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RESEARCH ARTICLE OPEN ACCESS

The Influence of Pillow Shape and Content on Neck Muscular Activity and Perceived Comfort

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Abstract:

Background: Using an appropriate pillow in terms of shape and content is necessary to maintain the neck's natural posture and to eliminate biomechanical stresses, particularly uncomfortable muscular activity.

Objectives: This study evaluated four different types of pillows regarding their traditional shapes (rectangular and cylindrical) and contents (memory foam and wool).

Methods: For each of the pillow conditions, bilateral sternocleidomastoid (SCM) and upper trapezius (UT) EMG activity and perceived comfort were recorded from ten healthy participants (5 male and 5 female) during 30-min sleeping tests in each of the supine and lateral positions.

Results: For both materials (wool/memory foam), the rectangular pillows felt more comfortable in the supine position, and the cylindrical ones provided more comfort in the lateral position. A significantly reduced muscular activity for the right UT muscle was recorded during sleep with rectangular pillows in the supine position. In the lateral position, Left UT and bilateral SCM muscles indicated significantly lower EMG values with cylindrical pillows.

Conclusions: The results suggested that pillow shape plays a crucial role in the management of neck muscle activation and perceived comfort according to the sleeping position. Furthermore, wool as a viable alternative to memory foam requires support from additional future studies.

Keywords: Ergonomic pillow, EMG, Sleep position, Comfort, Upper trapezius UT, Memory foam.

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1. INTRODUCTION

Sleep comprises approximately one-third of an individual's lifespan. Sufficient sleep duration (6-8 hours) with appropriate quality leads to beneficial effects on body health and functions (*e.g.*, physical restoration and memory processing) [1]. Sleep quality is directly related to the proper head and neck support to maintain cervical spine alignment [2]. Accordingly, it is widely reported that sleep-related neck pain and discomfort are associated with higher and longer muscle activity due to improper neck support [3, 4]. As a key element of sleep posture, the primary function of a pillow is to maintain the cervical spine in a neutral position during sleep, thereby reducing neck muscle activity and minimizing pressure on the intervertebral discs, nerve roots, and facet joints [5]. However, inappropriate pillow designs that provide inadequate support for the head and neck can cause poor sleep quality arising from biomechanical stresses on neck structures [6, 7].

In order to offer the optimal alignment for the cervical spine through an ergonomic pillow in the supine or lateral positions, previous studies have identified three fundamental parameters: pillow height, shape, and content (material) [5, 7]. The height of a pillow is closely related to the cervical vertebral angle and thereby affects cervical spine alignment [8], muscle activity of the neck and shoulder [3], pressures on the cervical and cranial regions [9], and perception of pillow comfort [10]. Several investigations have examined pillow height, and their findings consistently show that a height of seven to eleven centimeters is associated with improved sleep quality, better spinal alignment, proper pressure distribution, and reduced muscle tension [5].

The shape of the pillow determines the contact area between the pillow and the head-neck-shoulder complex during sleep [11]. In other words, the pillow shape directly defines the amount of support for the neck [2]. Previous studies have evaluated a relatively new shape of the pillow, a countered design (U-shaped: a pillow with higher sides and a lower, flattened center), in comparison to traditional forms such as rectangular and cylindrical pillows [2, 12]. In addition, the focus of investigations has mainly been on the effectiveness of new pillow designs in mitigating neck pain and related symptoms [7] rather than examining the improved sleep quality (or comfort) resulting from various pillow shapes in healthy individuals [5]. However, conflicting findings have also been reported regarding the usefulness of pillows with countered design in the management of neck pain and discomfort [13, 14].

Additionally, the role of pillow material has been recognized in maintaining pillow form stability, ensuring the intended shape is preserved [15], while also evenly distributing pressure under the head and neck [16]. Currently, the strongest evidence for improving sleep quality and comfort through proper neck support is reported for latex pillows, followed by memory foam [17-19]. In contrast, limited evidence has been documented for other common materials (*e.g.*, feather, polyester, and cotton) [6, 16], as well as specific materials (*e.g.*, water-based or spring pillows) [20, 21].

