Size and Retention of Tongue Bulb for Tongue Retaining Device

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In several treatment modalities for snoring and obstructive sleep apnea (OSA), oral appliances mainly including mandibular advancement appliance (MAA) and tongue retaining device (TRD) are recognized as a non-invasive, reversible alternative with favorable results. Tongue bulb is a major component of TRD which prevents the tongue from approaching the posterior wall of the pharynx and can be combined with MAA. Determination of tongue bulb size for the patient is important for therapeutic effect, but frequently needs time-consuming work. For effective fabrication and standardization of tongue bulbs, this study aimed to categorize tongue bulb size for healthy young men and to examine its relation with maximum retention force and with physical parameters including tongue-related variables.

36 non-snoring, asymptomatic young men with normal occlusion were voluntarily participated in this study (mean age: 24.47±2.58 years). Experimental procedures consisted of prefabrication of tongue bulb set (20 types with a width of 27-36mm and thickness of 8 and 10 mm), determination of tongue bulb size and the maximum retention force for each subject, and measurement of physical parameters including body mass index (BMI), neck circumference and width, thickness and length of tongue.

This study showed that there was significant difference of retention force among the bulb size-related groups both in upright and supine position ($p<0.05$) and that retention force increased with bulb size. Correlation of tongue bulb size with physical parameters was not clearly verified and there was no significant difference in retention force between upright and supine positions.

Based on our results, it can be suggested that retention force relates with tongue bulb size, ultimately with tongue volume. A further study needs to be performed in the patients with snoring and OSA.

Key words : Snoring, Tongue retaining device, Tongue bulb, Retention force

I. INTRODUCTION

Snoring and obstructive sleep apnea (OSA), together categorized as sleep-disordered breathing (SDB), are highly prevalent sleep disorders.[1] Habitual snoring is reported to be roughly 40% in men and 20% in women[2] and OSA affects approximately 2% of middle-aged women and 4% of middle-aged men.[3] SDB is caused by the collapse of the pharyngeal airway during sleep because of reduced muscle tone.[1] While the main complaint with snoring is social annoyance, the snorers with OSA frequently relate to significant medical problems including cognitive impairment, impaired quality of life, traffic accident and even cardiovascular disease,[4-7] which needs snoring and OSA to be treated.

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Medical treatment of SDB employs lifestyle modification (i.e., weight loss, cessation of smoking and alcohol ingestion, and sleep position training), medication, nasal continuous positive airway pressure (CPAP) and upper airway surgery including uvulopalatopharyngoplasty (UPPP), tracheostomy and maxillo-facial surgery.[8] Due to the effectiveness and the safety, CPAP is considered as the primary treatment for OSA, but long-term compliance with CPAP varies among studies.[9-11] Success rates for surgical procedures are variable as well.[12-14] Oral appliance can be non-invasive, reversible alternative with favorable results within a short time. Because of the benefits of oral appliances in patients with OSA, the American Academy of Sleep Medicine (AASM)[15] recommended that oral appliances be used in patients with primary snoring or mild OSA who do not respond to or who are not appropriate candidates for behavioral treatments.[1] It is also recommended that oral appliances be used in patients with moderate to severe OSA who fail or refuse CPAP or surgical treatments.[1]

Although at least 15 different oral appliances are currently available, the majority of which are designed to hold the mandible or tongue in a protruded position during sleep; i.e., tongue retaining devices (TRD) and mandibular advancement appliances (MAA).[16-20] Although the precise mode of action of oral appliances remains to be determined, possible mechanisms include increased upper airway caliber, activation of upper airway dilator muscles, or decreased upper airway compliance.[21]

Ferguson *et al.*[21] indicated that mandibular and tongue protrusion increase the cross-sectional area of upper airway and alter the shape of the upper airway during wakefulness. Cho *et al.*[22] compared three kinds of oral appliances using cephalometry and suggested that the mandibular advancement -tongue retaining appliance (MATRA) may result in more positive effect on the treatment of snoring and OSA compared to the MAA and TRA, especially for the patients whose upper airway obstruction occurs in the lower oropharynx.

