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Original Article

Effect of pillow size preference on extensor digitorum communis muscle strength and electromyographic activity during maximal contraction in healthy individuals: A pilot study

Jia-Chi Wang [a,b], Rai-Chi Chan [a,b], Han-Lin Wu [a], Chih-Jou Lai [a,b,*]

[a] *Department of Physical Medicine and Rehabilitation, Taipei Veterans General Hospital, Taipei, Taiwan, ROC*
[b] *Department of Physical Medicine and Rehabilitation, National Yang-Ming University, Taipei, Taiwan, ROC*

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Abstract

Background: Cervical pillow height is an important factor that affects the perception of pillow comfort. However, few studies have addressed methods for predicting a patient's preferred cervical pillow size. We studied the effect of pillow size preference on the strength and electromyographic (EMG) signals of the upper extremity muscle. If the response of the upper extremity muscle is affected by pillow size preference, this would aid in devising an alternate strategy for selecting the optimal pillow size.
Methods: Twenty-nine healthy individuals (mean age: 28.6 years, range: 24−55 years) participated in this study. The participants performed isometric maximal finger extension in the supine position with their heads supported on four different size preferences of cervical pillow (the most comfortable, next most comfortable, worst, and next worst). Maximal contraction force and peak-to-peak EMG amplitude of the extensor digitorum communis (EDC) during contraction were measured. One-way repeated-measures analysis of variance was used to evaluate the effect of pillow size preference. We also explored the relationship between anthropometric parameters and the individual's cervical pillow height preference.
Results: The two most comfortable pillows were associated with significantly larger maximal EDC force than the two worst pillows. However, no significant differences in EMG were observed between pillows. No statistically significant correlation was found between anthropometric parameters and pillow height preference.
Conclusion: The results suggest that anatomical body measurements are not good predictors of optimal pillow height. As EDC muscle strength is affected by pillow height preference, maximal EDC muscle strength may be a useful complement for selecting the optimal pillow size.

Keywords: bedding and linens; electromyography; muscle strength

1. Introduction

Cervical pillows come in a variety of heights and curves, with the goal of maintaining proper cervical spine alignment. Recent studies have shown that cervical pillow height is an important factor that affects the perception of pillow comfort.[1,2] Erfanian et al[1] showed that a cervical pillow with a uniform height is not appropriate for everyone. Therefore, the "best" cervical pillow height differs among individuals.

Nevertheless, few studies have addressed methods for predicting a patient's preferred cervical pillow size. When trying to select a comfortable pillow among several sizes, most consumers base their choice on their physical "size". Erfanian et al[1] found no statistically significant correlation between cervical dimensions and pillow height preference. The authors concluded that cervical measurements are not useful for

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Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

* Corresponding author. Dr. Chih-Jou Lai, Department of Physical Medicine and Rehabilitation, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Beitou District, Taipei 112, Taiwan, ROC.
E-mail address: cjlai@vghtpe.gov.tw (C.-J. Lai).

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predicting appropriate cervical pillow height. Therefore, the physical size of an individual may not serve as a good predictor for pillow height preference. Hence, recommendations of optimal pillow height based on physical size are inappropriate. Without an effective tool to assist consumers in the selection of optimal pillow size, this has become a difficult task. Thus, it is necessary to develop methodologies for assessing the optimal pillow size.

Changes in cervical afferent input may play a role in the modulation of muscle response of the upper extremity. In a study conducted by Suter and McMorland,[3] neck pain was shown to cause substantial muscle inhibition in bilateral elbow flexors, but this muscle inhibition decreased immediately following cervical spine manipulation. Moreover, a growing body of evidence indicates that extremity muscle inhibition is reduced immediately after spinal chiropractic adjustment, which in turn immediately improves muscle strength.[3–6] A possible neurophysiologic mechanism is that the altered afferent information due to joint manipulation can affect efferent motor output to the surrounding musculature.[3,5,7] Taken together, this evidence suggests that altered cervical afferent input may affect upper extremity muscle activation. These results question whether changes in cervical alignment due to pillow size preference, which change sensory input, alter activation of the upper extremity muscles. Thus, it can be hypothesized that an uncomfortably sized pillow may produce noxious or inappropriate sensory input and result in a poor motor response. If the response of the upper extremity muscle is affected by pillow size preference, this would aid in devising an alternate strategy for selecting the optimal pillow size.

