



Maximal strength and endurance scores of the tongue, lip, and cheek in healthy, normal Koreans

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Abstract (J Korean Assoc Oral Maxillofac Surg 2017;43:221-228)

Objectives: The purpose of this study was to establish normative data for healthy Korean adults by measuring the maximal strength and endurance scores of the tongue, lip, and cheek, and to examine correlations between these measurements.

Materials and Methods: This study included 120 subjects that were divided into three groups according to age: young (20-39 years), middle-aged (40-59 years), and older (over 60 years); and by gender. Measurements were taken using the Iowa Oral Performance Instrument (IOPI).

Results: The mean maximal tongue strengths were as follows: young men (46.7±10.2 kPa) and women (32.1±7.9 kPa), middle-aged men (40.9±9.3 kPa) and women (36.9±8.6 kPa), and older men (35.2±9.0 kPa) and women (34.5±6.9 kPa). The mean tongue endurance scores were: young men (28.8±12.6 seconds) and women (20.8±13.5 seconds), middle-aged men (17.0±8.5 seconds) and women (15.3±5.2 seconds), and older men (15.8±6.7 seconds) and women (17.9±8.1 seconds). The mean maximal lip strengths were: young men (11.6±3.0 kPa) and women (11.4±3.8 kPa), middle-aged men (11.4±4.2 kPa) and women (11.1±5.1 kPa), and older men (14.5±3.9 kPa) and women (11.7±2.6 kPa). The mean lip endurance scores were: young men (41.1±23.9 seconds) and women (22.4±21.7 seconds), middle-aged men (24.3±10.3 seconds) and women (30.5±13.4 seconds), and older men (24.9±11.0 seconds) and women (12.8±7.6 seconds). The mean maximal cheek strengths were: young men (24.5±4.6 kPa) and women (20.5±4.3 kPa), middle-aged men (25.2±6.4 kPa) and women (21.2±5.5 kPa), and older men (22.4±5.3 kPa) and women (18.0±4.8 kPa). The mean cheek endurance scores were: young men (47.8±24.4 seconds) and women (43.9±25.0 seconds), middle-aged men (27.3±11.3 seconds) and women (20.0±14.6 seconds), and older men (21.7±14.5 seconds) and women (17.2±11.4 seconds).

Conclusion: The data collected in this study will provide an important database of standardized measurements for maximal strength and endurance scores of the tongue, lip and cheek in healthy, normal Koreans.

Key words: Iowa Oral Performance Instrument (IOPI), Tongue, Lip, Cheek, Korean

[paper submitted 2017. 5. 6 / accepted 2017. 6. 5]

I. Introduction

In the oromaxillofacial region, the tongue, lip, and cheek

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are closely related to functions such as pronunciation, mastication, and swallowing, and appropriate pressure and strength must be applied to them in order to perform these functions. Phonetics are created by the vibration of vocal cords in the larynx; and pronunciation is executed with the interaction of articulators such as the palate, lip, cheek, tongue, teeth, and gingivae, and is transmitted to the oral and nasal cavities through the pharyngeal cavity. Applying appropriate strength of the articulation organs is very important in accomplishing all these functions. Thus, it is difficult to expect accurate and clear pronunciation in patients with oral tissue loss, or who are post-reconstruction surgery or oral cancer surgery; and in

This research was supported by a grant from the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (Grant number: HI15C1535).

patients with cleft lip and palate resulting in severe malocclusion.

Swallowing is divided into oral, pharyngeal and esophageal phases¹. Among the three phases, the oral phase involves mastication of food by mechanical jaw movement and production of saliva for secretion by the salivary glands, thereby chemically creating a sufficient bolus to aid in swallowing by movement of the tongue to the pharynx, completing deglutition. Various neuromuscular systems are operated with sufficient pressure and endurance, and when muscle fatigue easily occurs, it is difficult to perform accurate movements during swallowing². Thus, the role of the tongue, lip, and cheek is very important in producing proper pronunciation and deglutition.