When regarding this result and clinical effectiveness, there is a possibility that use of tongue bulb, in a combined form with MAA (MATRA) rather than TRD alone, will increase in order to secure airway more effectively in the patients with snoring and OSA, though this type of appliance is not commonly available yet. However, it is not easy task to customize tongue bulb for each patient. According to our clinical experience, too loose tongue bulb can not perform its function properly, and too tight bulb can cause the patient's discomfort and poor compliance. There exist few studies concerning retention force of tongue bulb for TRD or MATRA and there is a need to standardize how to make tongue bulb and to investigate which size of bulb is commonly used in the patients with snoring or OSAS.

Prior to assessment in the snoring patients, this study aimed to categorize tongue bulb sizes in the normal subjects and to examine its relation with maximum retention force and with physical parameters including tongue-related variables.

Ⅱ. SUBJECTS AND METHODS

1. Subjects

36 non-snoring, asymptomatic young men were voluntarily participated in this study. Females were excluded to avoid any gender difference. All the subjects were healthy and fully dentate with class I key relation without significant malocclusion. Those with tooth missing except the 3rd molar were excluded. Their mean age was 24.47±2.58 years, ranging from 20 to 36 years. Prior to the examination, informed consent was given by all subjects who participated in this study.

2. Methods

Experimental procedures consisted of prefabrication of tongue bulbs, determination of tongue bulb size and the maximum retention force for each subject, and measurement of physical parameters including body mass index (BMI), neck circumference and width, thickness and length of tongue.

1) Prefabrication of tongue bulbs

For fabrication of tongue bulbs, 20-sized wax patterns were manufactured with baseplate wax. Width of the wax patterns were variable ranging from 27 to 36 mm (10 sizes) and each had two thicknesses of 8 and 10 mm. Their length (anteroposterior distance) was set at 25 mm. The wax patterns were made to be tapered forwards (from tongue base to tongue tip) with the opposing lateral walls of posterior 10 mm portion parallel.

Alginate impressions were taken from the completed wax patterns and then tongue casts were obtained by improved stone. The tongue casts were finished and polished with sand paper.

After applying separating medium to the tongue cast, 2.0-mm thick clear resin sheet was adapted to the tongue cast with a Biostar pressure adaptor. Tongue bulb was cut off the tongue cast with a separating disk, and the cut was made at the level of 1mm below the cast margin, which allowed the margin of the bulb to be flared. The tongue bulb was removed from the tongue cast and then finished and polished to avoid potential injury of oral soft tissue while it was inserted in oral cavity.

For measurement of retention force with a pull-gauge, a loop was made with light curing resin and adhered to the completed tongue bulb with adhesives and resin material. The 20-sized tongue bulbs were prepared for the following experiment (Fig. 1).

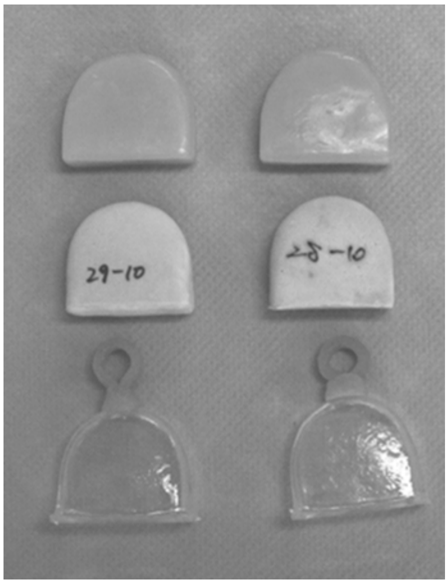

Fig. 1. Wax patterns, tongue casts and tongue bulbs with a loop.

2) Determination of tongue bulb size and measurement of the maximum retention force.

Each subject was asked to sit on dental chair in upright seated position and to be relaxed. After drying his tongue and the prefabricated tongue bulbs with gauzes and air syringe, various sized-tongue bulbs were placed one by one to find the most suitable tongue bulb for him. The subject was instructed to protrude his tongue with its muscles tense to secure close contact when he wore the tongue bulb. Following insertion of the bulb, the subjects was asked to be relaxed and a pull-gauge was put in the loop that clung to the tongue bulb, and then pulled out (Fig. 2). Retention force of the bulb was determined as the force at the moment that the bulb was pulled out from the tongue and the examination for each bulb was performed three times with a rest period of 5 minutes. The greatest force obtained from three measurements was recorded as the maximum retention force of the subject and the bulb size at that time was referred as the most appropriate size for the subject. The whole same procedures were repeated in supine position.