Therefore, the objective of this study was to determine the effect of pillow size preference on maximal voluntary contraction and electromyographic (EMG) activity of the extensor digitorum communis (EDC) muscle. Muscle activity was hypothesized to significantly differ with different pillow size preferences. In addition, the relationship between anthropometric parameters and the individual's cervical pillow height preference was investigated.

2. Methods

2.1. Participants

The inclusion criteria were healthy individuals aged >18 years who were able to understand and follow simple verbal instructions and had no injury to the cervicothoracic spine or dominant upper limb in the previous 6 months. Participants were excluded if they had a neurological or orthopedic condition on the dominant upper limb, cervicogenic dizziness/headache, or were currently receiving treatment for cervicothoracic spine pain.

2.2. Experimental procedure

The study was approved by the Institutional Review Board of Taipei Veteran General Hospital, Taipei, Taiwan. All participants provided informed consent.

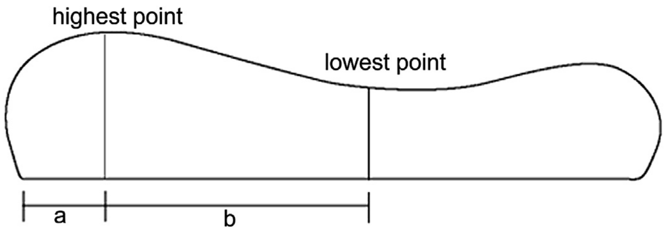

Fig. 1. Illustration of the pillow construction where ‘a’ represents the distance (in length) from the highest point of the pillow to its top edge and ‘b’ represents the distance (in length) from the highest point of the pillow to its lowest point.

2.3. Participant self-selection of preferred and non-preferred pillows

Eleven cervical pillows with the same content but different sizes were tested. To ensure consistency in materials and production, all cervical pillows were obtained from the same manufacturer; therefore, only the pillow size and curvature differed. The pillow construction is illustrated in Fig. 1. The detailed dimensions of the 11 trial pillows are shown in Table 1. The pillow height varied from 6 cm to 12 cm and pillow width from 31 cm to 34 cm. The length of the pillows was 61 cm. To assist in blinding of the participants and assessors, the trial pillows were covered with pillowcases of the same brand and color. The pillowcase of each pillow was numbered randomly from 1 to 11.

All participants were asked to test every trial pillow in the supine position and to select the most comfortable, next most comfortable, worst, and next worst of the 11 pillows. Participants were allowed as much time as needed to make their selection, and were given time to sit up, stretch, and move their neck between their evaluation of each pillow.

2.4. Measurements

The initial assessment included anthropometric parameters including body mass index (BMI), neck length, and neck width. All measurements were taken by the same physical therapist. The neck measurements were obtained with the participant's neck positioned in the neutral position while standing erect. Neck length was measured from the external occipital

Table 1
Details of the 11 trial pillows.

Pillow	Pillow dimensions (cm)			a (cm)	b (cm)
	Length	Width	Height		
1	61	31	6	6.0	12.5
2	61	31	6	5.0	12.5
3	61	31	7	6.5	12.0
4	61	31	7	4.0	12.0
5	61	31	8	4.5	15.0
6	61	31	8	4.0	12.0
7	61	31	9	3.5	14.5
8	61	31	9	4.0	13.0
9	61	32	10	5.5	12.5
10	61	34	11	5.5	12.0
11	61	34	12	5.5	12.5

protuberance to the seventh cervical spinous process. Neck thickness was measured with the participant standing erect against the wall, and the length from the apex of the cervical lordosis curve to the wall was recorded.

Thereafter, the individuals were in the supine position with their heads supported by a variety of pillow sizes. Pillows were tested in a randomized sequence among participants. The isometric maximal voluntary contraction force and surface EMG of the EDC of the participants' dominant arm were examined.

