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Comfort and Support Values Provided by Different Pillow Materials for Individuals with Forward Head Posture

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Abstract: Based on the pressure distributions in the head, neck, and upper body and the spine support values, this study aims to recommend the most suitable pillow for those with forward head posture (FHP) according to different sleeping positions. This descriptive cross-sectional study recruited thirty healthy 18- to 55-year-old men and women with body mass indexes of less than 30 kg/m^2. Participants tried five different pillows (viscose, fiber, cotton, goose feather, and wool) on a medium-firm hybrid mattress at room temperature with a humidity of 45–55%. Participants tried the pillows first in the supine position, then side-lying, and finally in the prone position. A pressure-mapping system was utilized to measure the pressure distributions of the head and shoulder areas in millimeters of mercury (mmHg) and the amount of support provided by the pillow to these regions in square centimeters (cm^2). When the comfort and support parameters of different pillow materials were compared among all participants, for the supine position, Pillow B and Pillow E provided higher head comfort ($p < 0.001$), while Pillow A and Pillow E provided higher shoulder support ($p = 0.044$). In the side-lying position, Pillow B provided higher head comfort ($p < 0.001$) and Pillow C ($p = 0.003$) higher shoulder comfort. In the prone position, Pillow B and Pillow E provided higher head comfort ($p < 0.001$), while Pillow E also provided higher shoulder support ($p = 0.002$). This study showed pillow materials affect the spine comfort and support of the participants, and these values may vary according to different spinal alignments, such as FHP. According to the preferred sleeping position, the pillow material that supports the spine and its comfort and support values may also change.

Keywords: ergonomic assessment; head-down tilt; household equipment; sleeping habit; sleep quality

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1. Introduction

People can perform their duties in a sitting position at a desk, standing, or walking, depending on their occupation. Today, 75 percent of workers do their jobs sitting down [1]. This rate can go up to 90 percent for software developers, 80.7 percent for accountants, and 80.3 percent for insurance sales representatives [2]. In modern working life, the behavior of employees working in a static position and long-term inactivity may cause them to adopt distorted body postures and thus cause musculoskeletal disorders. Many factors, such as sleeping with the head elevated too high, using the computer for a long time, and weakness in the back muscles, also cause this. Postural disorders and spinal diseases may accompany these changes [3]. A pillow can provide enough head and neck support to help people maintain normal neck and thoracic curvature. A comfy sleeping pillow has been shown in studies to assist with relaxing the neck muscles, enabling sleep, and effectively relieving pain in the neck, shoulders, back, and head [4].

Research on the support and comfort of human contact surfaces has addressed different points. Yu-Chi et al. concluded that choosing the right combination of mattress pad thickness and firmness is important for achieving optimum sleep posture and improving physiological measures during sleep [5]. Another study suggests the mattress material

plays a crucial role in reducing pressure during sleep, and memory foam and latex foam mattresses may be more suitable for people who want to relieve pressure points during sleep, especially in the supine and prone positions [6]. A different study examining mattress pressure values indicated the pressure distribution across the interface of the body and support surface is a significant factor in determining sleep quality. The study found uneven pressure distribution could cause poor sleep quality, characterized by reduced deep sleep and increased sleep fragmentation. Consequently, mattresses with even pressure distribution might be more effective in promoting better sleep quality for those seeking to improve their sleeping experience [7]. In addition to studies examining the pressure distribution of mattresses, studies on pillows have also been carried out. Lei et al. suggested many factors should be considered, including the person's height, BMI, sleeping position, and the distance between the neck and the mattress, to determine the appropriate pillow height for optimum ergonomic support during sleep. Therefore, personalized pillow height recommendations based on these factors may be more effective in promoting healthy sleep and preventing neck pain and other musculoskeletal disorders [8]. Based on the findings of another study, it can be concluded that the use of a body pillow during sleep can have several benefits, such as improving sleeping posture, reducing the number of positional shifts, and increasing the amount of deep sleep. Since deep sleep is essential for physical and mental health, body pillows can be considered a useful tool for individuals who experience discomfort while sleeping or desire to enhance the quality of their sleep [9]. While previous studies have provided valuable insights, it is hypothesized that the material type of the pillow may also impact the level of support, leading equally to improved pressure distribution and improve proprioception.

In current research on pillows, assessments can be made subjectively or objectively. Subjective evaluations are made by completing an evaluation form based on the person's self-report after the sleep test. In this evaluation form, the amount of comfort and support the person receives from the pillow is questioned. Although this method directly reveals one's own thoughts, it has poor reproducibility, the results can be easily manipulated, it takes a long time to be done, and it is not suitable for complex experiments [10]. Objective assessments can be made by analyzing body pressure distributions [11], EMG signals [12], and anthropometric characteristics [13]. According to the results of the studies, the evaluation method performed with body pressure distributions is the most effective method [3,14]. This may be because body pressure distribution can respond quickly to materials used, support arrangements, human weight, or lying positions.

Long-term high pressure applied to specific portions of the human body has been demonstrated in studies to have an effect on the human central nervous, blood circulation, and endocrine systems [15–17]. Furthermore, due to variances in subcutaneous tissue and tissue architecture, certain areas of the human body are extremely sensitive to pressure. In terms of ergonomics, the human body's pressure perception can be separated into dull and sensitive sections. Dull portions can handle higher pressures, but sensitive parts can only feel comfortable at low pressures. As a result, one of the primary goals in choosing a pillow should be to reduce pressure on sensitive points [18,19].