Although many studies have been conducted to determine the function of the tongue, lip, and cheek, which, as noted, all play an important role in proper pronunciation and deglutition, research has been based on patient subjective symptoms, with no standardized scale. To address this, a device called the Iowa Oral Performance Instrument (IOPI) (IOPI Medical, Redmond, WA, USA) was developed to measure the pressure of the anatomical structures in the oral cavity. The instrument is composed of a tongue bulb and a connecting tube, a data output terminal, and a pressure terminal with the functions of displaying the maximum value and elapsed time of compression with a start and stop function. (Fig. 1. A) As it became possible to collect objective data on the functions of the tongue, lip, and cheek, many studies have been conducted using this device. A study by Clark and Solomon³ used the IOPI to measure the maximal strength of the tongue, lip, and cheek in Americans. The subjects were divided into young, middle-aged and older age groups, measurements were made for

males and females, and mean values were presented. A study by Vitorino⁴ measured the maximal tongue strength and endurance in Portuguese-speaking Brazilians using the IOPI. A study by Vanderwegen et al.⁵ measured the maximal tongue strength and tongue endurance in Belgians speaking Dutch.

Internationally, many studies have already been reported using the IOPI device to establish normative data according to age groups and gender, but there is insufficient, well-documented normative data for Koreans. The current study utilized a new clinical test method using IOPI in order to establish standardized data that enables us to exclude measurements evaluated based on patient subjective symptoms for purposes of obtaining the maximal strength and endurance scores of the tongue, lip, and cheek by age group and gender.

II. Materials and Methods

1. Patients

Patients who visited the Department of Oral and Maxillofacial Surgery of Seoul National University Dental Hospital, Integrated Clinic and Pre-Doctoral Practice Center, over a period of three months (August to October 2015) were included in this study. For purposes of the study, patients with oral motor disabilities (dysphagia, dysarthria, facial or lingual nerve paralysis), and patients who had undergone surgeries on the tongue, lip, and cheek were excluded. Informed consent was obtained from all participating patients prior to the study. The subjects were divided according to age group: young (20-39 years), middle-aged (40-59 years), older (over 60 years), and by gender (male or female). Similar to previous studies^{4,6}, sample size was limited to 20 subjects per group. Therefore,

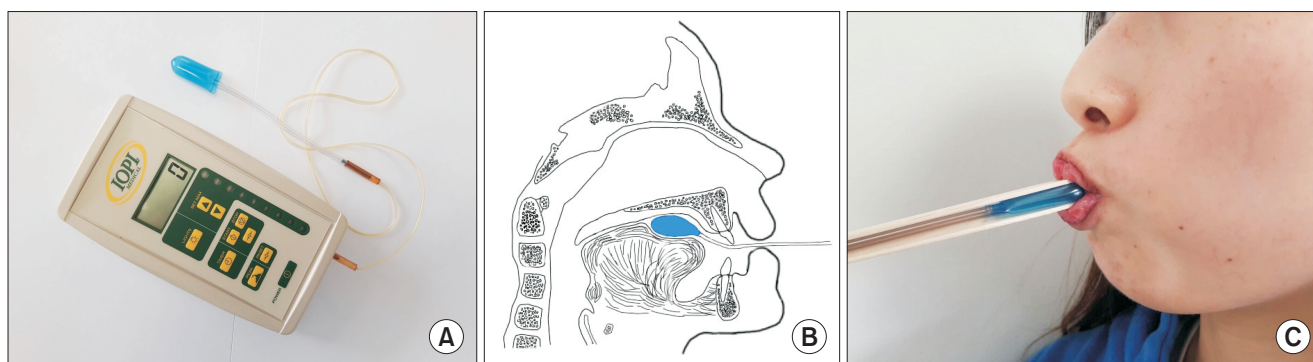


Fig. 1. A. The Iowa Oral Performance Instrument (IOPI) is used to measure the pressure of the anatomical structures in the oral cavity. B. The position of the tongue bulb placed on the maxillary anterior hard palate area when measuring the maximal tongue strength and endurance score. C. The tongue bulb is placed in between two tongue depressors, the lips must be pursed forward with maximum force when measuring the maximal lip strength and endurance score.

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we surveyed 20 men and 20 women aged 20-39 years, 20 men and 20 women aged 40-59 years, and 20 men and 20 women aged over 60 years, giving a total sample size of 120 subjects. The Institutional Review Board of Seoul National University, Seoul, Korea approved all protocols and informed consents (approval no. CRI15015).