An important issue that has received less attention is the influence of basic pillow shapes (rectangular and cylindrical) on sleep quality and perceived comfort among the general population, particularly considering their biomechanical impact on the cervical region. Furthermore, wool is another common material that has been less considered as a pillow filling. Natural wool with specific properties such as breathability, flexibility, thermal regulation, and moisture control might influence comfort or muscle activity, however, this topic needs more investigation. Therefore, the present study aimed to investigate the influence of two basic pillow shapes (rectangular and cylindrical) and also two common materials (memory foam and wool) on sternocleidomastoid and trapezius electromyographic (EMG) activity and the perceived comfort in the two most common positions (supine and lateral) during sleep. It was hypothesized that neck muscle activity and perceived comfort significantly differ under the influence of pillow conditions in different sleeping positions (supine and lateral).

2. METHODS

2.1. Participants

Ten healthy volunteers (5 males and 5 females) from the university population with a mean age of 23.9 ± 2.6 years and a body mass index of 23.2 ± 0.55 kg/m^2 participated in this experimental study. The exclusion criteria included injury, neurological or orthopedic conditions in the cervicothoracic spine within the preceding year, cervicogenic dizziness and headaches, sleep disorders, and ongoing treatment for neck symptoms. All participants read and signed an informed consent form prior to participation.

2.2. Instrumentation

Neck muscle EMG activity was monitored using an eight-channel data acquisition system (DLK900, Biometrics Ltd., Gwent, UK) with standard bipolar Ag-AgCl surface electrodes (10 mm diameter and center-to-center inter-electrode distance of 20 mm). The raw EMG signals with a bandwidth of 10-500 Hz and a sampling frequency of 1000 Hz were bilaterally collected from the sternocleidomastoid (SCM) and the upper trapezius (UT) muscles. The process of preparation and surface electrode placement followed the recommendations of SENIAM [22]. The location of electrodes was as follows: SCM at the most prominent area of the sternal head in the lower third of the distance from the sternal notch to the mastoid process; UT at 50% of the distance from the acromion to the C7 vertebra [23]. Visual Analog Scale (VAS) was used to subjectively assess individuals' comfort in using the pillows under study. Comfort was measured on a 100 mm line with the words "most comfortable" and "least comfortable" at both ends.

2.3. The Pillows

The pillows studied were available in two shapes: rectangular (R) and cylindrical (C) (Fig. **1**), with each shape made from two materials: wool (w) and memory foam (mf) (Rw, Rmf, Cw, and Cmf). The dimensions for the rectangular pillows were 49 cm × 30 cm × 14 cm, and for the cylindrical pillows, they were 49 cm × 22 cm × 15 cm. The height of all pillows during sleep, with the weight of the head and neck, met the recommended values (7-11 cm) [5]. The applied memory foam in this study was polyurethane. A 100% cotton covering textile was used for all pillows.

2.4. Experimental Design and Protocol

A repeated within-subject experimental design was recruited for the current study in which each participant completed four 60-min sleeping sessions with one-week interval for each of the pillow conditions: 1) rectangular with wool, 2) rectangular with memory foam, 3) cylindrical with wool, and 4) cylindrical with memory foam. The two most common sleeping positions, supine and lateral, were assessed in each pillow trial [24]. Each sleep position was maintained for 30 min [25]. The sequence of pillow conditions and also the sleeping position in each session were randomly selected by participants. All subjects were instructed to have no specific physical activity a day before the test session and were also required to wear shirts without collars.

Fig. (1). The Studied Pillows: Rectangular (left) and cylindrical (right).

