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Biomechanical Effectiveness and Anthropometric Design Aspects of 3-dimensional Contoured Pillow

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Objective: The aim of this study was to evaluate the effectiveness of 3 dimensional contoured pillow through analyzing contact pressure and to suggest its design guidelines through analyzing the posture of head and neck area.

Background: The quality of sleep is a very important factor closely related with human's health. To improve the quality of sleep, the verification of design factors affecting the posture of the head and neck is needed, and a pillow design that can induce proper posture is required.

Method: This study measured the contact pressures of the two reference groups (bead and cotton pillows) as a method to evaluate the design effectiveness of the contoured pillow. This study proposed 3-dimensional design guidelines by drawing anthropometry (head length) affecting cervical curvature angle (CCA) through the measurement of the participants' cervical curvature angles.

Results: In the design effectiveness evaluation, the contact pressure of cervical region was higher than that of a reference group (cotton pillow), and contract area increased, and contract pressure decreased in the shape distributing the occipital region's body pressure. This study proposed pillow's cervical supporting height by percentile of a head length [head length (%tile) (cervical supporting height) affecting the posture of the head and neck: 14.6cm (5%tile) (6.2cm), 15.5cm (25%tile) (6.7cm), 16.4cm (50%tile) (7.1cm), and 19.3cm (75%tile) (8.9cm)].

Conclusion: This study confirmed the contoured pillow's design effectiveness maintaining cervical angle comfortable to sleep with the shape supporting the cervical vertebrae and by reducing the contact load of the occipital region. Also, this study proposed pillow design guidelines based on the 3-dimensional contoured pillow design effectiveness, through which the study laid the foundation for pillow design in a systematic method.

Application: The results of this study are expected to be utilized as the basis data by which the optimum pillow type and pillow design according to main percentile can be standardized.

Keywords: 3-dimensional contoured pillow, Posture of the head and neck, Pillow design guideline, Effectiveness of pillow, Contact pressure

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1. Introduction

A human spends 1/3 of his/her life with sleep. Sleep has the following important functions: physical restoration (Opp, 2009; Schütz et al., 2009; Zager et al., 2007) energy conservation, preservation and protection (Amaranath, 2015), memory processing and

learning (Gradisar et al., 2008; Turner et al., 2007), and brain development (Morrissey et al., 2004). Therefore, Gordon and Grimmer-Somers (2011) reported that the quality of sleep is a very important factor closely related with human's health. They said one of the methods improving the quality of sleep is to maintain proper sleep posture. Modern people make an effort to use various pillows and find a pillow suitable to themselves as a method to seek proper sleep posture. Kim et al. (2011) asserted that the use of an unsuitable pillow causes insomniac and pain in the muscle of cervical region and becomes a cause of chronic fatigue.

There were many studies on pillow use to maintain proper posture, and most studies and pillow developments are based on the sleep posture of ideal pillow use in the previous studies (Cyriax, 1988; Liebenson, 1996). According to the previous studies mentioned above, cervical pain may occur or deteriorate, due to wrong sleep posture, and cervical curvature needs to be maintained in order to take ideal sleep posture. Therefore those previous studies report that cervical curvature needs to be maintained, and occipital region should be simultaneously supported through cervical region support for an ideal pillow.

In the same context, it was reported that the factors on spine curve from ear to shoulder (angle, distance in the sagittal and crown plane) in a supine position, which is a natural position during sleep, seriously affect the ideal posture of the head and neck for pillow use proposed by Chen and Cai (2012).

To embody the ideal posture of the head and neck for ideal pillow use, pillows of various materials and types are developed. Among these, the most representative type pillow is a contoured pillow. The contoured pillow encases the occipital region with a 3-dimensional shape, and is structured as a form supporting cervical vertebrae, and latex, rubber, and polyester are used as its material.

Studies on the diverse designs and effectiveness of the contoured pillow are actively carried out. Previous studies (Lavin et al., 1997; Erfanian et al., 2004; Chen and Cai, 2012) analyzed anthropometry, designed a new contoured pillow and analyzed design factors' effectiveness according to sleep duration through a video analysis.

Gordon et al. (2009) conducted a survey on pain and satisfaction with sleep according to the use of each pillow type, and the study result reported that pillows made with rubber showed higher satisfaction with pain relief, compared to the contoured pillow.

Although studies on effectiveness of various pillow designs inducing the ideal posture of the head and neck were performed, there were no basis data on the design effectiveness that measured and evaluated quantitative factors in terms of the posture of the head and neck supporting the cervical and occipital regions. Also, studies on the 3-dimensional contoured pillow design guidelines were insufficient.

This study evaluated design effectiveness by selecting a contoured pillow that can induce the cervical curvature posture by distributing contact load and supporting the occipital and cervical regions, due to the shape encasing the occipital region (Lee et al., 2000; Levangie and Norkin, 2005). Based on the design effectiveness result, this study proposed the design guidelines of a 3-dimensional contoured pillow by drawing the anthropometry affecting the effectiveness.