Although it has been claimed that the pillow's primary function is to optimize head and neck posture, there has been little research on its effectiveness in terms of head and neck posture [20]. A third of our lives are spent sleeping, during which the spine is out of our cognitive control. Pillows, as a result, serve a crucial function in maintaining proper head and neck posture and can alter muscle activity [21]. The position of the head and neck has a significant impact on sleep quality. It has been noted that while sleeping, cervical control decreases, putting undue strain on spinal tissues. During this time, symptoms, such as neck and shoulder pain, tension headaches, and muscle stiffness, diminish sleep quality [22]. As a result, there is an urgent need to research how alternative pillow materials might properly support the cervical spine, hence reducing neck pain and improving sleep quality [23].

Forward head posture (FHP) is the anterior cervical spine alignment; it is also known as "text neck," "scholar's neck," "wearies neck," and "reading neck." One of the most

frequent postural issues is FHP, which is a bad habitual cervical posture. FHP is significantly linked to a variety of musculoskeletal diseases, including neck pain, suboccipital trigger points, headache, restricted neck movement, and functional impairment of the neck and thorax. A lack of established back muscle strength as well as nutritional deficiencies, such as calcium deficiency, all contribute to this postural condition. Age is associated with decreased cervical ROM, thoracic kyphosis with greater cervical flexion, and forward head posture with larger deficits in cervical rotation and flexion ROM [24]. This sagittal plane cervical spine dislocation is distinguished by the position of the head anterior to the vertical line running through the lateral malleolus. This postural aberration is distinguished by an increase in upper cervical extension and lower cervical flexion, which might result in compensatory responses, such as thoracic kyphosis and rounded shoulders. These structural changes result in muscular tension imbalances, altered muscle strength and morphology, diminished cervical spine and thorax mobility and function, and altered muscle recruitment around the neck and back. These biomechanical changes could affect the stresses on the neck and back musculoskeletal structure during functional activity and various resting positions, including sleeping postures [25].

Scientific evidence suggests head postural changes affect the development and persistence of neck pain [26]. Kiatkulanusorn et al. argued pillows or mattresses specifically designed for people with FHP could reduce muscle fatigue and potential musculoskeletal pain in patients with FHP [25]; therefore, it should be one of the main factors in choosing an ergonomically correct pillow. In addition, the cervical muscles play an important role in the control of neck posture. During sleep, the ideal pillow should support and maintain good spinal alignment while minimizing biological stress on the musculoskeletal system. Consequently, maintaining horizontal alignment of the spine in the side position while utilizing the most suitable pillow is essential. In addition, a good support cushion should reduce the activity of the neck and back muscles, encourage symmetrical activation of the bilateral muscles, and provide a pleasant feeling of relaxation [27,28]. The reduced ability of these muscles to maintain the upright posture of the cervical spine may indicate their endurance is impaired, and they are unable to maintain cervical lordosis. Because various studies frequently report a significant association between weak neck muscles, poor posture, and the experience of neck pain and because a pillow can reduce pain and disability, individuals with a forward head posture may have different pillow needs [29,30].

Pillow comfort research is relatively new, and the factors affecting the selection of the right pillow are still unclear. For example, it is not correct to accept the head and neck regions as a whole and accept comfort and support demands as similar. Because the position of the head in relation to the height varies in normal head posture, the comfort or support properties of the pillow may be affected. Due to differences in head posture, the comfort and support demands of the head and neck areas in contact with the pillow will also vary [31]. There is consensus among researchers that supporting the natural lordotic curve of the cervical spine is necessary to achieve longer periods of deep sleep [27]. In addition, a pillow can improve sleep quality by cooling the head, lowering body temperature, reducing sweating, or slowing the heart rate during sleep. However, the evidence to support these claims is currently limited. It has been claimed by pillow manufacturers that many design-related pillow parameters are effective in improving sleep quality and reducing neck pain. However, most of these recommendations are based on personal experience [22,32].

There is no consensus on the most effective pillow, despite several prior studies focused on developing and evaluating neck support pillows with the goals of minimizing awakening symptoms, offering relaxation, and guaranteeing a proper resting position. Available on the market are numerous pillows with various shapes, fillings, and materials. To choose the best pillow, it is necessary to consider a number of criteria, including pillow designs (such as shapes and height) and the material used. A cushion should provide a proper alignment position angle and the least amount of muscular activation to prevent unneeded physiological stress [33,34]. The void in the literature must be filled by an objective presentation of these cushion measures. Based on the pressure distribution in the

head, neck, and upper body and the spine support values, this study aims to recommend the most suitable pillow for those with forward head positions according to different sleeping positions. Two factors were used to evaluate the recommended pillows: comfort and support.

