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Research Article

The Influence of Age, Gender, and BMI on Tongue and Lip Strength in Healthy Adults

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Abstract

In recent years, there have been increasing studies in western countries investigating the measurement and training of tongue strength in patients with dysphagia; however, there are few similar studies in Asia, especially in the Chinese population. This study enrolled 15 healthy adults as the subjects to measure the left and right lip and anterior and posterior tongue strength, as well as to investigate the factors affecting it under the situations of maximum isometric strength, dry saliva and water swallowing. The research results showed that the strength of the left lip is higher than that of the right lip by 5-10%, and the strength of the anterior tongue is also higher than that of the posterior tongue by 5-10%. Gender has an effect on lip and tongue strength under the conditions of maximum isometric strength, dry saliva, and water swallowing, and the strength of men is stronger than that of women.

INTRODUCTION

The swallowing mechanism involved in food and fluid intake is very complicated. Only when the swallowing function is normal food and fluid can be safely and effectively transported from the mouth to the stomach. Once the swallowing mechanism has a problem, the swallowed materials may leak into the respiratory tract, which is called swallowing impairment or dysphagia (deglutition). In the U.S., the annual prevalence of dysphagia in ordinary adults is approximately 4% [1]. There is a significant increase in medical expenditures in patients suffering from dysphagia [2]. The incidence of dysphagia increases with the age. Taking the most common oropharyngeal dysphagia for example, approximately 13-60% healthy elderly people suffer from it, and as high as 80% of institutionalized residents may suffer from it [3,4].

Patients with dysphagia may experience many medical complications, especially aspiration pneumonia, which refers to the infection and swelling of the lungs and respiratory tract caused by food or fluid leakage. Aspiration pneumonia caused by dysphagia in patients living in nursing homes is usually life-threatening [5]. Dysphagia may induce weight loss and malnutrition. Unintentional weight loss and malnutrition have an impact on the health, wellbeing, and independence of the elderly [6,7], as well as increase their risk of hospitalization and death [6].

In addition to inducing physical problems, clients with dysphagia may suffer from depression and low self-esteem. The social impacts caused by dysphagia are discomfort or distress during food intake, which interferes with people's participation in social interactions and causes social isolation. Moreover, dysphagia may limit the dietary content of people, cause a failure to enjoy food intake, and interfere with quality of life. Therefore, early detection of swallowing impairment or prevention/delay of dysphagia has become an important issue.

The tongue is part of the structure of the mouth and jaw system, and its main function is to chew, form a bolus, and push it to the pharynx. The tongue is also associated with breathing and speaking functions. At the oral phase of the swallowing process, the tip of the tongue will squeeze the food against the hard palate and transport it to the base of the tongue. Afterwards, at the pharyngeal phase, the swallowing reflex starts and the suprahyoid muscles contract [8].

Suprahyoid muscles connect the jaw and the hyoid bone, and consist of the mylohyoid muscle, the geniohyoid muscle, and the digastric muscle. The contraction of these muscles will pull the anterior and upper parts of the hyoid bone, and then, close the epiglottis, and relax the upper sphincter of the esophagus to promote normal swallowing. Therefore, suprahyoid muscles are important muscles at the pharyngeal phase of swallowing. The movement of the bolus during swallowing depends on the push

of the oropharynx and the pull of the swallowing. The push of the oropharynx is derived from the pressure generated from contact between the tongue and the hard palate at the pharyngeal phase of swallowing. When the tip of the tongue is against the front teeth, it will also touch the hard palate, which will move the tongue and help to maintain and transport the bolus. Therefore, tongue-mandible pressure is associated with the functioning of the oral and pharyngeal phases of swallowing.

The function of the tongue can be evaluated by the pressure it produces. In general, the maximum isometric pressure it produces can be used as a standard value of patients' tongue muscle training. For example, the isometric movement of the anterior tongue is implemented by the tip of the tongue against the front teeth. The isometric resistance movement of the posterior tongue is implemented by the tongue against the hard palate [9].