2. Method

This study selected a contoured pillow with a shape encasing and supporting the occipital region and also supporting the cervical region. This study selected the following as reference groups for the effectiveness verification of cervical supporting type design: a bead pillow with characteristics opposite to the contoured pillow's, because shape change is small due to the pillow filled with hard plastic grains, and there is no part that can support the cervical region and a cotton pillow, of which shape naturally changes according to the occipital region shape, when one lies down, since the pillow is made of soft cotton.

This study measured and analyzed the contact pressures of the three types of pillows in order to evaluate design effectiveness on the supporting level of the occipital and cervical regions of the selected contoured pillow (Table 1).

Table 1. Characteristics of three types of pillows (Independent variable of pillow design effectiveness)

	Bead pillow	Cotton pillow	Contoured pillow
Image			
Size (mm)	540 (L) x 370 (D) x 170 (H)	600 (L) x 370 (D) x 160 (H)	641 (L) x 311 (D) x 115 (H)
Inside material	Plastic beads	Cotton	Polyurethane
Cover material	Cotton	All-Cotton	Cotton, Polyester
Characteristics	Almost no shape change. No cervical supporting part	Natural shape changes. No cervical supporting part.	3-dimensional shape encasing the occipital region and supporting the cervical region. Small shape change There is cervical supporting part.

Based on the studies (Levangie and Norkin, 2005; Kim et al., 2011) reporting that maintaining the 15 degrees of cervical curvature angle is an ideal posture of the head and neck, which is similar to a standing posture, this study measured and analyzed cervical curvature angle (CCA), and produced the anthropometric factors affecting the CCA.

The participants in the experiment changed clothes to experimental clothes for design effectiveness evaluation. After their basic physical information (height, weight, and BMI) was measured, the sizes related with pillow use (head breadth, head length, and head circumference) were measured.

The study group included four healthy males (mean age: 32.5±2.06, height: 174.3±5.5cm, weight: 80.7±14.0kg, BMI: 26.5±3.9kg /m^2, head breadth: 16.4±0.33cm, head length: 17.8±0.87cm, head circumference: 62.3±2.28cm) and five healthy females (mean age: 31.6±2.0, height: 164.2±5.3cm, weight: 53.5±4.5kg, BMI: 19.8±0.63kg/m^2, head breadth: 15.5±0.56cm, head length: 15.9± 1.76cm, head circumference: 56.7±4.38cm) (Table 2). This study received approval from the Public IRB designated by the Ministry of Health & Welfare, South Korea. All patients participated in the experiment after signing a participation agreement. They were paid monetary reward.

Table 2. Characteristics of participants

Participants	Sex/age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Head breadth (cm)	Head length (cm)	Head circumference (cm)
1	M/35	171	90.7	31.0	16.1	18.2	65
2	M/34	167	57.1	20.5	16.0	19.0	64
3	M/30	179	91.6	28.6	16.8	17.0	60

Table 2. Characteristics of participants (Continued)

Participants	Sex/age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Head breadth (cm)	Head length (cm)	Head circumference (cm)
4	M/31	180	83.4	25.7	16.6	16.9	60
5	F/34	160	50.9	19.9	15.3	13.5	52
6	F/34	168	58.2	20.6	16.0	15.0	56
7	F/30	167	56.3	20.2	14.5	15.5	55.5
8	F/30	156	45.8	18.8	16.0	16.5	55
9	F/30	170	56.2	19.4	15.7	18.8	65
M ± SD	32.0±1.95	168.7±6.96	65.6±15.91	22.7±4.03	15.9±0.61	16.7±1.63	59.2±4.30

BMI: Body Mass Index

2.1 Design effectiveness of contoured pillow

2.1.1 Measurement of contact pressure

As shown in Figure 1, the contact pressure was measured in the natural supine position by locating head on a pillow equally, based on tragion's location, after spreading a pressure mat (Pliance, mat-type, Novel GmbH, Munich, Germany) on a pillow. And then, the contact pressure was measured from the three types of pillows (bead, cotton, and contoured pillows) mentioned above