20-sized tongue bulbs were classified into four groups (group I, II, III, and IV) listed in Table 1 and the subjects were categorized into the groups on the basis of tongue bulb size with the maximum retention force for them in upright and supine position, respectively. The larger bulbs (35mm×10mm, 36mm×8mm, 36mm×10mm) were excluded from categorization because there were no subjects applicable to them in this study.

Fig. 2. Measurement of retention force for a tongue bulb with a pull-gauge.

Table 1. Categorization of the subjects based on the size of tongue bulb.

Type	Width × Thickness	Group	No. of subjects	
			upright position	Supine position
Aa	27mm×8mm	I	8	7
Ab	27mm×10mm			
Ba	28mm×8mm			
Bb	28mm×10mm			
Ca	29mm×8mm	II	8	9
Cb	29mm×10mm			
Da	30mm×8mm			
Db	30mm×10mm			
Ea	31mm×8mm	III	9	8
Eb	31mm×10mm			
Fa	32mm×8mm			
Fb	32mm×10mm			
Ga	33mm×8mm	IV	11	12
Gb	33mm×10mm			
Ha	34mm×8mm			
Hb	34mm×10mm			
Ia	35mm×8mm			
Ib	35mm×10mm		0	0
Ja	36mm×8mm			
Jb	36mm×10mm			

3) Measurement of width, thickness and length of tongue

Direct measurement with a millimeter ruler was used to determine the width, thickness and length of tongue while the subject was asked to open and protrude tongue as far as possible. At the most protruded position, tongue width between both oral commissures was measured and tongue thickness at the right oral commissure. Tongue length was determined as the distance from labial surface of lower incisors to tongue tip. Special caution was given not to displace the tongue during all measurement.

4) Measurement of body mass index (BMI) and neck circumferences

Physical examination included measurement of BMI as calculated by dividing weight (kg) by the square height (m^2) and neck circumference at the level of the cricoid cartilage.

3. Statistical Analysis

Collected data was processed using SPSS Window program ver 12.0. Correlation between physical parameters was evaluated with Pearson's Correlation Coefficients and difference of the maximum retention force between supine and upright positions was assessed by paired t-tests. One-Way ANOVA and Multiple Comparison t-tests were used to determine any difference in retention force and physical parameters among the experimental groups related to tongue bulb size.

Ⅲ. RESULTS

Table 2 demonstrates the physical parameters including BMI, neck circumference and tongue-related variables and the maximum retention force measured in all the subjects. BMI was positively correlated with neck circumference (γ=0.732, p=0.000) and negatively correlated with tongue length (γ=−.360, p=0.031). There was no correlation between other parameters (Table 2).

Table 2. The means of physical parameters and the maximum retention force.

	Range	Mean±SD	
BMI (kg/m^2)	18.4 ~ 30.0	22.74 ± 2.58	p=0.031* (BMI–Neck circumference)
Neck circumference (cm)	31.0 ~ 44.0	37.11 ± 3.19	
Tongue width (mm)	40.0 ~ 56.0	47.03 ± 3.75	
Tongue thickness (mm)	7.0 ~ 20.0	11.94 ± 3.11	p=0.000* (Neck circumference–Max retention force in upright position)
Tongue length (mm)	16.0 ~ 53.0	33.53 ± 8.32	
Max retention force in upright position (g)	320 ~ 2400	997.78 ± 641.90	p=0.593§ (upright–supine)
Max retention force in supine position (g)	320 ~ 2160	952.22 ± 573.52	

*; Pearson's correlation coefficients § paired t-test (N=36)

In comparison of the maximum retention force related to measurement position, the maximum retention force measured in upright position (997.78±641.90 g) was somewhat larger than that measured in supine position (952.22±573.52 g), but there was no significant difference between them (p=0.593, Table 2).

When the subjects were divided in four groups, Ⅰ, Ⅱ, Ⅲ, and Ⅳ (Table 1), based on the tongue bulb size related to the maximum retention force obtained in upright position, the retention force in group Ⅲ and Ⅳ was significantly higher compared with group I and II groups (p=0.007)(Table 3). Group Ⅰ showed significantly lower retention force compared with group Ⅲ and Ⅳ, respectively ($p<0.05$). Group 2 also exhibited significantly lower retention force compared with group Ⅲ and Ⅳ, respectively ($p<0.05$)(Fig. 3). The four groups showed significant difference in tongue width (p=0.002) and tongue length.(p=0.049) BMI, neck circumference and tongue thickness did not reveal significant difference among the four groups (Table 3).