At the start of each test session and after the placement of EMG electrodes, the subjects were tested for maximal voluntary contraction (MVC) of the SCM and UT muscles. Furthermore, to measure the MVC of the UT muscle, the subject was asked to sit and raise the shoulder as far as possible against manual resistance applied to the distal third of the clavicle [26]. For the SCM muscle, in the supine position, the subject was first asked to flex their head while rotating it to the opposite side and then was required to maintain the head against the manual resistance applied to the temporal region of the head in an oblique posterior direction [26]. EMG signals were recorded for each of the relevant muscles twice with an interval of 2 min for 5 seconds. Next, the subject was asked to lie on the bed and use each pillow for 30 min in the supine position and 30 min in the lateral position (on the right side) (Fig. **2**). During tests, the participants were asked to keep their eyes closed to avoid the effect of visual stimulations. Participants were blinded to the material and shape of the pillows during the experiment. The EMG signals were recorded from the start of each sleeping position and every 10 minutes for 30 s duration. After using the pillow for 30 min in each of the sleeping positions (supine and lateral), the perceived comfort level was measured through the VAS.

Fig. (2). Participant while using the pillows in the supine position.

2.5. Data Processing

Post-processing of raw EMG data was fulfilled offline in MATLAB® (MathWorks®, Natick, MA, USA). As the recording system applied a band-pass filter (10-500 Hz), there was no need for a digital filter. First, all EMG signals were full wave rectified and then the root mean square (RMS) values were obtained using a moving 200-ms window [27]. The greatest RMS value of the two MVC trials in the target muscle was used to normalize the RMS values of 30-s recordings (%MVC). For each muscle, four normalized RMS scores were obtained in each pillow test session with each of the supine and lateral sleeping positions (8 RMS scores).

2.6. Statistical Analysis

The normality of data was assessed through the Shapiro-Wilk test. As the data indicated a normal distribution and also there were no main effects or interactions for gender, a two-factor repeated measures analysis of variance (ANOVA) was run to analyze the effects of pillow conditions (2 shapes * 2 materials) and sleeping time (4 points) on EMG activity of bilateral SCM and UT muscles, separately, in each of the sleeping positions (supine and lateral). For the perceived comfort of pillow, the influence of pillow conditions was only analyzed. Huynh–Feldt Epsilon corrections were used when the data did not follow Sphericity assumptions. The least significant difference (LSD) test as post-hoc adjustment was conducted for pairwise comparison. All statistical tests were performed using the SPSS software version 20.0 (SPSS Inc., Chicago, IL, USA). The alpha level equal to or less than 0.05 was accepted as significant.

Table 1. Means ± SD of VAS scores in two sleeping positions and four pillow conditions.

Pillow Condition	Supine VAS	Lateral VAS
Rectangular memory foam	8.67±0.644	7.08±0.707
Cylindrical memory foam	6.71±0.432	8.31±0.568
Rectangular wool	8.21±0. 528	6.74±0.843
Cylindrical wool	6.30±0.843	8.48±0.441

3. RESULTS

3.1. Pillow Comfort

Table **1** presents the mean scores of perceived comfort for the studied pillows. A significant main effect of pillow condition was found for the perceived comfort in both the supine and lateral sleeping positions (Table **2**). In the supine position, significantly higher levels of comfort were reported for the rectangular pillows (R_{mf} and R_w) compared to the cylindrical ones (C_{mf} and C_w) ($p < 0.05$). Regarding lateral position, the cylindrical pillows (C_{mf} and C_w) were perceived as more comfortable than the rectangular pillows (R_{mf} and R_w) ($p < 0.05$). However, there were no considerable differences between memory foam and wool materials in the pillows with the same shape ($p > 0.05$).

3.2. Muscle Activity

The mean levels of EMG activity for the bilateral UT and SCM muscles are shown in Figs. (**3** and **4**), respectively. There was a significant main effect of pillow condition for the right and left UT muscles in the supine and lateral sleeping positions, respectively (Table **2**). Pairwise comparisons revealed that lower levels of EMG activity for the right UT muscle were induced through both the R_{mf} (p = 0.050) and R_w (p = 0.031) pillows compared to the C_{mf} in the supine position (Fig. 3). In the lateral position, less EMG values of the left UT muscle were observed for the C_w compared to the R_{fm} (p = 0.009) and R_w (p = 0.030) and also for the C_{fm} compared to the R_w (p = 0.010) (Fig. 3).