2. Materials and Methods

2.1. Participants

This descriptive cross-sectional study recruited healthy 18- to 55-years-old men and women with a body mass index (BMI) of less than 30 kg/m^2. Exclusion criteria included a history of neck pain, carpal tunnel syndrome, a shoulder joint lesion in the past three months, cervical spine trauma, inflammatory or viral illnesses of the spine, spinal surgery, or congenital spinal deformities. All experimental procedures in this study were approved by the Human Ethics Committee of Çankırı Karatekin University (approval number: 19/01/2023-30). Study protocol was registered with the United States National Library Trial Registry (ClinicalTrials.gov Identifer: NCT05707715) There is FHP if the imaginary line between the tragus of the ear and the middle of the shoulder is not on the same line when viewed from the side. Additionally, the horizontal distance between those two vertical lines indicates the severity of FHP (Figure 1). The level of FHP is classified as mild or severe based on the horizontal length. To analyze at least 15 participants and thus obtain a good estimate of the mean effect, the participants were divided into two groups according to their median values. This value was close to the 2.5 cm value accepted in another study [35]. The slight FHP is accepted to be lower than 2.8 cm, and the severe FHP is greater than 2.8 cm. Thirty participants (15 with mild and 15 with severe FHP) were included in the study. The following is some basic information about the subjects: age 25 $\pm$ 2, height 172.1 $\pm$ 4.3 cm, and weight 60.2 $\pm$ 4.2 kg for men; for women, age 25 $\pm$ 2 years, height 161.1 $\pm$ 3.1 cm, and weight 51.4 $\pm$ 2.8 kg. The Pittsburgh Sleep Quality Index was used to measure the current sleep quality of the participants [36], and the International Physical Activity Questionnaire was used to measure the level of physical activity, which is one of the possible factors that can change their sleep habits [37]. Sleeping pillows with five different materials (cotton, fiber, wool, viscose, and goose feather), which are the most preferred on the market, were chosen as examples. Analyses were carried out between November and December 2022 at the ASO Technopark Campus in Ankara. The shapes and basic parameters of the pillows are shown in Table 1 and Figure 2.

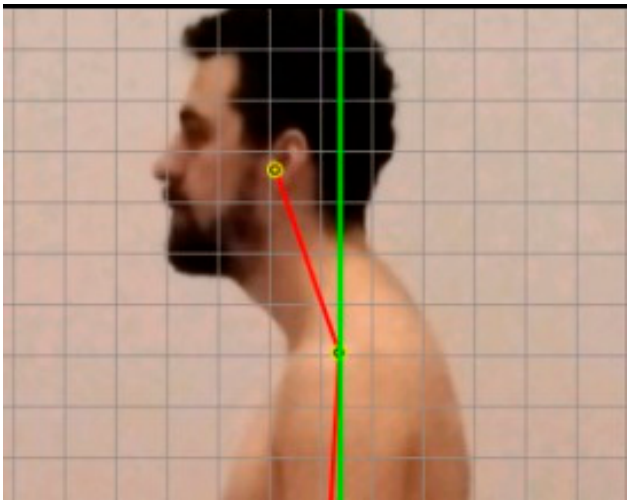

Figure 1. Forward head posture measurement.

Table 1. Structural features of pillow designs.

Pillow Designs	Fabric Type	Pillow Stuffing	Weight	Size (cm)
Pillow A (Viscose)	35% Viscose, 65% Polyester	50 DNS Polyurethane Viscose	800 gr.	57 × 37 × 10
Pillow B (Fiber)	100% Cotton	100% Microgel	1000 gr.	50 × 70 × 19
Pillow C (Cotton)	100% Cotton	100% Cotton	1000 gr.	50 × 70 × 16
Pillow D (Wool)	100% Cotton	100% Wool	900 gr.	50 × 70 × 15
Pillow E (Goose feather)	100% Cotton	70% Goose jowl feather, 30% Goose back feather	1150 gr.	50 × 70 × 16

Figure 2. Mattress and pillows used in the research. (**A**). Viscose pillow, (**B**). Fiber pillow, (**C**). Cotton pillow, (**D**). Wool pillow, (**E**). Goose feather pillow).

2.2. Determination of Forward Head Posture

The postures of the participants were evaluated with the PostureScreen mobile application. According to the results of the lateral posture analysis obtained from the application, a tilt above 2.8 cm was accepted as severe forward head posture. To assess forward head posture, participants were asked to stand at a distance of 3.5 m with their feet 30 cm apart. The participants' postures were analyzed using a high-resolution camera positioned 1.5 meters away. Relevant reference points were determined manually based on the image obtained with the tablet camera. The measurements were made automatically by the PostureScreen mobile application after the reference points were placed, and the vertical lines

of the 13 parameters as well as the means of deviation from the middle and middle part were displayed. Next, the analysis results were obtained in PDF file format [38]. Overall, the stance was analyzed from the region above to the region below. The app was able to detect changes in selected variables, including sagittal and coronal plane translations and angulations, with intraclass correlation coefficients (ICCs) reaching 0.84 [39].

2.3. Comfort and Support Assessment

A pressure mapping system (X3 SENSOR PX 100:64.160.02, X-Sensor®, Calgary, AB, Canada) was utilized to measure the pressure distributions of the head and shoulder areas in millimeters of mercury (mmHg) and the amount of support provided by the pillow to these regions in square centimeters (cm^2). The pressure-mapping system used has a sensing area of 81.3 × 203.2 cm (32″ × 80″) and provides high-resolution sensing (1.27 cm or 0.5″) using 10,240 sensing points with an accuracy of ±2 mmHg. It is calibrated to measure values between 5 and 200 mmHg. For the purpose of our study, the pressure-mapping system was positioned under the pillow, and the patients were asked to lie on the mapping system once in supine, side-lying, and prone positions. Pressure distribution was recorded for 1 minute for each lying position. The purpose of these measurements was to describe the pressure distribution created by the participants in the pillow and the supported areas as well as to find the differences that may occur between the pillows. A lower average pressure measured by the device was defined as indicating "higher comfort", while greater contact between the head area and the pillow was considered to indicate "better support" (Figure 3).