As the tongue and lip strength, and the related factors affecting them, have not been investigated in the healthy Chinese population, this research team is motivated to conduct this study.

Evaluation of Tongue Strength

Many instruments can measure tongue strength. Currently, the Iowa Oral Performance Instrument (IOPI) (Figure 1) is used most frequently. IOPI contains a tongue bulb, connecting tube, and the machine body. The tongue bulb is a rubber ball of 3.5 cm in length and 1.5 cm in width, containing 2.8 c.c. of air inside. The tongue bulb is connected to the IOPI instrument body by a curved hose of approximately 11.5 cm in length.

Based on the systemic literature review and integrated empirical analyses, IOPI is the most suitable tool for measuring tongue strength and endurance in adults [10]. Previous studies testing the IOPI showed extremely high reliability [10-13]. IOPI can be used to measure the anterior and posterior tongue strength, and its unit of pressure is kilopascals (kPa) [9,11,14].

Many studies have enrolled healthy adults as the subjects to measure the maximum isometric strength of the anterior and posterior tongue [10,11,13]. In general, during isometric movement or swallowing, the anterior tongue strength is stronger; however, this result may vary with age, gender, site of the tongue, etc. [14]. A past study showed that the maximum isometric pressure of the tongue in healthy adults decreases with the increase in age, and gender has significant effect on it [13-15] (Figure).

Figure 1

Tongue Strength during Swallowing

While the maximum isometric tongue strength is most frequently measured, tongue strength during swallowing is seldom measured. The tongue strength generated in healthy adults during swallowing is smaller than that of the maximum isometric tongue strength [13, 16]. Gingrich (2011) [17] recruited healthy adults at various ages as the participants, and requested them to swallow 10 c.c. of food of different textures, respectively. The results showed that the tongue strength used during swallowing is 30%~50% of that of the maximum isometric tongue strength.

As successful swallowing is the result of the accuracy and coordination of human nerves and muscles, swallowing is a complex skill. From the perspective of rehabilitation, training of the swallowing skill can be completed using exercise [18]. For example, intervention with progressive isometric resistance exercise in patients can enhance tongue strength [19-21].

METHODS

Research Participants

The research protocol was submitted to the Research Ethics Committee of a regional hospital for review and approval (Research Ethics Committee of JEN-AI HOSPITAL No. 107-35). The inclusion criterion of the research participants was: adults over the age of 20 whose lips, teeth, tongue, palate, and chewing are normal. The exclusion criterion was: adults suffering from nervous system disease, gastrointestinal disease, gastroesophageal reflux, and head and neck disease. There were 15 research participants, including 4 male and 11 female participants that gave their consent to participate in this study. The mean age was 29.5 years old (±11.2 years old), and the age range was 20~56 years old. After the study group members explained the informed consent form, all the research participants had sufficient time to read the informed consent form content and were provided with an opportunity to ask any question about the study.

Measurement procedures

This study used Iowa Oral Performance Instrument (IOPI) Model 3.1 to measure tongue and lip pressure (IOPI Medical LLC., 2018). IOPI is a clinical instrument using an inflatable tongue bulb and a pressure sensor to measure tongue strength and endurance, and its readings are displayed in kilopascals (kPa). Before the measurement, the height and weight of every research participant were measured to calculate his/her BMI. During the measurement, the research participants took a sitting position.

Measurement of maximum isometric tongue strength

The maximum isometric pressure (MIP) of both the anterior and posterior tongue was measured 3 times [11]. The participants

were instructed to follow the instructions from the evaluator: "When I say 'Start,' please lift the pressure bulb upward on your anterior/posterior tongue to flatten it as hard as you can." During the measurement, the evaluator encouraged the participants to lift their tongue as hard as they could. The measurements were performed at an interval of 30-60 seconds, allowing the participants to take a rest.