2. Method

The maximal strength and endurance of the tongue, lip, and cheek was measured using the sterilized tongue bulb. To measure maximal tongue strength, the examiner held the tube and placed the tongue bulb on the maxillary anterior lingual hard palate area and asked the subject to press on the bulb using the tongue with maximum force for two seconds. After obtaining the measured value of the maximal tongue strength (kPa), the subject was given a one-minute rest time and was asked to repeat the measurement two additional times. Out of three measurements, the highest measured value was used as data. Tongue endurance was measured in seconds by the length of time the IOPI light was maintained with 50% of the maximal tongue strength. Data was obtained by placing the bulb of the IOPI device on the subject's mouth in the same way as when measuring the maximal tongue strength, and values were acquired using the start and stop button of the IOPI device.(Fig. 1. B)

To measure maximal lip strength, the bulb was placed in between two tongue depressors and the subject was asked to purse the lips forward with maximum force to avoid the influence of teeth force.(Fig. 1. C) To measure cheek strength, the bulb was placed between the subject's teeth and cheek while the teeth are in a lightly occluded position, and the subject was asked to apply pressure with the strength of the cheeks only. Maximal lip and cheek strengths were also measured three times, the same way the maximal tongue strength was measured, by applying maximum force for two seconds with a one-minute rest time in between measurements. Lip

and cheek endurences were measured by the length of time maintained at 50% of maximal strength.

3. Statistical analyses

Descriptive statistics according to age group and gender were calculated. Kolmogorov-Smirnov and Shapiro-Wilk normality tests were performed to ascertain data normality. If data satisfied the assumption of normality, the nominal variables of age group and gender were used as independent variables to perform two-way ANOVA. Post-hoc analyses were performed with Bonferroni's method. In addition, Pearson's correlations were performed to identify associations between age group and obtained measurements. Significance was set at $P < 0.05$. IBM SPSS Statistics ver. 22.0 (IBM Co., Armonk, NY, USA) was used to conduct all analyses.

III. Results

1. Maximal tongue strength

The mean maximal tongue strength was 46.7 ± 10.2 kPa for young men, 32.1 ± 7.9 kPa for young women, 40.9 ± 9.3 kPa for middle-aged men, 36.9 ± 8.6 kPa for middle-aged women, 35.2 ± 9.0 kPa for older men, and 34.5 ± 6.9 kPa for older women.(Table 1) The mean values for males were higher than those for females in all age groups. The values for the 20- to 39-year-old male group and the 40- to 59-year-old female group were the highest among the other groups. All data were confirmed to satisfy the normal distribution through normality test, and two-way ANOVA was conducted to examine the relationship between the maximal tongue strength by age group and gender. The significance level of the interaction between age groups and gender was 0.001.(Table 2) In the interpretation of the main effect, there was a significant difference between the results for the age groups and gender ($P = 0.041$ and $P = 0.000$, respectively); however, there was

Table 1. Maximal strength and endurance scores of tongue, lip, cheek according to age groups

		Maximal tongue strength (kPa)	Tongue endurance (s)	Maximal lip strength (kPa)	Lip endurance (s)	Maximal cheek strength (kPa)	Cheek endurance (s)
20-39 yr	Male (n=20)	46.7±10.2	28.8±12.6	11.6±3.0	41.1±23.9	24.5±4.6	47.8±24.4
	Female (n=20)	32.1±7.9	20.8±13.5	11.4±3.8	22.4±21.7	20.5±4.3	43.9±25.0
40-59 yr	Male (n=20)	40.9±9.3	17.0±8.5	11.4±4.2	24.3±10.3	25.2±6.4	27.3±11.3
	Female (n=20)	36.9±8.6	15.3±5.2	11.1±5.1	30.5±13.4	21.2±5.5	20.0±14.6
≥ 60 yr	Male (n=20)	35.2±9.0	15.8±6.7	14.5±3.9	24.9±11.0	22.4±5.3	21.7±14.5
	Female (n=20)	34.5±6.9	17.9±8.1	11.7±2.6	12.8±7.6	18.0±4.8	17.2±11.4

Values are presented as mean±standard deviation.