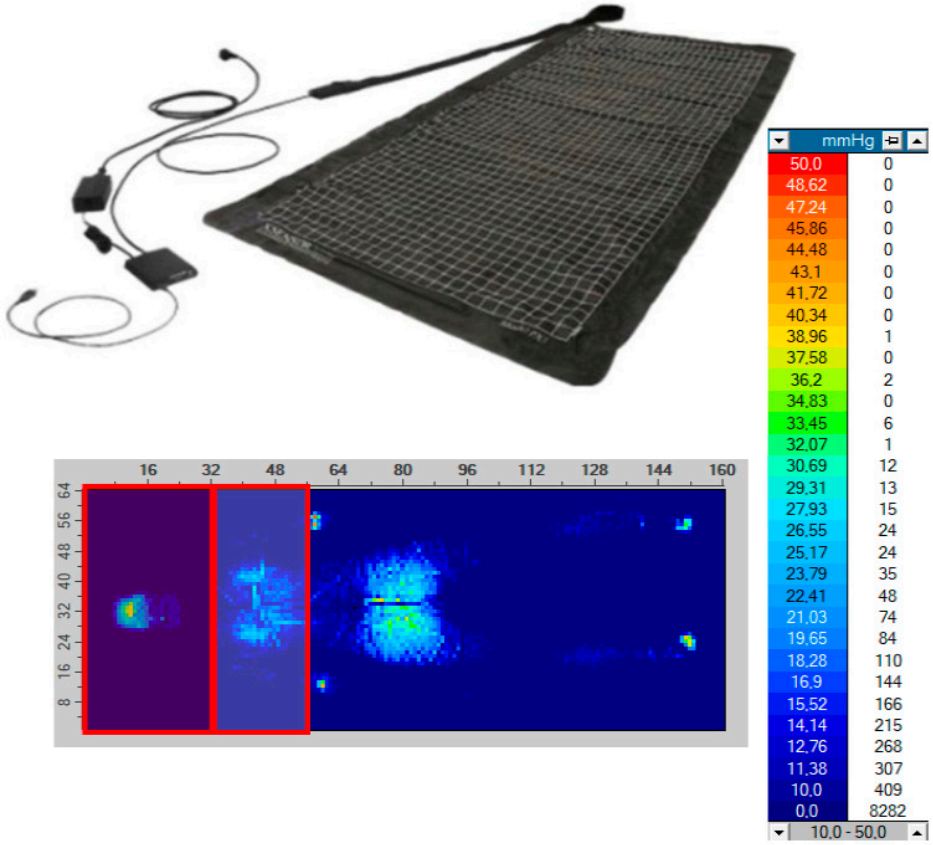

Figure 3. Pressure-mapping blanket (**upper** panel) and pressure distribution map (**lower** panel). Upper panel: The X3 R&D Mattress System is a full body pressure mapping blanket used to accurately test mattresses and mattress components. This blanket consists of 10,240 sensing points. The ComfortMap image shows how well a mattress conforms to a patient's body, and the curve illustrates pressure distribution. For analyzing the pressure distribution, pressure was measured in mmHg and recorded from each sensing point for each participant in each group.

2.4. Experimental Procedure

Participants tried five different pillows on a medium-firm hybrid mattress at room temperature with a humidity of 45–55%. Participants tried the pillows first in the supine position, then side-lying, and finally in the prone position. While trying the pillows, the researchers instructed the participants to relax and then take deep breaths with their eyes closed. Evaluation of body pressure distribution was initiated after participants had inhaled and exhaled at least five times. The participants were advised to retain their arms on both sides of their bodies while lying supine. The participants were allowed to bend their knees while lying on their right side in the side-lying position. Data on the distribution of body pressure in the head and neck were gathered. To decrease tiredness, a two-minute rest interval was provided during the position transfer. To reduce the impact of continuous testing on subjective evaluation, subjects were allowed to get up and move around for 5 min between pillow tests.

2.5. Sample Size

"We used G*Power 3.0.1 (Franz Faul, University of Kiel, Kiel, Germany) to determine the required sample size. With an alpha of 0.05, power of 0.80, effect size of 0.86, and two tails, the software predicted a sample size of 28 (14 per group) based on the means and standard deviations from the pilot study. To account for a 10% dropout rate, we expanded the sample size to 32."

2.6. Statistical Analysis

For continuous variables, mean and standard deviations were computed, and for categorical variables, percentage frequency distributions were computed. The mean and standard deviation were utilized in the descriptive analysis. The Shapiro–Wilk test was performed to determine the normality of the quantitative data. Based on these findings, the Friedman test and various post-hoc comparisons (Bonferroni adjustments) were utilized to compare the five different pillow variables as needed. The "chi-square" test and the "Student's *t* test" were used to compare the mild and severe FHP groups. p values less than 0.05 were considered statistically significant. SPSS 28.0 (IBM SPSS Inc., Armonk, NY, USA) was used for all statistical analyses.

3. Results

Between January and February 2023, 112 participants were screened, and 34 met the eligibility criteria, entered the study, and were allocated to the mild (17) and severe (17) FHP groups. Four of the participants were excluded because they could not complete the pillow assessment for sensor device or time-related reasons. As a result, the data from these four participants were not included in the analysis. Table 2 shows the distribution of the participants based on the severity of FHP and the similarity between the groups regarding the baseline demographic and clinical characteristics.

In the supine position, Pillow D ($p = 0.011$) provided better head comfort in participants with mild FHP, while Pillow C ($p = 0.045$) and Pillow E ($p = 0.046$) provided better head support. There was no difference between the groups in the rest of the support and comfort parameters of the head and shoulder region ($p > 0.05$). In the side-lying position, the support and comfort values provided by the pillows did not differ between the groups separated according to the FHP degree ($p > 0.05$). In the prone position, the support values provided to the shoulder-upper back region were higher for the A ($p = 0.040$) and D ($p = 0.022$) pillows for individuals with a mild FHP group. There was no difference between the groups in the rest of the support and comfort parameters of the head and shoulder region ($p > 0.05$) (Table 3).