During the measurement of swallowing strength, the evaluator's instruction was: "I will place the pressure bulb in your mouth. When you are ready, start to swallow saliva/water. Make sure not to bite the connecting tube. Are you ready? OK! Start!"

For the placement of pressure bulb, the pressure bulb was attached to the hard palate, namely, the posterior side of alveolar ridge, of the research participants. The sealing side of pressure bulb was at the posterior side of the incisors and the pressure bulb should be laid flat on the tongue surface. Regarding the placement at the posterior tongue, the top end of the pressure bulb was placed between hard palate and soft palate. The sealing side of the pressure bulb was at about the first molar.

The research participants were requested to press the pressure bulb using their tongue as hard as possible for approximately 2 seconds. The participants were allowed to take a rest for 30-60 seconds between 2 measurements. The highest value among the 3 measurement values was the tongue strength. If the values continued to decrease in the 3 measurements, the resting time might be insufficient.

Lip strength measurement

The pressure bulb was placed under orbicularis oris muscle (exactly at the interior side of the research participants' lip corner), namely, the external side of the central incisors. The research participants were instructed to "pout as hard as they could for approximately 2 seconds, and lift the pressure bulb upward to the teeth" (count 001, 002 silently).

During the measurements, visual and verbal encouragements could be used to help research participants. Between the 2 measurements, the research participants were allowed to take a rest for 30-60 seconds. The highest value among the 3 measurement values was the lip strength. If the values continued to decrease in the 3 measurements, the resting time might be insufficient.

Swallowing strength measurement

The swallowing strength was measured under 2 conditions: one was dry saliva swallowing and the other was water swallowing.

Tongue endurance

Once the research participants reached the maximum isometric pressure of the anterior tongue, the stopwatch was started to count the time until the pressure started to decrease, and such a period of time was tongue endurance. In other words, tongue endurance was the period of time where the research participants maintained the maximum anterior isometric tongue pressure.

Statistical Analysis

This study used the software IBM SPSS 23.0 (IBM, Armonk, NY, USA) to analyze the data. As this study only enrolled a few participants, this study analyzed the differences between left and right lips and anterior and posterior tongue strength using Wilcoxon Signed Ranks Tests. In addition, this study tested the differences in various attributes (variables) using Mann- Whitney U Tests.

RESULTS

Descriptive Data

This study recruited a total of 15 research participants, and more than 70% of them were female (73.3%). The age of most of them was 20-39 years (79.9%); the BMI of 60% of the participants was within the normal range (18.5-24 kg/m^2) (Table 1).

Table (2) includes the measurement of the maximum isometric strength, as well as the anterior and posterior tongue strengths under dry saliva and water swallowing. In terms of the measurement of the maximum isometric strength, the mean of various sites was : right lip 25.57 (±4.42), left lip 30.14 (±10.38), anterior tongue 58.71 (±13.11), posterior tongue 56.14 (±5.64); dry saliva swallowing - right lip 24.57 (±5.94), left lip 26.14 (±9.31), anterior tongue 53.50 (±12.65), posterior tongue 53.79 (±11.18); water swallowing - right lip 24.14 (±8.12), left lip 25.50 (±7.62), anterior tongue 52.57 (±11.86), posterior tongue 52.43 (±9.43). During the measurement of the participants' maximum anterior isometric strength, the period of time where they maintained the maximum isometric strength was the tongue endurance, and the mean was 3.56 seconds (±2.41).

Inferential Statistics

(1) Comparison analysis of the left and right lip strength: As shown in Table (3), there was statistically significant difference in the maximum isometric strength of the left and right lips ($p < .05$), while there was no statistically significant difference between dry saliva and water swallowing.

(2) Comparison analysis of the anterior and posterior tongue strength: As shown in Table (4), there was no statistically significant difference in anterior tongue and posterior tongue strength under the maximum isometric strength, dry saliva, or water swallowing. The mean of the anterior tongue was higher than that of the posterior tongue by approximately 5~10%.