When the subjects were divided into the four groups according to the maximum retention force measured in supine position, group Ⅳ exhibited the highest maximum retention force, followed by group Ⅲ, Ⅱ and Ⅰ in order (p=0.034)(Table 4). Significant difference was found to be between group I and IV (p=0.005)(Fig. 3). There was a trend of difference between group 1 and Ⅲ (p=0.081) and between group Ⅱ and Ⅳ (p=0.059). Neck circumference was significantly different among the four groups (p=0.036)(Table 4).

Table 3. Comparison of the tongue bulb size-related groups in upright position.

Group	N	Max retention force(g)	BMI(kg/m^2)	NC(cm)	TT(mm)	TW(mm)	TL(mm)
Ⅰ	8	600.00 ± 35.46	22.10 ± 3.11	35.28 ± 3.81	11.38 ± 2.45	44.13 ± 2.47	28.88 ± 9.08
Ⅱ	8	607.50 ± 197.97	22.92 ± 2.39	38.15 ± 2.36	10.75 ± 1.83	47.50 ± 4.17	39.38 ± 6.07
Ⅲ	9	1266.67 ± 693.69	22.39 ± 2.70	37.28 ± 3.36	13.44 ± 3.88	50.33 ± 3.24	35.11 ± 8.12
Ⅳ	11	1350.91 ± 760.39	23.40 ± 3.35	37.56 ± 2.93	12.00 ± 3.44	46.09 ± 2.55	31.36 ± 7.35
ANOVA		p=0.007	p=0.780	p=0.298	p=0.324	p=0.002	p=0.049

BMI=tody mass index, NC=neck circumference, TT=tongue thickness, TW=tongue width, TL=tongue length

Table 4. Comparison of the tongue bulb size-related groups in supine position.

Group	N	Max retention force(g)	BMI(kg/m^2)	NC(cm)	TT(mm)	TW(mm)	TL(mm)
Ⅰ	7	520.00 ± 140.95	21.54 ± 2.91	34.43 ± 3.21	11.14 ± 2.54	44.29 ± 2.63	29.00 ± 9.80
Ⅱ	9	815.56 ± 410.70	23.50 ± 2.73	38.80 ± 2.97	11.77 ± 2.54	47.89 ± 5.25	36.89 ± 7.29
Ⅲ	8	1010.00 ± 610.48	23.15 ± 3.30	36.65 ± 3.87	13.63 ± 3.78	48.13 ± 3.56	29.25 ± 7.29
Ⅳ	12	1268.33 ± 655.96	22.63 ± 2.77	37.72 ± 1.81	11.42 ± 3.26	47.25 ± 2.53	36.50 ± 6.91
ANOVA		p=0.034	p=0.584	p=0.036	p=0.377	p=0.175	p=0.058

BMI=tody mass index, NC=neck circumference, TT=tongue thickness, TW=tongue width, TL=tongue length

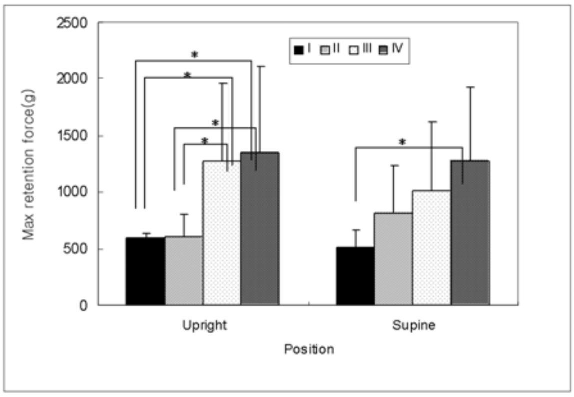

Fig. 3. The maximum retention force of tongue bulb related to measurement position.(*; p<0.05, Multiple comparison t-tests)

Ⅳ. DISCUSSION

In assessment of the physical parameters for normal non-snorers, significant correlation was found only between BMI and neck circumference (γ =0.732, p=0.000), and there was no correlation between other physical parameters in this study (Table 2). Although tongue length was negatively correlated with BMI, it is difficult to place clinical significance on it. It is likely that lack of correlation between physical parameters is related to selection of subjects without snoring and/or OSA in this study and to difficulty in accurate measurement of width, thickness and length of tongue.