Table 2. Demographic, physical, and psychosocial characteristics of individuals with FHP.

Features	FHP< 2.8 cm (n = 15)	FHP ≥ 2.8cm (n = 15)	*p*
Gender (n(%)) Female Male	11 4	8 7	0.450 [a]
Age	30.00 ± 7.72	30.60 ± 8.26	0.867 [b]
BMI	23.99 ± 3.12	22.84 ± 3.08	0.714 [b]
Physical Activity Level (IPAQ)	1491 ± 1007	1626 ± 675	0.279 [b]
Pittsburg Sleep Quality Index	5.67 ± 2.80	5.62 ± 2.10	0.959 [b]
Head Anterior Tilt (cm)	1.70 ± 0.77	4.01 ± 0.70	>0.00 [b]

[a] Chi square test, [b] Student's *t* test. FHP: forward head posture, BMI: body mass index, IPAQ: International Physical Activity Questionnaire, cm: centimeter.

When the comfort and support parameters of pillow materials were compared among all participants, Pillow B and Pillow E provided higher head comfort ($p < 0.001$), while Pillow E also provided higher shoulder support ($p = 0.044$) in the supine position. In other parameters, there was no difference between the pillows ($p > 0.05$). In the side-lying position, Pillow B provided higher head comfort ($p < 0.001$) and Pillow A ($p = 0.003$) higher head support. There was no difference between the pillows in other parameters ($p > 0.05$). In the prone position, Pillow B and Pillow E provided higher head comfort ($p < 0.001$), while Pillow E also provided higher shoulder support ($p = 0.002$). There was no difference between the pillows in other parameters ($p > 0.05$) (Table 4). Pairwise comparisons of pillows with the help of post-hoc tests are also shown in Figure 4.

Table 3. Comfort and support values provided by different pillow designs according to the severity of FHP.

Pillow Designs		**FHP< 2.8 cm (n = 15)**		**FHP ≥ 2.8 cm (n = 15)**		***p***	
Supine Position		**Head**	**Shoulder-Upper Back**	**Head**	**Shoulder-Upper Back**	**Head**	**Shoulder-Upper Back**
Pillow A (Viscose)	Comfort (mmHg)	18.69 ± 2.11	18.44 ± 1.81	19.29 ± 2.06	18.47 ± 2.22	0.445	0.976
	Support (cm^2)	308 ± 87	1083 ± 201	301 ± 125	1055 ± 236	0.872	0.731
Pillow B (Fiber)	Comfort (mmHg)	14.65 ± 0.88	18.15 ± 1.84	15.90 ± 2.59	18.72 ± 2.12	0.087	0.438
	Support (cm^2)	363 ± 146	1197 ± 226	287 ± 157	1106 ± 262	0.182	0.321
Pillow C (Cotton)	Comfort (mmHg)	16.24 ± 1.46	18.46 ± 1.42	17.52 ± 3.02	18.53 ± 1.72	0.150	0.897
	Support (cm^2)	383 ± 164	1148 ± 176	266 ± 140	1150 ± 221	0.045 *	0.980
Pillow D (Wool)	Comfort (mmHg)	16.38 ± 1.20	18.88 ± 1.86	17.59 ± 1.22	18.92 ± 2.26	0.011 *	0.952
	Support (cm^2)	392 ± 164	1164 ± 300	288 ± 168	1096 ± 252	0.098	0.509
Pillow E (Goose feather)	Comfort (mmHg)	15.44 ± 1.27	19.18 ± 1.39	16.16 ± 1.20	18.76 ± 1.81	0.289	0.489
	Support (cm^2)	427 ± 172	121 ± 225	308 ± 138	1158 ± 231	0.046 *	0.515
Side-lying Position		Head	Shoulder-upper back	Head	Shoulder-upper back	Head	Shoulder-upper back
Pillow A (Viscose)	Comfort (mmHg)	17.58 ± 1.63	22.96 ± 1.93	17.94 ± 2.01	23.13 ± 2.27	0.593	0.824
	Support (cm^2)	232 ± 93	1444 ± 258	211 ± 98	1346 ± 270	0.552	0.318
Pillow B (Fiber)	Comfort (mmHg)	15.05 ± 2.42	23.19 ± 1.83	14.71 ± 1.31	23.27 ± 2.49	0.638	0.922
	Support (cm^2)	185 ± 101	1548 ± 323	155 ± 65	1399 ± 285	0.349	0.192
Pillow C (Cotton)	Comfort (mmHg)	16.39 ± 2.14	23.44 ± 2.17	16.69 ± 2.66	23.66 ± 2.83	0.741	0.814
	Support (cm^2)	167±77	1495 ± 240	153 ± 63	1396 ± 262	0.606	0.291
Pillow D (Wool)	Comfort (mmHg)	16.69 ± 2.66	23.53 ± 2.18	16.89 ± 2.08	22.94 ± 2.58	0.439	0.507
	Support (cm^2)	192 ± 85	1491 ± 332	176 ± 81	1383 ± 268	0.605	0.339
Pillow E (Goose feather)	Comfort (mmHg)	16.37 ± 2.39	23.47 ± 1.75	15.65 ± 1.92	23.78 ± 2.66	0.375	0.703
	Support (cm^2)	184 ± 100	1555 ± 395	173 ± 46	1383 ± 244	0.707	0.162