EDC muscle activity was recorded using silver/silver chloride surface electrodes (model 9013S0242, Alpine Biomed, Skovlunde, Denmark). After careful cleansing of the skin area, surface electrodes were placed over the belly of the EDC, at a 20-mm interelectrode distance. The electrodes were positioned in the middle of the forearm, approximately half the distance between the radial and ulnar borders, confirming correct placement with finger extension prior to electrode application.[8]

After sensor placement, isometric maximal voluntary contractions of the EDC in each individual were measured using a purpose-built dynamometer.[9,10] The device consisted of a forearm support, strain gauge (SM-50, Interface Inc., Scottsdale, AZ, USA) mounted on a brass plate that did not allow any movement to ensure that the contraction force was isometric, and a digital strain gauge indicator (model 9830, Interface Inc.). Measurements were taken with the forearm flat and pronated, the elbow extended, and the shoulder at 20° abduction. The forearm, wrist, and metacarpal bone were secured firmly with a strap. The plate of the dynamometer was placed on the dorsum of the proximal phalanges (Fig. 2). The participants practiced once before the actual test for initial familiarization with the testing procedure. Then, the blinded assessor instructed and encouraged participants to perform maximal contraction against the resistive contact. The maximal voluntary contraction was maintained for 3 seconds and was repeated three times with 1-minute rest intervals between the trials. Surface EMG was measured using a Medelec Synergy device (Viasys Healthcare, Oxford Instruments, Abingdon, UK) during these contractions. A sampling frequency of 800 Hz and a bandwidth between 10 Hz and 1000 Hz were used. The 3-second EMG segments were used to determine the peak-to-peak EMG amplitude. For measuring both strength and EMG activity, the mean value of three repetitions was used for further analysis.

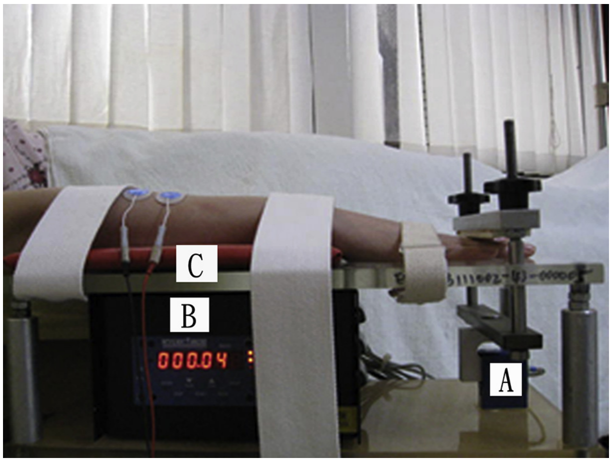

Fig. 2. The purpose-built dynamometer consisting of (A) a strain gauge load cell mounted on a plate; (B) a digital strain gauge indicator; and (C) a forearm support.

2.5. Statistical analysis

The repeated-measures one-way analysis of variance (ANOVA) was used to determine the effects of pillow height preference on the maximal contraction force and peak-to-peak EMG amplitude of the EDC. *Post hoc* analyses were performed with the least significant difference test to evaluate the significance of between-pillow pair-wise comparisons. In addition, Pearson correlations were used to assess the significance of associations between anthropometric parameters and the height of the best self-selected pillow. All statistical analyses were performed using SPSS Statistics 21.0 (IBM Corp., Armonk, NY, USA). For all analyses, statistical significance was defined as $p < 0.05$.

3. Results

Twenty-nine individuals (13 men and 16 women, mean age: 28.6 years, range: 24–55 years) participated in the study. Demographic and clinical characteristics of the participants are presented in Table 2. The distribution of the best and the worst self-selected pillows across the 11 trial pillows is shown in Fig. 3. The pillows that were graded as the best and worst differed from person to person.

3.1. Maximal contraction force and peak-to-peak EMG amplitude of the EDC

Table 3 shows the EDC force and EMG activity between pillows. Maximal force of the EDC significantly differed across the four pillows (F = 7.962, $p < 0.001$). The maximal EDC contraction force was the highest for the most comfortable pillow and the lowest for the worst pillow. Pairwise

Table 2
Demographics and anthropometric measurements of the participants.

