Dental, Oral and Craniofacial Research

Research Article

ISSN: 2058-5314

# Analysis of factors related to tongue pressure during childhood

**Takuya Asami[1], Akiko Ishizaki[1]*, Ayano Ogawa[1,2], Hyosong Kwon[1,3], Kimiko Kasama[1], Akinobu Tanaka[1,4] and Shouji Hironaka[1]**

[1]Department of Special Needs Dentistry, Division of Hygiene and Oral Health, School of Dentistry, Showa University, Japan

[2]Kanagawa children's medical center, Japan

[3]K Dental Clinic, Japan

[4]Tanaka Dental Clinic, Japan

## Abstract

**Aim:** Tongue pressure caused by contact between the tongue and palate during eating and pronunciation is regarded as an effective index to evaluate the muscle strength of the tongue. There are few reports of tongue pressure measurement in children. In this study, we investigated the changes in tongue pressure during childhood and clarified factors related to it.

**Methods:** A questionnaire was completed by the parents of 27 children for whom it was difficult to measure tongue pressure and 209 children who were able to comply. Measurements were taken of grip strength, body composition, occlusal force, tongue thickness, and tongue pressure (JMS tongue pressure measurement device using balloon-based).

**Results:** Tongue pressure (kPa) was 11.8 ± 7.7 for 3 year old, 16.7 ± 7.5 for 4 year old, 22.1 ± 9.5 for 5 year old, and 25.4 ± 8.2 for 6 year old, showing a moderate correlation with age. Tongue pressure was moderately correlated with height, weight, grip strength, and skeletal muscle mass. There was almost no correlation between occlusal force and tongue thickness.

**Conclusions:** Maximum tongue pressure increased with age. Tongue pressure was related to grip strength, suggesting that tongue pressure was related to physical function and generalized muscle strength.

## Introduction

The tongue plays important roles in oral function, especially eating and pronunciation. Pressure to the tongue caused by contact with the palate during eating and pronunciation is regarded as an effective standard to evaluate the muscle strength of the tongue [1,2]. Tongue pressure measurement is now widely used to test the oral function test of adults and the elderly [3-5]. Tongue pressure is reported to be associated with grip strength, clear pronunciation, and performance of the Repetitive Saliva Swallowing Test in adults and the elderly [6-9] and with lip-closure forces, masticatory performance, the decayed, missing, and filled teeth index in school-age children [10,11].

On the other hand, there are few reports of tongue pressure measurement in children due to the difficulty of children to understand the instructions of the measuring method, low possibility of reproducibility, and the limited number of instruments for measurements in children [12]. Particularly, there has been no study of the tongue pressure for children using the balloon-based JMS tongue pressure measurement device (JMS, Hiroshima, Japan).

Therefore, the aims of this study were to conduct tongue pressure measurements of children to clarify changes and factors related to tongue pressure in childhood.

## Materials and methods

The study protocol was approved by the Ethics Committee of Showa University School of Dentistry (Issue #2014-015 in 2014) and written consent was obtained from the parents of the study participants and agreement for participation was obtained from each of the child participants.

### Study design

This cross-sectional study included a survey that was conducted in February 2016.

### Participants

The study participants consisted of 209 children (average age, 62.4 ± 12.9 months) recruited from four nursery schools in Kashima city, Ibaraki, Japan. The school staff distributed letters and collected the completed consent forms. The response rate was 54.0%. Of the 270 children for whom a consent form was completed, 23 were absent from school on the day of testing, 11 did not submit a completed questionnaire, and tongue pressure could not be measured in 27 (Figure 1). Finally, a total

***Correspondence to:*** Akiko Ishizaki, DDS, PhD, Department of Special Needs Dentistry, Division of Hygiene and Oral Health, School of Dentistry, Showa University, Japan, Tel: 81-3-3784-8172; E-mail: akiko.i@dent.showa-u.ac.jp

***Key words:*** *maximum tongue pressure, JMS tongue pressure measurement device, maximum grip strength, tongue thickness*