Table 3. *Cont.*

Pillow Designs		FHP< 2.8 cm (n = 15)		FHP $\geq$ 2.8 cm (n = 15)		*p*	
Supine Position		**Head**	**Shoulder-Upper Back**	**Head**	**Shoulder-Upper Back**	**Head**	**Shoulder-Upper Back**
Prone Position							
Pillow A (Viscose)	Comfort (mmHg)	18.82 ± 1.77	20.25 ± 2.05	18.45 ± 2.71	19.38 ± 2.73	0.654	0.328
	Support (cm^2)	430 ± 187	1001 ± 291	488 ± 219	788 ± 247	0.444	0.040 *
Pillow B (Fiber)	Comfort (mmHg)	14.86 ± 1.42	20.73 ± 2.64	14.64 ± 0.90	19.04 ± 2.64	0.619	0.092
	Support (cm^2)	403 ± 194	1011 ± 301	499 ± 279	845 ± 167	0.286	0.073
Pillow C (Cotton)	Comfort (mmHg)	16.77 ± 1.77	20.97 ± 2.19	16.36 ± 1.40	19.18 ± 2.84	0.492	0.064
	Support (cm^2)	411 ± 144	991 ± 237	498 ± 268	908 ± 193	0.279	0.299
Pillow D (Wool)	Comfort (mmHg)	17.24 ± 1.72	20.31 ± 2.84	17.55 ± 2.28	20.04 ± 2.46	0.683	0.789
	Support (cm^2)	480 ± 185	970 ± 245	490 ± 269	776 ± 189	0.908	0.022 *
Pillow E (Goose feather)	Comfort (mmHg)	16.23 ± 1.35	21.67 ± 2.44	15.43 ± 1.33	20.09 ± 2.36	0.116	0.083
	Support (cm^2)	461 ± 167	1031 ± 225	442 ± 214	913 ± 214	0.792	0.154

p: Student's *t* test, FHP: forward head posture, * statistically significant difference.

Table 4. Comparison of comfort and support values provided to individuals with FHP by different pillow designs.

Pillow Designs	**FHP (n = 30)**							
	Head				**Shoulder and Upper Back**			
Supine Position	**Comfort (mmHg)**	***p***	**Support (cm^2)**	***p***	**Comfort (mmHg)**	***p***	**Support (cm^2)**	***p***
Pillow A (Viscose)	18.98 ± 2.07^{L}	<0.001 *	304 ± 106	0.948	18.46 ± 1.99	0.455	1069 ± 216^{L}	0.044 *
Pillow B (Fiber)	15.28 ± 2.00^{H}		325 ± 154		18.43 ± 1.97		1151 ± 245	
Pillow C (Cotton)	16.88 ± 2.42^{L}		325 ± 161		18.50 ± 1.55		1149 ± 196	
Pillow D (Wool)	16.99 ± 1.34^{L}		340 ± 171		18.90 ± 2.03		1130 ± 274^{L}	
Pillow E (Goose feather)	15.80 ± 1.80^{H}		368 ± 164		18.97 ± 1.60		1186 ± 226^{H}	
Side-lying Position								
Pillow A (Viscose)	17.76 ± 1.81^{L}	<0.001 *	221 ± 95^{H}	0.003 *	23.05 ± 2.07	0.336	1395 ± 264	0.201
Pillow B (Fiber)	14.88 ± 1.92^{H}		170 ± 85		23.23 ± 2.14		1473 ± 309	
Pillow C (Cotton)	16.54 ± 2.38^{L}		160 ± 70^{L}		23.55 ± 2.48		1445 ± 252	
Pillow D (Wool)	17.18 ± 2.04^{L}		184 ± 82		23.24 ± 2.37		1437 ± 301	
Pillow E (Goose feather)	16.01 ± 2.16		179 ± 77		23.63 ± 2.22		1469 ± 334	
Prone Position								
Pillow A (Viscose)	18.63 ± 2.26^{L}	<0.001 *	459 ± 202	0.960	19.81 ± 2.41	0.076	894 ± 286^{L}	0.002*
Pillow B (Fiber)	14.75 ± 1.18^{H}		451 ± 241		19.89 ± 2.79		928 ± 254	
Pillow C (Cotton)	16.57 ± 1.58^{L}		454 ± 216		20.07 ± 2.65		950 ± 217	
Pillow D (Wool)	17.40 ± 1.99^{L}		485 ± 227		20.17 ± 2.61		873 ± 236^{L}	
Pillow E (Goose feather)	15.83 ± 1.38^{H}		452 ± 189		20.88 ± 2.49		972 ± 224^{H}	

p: Friedman test. ^{H}: Higher profile pillow compared to pairwise comparisons using Bonferroni correction. ^{L}: Lower profile pillow compared to pairwise comparisons using Bonferroni correction. FHP: forward head posture, * statistically significant difference.