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Table 2. Differences between age groups and genders with two-way ANOVA test, and across age groups including post-hoc results

	Maximal tongue strength	Tongue endurance	Maximal lip strength	Lip endurance	Maximal cheek strength	Cheek endurance
Two-way ANOVA test						
Age	0.041*	0.000*	0.070	0.002*	0.030*	0.000*
Gender	0.000*	0.150	0.117	0.005*	0.000*	0.107
Age×gender	0.001*	0.063	0.246	0.002*	0.981	0.891
Post-hoc analysis						
Young vs. middle-aged	0.964	0.000*	0.963	0.439	0.820	0.000*
Middle-aged vs. older	0.098	0.935	0.087	0.046*	0.030*	0.551
Young vs. older	0.055	0.001*	0.150	0.001*	0.123	0.000*

*Significant differences at $P < 0.05$.

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no significant difference in post-analysis among age groups ($P > 0.05$).

2. Tongue endurance

Data were normally distributed. Mean tongue endurance was 28.8 ± 12.6 seconds for young men, 20.8 ± 13.5 seconds for young women, 17.0 ± 8.5 seconds for middle-aged men, 15.3 ± 5.2 seconds for middle-aged women, 15.8 ± 6.7 seconds for older men, and 17.9 ± 8.1 seconds for older women. (Table 1) The mean values for males were higher than those for females in all age groups except for those over 60 years of age. Values were highest in the 20- to 39-year age group for both males and females. Two-way ANOVA showed there were no significant differences in tongue endurance between age groups and gender ($P > 0.05$). (Table 2) Therefore, the main effects between age groups and gender were analyzed. However, there were significant differences among the age groups ($P = 0.000$), indicating significance in the endurance scores of the tongue according to the age groups. Post-hoc analysis showed significant differences between the young and middle-aged groups, and between the young and older-aged groups ($P < 0.001$ and $P = 0.001$, respectively). There was no significant difference between genders ($P > 0.05$).

3. Maximal lip strength

The data was normally distributed. Mean maximal lip strength was 11.6 ± 3.0 kPa for young men, 11.4 ± 3.8 kPa for young women, 11.4 ± 4.2 kPa for middle-aged men, 11.1 ± 5.1 kPa for middle-aged women, 14.5 ± 3.9 kPa for older men, and 11.7 ± 2.6 kPa for older women. (Table 1) The mean values for males were higher than those for females in all age groups. The values were highest in those over 60 years of age in both genders. Two-way ANOVA showed there was no significant

differences in maximal lip strength by age group and gender ($P > 0.05$). (Table 2)

4. Lip endurance

Data was normally distributed. The mean lip endurance was 41.1 ± 23.9 seconds for young men, 22.4 ± 21.7 seconds for young women, 24.3 ± 10.3 seconds for middle-aged men, 30.5 ± 13.4 seconds for middle-aged women, 24.9 ± 11.0 seconds for older men, and 12.8 ± 7.6 seconds for older women. (Table 1) The mean values of males were higher than those of females in other age groups except for 40- to 59-year age group. The values were highest in the 20- to 39-year-old male group, and the values of the 40- to 59-year-old female group. Two-way ANOVA showed there was a significant difference in lip endurance by age group and gender ($P = 0.001$). (Table 2) There was a significant difference among age groups ($P = 0.002$). Post-hoc analysis showed a significant difference between the middle-aged and the older groups, and between the young and older groups ($P = 0.046$ and $P = 0.001$, respectively). There was also a significant difference between genders ($P = 0.005$).

5. Maximal cheek strength

Data were normally distributed. Mean maximal cheek strength was 24.5 ± 4.6 kPa for young men, 20.5 ± 4.3 kPa for young women, 25.2 ± 6.4 kPa for middle-aged men, 21.2 ± 5.5 kPa for middle-aged women, 22.4 ± 5.3 kPa for older men, and 18.0 ± 4.8 kPa for older women. (Table 1) The mean values for males were higher than those for females in all age groups. The values were highest in the 40- to 59-year-old male and female groups. Two-way ANOVA was conducted to examine the relationship between the maximal cheek strength by age group and gender, and there was no significant difference in

the interaction between age groups and gender ($P>0.05$). (Table 2) Therefore, the main effects of age groups and gender were analyzed. The significance level was 0.030 indicating that the cheek strength was significantly different according to age groups. Post-analysis showed that there was a significant difference between the middle-aged and the older groups ($P=0.030$). There was also a significant difference between genders ($P=0.000$).