A significant main effect of pillow condition was also found for the right and left SCM muscles only in the lateral position (Table 2). Lower EMG activity levels of the right SCM muscle were recorded for the C_w pillow compared to the R_{fm} (p = 0.003) (Fig. 4). For the Left SCM muscle, less activity was obtained during sleep with the C_w compared to the R_{fm} (p = 0.026) and R_w (p = 0.011) and also for the C_{fm} compared to the R_w (p = 0.046) (Fig. 4).

Table 2. Summary of repeated measures analysis of variance (ANOVA).

Measure	Sleeping Position	Time			Pillow Condition			Time*pillow Condition		
		F	P	ES	F	P	ES	F	P	ES
Comfort	*Supine*	-	-	-	11.597	**0.000***	0.563	-	-	-
	Lateral	-	-	-	13.529	**0.000***	0.604	-	-	-
Right UT	*Supine*	0.123	0.946	0.013	3.744	**0.022***	0.295	0.560	0.826	0.059
	Lateral	0.253	0.858	0.027	1.316	0.290	0.370	0.947	0.490	0.095
Left UT	*Supine*	0.146	0.931	0.016	0.895	0.412	0.090	0.814	0.522	0.083
	Lateral	0.448	0.720	0.047	5.288	**0.005***	0.128	0.573	0.671	0.060
Right SCM	*Supine*	0.471	0.705	0.050	0.779	0.516	0.080	0.255	0.990	0.024
	Lateral	0.062	0.979	0.007	3.622	**0.026***	0.287	0.391	0.936	0.042
Left SCM	*Supine*	1.128	0.355	0.111	1.029	0.395	0.103	0.590	0.641	0.062
	Lateral	0.029	0.993	0.003	3.841	**0.021***	0.299	0.150	0.962	0.016

Note: *p < 0.05, **ES**: Effect Size, **UT**: Upper Trapezius, **SCM**: Sternocleidomastoid.