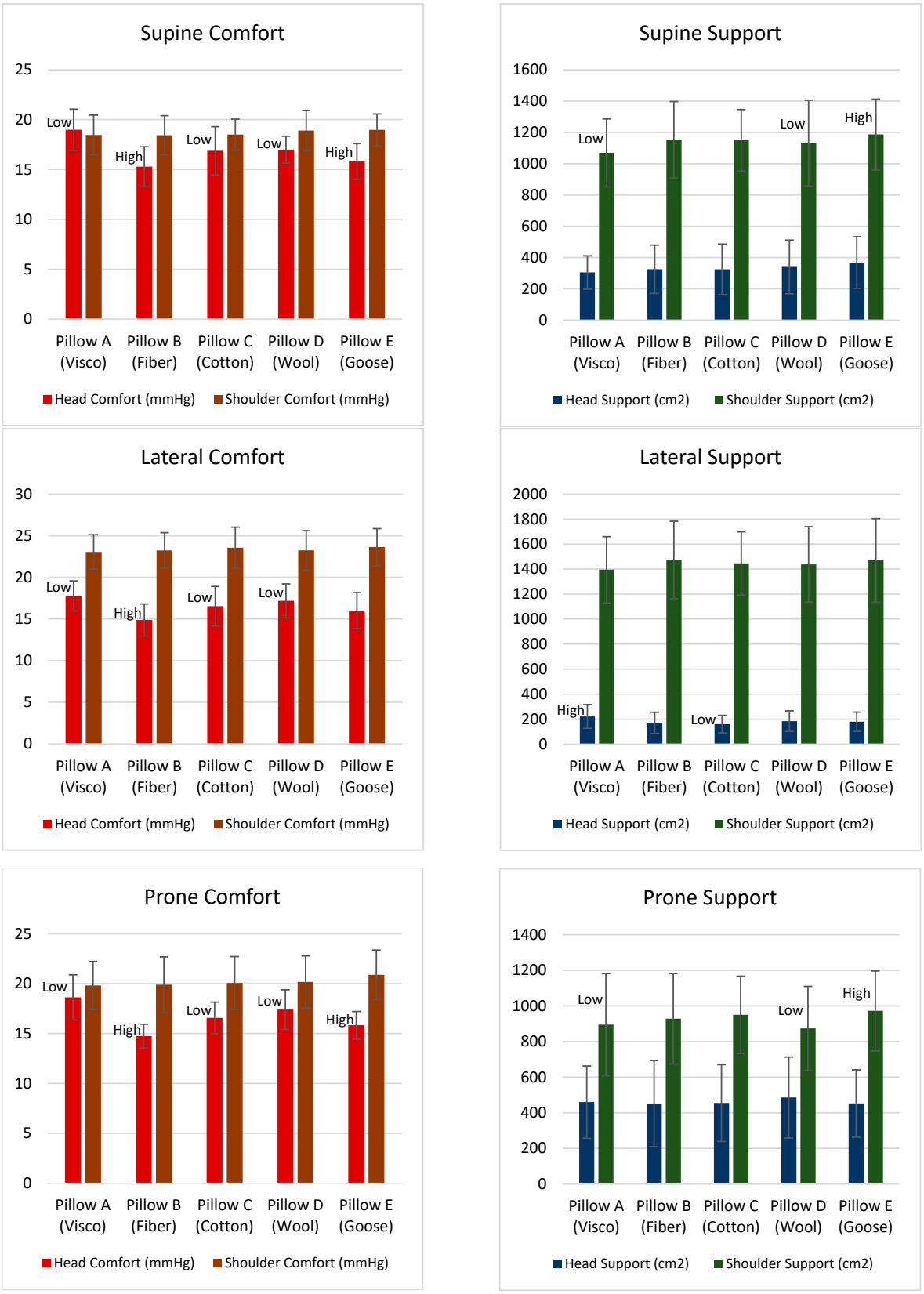

Figure 4. Graphical representation of the comfort and support values provided to individuals with FHP by different pillow designs.

4. Discussion

The higher comfort and better support of the pillow are often used to reduce stress on the body while sleeping. An efficient pillow eliminates unwanted muscle activation, improves spinal support, enhances proprioception, and reduces segmental pressure. Unfortunately, the effects of various pillow materials on the neck and upper back regions of individuals with FHP is still unknown. Our study revealed five main findings. First, in the supine position, Pillow D, made of wool material, provided more head comfort in mild FHP, while Pillow C made of cotton material, and Pillow E made of goose down material, provided more head support in mild FHP. Second, in the prone position, Pillow A, made of viscose material, and Pillow D, made of wool material, provided more upper back support in mild FHP. Thirdly, in the supine position, Pillow B, made of fiber material, and Pillow E, made of goose down material, provided higher levels of head comfort, while Pillow E, made of goose feathers, provided better upper back support. Fourth, in the side-lying position, Pillow B, made of fiber material, provides a higher level of head comfort, while Pillow A, made of cotton material, had better head support. Finally, in the prone position, Pillow B and Pillow E made of fiber and goose down, respectively, provided higher levels of head comfort, while Pillow E, made of goose down, provided better back support. According to our study findings, the comfort and support values provided by different pillow materials may differ according to the posture of the head. In addition, the pillows made of goose down in the supine position provided higher head comfort and better back support than other pillows, the fiber pillow in the side-lying position increased the head comfort, the cotton pillow increased the head support, and the goose down pillows provided higher comfort and better support in the prone position.