6. Cheek endurance

Data were normally distributed. Mean cheek endurance was 47.8 ± 24.4 seconds for young men, 43.9 ± 25.0 seconds for young women, 27.3 ± 11.3 seconds for middle-aged men, 20.0 ± 14.6 seconds for middle-aged women, mean 21.7 ± 14.5 seconds for older men, and 17.2 ± 11.4 seconds for older women. (Table 1) The mean values for males were higher than those of females in all age groups. The values were highest in the 20- to 39-year-old male and female groups. Two-way ANOVA showed there were no significant difference in the interaction between age groups and gender ($P>0.05$). (Table 2) Therefore, the main effects of age groups and gender were analyzed. The significance level was 0.000, indicating that the cheek strength was significantly different according to age groups. Post analysis showed significant differences between the young and the middle-aged groups, and between the young and older groups (both $P<0.001$). There was no significant difference between genders ($P>0.05$).

7. Pearson's correlations

There was a correlation between age and cheek endurance (-0.486), between tongue strength and cheek strength (0.429), and between tongue endurance and cheek endurance (0.588). (Table 3, Fig. 2)

IV. Discussion

This study aimed to measure the maximal strength and endurance scores of the tongue, lip, and cheek, and to examine correlations across age groups and genders. We found significant correlations across age groups between maximal tongue and cheek strength and tongue, lip, and cheek endurance. There were significant differences in maximal tongue strength, maximal cheek strength, and lip endurance by gender. In addition, age group and cheek endurance, and tongue endurance and cheek endurance had higher correlations when compared to other measurements.

Among the many studies conducted on maximal tongue strength in a number of countries, a study by Vanderwegen et al.⁵, with the largest sample size that was subdivided into age groups, showed 57.1 kPa for young men, 47 kPa for young women, 53 kPa for middle-aged men, 47.3 kPa for middle-aged women, 37 kPa for older men, and 34 kPa for older women; while the maximal tongue strength measured in this study showed 46.7 kPa for young men, 32.1 kPa for young women, 40.9 kPa for middle-aged men, 36.9 kPa for middle-aged women, 35.2 kPa for older men, and 34.5 kPa for older women. Decreasing tendency with age in men and the highest measurement for middle-aged women coincided with the study conducted by Vanderwegen et al.⁵; however, overall measurements in the Korean population were found to be lower by about 10 kPa. In a study by Clark and Solomon³, in an American population, the anterior and posterior tongue were measured, but with a higher degree of strength for the anterior tongue; mean tongue strength was 55.8 kPa for young adults, 62.8 kPa for middle-aged adults, and 51.0 kPa for older adults, whereas the mean measurements in this study showed 39.4 kPa for young adults, 38.9 kPa for middle-aged adults, and 34.8 kPa for older adults. Both studies confirmed that the measurements of middle-aged adults were

Table 3. Correlations between age, maximal strength and tongue, lip and cheek endurance

	Age	Maximal strength of tongue	Tongue endurance	Maximal strength of lip	Lip endurance	Maximal strength of cheek	Cheek endurance
Age	1						
Maximal tongue strength	-0.156	1					
Tongue endurance	-0.279**	0.185*	1				
Maximal lip strength	0.082	0.242**	0.208*	1			
Lip endurance	-0.232*	0.304**	0.211*	0.026	1		
Maximal cheek strength	-0.094	0.429**	0.207*	0.126	0.197*	1	
Cheek endurance	-0.486**	0.351**	0.588**	0.240**	0.209*	0.189*	1

*The correlation coefficient is significant at the 0.05 level.