Age (y)	28.6 ± 4.02
Sex (M/F), *n*	13/16
Body length (cm)	166.92 ± 8.8
Body weight (kg)	58.38 ± 10.4
BMI (kg/m^2)	20.83 ± 2.19
Neck length (cm)[a]	11.7 ± 1.7
Neck thickness (cm)[b]	4.1 ± 0.9

Data are presented as *n* or mean ± standard deviation.
BMI = body mass index; F = female; M = male.

[a] Neck length was measured from the external occipital protuberance to the seventh cervical spinous process.

[b] Neck thickness was measured from the apex of cervical lordosis curve to the wall.

Fig. 3. Best pillow frequency distribution.

comparisons revealed significantly greater EDC force for the two best pillows compared with the two worst pillows. The best pillow was associated with a larger EDC force than the second-best pillow; however, this difference was not statistically significant ($p = 0.365$). The EMG amplitude of the EDC was not significantly different between pillows ($F = 0.741$, $p = 0.531$).

3.2. Relationship between the anthropometric parameters and height of the best self-selected pillow

The height of the best self-selected pillow did not correlate with any anthropometric parameters obtained in this study, including body weight, body length, BMI, neck length, and neck thickness.

4. Discussion

Among all the related studies in the literature, the present study is the first to explore the effects of pillow size preference on the response of the upper extremity musculature. As hypothesized, pillow size had significant effects on forearm muscle response. Significantly greater muscle force was found with the two most comfortable pillows compared to that with the two worst pillows. In addition, we confirmed that the optimal pillow size varies among individuals.

4.1. Relationship between pillow size preference and strength measurements

A possible explanation for the change in the EDC muscle response according to different pillow size preferences is that altered afferent input of the cervical spine caused by uncomfortable pillows results in reflex-type muscle inhibition of the upper extremity. Inhibition is frequently observed in muscles that cross the joints owing to joint pathology.[11] However, several studies demonstrated that muscle inhibition due to spinal dysfunction can occur in muscle groups that are not directly connected to the spine.[3,12] Suboptimal cervical alignment due to an uncomfortable pillow may produce noxious or uncomfortable sensory inputs and therefore affect the normal efferent outflow to muscles of the upper extremity, causing significantly decreased EDC strength. A corresponding increase in EDC muscle force with the use of the two best pillows indicates overall improved EDC activation. Further studies measuring muscle inhibition using the interpolated twitch technique should continue to investigate whether muscle inhibition is the mechanism responsible for these force changes.[3,5,13]

The differences in muscle strength between the pillow size preferences can also likely be explained by a mechanical effect. Clinicians have postulated that abnormal cervical spine alignment alters the muscle response of the upper extremity. Manual muscle testing, when employed by chiropractors, is not just a test for functional integrity of the muscle and nerve supply; rather, it may also serve as a means to diagnose structural dysfunction.[14] In a study by Farmer and Wisneski[15] the pressure within the interforamen showed significant changes with varying degrees of flexion and extension of the cervical spine. Thus, alterations in cervical alignment caused by various pillow size preferences could alter the pressure within the interforamen that interferes with intraneural microcirculation homeostasis, which is essential for nerve root function.[16] Sleeping on a pillow of improper height may place the cervical spine vertebrae into misalignment, causing discomfort. Minimal joint misalignment may place pressure on the nerve root and interfere with nerve impulse transmission. Conversely, sleeping on a comfortable pillow of an appropriate height may place the cervical spinal vertebrae into better alignment. A reduction of the interference to the nervous system would

Table 3
Means and standard deviations (SD) for maximal force and electromyographic (EMG) activity of the extensor digitorum communis between pillows.

Variable		mean ± SD	F	p^a	*Post hoc* test
Maximum force (kg)	Most comfortable pillow (1)	2.521 ± 0.304	7.962	<0.001	1 > 3*
	Next most comfortable pillow (2)	2.321 ± 0.272			1 > 4*
	Next worst pillow (3)	1.668 ± 0.197			2 > 3*
	Worst pillow (4)	1.647 ± 0.211			2 > 4*
EMG amplitude (μV)	Most comfortable pillow (1)	19,340 ± 30,558	0.741	0.531	
	Next most comfortable pillow (2)	16,935 ± 28,259			
	Next worst pillow (3)	15,792 ± 24,512			
	Worst pillow (4)	31,043 ± 82122			

[a] p value for repeated-measures analysis of variance.