(3) Effect of demographic variables on mouth strength: Gender had significant effect on the maximum isometric strength of the left and right lips and anterior tongue ($p < .05$). Under dry saliva swallowing, gender only had effect on the right lip ($p < .05$). Under water swallowing, gender had significant effect on the left and right lips (Table 5). The lip and tongue strength of male adults were both higher than those of female adults. Age and BMI did not have significant effect on mouth strength under different conditions.

DISCUSSION

The purpose of this study was to investigate the tongue and

Table 1: The Demographic variables of participants.

Variables	No (%)	Mean (SD)
Gender		
Male	4 (26.7)	
Female	11 (73.3)	
Age (years)		29.53 (11.24)
Young adults (20-39)	12 (79.9)	
Middle-agers (40-60)	3 (20.1)	
Body mass index (BMI)		
Normal (18.5~24)	9 (60.0)	
Abnormal (>24)	6 (40.0)	
(N = 15)		

Table 2: Oral Strength under Different Conditions (kPa).

Site Condition	Right lip Mean(SD)	Left lip Mean(SD)	Anterior tongue Mean(SD)	Posterior tongue Mean(SD)	Tongue endurance Mean(SD)
Maximum isometric strength	25.57(4.42)	30.14(10.38)	58.71(13.11)	56.14 (5.64)	3.56 seconds (2.41)
Dry saliva swallowing	24.57(5.94)	26.14 (9.31)	53.50(12.65)	53.79(11.18)	
Water swallowing	24.14(8.12)	25.50 (7.62)	52.57(11.86)	52.43 (9.43)	
(N = 15)					

Table 3: Comparison Analysis of Left and Right Lip Strength (kPa).

Condition	Right lip Mean(SD)	Left lip Mean(SD)	*z*	*p*
Maximum isometric strength	25.57(4.42)	30.14(10.38)	–2.24	.025*
Dry saliva swallowing	24.57(5.94)	26.14 (9.31)	–0.98	.327
Water swallowing	24.14(8.12)	25.50 (7.62)	–1.84	.065
(N = 15)				

Table 4: Difference in Anterior and Posterior Tongue Strength (kPa).

Condition	Anterior tongue Mean(SD)	Posterior tongue Mean(SD)	*z*	*p*
Maximum isometric strength	58.71(13.11)	56.14 (5.64)	–.98	.327
Dry saliva swallowing	53.50(12.65)	53.79(11.18)	–.28	.777
Water swallowing	52.57(11.86)	52.43 (9.43)	–.54	.593
(N = 15)				

Table 5: Effect of Gender on Mouth Strength (kPa).

Strength	Male Mean(SD)	Female Mean(SD)	*z*	*p*
Maximum isometric strength				
Right lip	30.50 (3.11)	23.60 (3.13)	3.73	.003*
Left lip	39.75(13.65)	26.30 (6.00)	2.65	.021*
Anterior tongue	69.75(14.41)	54.30(10.17)	2.30	.041*
Posterior tongue	57.75 (6.70)	55.50 (5.42)	.66	.522
Dry saliva swallowing				
Right lip	29.75 (7.27)	22.50 (4.09)	2.41	.033*
Left lip	33.50(15.02)	23.20 (4.02)	2.10	.057
Anterior tongue	51.25(22.31)	54.40 (7.89)	–.41	.691
Posterior tongue	51.25(16.66)	54.80 (9.16)	–.52	.611
Water swallowing				
Right lip	32.00(11.80)	21.00 (3.23)	2.85	.015*
Left lip	32.75(11.76)	22.60 (2.27)	2.77	.017*
Anterior tongue	52.25(19.67)	51.90 (8.52)	.32	.752
Posterior tongue	50.25(10.78)	53.30 (9.31)	–.53	.605
(N = 15)				

lip strength of healthy adults, as well as the factors affecting it. The tongue and lip maximum isometric strengths (pressure, kPa) measured in this study were within the value range described in past studies [11,13,14,15,22].

