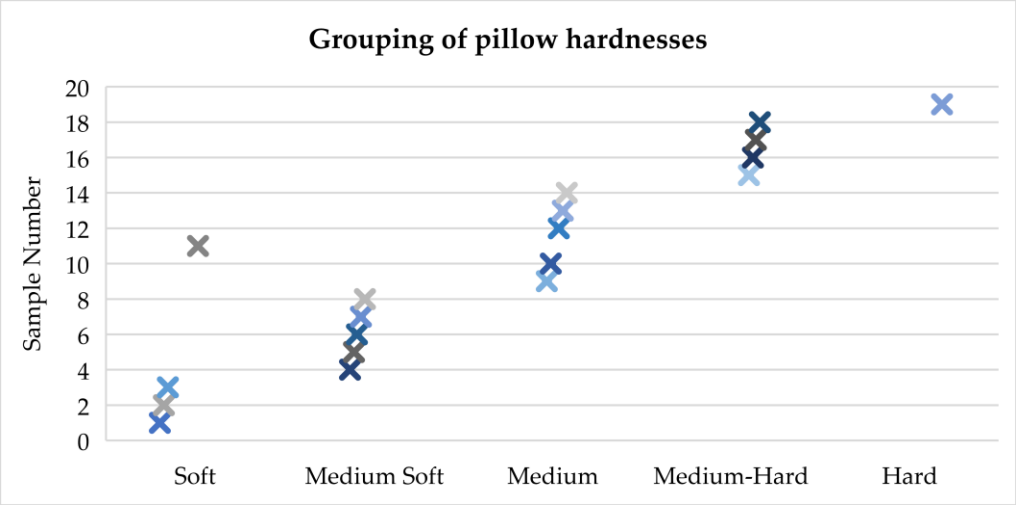

Figure 6: Grouping of pillow hardness

The hardness group of the 19 sample pillows is shown in Figure 6. While most of the pillows are in the middle group, only the nineteenth example, the wool pillow, is in the hard category. In addition, some pillows have a specific difference between the first test and the second test, while some tests have observed that the height remains the same. The reason is that some of the fillers are shape-memory. This ensures that the products do not lose hardness over the years.

It has been observed that the pillow hardness evaluation results from the test device were compatible with each other when compared to the participant evaluations. Figure 7 also includes pillows that the users categorize their hardness and comfort as a result of subjective evaluations. Besides, the most preferred pillows by the individuals were medium-soft and medium hardness ones. When asked which pillow would make you feel more comfortable with, it was pointed out that bead fiber pillows, goose feather pillows and bamboo pillows is more comfortable. Although the fill quantity (750 g, 800 g, 1000 g) was different, the comfort felt was similar.

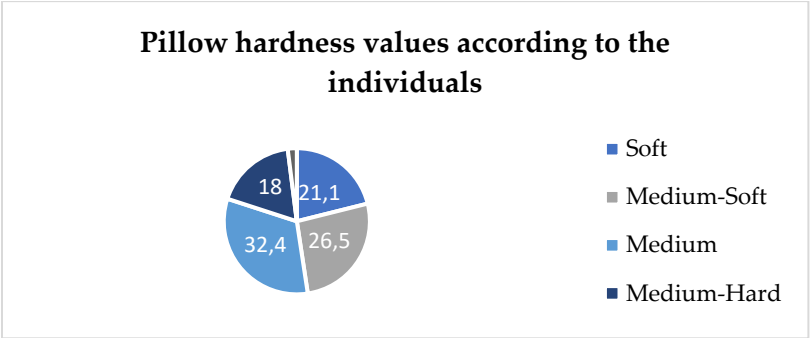

Figure 7: Pillow harness values according to the individuals

4. Discussion and Conclusion

As a result, a new device has been provided that can accurately assess the hardness of the pillow, which solves the problem that the pillow hardness predicted by the material properties has low accuracy, applying pressure appropriate to the weight of the human head on all types of pillows. Pillow hardness categories were developed to evaluate the hardness of a pillow.

5. Acknowledge

We would like to thank to Yataş Yatak ve Yorgan San. Tic. A.Ş. to provide encouragement and patience throughout the duration of this project. Special thanks go to Mr. Erkan EKİNCİ for his valuable and constructive suggestions during the planning and development of this research study.

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