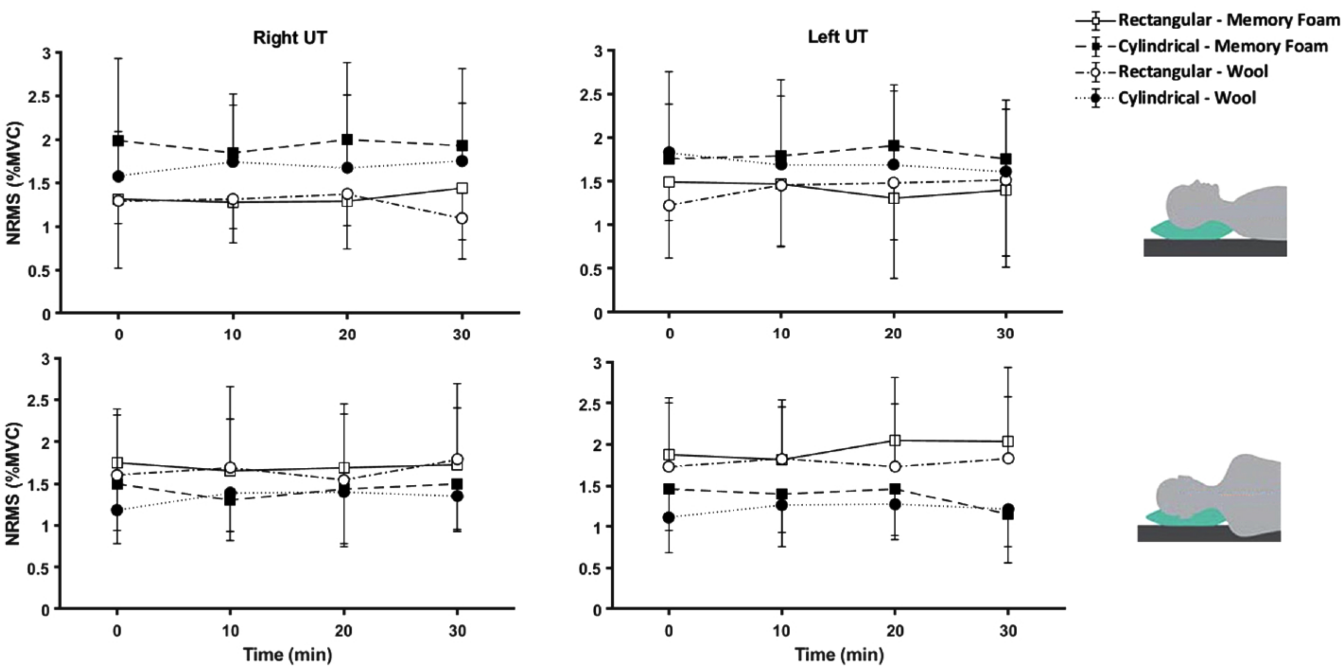

Fig. (3). Changes in mean values of normalized RMS (NRMS) for right and left upper trapezius (UT) muscles during 30 min sleeping with four pillow conditions in each of the supine (top row) and lateral (bottom row) positions. Error bars represent standard deviation values.

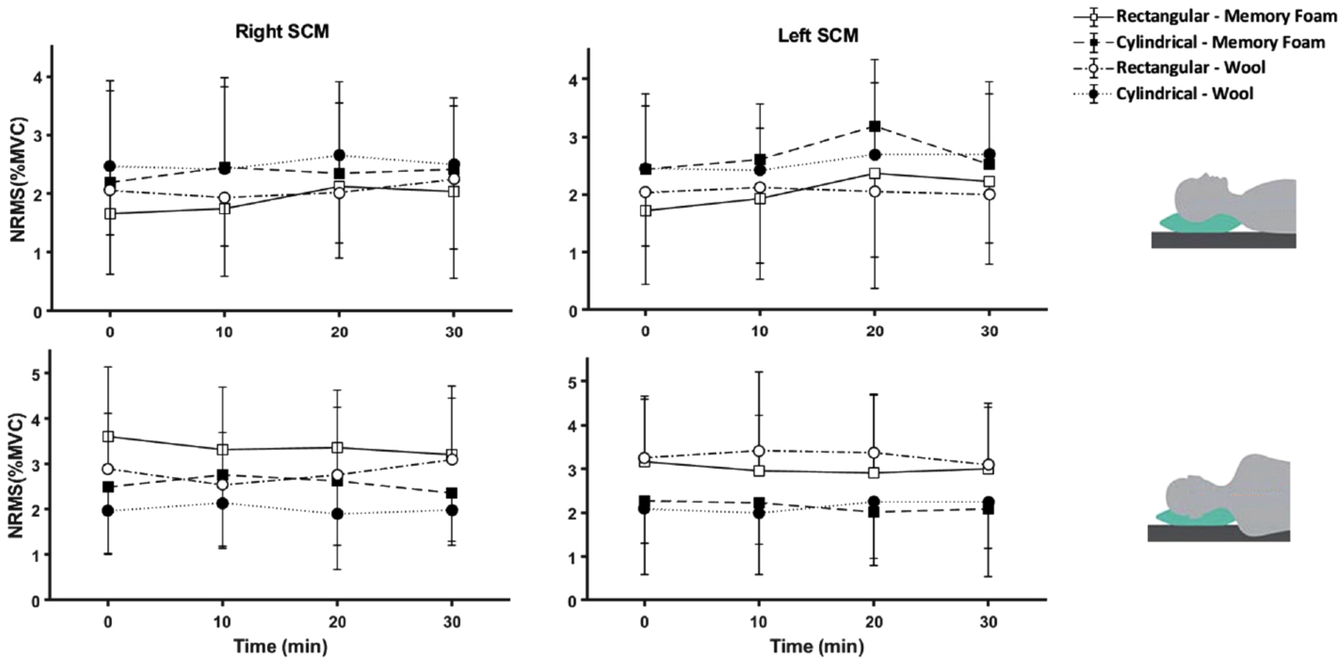

Fig. (4). Changes in mean values of normalized RMS (NRMS) for right and left sternocleidomastoid (SCM) muscles during 30 min sleeping with four pillow conditions in each of the supine (top row) and lateral (bottom row) positions. Error bars represent standard deviation values.