Regarding the measurement of lip/tongue strength, the pressure bulb should not be placed between lips, but should be placed beside the cheeks, namely, the interior side of the lip corner, as lip closure is dependent upon the orbicularis oris muscle surrounding the mouth. Although a previous study indicated that there is no significant difference in maximum isometric strength between the left and right lips [14], this study found that there is statistically significant difference in maximum isometric strength between and left and right lips (p=.025). Dry saliva swallowing and water swallowing did not have significant effect, and the reason might be that the sample size was too small (only 15 participants). Further investigations can be performed after the sample size is expanded in the future.

Regarding the maximum isometric strength of the anterior and posterior tongue, the maximum isometric strength of the anterior tongue was higher than that of the posterior tongue by 2.57kPa. This result is consistent with that in the past studies – the anterior tongue strength is higher than the posterior tongue strength by 5-10% [14, 15, 22]. There was no significant difference in pressure (kPa) derived from the anterior and posterior tongue under maximum isometric strength, dry saliva and water swallowing. These results were consistent with that of the past study [11].

Regarding the effect of gender, age, and BMI on the left and right cheeks (lips) and anterior and posterior tongue strength under maximum isometric strength, dry saliva, and water swallowing, only gender had effect on the left and right lips and anterior and posterior tongue strength. Clark and Solomon (2012) [14] discovered that gender has effect on the pressure (kPa) of the left and right lips. However, gender does not have effect on anterior and posterior tongue pressure [13-14].

This study found that gender had effect on anterior and posterior tongue pressure. Among the 15 research participants, the range of their left and right lip strength and anterior and posterior tongue strength (pressure) was wide. The standard deviation of the measurement values of the left and right lip strength under maximum isometric strength, dry saliva swallowing, and water swallowing was 4.42~10.38kPa, and that of the measurement values of the anterior and posterior tongue strength was 5.64~13.11kPa, revealing the variability of the research participants. This was also the reason why the measurement under every condition should be performed 3 times to reduce the variability of the research participants as much as possible.

A previous study showed that among 171 research participants, the mean lip strength of males was 33.8(±15.1) and that of females was 22.4(±7.5); there was significant difference between male and female, and this result was consistent with the result of this study [14]. The measurement of tongue strength was mainly performed on the anterior tongue, as the posterior tongue is a critical strength for pushing bolus and fluid from the mouth to the pharynx, and the swallowing at the pharyngeal phase is not self-controlled. Therefore, most of the studies mainly measured anterior tongue strength to determine the measurement of tongue strength and endurance.

In terms of methodology, past studies using IOPI all performed measurements 3 times, and used the maximum instead of the mean as the strength value. A study [15] showed if healthy research participants were allowed to look at the IOPI, there was no significant difference in the 3 measurement values of tongue strength. If they were not allowed to look at the IOPI, the first measurement value was usually the highest. Similar results were obtained in other studies. If the measurement time is limited, a single measurement value collected from participants who are not allowed to look at IOPI may be used clinically.

LIMITATIONS AND SUGGESTIONS

It is preferable to expand the sample size in the future to enroll an equal number of male and female participants at all ages to increase the verification power, as well as to establish a model of measurement for the left and right lip strength and anterior and posterior tongue strength under different conditions, in order to further apply such a model to clinical swallowing evaluation.

CONCLUSION

Overall, the measurements of the lip and tongue strength of healthy adults in this study may help understand how lip and tongue strength is derived under the conditions of maximum isometric strength, dry saliva, and water swallowing, as well as the effect of gender on tongue and lip strength. The research results may serve as reference for target value setting of tongue and lip strength in the future development of oral rehabilitation exercise programs for patients with dysphagia.

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