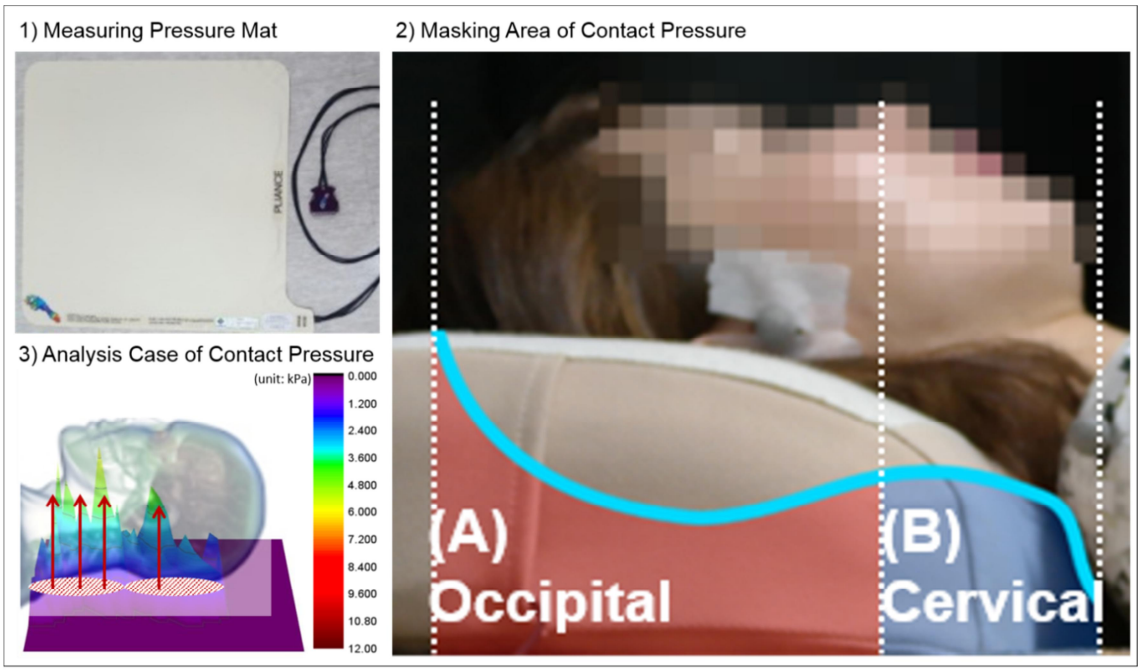

Figure 1. Measuring and analyzing contact pressure of occipital and cervical regions, 1) measuring pressure mat (pliance, mat-type, novel GmbH, Munich, Germany, 2) masking area of contact pressure ((A) occipital region, (B) cervical region), 3) analysis of contact pressure

for three minutes, respectively. The experimental on the three types of pillows were carried out randomly according to each participant. The contact pressure was measured by connecting the pressure mat with a notebook computer wirelessly through data acquisition equipment (Novel, Inc.).

2.1.2 Analysis of contact pressure

The pressure data of the three types of pillows measured by the pressure mat were measured with three independent variables, namely contact area (unit: m^2), contact pressure (unit: kPa), and contact force (unit: N), based on the occipital and cervical regions, which are the masked areas of Figure 1, 2). First, the contract area is the data on the area where contract pressure occurs, and the result on the supporting area can be checked. Second, the contact pressure was analyzed being divided into mean pressure and peak pressure. The mean pressure is the mean value of sensor units' pressure data on the occurrence of contact pressure. The peak pressure is the maximum pressure value among the sensor units' pressure values on the occurrence of contract pressure. The low mean pressure and peak pressure data values mean that contact pressure is evenly distributed in the wide range. Third, the contact force is the data on the contact force within the occipital and cervical regions. Namely, it is the data on the force value imposed upon each region. Therefore, this study evaluated the design effectiveness of three types of pillows through 3 independent variables, which are the quantitative data on the supporting level of the occipital and cervical regions.

2.2 Design guidelines of contoured pillow

2.2.1 Measurement of cervical curvature angle (: CCA)

Cervical curvature angle (CCA) was measured by referring to a paper of Kim et al. (2011). The participants conducted the experiment with natural supine position in the three types of pillows (bead, cotton, and contoured pillow). To measure CCA, the CCA was shot with a digital camera from the side by attaching reflection markers on the tragion and shoulder tip point. According to the measuring method of Kim et al. (2011) as shown in Figure 2, this study defined the angle of the line segment and base line connecting the (a) tragion and (b) STP as (c) CCA.

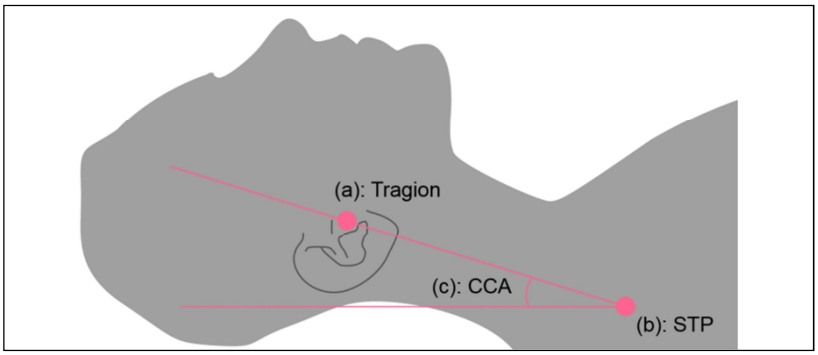

Figure 2. The method of measuring cervical curvature angle [(a) Tragion, (b) STP: Shoulder Tip Point, (c) CCA: Cervical Curvature Angle), Kim et al. (2011)]