Many researchers pointed out that the physical condition of the patient is important aspect of the evaluation for the patients with SDB.[23)] Larger neck circumference and higher BMI is considered to be a predictor of the patients with SDB.[24-26)] In contrast to close association of BMI and neck circumference with snoring and OSA, the extent to which tongue size is less clearly understood. Do *et al.*[27)]evaluated whether tongue volume correlates with BMI and neck circumference and indicated that there is a trend for patients with SDB to have larger tongue size compared withnon-SDB patients, but that tongue size is independent of AHI and correlates significantly with BMI and neck circumference. However, conflicting results also existedin other studies.[28-30)]

Snoring is often the result of the base of the tongue compromising the upper airway that led to reduced airflow. In an attempt to maintain the required oxygen to the lungs, the speed of the airflow should be increased, which causes vibration of soft tissue (mainly uvula) and sound of snoring.[4,31,32)] While snorings due to partial obstruction of upper airway, OSA is caused by transient complete obstruction of upper airway by backward movement of the tongue, which then resulted in frequent awakenings and disruption of sleep, explaining the hypersomnolence.[2,33)] Moderate to severe OSA is associated with increased mortality and morbidity, although the long-term consequences of mild to moderate OSA are less clear.[1)]

Dental therapy with oral appliance represents only a small part of clinical care in the patients with

SDB, but the growing recognition of the effectiveness of dental care combined with the remarkable prevalence of SDB assures that the importance of dental therapy will steadily increase.[34)] The basic mode of function of oral appliances is to prevent the tongue from approaching the posterior wall of the pharynx and causing an obstruction.[4)] This posterior movement of the base of the tongue is minimized or prevented by use of either a TRD or a MAA.[35)]

TRD consists of a hollow bulb (tongue bulb) supported by trays that fit over the maxillary and mandibular teeth or edentulous ridges.[17)] To prevent the tongue from approaching the posterior wall of the pharynx, the patient projects the tip of the tongue into a bulb, thereby creating a suction which retains the tongue in an anterior position. TRD is reported to be effective in offsetting fluctuation of genioglossual muscle activity and in treating patients with OSA.[4)]

In addition, it is thought that the effect of TRD is intensified when it was combined with MAA. As discussed earlier, Cho *et al.*[22)] analyzed changes of the oropharyngeal space related with the use of TRD, MAA and the combination of both (mandibular advancement-tongue retaining appliance, MATRA) and represented that only MATRA significantly increased both the upper and lower oropharyngeal space consistently, though MAA and TRD increased the upper oropharyngeal space. Therefore, they concluded that the MATRA may result in a more positive effect on the treatment of snoring and OSA compared to the MAA and TRD, especially for the patients whose upper airway obstruction occur in the lower oropharynx. This finding has been supported by clinical effectiveness of MATRA for the patients with SDB who did not respond to MAA in our clinic. In clinical setting, fabrication of oral appliance (MATRA) for the patients with SDB needs procedures as follows; taking impressions of dental arches, fabrication of a customized tongue bulb and determination of distance of mandibular advancement and tongue thrust, laboratory procedures and insertion and titration of the appliance to obtain favorable results. While some patients are easily coordinated with tongue bulb, others, especially those with abnormal muscle tone of tongue, frequently need repeated, time-consuming work for determination of their tongue bulb size. As mentioned previously, too loose tongue bulb can not perform its function properly whereas too tight bulb can cause the patient's discomfort and poor compliance. That's why we are interested in standardization of tongue bulb size. Prior to examination in the patients with SDB, categorization of tongue bulb size and comparison of retention force was performed first in normal subjects here. Standard set of tongue bulbs (20 sizes) ranging from a width of 27 to 36 mm were prefabricated and assessed in this study. All subjects were evenly distributed into the four groups related with tongue bulb size although our sample size was relatively small.