* Significant differences between the pillows as indicated by *post hoc* least significant difference tests at $p < 0.01$.

thereby allow the muscles to more fully express their functional potential, including an improvement in strength.

In this study, muscle strength of the EDC was affected by pillow size preference; therefore, this result may help in finding an alternative strategy for selecting the optimal pillow size. To reveal its clinical value, further studies are needed to investigate whether measuring quantitative force of the upper extremity is an objective method to determine the optimal pillow size.

4.2. Relationship between pillow size preference and EMG

Although the maximal EDC force significantly differed across pillows, EMG did not significantly differ between pillows. Two potential factors may account for the differences between the two measurements. The first one could be electrical crosstalk from surrounding muscles. It is important to recognize that the bipolar surface EMG detected above a particular muscle is not always a selective representation of the electrical activity of that muscle.[17,18] As the EDC muscle is small and close to the adjacent musculature, the detection of crosstalk signals is a concern. Thus, the surface EMG activity may not represent the electrical activity of the EDC muscle. Another explanation may be that fast muscle fibers inside the EDC muscle were not located in the region near the electrode. Fast fibers generally have larger diameters and generate high signal amplitude. Thus, the relative location of fast muscle fibers with respect to the electrodes could also influence the magnitude of the surface EMG signal.[19]

Although no significant difference in EMG was observed between pillows, the EMG data of the worst pillow exhibited a higher peak-to-peak EMG amplitude and greater variability than did that of other pillows. In this study, a dynamometer was used to measure isometric maximal voluntary contraction of the EDC. The forearm, wrist, and metacarpal bone were secured with a strap. When performing finger extension during uncomfortable neck support, the EDC as well as the other wrist and finger extensor muscles of the forearm are probably recruited to resist the strap which is used to constrain the metatarsal bone and the resistive plate of the dynamometer. The potential for recruiting a number of muscles during finger extension on the worst pillow and differences between individuals might lead to large variability in the EMG amplitude during finger extension on the worst pillow.

4.3. Relationship between anthropometric parameters and pillow height preference

Our study found that the height of the best self-selected pillow did not correlate with anatomical parameters, including body weight, body length, BMI, neck length, and neck thickness. These results were similar to those of Erfanian et al,[1] who assessed whether cervical measurements were predictive of the preferred cervical pillow height, given a choice of four different heights. A total of 105 individuals were assessed using three specific cervical measurements. After approximately 10 minutes of pillow trials, participants were asked to choose the most comfortable pillow. The authors noted no statistically significant relationships between the cervical measurements and pillow height preference. Therefore, in light of the findings of Erfanian et al[1] and those of our study, optimal pillow height recommendations based on anatomical body measurements may be inappropriate.

Some limitations to the present study need to be mentioned. The first was the reliance on the short timeframe used for comfort rating and pillow selection. Evaluating pillows after a short time might not allow for the selection of a pillow that will provide the best sleep quality over an extended period, because a longer duration may be needed for becoming accustomed to a new pillow. Second, the current findings are limited to healthy individuals. Further studies should be conducted with patients with cervical pain. Third, this study only evaluated the pillow size preference in relation to the muscular response of the forearm. There are various cervical pillows with different designs and filling materials on the market. As only one type of commercially available cervical pillow was assessed in our study, we are unable to generalize our findings to any other cervical pillow. Further studies investigating different pillow designs and filling materials are necessary to determine whether such findings are consistent with different types of pillows. Lastly, in our study, we tested only the largest peak-to-peak amplitude of surface EMG muscle activities, which gives a rough estimate of signal intensity. Future studies using different approaches to define EMG amplitude, such as average rectified amplitude or root mean square amplitude, should be conducted to see if the amplitude of surface EMG is affected by pillow size preference.

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