2.2.2 CCA data of three types of pillows

Each CCA in the three types of pillows were measured as follows, respectively: bead pillow: 38.0±6.7°, cotton pillow: 20.0±7.0°,

and contoured pillow: 15.7±5.0°. Levangie and Norkin (2005) mentioned that CCA in the standing position was the most ideal CCA value in the posture of the head and neck. Kim et al. (2011), based on such a previous study, said 15° of CCA is the most ideal angle in the posture of the head and neck. Therefore the contoured pillow showed the result the most close to 15° of CCA of the ideal posture of the head and neck in the three types of pillows, based on the previous study. In the multivariate analysis of CCA among the three types through variance analysis, significant differences were shown between the bead and contoured pillows ($p<0.05$); However, no significant difference ($p>0.05$) was shown between the cotton and contoured pillows.

2.2.3 Anthropometry factors of contoured pillow

This study carried out a correlation analysis between the pillow-related anthropometric data (head breadth, head length, and head circumference) and contoured pillow's CCA data. Table 3 shows the correlation analysis result with CCA. Contoured pillow's CCA was analyzed on the basis of standardized data ((|CCA-15|) based on 15°, as well as 9 participant's measured data. As a result of the correlation analysis, there was no correlation between the pillow-related anthropometry and CCA result, but there was a correlation between the pillow-related anthropometry and CCA-standardized data, based on 15°. There was a positive correlation (*: $p<0.05$) between head length (0.778*) and head circumference (0.698*).

Table 3. Correlation analysis between head size and CCA data

		Head breadth	Head length	Head circumference
CCA	Pearson coefficient of correlation	0.109	-0.046	-0.175
	Significance P.	0.781	0.907	0.652
	N	9	9	9
|CCA-15|	Pearson coefficient of correlation	0.447	0.778*	0.698*
	Significance P.	0.228	0.014	0.037
	N	9	9	9

Significance P.: p-value, *: $p<0.05$

This study confirmed that pillow use posture is closely correlated with pillow type design and user's head size through a correlation analysis with CCA, one of the factor judging the effectiveness of the posture of the head and neck. Especially, the correlation with head length was high, and also high correlation with head circumference was shown. However, there was a very strong positive correlation with head length (Pearson coefficient of correlation: 0.940**), and the coefficient of head circumference was lower than that of head length. Therefore this study selected head length as the major anthropometry in the contoured pillow design guidelines. Actually, the guidelines' development was applied as such.

2.2.4 Method of developing design guidelines of contoured pillow

This study defined the contoured pillow's key sizes in Figure 3, related with the head length drawn as major anthropometry mentioned above, as ① supporting occipital height and ② the highest cervical supporting height.

This study drew major percentiles from the head length (horizontal distance from glabella to occipital protrusion point) based on Koreans aged 30~34 (both genders) as the 5th percentile (14.6cm), 25th percentile (15.5cm), 50th percentile (16.4cm), 75th percentile (19.3cm), and 95th (20.6cm). The 50th percentile of lead length was 16.cm, which was the value similar to 16.7±1.56cm,

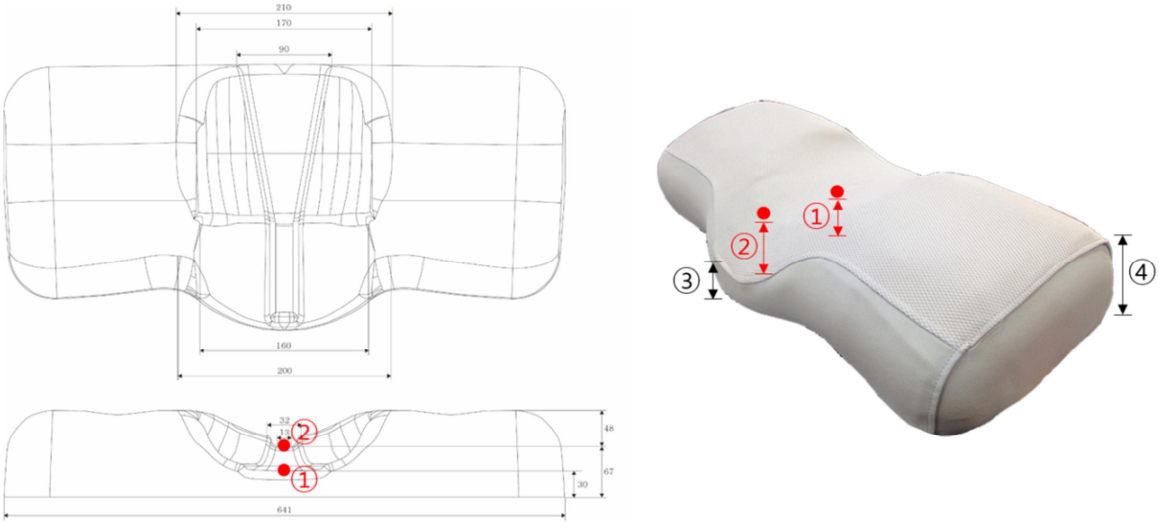

Figure 3. Significant dimension of 3-dimensional contoured pillow (① occipital supporting height, ② the highest cervical supporting height, ③ the lowest cervical supporting height, ④ pillow height

the mean head length of the participants in this study.