There were no significant effects of time or interaction of time with pillow condition for any of the considered muscles in each of the sleeping positions (Table **2**).

4. DISCUSSION

An ergonomic pillow with an appropriate design can effectively reduce the biomechanical stress on the neck region [2], particularly in the form of undesirable muscular activity (muscular load) [3, 28, 29], and thereby promote the quality of sleep [5]. From this perspective, the present study evaluated the influence of different pillow designs in terms of traditional shape (rectangular/ cylindrical) and content (memory foam/wool) on neck muscular activity and perceived comfort. This study revealed two main findings. First, depending on sleeping position (supine or lateral), the pillow shape can play a significant role in providing comfort and less neck muscular activity during a 30-min sleeping test. Second, the wool material, which tested here as a new pillow content, was relatively achieved similar (or even a little better) consequences for perceived comfort and neck muscular activity in both of the sleeping positions compared to the memory foam material.

In the supine position, although bilateral UT and SCM muscles indicated lower mean activity levels while using the rectangular pillows compared to the cylindrical ones (Fig. **3**), only right UT EMG values were significantly smaller (Table **2**). A previous study has also reported lower EMG activity of neck and shoulder muscles for a basic or rectangular pillow design in a supine position [16]. Naturally, muscular activity can be at its lowest rate in a symmetric lying supine position with appropriate support for the neck and shoulder [30], which may be afforded more effectively by rectangular pillows in the current experiment. Further, significantly higher levels of perceived comfort were reported for the rectangular pillows in relation to the cylindrical ones in the supine position (Table **1**). An optimal comfortable pillow shape in the supine position has been recognized by a design that can provide sufficient support for the head, neck, and shoulders [11]. In this regard, the rectangular pillows in the current study appeared to be more effective than the cylindrical design, as they provided greater comfort in the supine position.

There are two justifications for the higher EMG activity of the right UT muscle under the influence of cylindrical pillows in the supine position (Fig. **3**). First, the cylindrical shape design supports only the weight of the neck and head, which is accompanied by support from the bed surface on the elbow joint in a crossed position of the upper limb across the chest (Fig. **2**). In this situation, the hanging shoulder joint and scapula bone are likely to move into external rotation and retraction, respectively. Thus, there is a continuous stretch on the UT muscle that can induce a higher spindle discharge on alpha motor neuron pools and this can lead to a higher tonic activity [31]. Second, all the participants declared that they prefer the right-side lateral sleeping position, therefore, there has always been a tendency for them to change from the supine to the lateral position. This can lead to a continuous relative readiness in the muscles of the right side of the body (in particular, neck and shoulder muscles) for rotation. In addition, as the cylindrical pillows were found to be more comfortable during lateral sleeping positions in this study, their presence in the supine position can further induce a tendency to rotation. This mental state may finally be a cause for higher basic mean activity in the right UT muscle during sleep in the supine position.

Regarding the lateral position, higher reported perceived comfort for the cylindrical pillows in relation to the rectangular samples (Table **1**) was obviously supported by a significantly reduced muscular activity in most of the monitored muscles (Left UT and bilateral SCM) (Table **2**) (Figs. **2** and **3**). As all of the participants adopted a right side sleeping position, the right shoulder was in contact with the ground in which an inappropriate neck support can lead to a higher EMG activity of UT muscle on the upper side (left side here) to maintaining the cervical alignment. A recent study has also indicated that the activation of UT muscle on the upper side during lateral sleeping positions was significantly affected by a rectangular pillow design [29]. Accordingly, this study's findings confirmed this issue by recording the highest EMG values for the left UT muscle while sleeping on rectangular pillows in the lateral position (Fig. **2**). However, the more appropriate contact form of the cylindrical pillows with the neck area has possibly provided sufficient support for it in the current experiment and afforded a lower level of left UT muscle activity in the lateral position.