In regard with retention force of bulb size-related groups, measurement of the maximum retention force for tongue bulb in upright seated position showed the greater retention force in group Ⅲ and Ⅳ (larger groups) than group Ⅰ and Ⅱ (smaller groups)(p=0.007, Table 3). Increase of retention force is thought to be related with increase of bulb size but it is interesting that there existed a big difference in retention force between group Ⅱ (width of 29 and 30 mm) and Ⅲ (width of 31 and 32 mm), despite a little difference of width of bulb between them. Measurement in supine position also showed similar results (significant difference among the four groups, p=0.034), but the difference between group Ⅱ and Ⅲ was not significant. Difference between upright and supine positions may be explained by the influence of the gravitational pull. Pae[36)] and Yilidrim *et al.*[37)] demonstrated an increase of uvula width and tongue length as well as a decreased superior-posterior airway space in the supine posture. Pracharktam *et al.*[38)] indicated that reduced the superior-posterior pharyngeal space, when changing from upright to supine posture, may depend more on the gravitational pull of the soft palate and the tongue backwards. However, there was no significant difference in the maximum retention force between the upright and supine positions in this study although the force values were a bit smaller in supine position than in upright seated position. This result may be in part due to measurement during wakefulness.

Due to small sample size in this study, classification related to the thickness of tongue bulb was not performed, which may explain no significant difference in tongue thickness among the groups. On the while, tongue width exhibited significant difference among groups in upright position (p=0.002)(Table 3).

V. CONCLUSIONS

In this study with non-snoring normal young men, the subjects corresponding to the tongue bulbs with a width of 31 to 35 mm exhibited greater retention force than those with a width of 27 to 30 mm. Correlation of tongue bulb size with physical parameters was not clearly verified and there was no significant difference in retention force between upright and supine positions.

Based on our results, it can be suggested that retention force relates with tongue bulb size, ultimately with tongue volume. A further study needs to be performed in the patients with snoring and OSA in the near future.

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국문요약

혀 유지구의 크기와 유지력 평가

단국대학교 치과대학 구강내과학교실

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구강장치를 이용한 코골이와 수면무호흡증의 치료는 하악이나 혀를 전방으로 이동시켜 기도공간을 확보하는데, 하악전방이동장치(mandibular advancement appliance, MAA)와 혀견인장치(tongue retaining device, TRD)가 주로 이용된다. 이 중 혀견인장치는 전치의 순측에 위치되는 혀 유지구(tongue bulb) 속에 생기는 음압을 이용하여 혀가 뒤로 밀리지 않도록 하는 구강장치로서 단독 혹은 하악전방이동장치와 복합된 형태로 사용하여 코골이와 수면무호흡증의 치료에 효과를 보이는 것으로 보고되고 있다.

본 연구는 혀견인장치의 제작을 용이하게 하고 표준화하기 위해 개개인에 적합한 혀 유지구의 크기를 조사하여 분류하고 혀 유지구의 크기와 유지력의 관계 및 신체적 변수와의 관계를 조사해 보고자 하였다. 환자를 대상으로 하기에 앞서, 정상인 젊은 남성을 대상으로 시행하였다.

실험을 위해 투명 아크릴 레진 판을 이용하여 폭(27-36 mm)과 두께(8, 10 mm)를 달리한 20 가지 크기의 혀 유지구를 제작하고 준비하였다. 코골이와 수면무호흡증이 없는 36명의 젊은 남성 지원자들(평균연령: 24.47±2.58세)을 대상으로 다양한 크기의 혀 유지구를 장착하여 유지력을 측정하여 최대유지력을 보이는 혀 유지구를 그 환자에게 적합한 크기의 유지구로 결정하고 측정한 값들을 기록하였다. 측정은 앉은 자세와 누운 자세에서 각각 시행하였다.

실험 결과, 앉은 자세와 누운 자세 모두에서 혀 유지구 크기에 따라 분류한 네 군의 유지력 사이에는 통계적으로 유의한 차이가 있었다 ($p<0.05$). 즉, 피검자에게 가장 적합한 크기의 유지구로 조사한 결과 유지구의 크기가 증가할수록 유지력이 증가하는 양상을 보였다. 신체적 변수와 혀 유지구 크기 사이의 관련성은 뚜렷하게 관찰되지 않았으며, 측정 자세에 따른 유지력 간에도 유의한 차이는 없었다. 본 연구의 결과는 혀 유지구의 유지력은 유지구의 크기, 즉 혀의 부피와 관련이 있음을 보여준다.

주제어 : 코골이, 혀견인장치, 혀유지구, 유지력