This study classified the participants' head length based on the percentile data of Size Korea, and proposed the highest cervical supporting height (Figure 3.② the highest cervical supporting height) of the 5th, 25th, 50th, 75th, and 95th percentiles (no subject data) of Koreans' head length using the participants' CCA data.

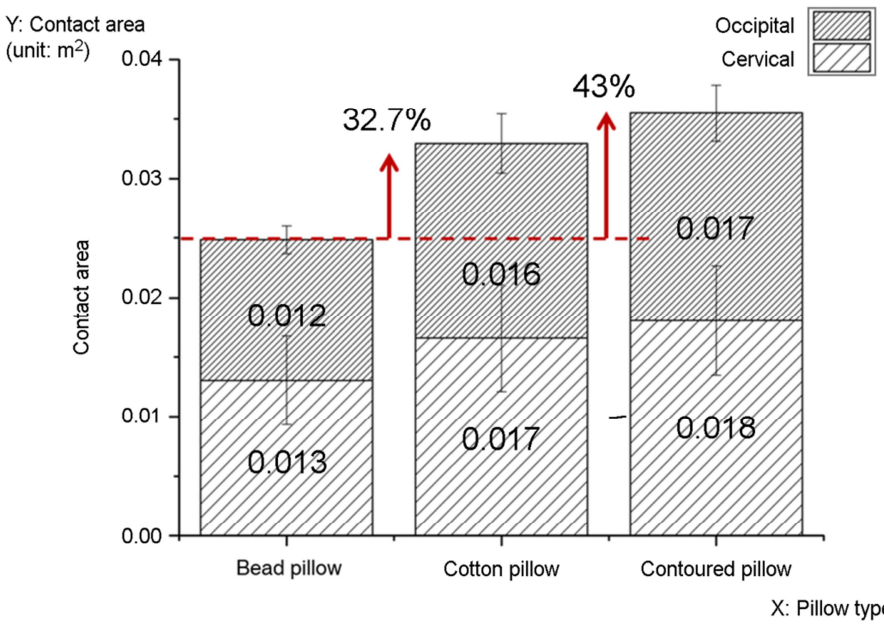

Figure 4. Result of contact pressure area by 3 pillow types (unit: m^2, Y axis: contact area, X axis: pillow type)

Cervical supporting height was drawn by applying |CCA-15|/3 to the cervical supporting height (6.7cm) of the contoured pillow (Figure 4). In consideration of the correlation between the participants' CCA data and head length, this study applied |CCA-15|/3 to the height guidelines by percentile (See the result: Table 4).

2.3 Statistical analysis

Concerning the independent variables, namely CCA, contact area, contact pressure, and contact force, their mean values of the three types of pillows were compared. A multivariate analysis was used to identify significant main effects of pillow type. Individual effects across condition and pillow type were evaluated using a repeated measures analysis of variance (ANOVA). Where main effects were identified, follow-up post hoc comparisons (Tukey's honest significant difference) were performed. The probability associated with a type I error was set at 0.05 for all observations. All statistical analyzes were performed using SPSS, Version 12.0.

3. Results & Discussion

3.1 Result of pillow's design effectiveness

3.1.1 Result of contact area by 3 pillow types

In the contact area result, which is the result of the area where the contact pressure was measured, the contact area of the contoured pillow was demonstrated to be the widest, followed by those of the cotton pillow and bead pillow. The contract area of the cotton pillow increased 32.7%, compared to that of the bead pillow, and the contact area of the contoured pillow increased 43%, compared to that of the bead pillow. Namely, the other pillows' contact areas increased, compared to the bead pillow.

The post-hoc test result of a variance analysis among the pillow type variables on contact pressure is shown in Table 4.