**The correlation coefficient is significant at the 0.01 level.

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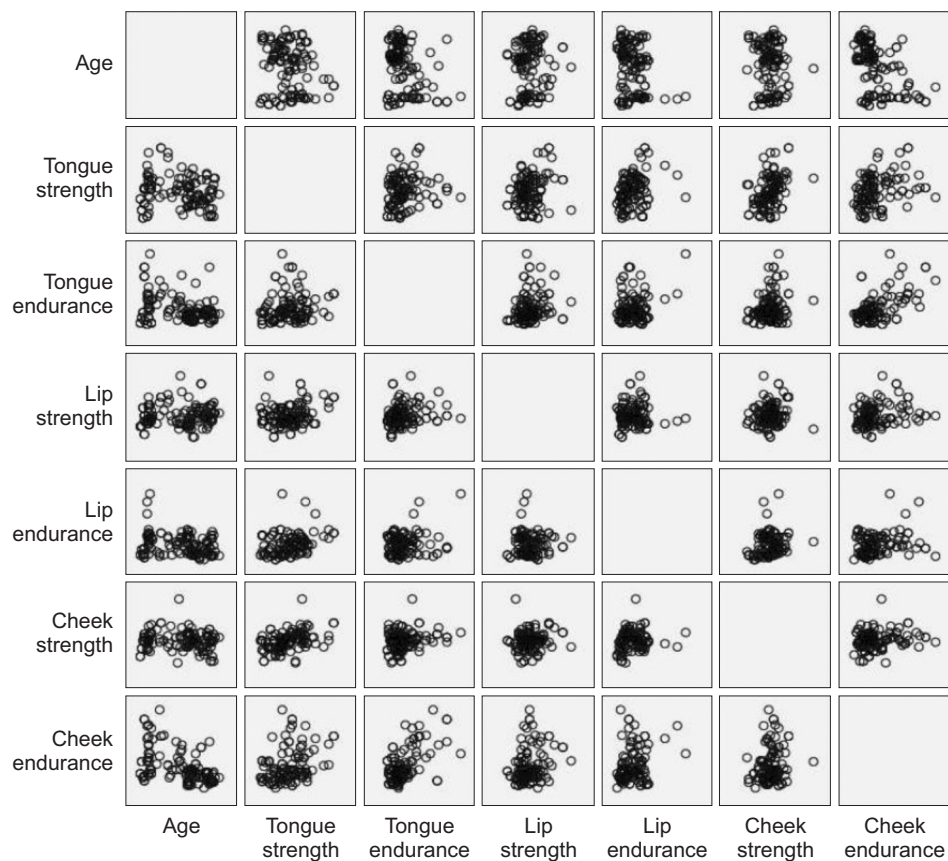


Fig. 2. Correlation between age, maximal strength and endurance scores of the tongue, lip and cheek.
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larger or nearly similar to those of young adults. In addition, a decreasing tendency regarding maximal tongue strength in older adults was observed, which seemed to be caused by the effects of aging.

According to the study by Vanderwegen et al.⁵, on tongue endurance, the measurements were 28.7 seconds for young men, 26.9 seconds for young women, 28.8 seconds for middle-aged men, 18.3 seconds for middle-aged women, 21.7 seconds for older men, and 15.4 seconds for older women; whereas the measurements in this study were 28.8 seconds for young men, 20.8 seconds for young women, 17.0 seconds for middle-aged men, 15.3 seconds for middle-aged women, 15.8 seconds for older men, 17.9 seconds for older women. Study by Vanderwegen et al.⁵ and this study showed that tendency or measurements between age groups and genders were similar except for older women. Similar results have been found in the studies by Vitorino⁴ and Lazarus et al.⁷. However, the measurements of tongue endurance in this study were shown to be significantly lower compared to other studies⁸⁻¹⁰.

An insufficient number of studies measuring maximal lip strength have been reported, but the results of a study of 171 Americans (aged 18-89 years) by Clark and Solomon³

showed 27.5 kPa for young adults, 27.0 kPa for middle-aged adults, and 31.9 kPa for older adults, while the measurements in this study showed 11.5 kPa for young adults, 11.3 kPa for middle-aged adults, and 13.1 kPa for older adults. The measurements of young adults and middle-aged adults, and in the older adults were similar in both studies, but overall measurements in the Korean population were found to be lower by about 15 kPa. It is likely that the differences in measurements might not only come from the differences between Asian and Western subjects, but also from the possibility of measurement errors, since subjects who were not taught how to compress the lips might have exerted force using the anterior teeth.