Four of the pillows (Pillow B, C, D, and E) we investigated in the studies on comfort and support levels of pillows were classified as "traditional", "standard", or "regular" pillows, while the pillow made of viscose material (Pillow A) was classified as contour-type, ergonomic, or orthopedic. Our first and second findings were related to the fact that the comfort and support levels provided by pillows may vary with the severity of FHP. Previous studies examining the relationship of pillow materials to the cervical spine have generally investigated muscle activations in this region. Fazli et al. showed the ergonomic latex pillow changed the craniovertebral angle and increased the endurance of the neck extensor muscles, unlike traditional pillows [30]. In another study, it was shown all the different pillow designs cause unwanted superficial muscle activation and are not suitable for individuals with FHP [25,40]. Even though these studies that look at how the pillow affects the spine have objective data, there are still indirect ways to measure the health of the spine. Regarding sleep quality and symptoms, pillow shape was the primary cause of the three major sleeping symptoms (head tiredness, neck fatigue, and shoulder pain) that affected sleep quality [41]. Therefore, it can be stated the design of a pillow's shape for each body part (head, neck, and shoulders) is the most significant component for best comfort. Radwan et al. showed moderate evidence that a contoured pillow design containing memory foam or latex material can improve sleep quality and spinal alignment and reduce sleep-related neck pain. In our study, the support and comfort levels provided to the spine by Pillow A, which is contour designed and produced from viscose material, remained not extremely higher than those provided by conventional pillows. This result may have occurred because the spinal alignments in individuals with FHP are different from normal posture [32]. As a result, Pillow A, produced from contour designed viscose material, is insufficient in terms of head comfort and back support for individuals with FHP. Among the traditional pillow materials, we can say Pillow E, produced from goose feather material, is the most suitable pillow for sleeping on the back and in the prone position, while Pillow B, produced from fiber material, is the most suitable pillow for the side-lying position.

According to the other results of our study, effective pillow materials may differ according to sleeping position. There are many pillow parameters that affect sleep comfort and quality. Pillow height influences spinal alignment, activation of cervical muscles, subjective comfort, and overall pressures in the cervical and cranial regions. This variable

was standardized by choosing pillows of almost the same height in our study [42,43]. The shape of a pillow is a very important element in pillow design as it contributes to the amount of neck support and the overall comfort level of the wearer. The sleeping position can also determine the most suitable pillow shape for each user. In studies examining the effect of contour pillow design on sleep quality, Gordon et al. analyzed five different pillows similar to our study and found contour pillows, such as Pillow A, provided higher sleep quality and pillow comfort than other traditional feather pillows [44]. Cai and Chen similarly examined an experimentally designed "U-shaped" contour pillow to measure various items related to sleep quality and showed this pillow was effective in increasing rapid eye movement (REM) sleep duration and sleep quality score. These findings suggest contour pillows provide deeper and better-quality sleep [45]. Our study results showed that contrary to the studies mentioned, the support and comfort data provided by the viscose pillow to the spine were lower than those provided by the traditional pillows. Another important element of the pillow is the material. It was concluded that sleep quality, neck comfort, and waking symptoms varied greatly depending on which pillow was used [44]. The effect of pillow materials on the human body has been investigated before. Fazli et al. demonstrated the ergonomic latex pillow increases functional capacity in patients with cervical spondylosis using self-reported subjective methods, such as the Neck Disability Index and the Numerical Pain Rating Scale [46]. Gordon et al. reported the use of latex pillows for 28 days will lead to an increase in quality of life and cervical spine joint opening compared to the use of traditional pillows in patients who wake up at night due to cervical pain. This study was also supported subjectively by the self-report method or by objective measures, such as range of motion, which could not measure the comfort and support value provided by the pillow [47]. Vanti et al. showed that when individuals with nonspecific neck pain regularly used a spring pillow for four weeks, their head and neck pain were significantly reduced. Similarly, these measurements were carried out with indirect outcome measures, such as the Neck Disability Index [48]. Since the objective measurement method used in our study was measured with pressure sensors, independent of the participant's feedback, there was no need for an average evaluation period of four weeks, such as other studies. The comfort and support values investigated in previous studies were subjectively obtained from the participants by the self-reporting method [39]. We used the Visual Analog Scale to measure pillow comfort subjectively. In a prior study, orthopedic pillows were found to be more comfortable than traditional pillows when evaluated with the VAS [49]. However, our study is unique in that we utilized objective measures to evaluate the comfort and support properties of pillow materials and their association with cervical spine disorders. Our study is the first to use objective outcome measures for comfort and support values of pillow materials and to examine their relationship with cervical spine disorders.

Our study is the first to use objective measures to look at how comfortable and supportive different pillow materials are and how they relate to problems with the neck and spine. Similar to our study, other studies were conducted to measure the support and comfort values of pillows with the help of pressure sensors; however, these studies did not evaluate the pillow material. Kim et al. investigated the comfort values provided by different pillow shapes with the help of a pressure mat and showed the contour designed pillow reduced the pressure values in the occipital region [50]. Ren et al. investigated the pressure values provided by four different pillows, whose heights vary between 11 and 17 cm, with the help of a pressure mat and stated the height of the pillow with the least pressure on the head is 11 cm [28].

Study Limitations

Firstly, the study's sample size could have been larger, which is the first limitation. Participants were evaluated in a state of completely relaxed rest, rather than during actual sleep, limiting the clinical application of these findings to asymptomatic adults. Additionally, only a medium-firm hybrid mattress was used, and while conventional pillows were

of similar height, the viscose pillow's height differed due to production standards, which is another limitation. Sleep health includes both subjective and objective parameters, and although the study objectively demonstrated spine-related comfort and support parameters, these data alone cannot explain sleep quality and comfort levels. Future studies should include subjective outcome measurements taken from individuals using the self-report method to support the results. Despite having clear exclusion criteria, we did not ask the participants about ear diseases or breathing problems, which could affect their posture and sleep, indicating another limitation of the study.

5. Conclusions

This study showed pillow materials affect the spine comfort and support of the participants, and these values may vary according to different spinal alignments, such as FHP. According to the preferred sleeping position, the pillow material that supports the spine and increases its comfort will also change. This study revealed the pillows that support the spine of the individual and provide comfort objectively. These results can be blended with the preferences and feedback of the people about the pillow in future studies and may help in choosing a personalized pillow.

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