Table 4. Follow-up post hoc comparison (Tukey's HSD) in the result of contact area

Region	Type of pillow		Significance probability
Occipital	'Bead pillow'	'Cotton pillow'	**0.000***
		'Contoured pillow'	**0.000***
	'Cotton pillow'	'Contoured pillow'	0.531
Cervical	'Bead pillow'	'Cotton pillow'	0.204
		'Contoured pillow'	**0.049***
	'Cotton pillow'	'Contoured pillow'	0.745

(*) $p < 0.05$

3.1.2 Result of contact pressure by 3 pillow types

Upon looking at (A) Mean Pressure result from Figure 5, the mean pressure was 1.4kPa in the occipital region of the contoured pillow, smaller than the that of the bead pillow, and it was 1.8kPa in the cervical region of the contoured pillow, higher than that of the cotton pillow, and the same as that of the bead pillow. Upon looking at (B) Contact Peak Pressure result, it was 4.4kPa in the occipital region of the contoured pillow, the smallest, and it was 7kPa in the cervical region of the contoured pillow, the highest.

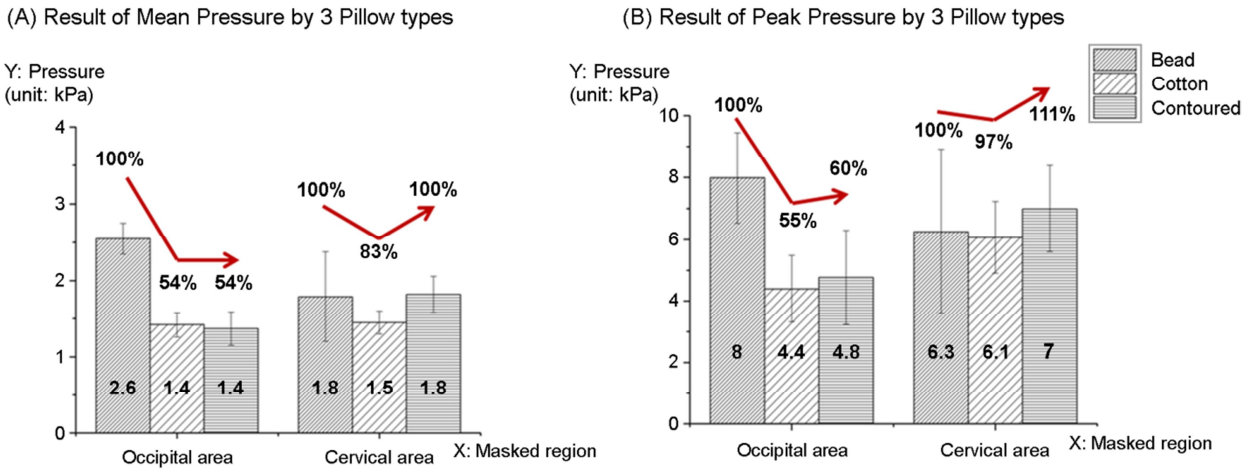

Figure 5. Result of contact pressure [(A): mean pressure, (B): peak pressure)] by 3 pillow types (unit: kPa, Y axis: pressure, X axis: masked region)

The post-hoc test result of a variance analysis among the three types of pillows in terms of contact pressure is shown in Tables 5 and 6.

Table 5. Follow-up post-hoc comparison (Tukey's HSD) in the result of contact pressure (mean pressure)

Region	Type of pillow		Significance probability
Occipital	'Bead pillow'	'Cotton pillow'	**0.000***
		'Contoured pillow'	**0.000***
	'Cotton pillow'	'Contoured pillow'	0.851
Cervical	'Bead pillow'	'Cotton pillow'	0.152
		'Contoured pillow'	0.984
	'Cotton pillow'	'Contoured pillow'	0.111

(*) $p < 0.05$

Table 6. Follow-up post-hoc comparison (Tukey's HSD) in the result of contact pressure (peak pressure)

Region	Type of pillow		Significance probability
Occipital	'Bead pillow'	'Cotton pillow'	**0.000***
		'Contoured pillow'	**0.000***
	'Cotton pillow'	'Contoured pillow'	0.836
Cervical	'Bead pillow'	'Cotton pillow'	0.974
		'Contoured pillow'	0.684
	'Cotton pillow'	'Contoured pillow'	0.550

(*) $p < 0.05$

3.1.3 Result of contact force by 3 pillow types

In the contact force from Figure 6, the contact force in the occipital region of the contoured pillow was 23.2 N, low at just 79% of the bead pillow; however, it was 33N in the cervical region of the contoured pillow, higher about 38%, compared to the other pillow types.