In the case of lip endurance, comparison with other studies is difficult because data based on age group and gender have not yet been sufficiently reported. A study comparing lip endurance between a trumpet player and a non-trumpet player showed approximate average measurements of 284 seconds for the trumpet player and 98 seconds for the non-trumpet player¹¹. The average of the total mean value of lip endurance in the current study was 26 seconds, which was significantly different from that of the study by Johnson¹¹; however, it must be taken into consideration that average subject age in

that study was in the 20s and the number of subjects in the study was 28. According to Robin et al.¹², people with developed tongue skills, such as trumpet players or those who debate, exhibited remarkably higher tongue endurance scores than non-trumpet playing people.

As for maximal cheek strength, in the study by Clark and Solomon³, in 171 Americans (aged 18-89 years), the measurements were 30.8 kPa for young adults, 33.9 kPa for middle-aged adults, and 29.0 kPa for older adults, while the measurements in this study were 22.5 kPa for young adults, 23.2 kPa for middle-aged adults, and 22.0 kPa for older adults. Although there was a similarity in the tendency of measurements to be highest in the middle-aged group and lowest in the older age group, overall measurements were found to be lower by about 8 kPa for Koreans.

As for cheek endurance, the average measurement of healthy non-instrument playing people in the study by Johnson¹¹ was 106 seconds, but the average measurement in this study was 29.6 seconds. However, as mentioned above, the subjects' average age in that study was in the 20s and the number of subjects in the study was 28.

Many studies have been conducted on patients who have received treatment that has correlated with the strength and endurance of tongue, lip, and cheek, and with functions such as pronunciation, mastication, and swallowing. In a study by Lazarus et al.¹³, which was reported in the Department of Radiation Oncology at the University of Chicago, patients with oral or oropharyngeal cancer who had been treated with chemotherapy were evaluated during preoperative treatment and one, three, six, and 12 months postoperative treatment to assess the effect of tongue strength on swallowing. The results revealed that there was a slight decrease in maximal tongue strength immediately after treatment, but significant recovery was observed after six to 12 months. According to a study by Lazarus et al.¹⁴, and reported in the Department of Otorhinolaryngology, New York University School of Medicine, the structural movement of the tongue and pharynx during swallowing were reduced in patients with head and neck cancer when compared to normal healthy individuals, which necessitated physiological muscle strengthening and tongue strengthening programs for tongue strength and function. Also, a study by Van Lierde et al.¹⁵ reported in the Department of Plastic Surgery at Ghent University Hospital in Belgium used IOPI to measure maximal strength and endurance of the lip and tongue in 25 subjects aged 10.6 years on average with a unilateral cleft lip and palate that had lip surgery at an average age of 5.5 months using a modified Millard tech-

nique. The results of the IOPI showed that there was no significant difference between the subjects and a control group.

Several other devices other than IOPI were introduced as ways to measure maximal tongue and lip strengths. A study by Lee et al.¹⁶ used a BCL-3L (CAS, Seongnam, Korea), a strain gauge load cell, to measure the strength of anterior and lateral borders of the tongue. A study by Yoshikawa et al.⁶ compared three types of tongue pressure measurement devices. One was IOPI, the second was a stable, adhered, three-air-filled bulb manometry system, and the most recent was a new device that can measure maximal tongue strength and tongue strength during swallowing. The efficiency of this new device has been verified by comparing it with other manometers. However, IOPI is considered to be the most efficient device because it is portable, has a small size, and is easy to use; it can also measure endurance, and several studies using this device have already been reported.

Future studies are needed that measure the maximal strength and endurance of the tongue, lip, and cheek in patients with a deficiency or who have undergone reconstructive surgery. Studies are also needed with measurements obtained preoperative, one-, three-, six-, and 12-month postoperative treatments to evaluate the characteristics of the tongue, lip, and cheek. Also, since this study was conducted in Seoul only, it is suggested that more data be collected nationwide. In relation to IOPI, additional studies must be conducted to evaluate the correlation between the strength and endurance of the tongue, lip, and cheek, as well as pronunciation, mastication, and swallowing.

V. Conclusion

This study examined maximal strength and endurance of the tongue, lip, and cheek across age groups and genders in 120 Koreans, and compared the measurements with previous studies to evaluate Korean characteristics. The data collected in this study will provide an important database of standardized measurements for maximal IOPI strength and endurance scores for tongue, lip, and cheek in healthy, normal Koreans.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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