From a physiological perspective, the SCM muscle is one of the primary sources of proprioceptive input regarding the orientation of the head in space, and it also plays a significant role in maintaining head balance [32, 33]. It has been suggested that the activity of the SCM muscle was reduced if the cervical spine was aligned horizontally during side-lying by providing appropriate neck and head support [3, 4, 29]. Moreover, a higher contralateral SCM EMG activity (upper side) has also been reported in the lateral position with a rectangular pillow [28]. An asymmetrical bilateral SCM activity is possibly related to the incorrect cervical alignment in the lateral position while using a rectangular pillow design. Similarly, in the present study, the use of rectangular pillows resulted in higher SCM activity, particularly on the left side, compared to the cylindrical design (Fig. **4**), which was accompanied by significantly lower EMG values. As noted, these favorable findings, in terms of reduced unnecessary SCM muscle activity with cylindrical pillows, can be attributed to their better ability to support the cervical spine [34, 35].

Moreover, the feasibility of wool as a pillow filling compared to the more commonly used material, memory foam should be elaborated.. The usefulness of memory foam as a pillow content has been comprehensively evaluated by previous studies relevant to sleep quality and comfort [13, 36], cervical alignment [15, 36], muscular activity [16, 29], and pressure distribution [12, 14]. However, in the current experiment for pillows that had the same shape but different content (R_{mf} and R_w or C_{mf} and C_w), there were no considerable differences between wool or memory foam materials relevant to both the perceived comfort and neck muscular activity. Interestingly, in limited cases of comparison between the two main shapes, the wool pillows had better results for muscular activity. In the supine position, the C_w pillow provided UT EMG activity levels more analogous to the rectangular pillows (R_w and R_{mf}) unlike C_{mf} which significantly had higher activity levels (Fig. **3**). In addition, the similar pattern was observed for the R_w in the lateral position regarding right SCM EMG activity in relation to cylindrical pillows (C_w and C_{mf}). Unfortunately, no study was found for comparison in which the biomechanical impacts of wool assessed as a pillow content. However, whether a wool pillow is more effective than other pillows remains to be evaluated by future studies.

CONCLUSION

The findings of this study highlight the significance of congruence between pillow shape and sleeping position in providing comfort and reducing unnecessary neck muscle activation. In this regard, a higher level of perceived comfort with less neck muscular activity was distinctively observed for rectangular and cylindrical pillows in the supine and lateral positions, respectively. Therefore, it can be suggested that subjects who who primarily sleep in the supine position would benefit more from a rectangular pillow design, while those who sleep more often in a side-lying position may find a cylindrical pillow more suitable. Additionally, for both pillow shapes, the findings indicated the biomechanical advantage of wool as a pillow material, evidenced by reduced neck muscle activity and acceptable levels of perceived comfort in both supine and lateral sleeping positions. This suggests that wool could be considered a promising material for pillow design. However, further studies should be conducted in real-world settings or incorporating more comprehensive evaluation methods (such as cervical alignment, pressure distribution, and sleep quality) as well as during long-term usage of pillows with diverse populations to validate the current findings.

AUTHORS' CONTRIBUTION

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

LIST OF ABBREVIATIONS

EMG	=	Electromyographic
SCM	=	Sternocleidomastoid
UT	=	Upper trapezius
VAS	=	Visual Analog Scale
MVC	=	Maximal voluntary contraction
LSD	=	Least significant difference

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Ethics Committee of Urmia University of Medical Sciences, Iran approved the study protocol (IR.UMSU.REC.1397.481).

HUMAN AND ANIMAL RIGHTS

All human research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

Verbal informed consent was obtained from all participants involved in the study. Since the topic was not sensitive and the information gathered did not pose any adverse social or individual consequences, the Ethics Committee approved that verbal consent was sufficient.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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