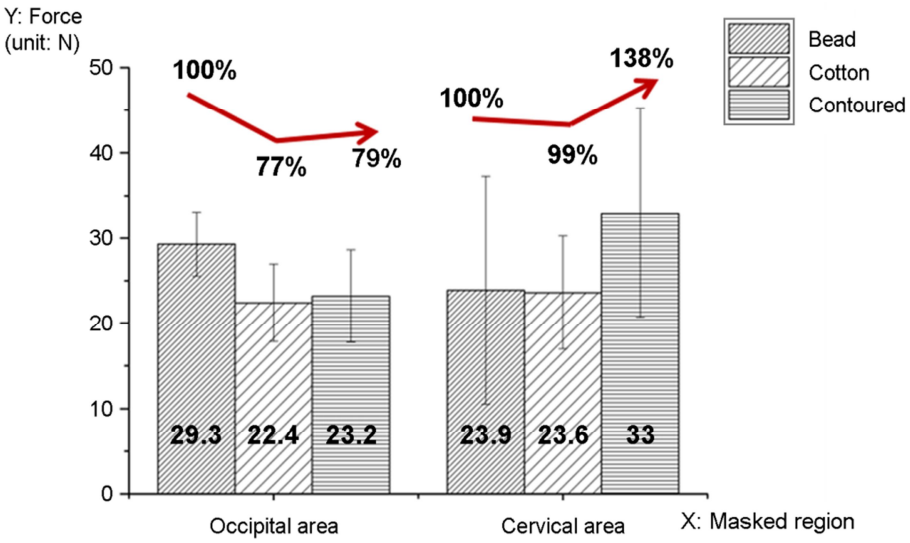

Figure 6. Result of contact force by 3 pillow types (Unit: N, Y axis: force, X axis: masked region)

The post-hoc test result of a variance analysis among the pillow types in terms of contact force is shown in Table 7.

Table 7. Follow-up post-hoc comparison (Tukey's HSD) in the result of contact force

Region	Type of pillow		Significance probability
Occipital	'Bead pillow'	'Cotton pillow'	**0.010***
		'Contoured pillow'	**0.025***
	'Cotton pillow'	'Contoured pillow'	0.931
Cervical	'Bead pillow'	'Cotton pillow'	0.998
		'Contoured pillow'	0.215
	'Cotton pillow'	'Contoured pillow'	0.196

(*) $p < 0.05$

3.1.4 Discussion of contoured pillow design effectiveness

Upon looking at the design effectiveness evaluation result of the 3-dimensional contoured pillow, pillow's shape heavily affects the posture of the head and neck.

According to the post-hoc test result among the variables, there was a significant difference between the bead pillow and the other types of pillows in the occipital region, and no significant difference was shown between the cotton pillow and the contoured pillow. A significant difference was revealed between the bead pillow and the contoured pillow only in the contact area in the cervical region. This is the result, arising from the morphological characteristics of the cotton pillow and contoured pillow, which are the types that can support the occipital region in a shape encasing the occipital region, compared to a hard bead pillow. In the cervical region, there was a significant difference between the bead pillow and contoured pillow only in the contact area, which is judged to be derived from the morphological characteristics of the contoured pillow that can clearly support the cervical region.

As for the contoured pillow that can support cervical region, the effectiveness of design characteristics that can evenly support the occipital region and cervical region was verified through the result of contact pressure, area and force of 3.1 of this study, as shown in the post-hoc test result mentioned above and the morphological design characteristics factors in Table 1.

The design shaped like encasing the occipital region of the contoured pillow had an effect of reducing the peak pressure by widening the contact area of the occipital region. Regarding the design of the contoured pillow that can support cervical region, the cervical region supporting effect was verified through the result of increasing the contact area and contact pressure in the cervical region. Through this, this study ascertained a phenomenon inducing the proper posture of the head and neck.

Upon referring to CCA data in 2.2 of this study, the design effectiveness of the contoured pillow is forecast to be affected by individual anthropometry including user's head length. In this regard, pillow design guidelines by user's anthropometry are needed in order to optimize the design effectiveness of the 3-dimensional contoured pillow.

3.2 Design guidelines of 3-dimensional contoured pillow

The design guidelines of the 3-dimensional pillow were drawn by selecting cervical supporting height as a major size. This study proposed the following: 6.2cm for the users belonging to 5%tile with 14.6cm in head length; 6.7cm for the users belonging to

Table 8. Guidelines of cervical supporting height in 3-dimensional pillow

Head length of Korean (%tile) (unit: cm)	Head length of subject (unit: cm)	CCA (unit: degree)	|CCA-15|	Pillow guidelines of cervical supporting height (unit: cm)
14.6 (5% tile)	13.5	16	1	**6.2**
	15	17	2	
15.5 (25% tile)	15.5	15	0	**6.7**
16.4 (50% tile)	16.5	18	3	**7.1**
	16.9	10	5	
	17	20	5	
19.3 (75% tile)	18.2	13	2	**8.9**
	18.8	7	8	
	19	25	10	
20.6 (95% tile)	No subject data			

*Guidelines of cervical supporting height = 6.7 ± mean of |CCA-15| / 3

25%tile with 15.5cm in head length; 7.1cm for the users belonging to 50%tile with 16.4cm in head length; 7.1cm for the users belonging to 75%tile with 19.3cm in head length. However, the proposed size was not drawn for the users belonging to 95%tile with 20.6cm in head length, due to no subject data (Table 8).

The design of the 3-dimensional contoured pillow needs to maintain the design taking on a shape encasing the occipital region and evenly supporting the cervical and occipital regions. As shown in the effectiveness evaluation of this study, the cotton pillow made of soft material showed an effect to widen the contact area, but there was no sharp increase of contact force, which can be an actual support effect. Therefore a material having stiffness that can simultaneously maintain the softness and shape for cervical support effect should be used.

In the effectiveness evaluation of the contoured pillow used in this study, the part supporting the cervical region and the part supporting the occipital region were divided, and this study confirmed huge cervical region support effect. Based on this, a design dividing the part supporting the cervical region and the part supporting the occipital region should be made.

4. Conclusion

This study laid quantitative basis for design factors through design effectiveness evaluation. This study drew head length as a major anthropometry affecting CCA result, based on CCA data of the contoured pillow. In this study, the cervical supporting height of the 3-dimensional contoured pillow corresponding to the 5%tile, 25%tile, 50%tile, and 75%tile of the head length size of Koreans aged 30~34, on the basis of the participants' head length, was proposed as 6.2cm, 6.7cm, 7.1cm, and 8.9cm, respectively.

This study selected the cervical supporting height as the size of a contoured pillow that should be considered through head length. Since the cervical supporting height was higher than the supporting height of the occipital region in the 3-dimensional pillow utilized in this study, this study judged the cervical supporting height affected CCA data and design effectiveness result more, and therefore the cervical supporting height was selected as significant dimension.

Upon looking at the results of previous studies on cervical supporting height, namely supporting neck's height in pillow design, which are similar to this study, Chen and Cai (2012) carried out a study, "Ergonomic Approach for Pillow Concept Design". The study drew design concept on the ergonomic pillow by reflecting major anthropometry including the head, neck and shoulder, as well as head length. As for the mean head length of the 40 participants, it was 19.04cm (N: 20) for men, and 17.88cm (N: 20) for women, and the proposed cervical supporting height was drawn to be 9cm. Although more complex pillow types and various sizes were applied, the cervical supporting height showed similar results. In a study of Isabel C.N. Sacco et al. (2015) that proposed the most comfortable neck's height among the three heights in the supine position by utilizing the pillows with 5cm, 10cm, and 14cm in supporting neck's height utilizing EMG, it was reported that the lowest muscle activity was revealed at 10cm. Concerning the results in the previous studies that proposed cervical supporting height similar to the result of this study, it was confirmed that the proposed height was revealed within similar range, although dimensions were different, and study methods were different. Based on the head length of pillow users proposed in this study, optimization by complementing the method proposing the supporting height of neck and head is considered to be needed.

In the previous studies on the effectiveness of pillow design, the methods measuring interface pressure or through questionnaire surveys were conducted. A study of Gordon et al. (2009), "Pillow Use", evaluated the comprehensive quality of sleep regarding six pillow types through the measurement of sleep duration and time to get asleep. The six pillow types were customized, polyester, foam regular, foam contour, feather, and rubber pillows. Among those six types of pillows, the pillow that was the most comfortable and that showed the highest quality of sleep was the rubber pillow, followed by the customized pillow. A study of Lin and Wu (2015) on the evaluation of pillows through interface pressure measurement reported that designing in consideration of pillow

shape by reflecting the shapes of head and neck was important. A factor to consider for pillow design asserted by the two previous studies was that a pillow reflecting the shapes (dimensions) of user's head and shoulder should be used. From such a direction, this study carried out the effectiveness evaluation of the contoured pillow designed in reflection of the shapes of head and shoulder. For design effectiveness result, the evaluation on design effectiveness of the contoured pillow encasing the head and supporting the neck was made through contract pressure measurement.

This study ascertained the cervical supporting power of the contoured pillow in the design effectiveness evaluation. This is judged to be derived from the design shape lowering contact load and enhancing supporting power of the cervical region. Therefore a pillow should be designed by dividing the part encasing the occipital region, and the part supporting the cervical region in order to reduce contact load and enhance the support effect of the cervical region.

There are, however, three limitations in the method of carrying out his study. First, there is a limitation on sleep posture. The participants participated in the experiment in a supine position. However, the ratio of supine position in the entire sleep is 25%, and there is a limitation to say that the proposed design of this study has considered the sleep posture. Second, there is a limitation in terms of the number of participants and the homogeneity of samples. In this study, an experiment by gathering samples with homogeneity targeting specific sizes was not carried out. In this regard, there is a limitation that many samples with homogeneity by major percentile need to be secured so that the proposed dimensions by major percentile are strongly asserted.

Although the expressions cannot be optimized, deriving from the second limitation in this study, optimization on the expressions proposing cervical supporting height is required on the basis of CCA data through securing of many samples.

Aside from the three limitations mentioned above, the design guidelines development method of this study is expected to be utilized as the basis data for a standardized pillow design considering optimum pillow type and body type in a situation that various types of pillows are developed by emphasizing the importance of pillow and sleep posture.

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