**Special Issue: Research on human food, chewing and swallowing**

Shigeru Watanabe, DDS, PhD

Professor of Division of Pediatric Dentistry,

School of Dentistry, Meikai University, Japan

Published: August 31, 2017

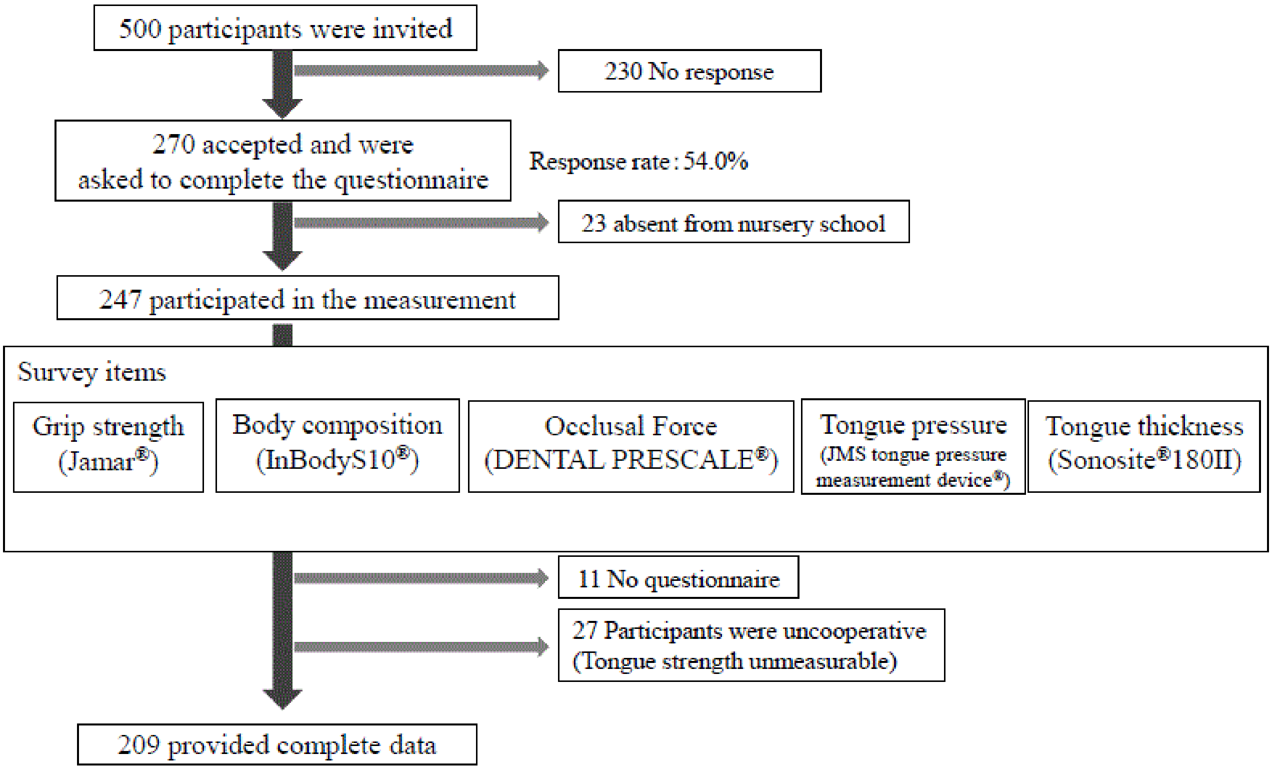


**Figure 1.** Flow diagram.

of 209 children (113 boys and 96 girls; age: 3–6 years) were enrolled in this study. None of the study participants had any current illnesses and oral habits at the time of investigation or a known medical history of orthopedic dysfunction that could affect the test results.

## Grip strength

The maximum grip force was measured using a Jamar® Smart Hand Dynamometer (Patterson Medical Ltd., Sutton-in-Ashfield, UK). The position of the dynamometer was set according to the manufacturer's instructions and the children were instructed to grip the instrument with as much force as possible [13-15]. Two successive trials were conducted to estimate grip strength and the maximum value was recorded.

## Body composition

Skeletal muscle mass was measured using a body composition analyzer (InBodyS10®; Biospace Co., Ltd, Seoul, Korea). This device uses multiple-frequency bioelectrical impedance analysis technology and has six 8-point tactile electrodes that are attached to the left and right thumbs, middle fingers, and ankles. In accordance with the manufacturer's instructions, the children were seated in an upright position and instructed not to make contact between their arms or legs and to talk or move during the 2-min measurement period [16,17].

## Occlusal force

The occlusal force was measured using occlusal pressure measurement film (Dental Prescale® 50H type SS size and S size; Fuji Film Co., Tokyo, Japan). The children were instructed to sit on a chair in an upright position so that Frankfurt plane was parallel to the floor. The children were asked to clench the film with maximum force. After two successive trials, the films were stored in a cool, dark place prior to analysis. Occlusal force was analyzed using an Occluzer® FPD-707 image scanner (GC, Tokyo, Japan) [18]. Of the two values, the larger occlusal force was included for analysis [17,19].

## Tongue pressure

MTP was measured using a JMS tongue pressure measurement device® (Figure 2A). The participants were instructed to assume a relaxed sitting position, while maintaining the Frankfurt plane horizontally. In addition, the participants were asked to place a balloon (Figure 2B) on the anterior part of the palate and then to close their lips around a hard ring bit using the upper and lower incisors. The participants were then asked to press the tongue against the roof of the mouth as hard as possible while the measured value was stable (Figure 2C). The pressure was measured (in units of kilopascals) using a digital voltmeter attached to the tongue pressure manometer. Measurements were made in duplicate separated by an interval for rest and the larger of two measurements was used for analysis [10,11].

## Tongue thickness

Tongue thickness was measured using the Sonosite® 180 Plus Portable Ultrasound System (Fuji Film Co.). The measurement points were located on the upper and lower surfaces of the lingual muscles in the center of the plane perpendicular to the Frankfurt horizontal plane in a frontal section. This perpendicular plane went through the distal surfaces of the bilateral mandibular second primary molars. The measurement point on the coronal plane is shown in Figure 2D. The vertical distance was measured from the surface of the mylohyoid muscle to the tongue dorsum (Figure 2E) [20-22]. Measurements were performed twice in freeze-frame with the tongue in a resting position and the mean values were obtained.

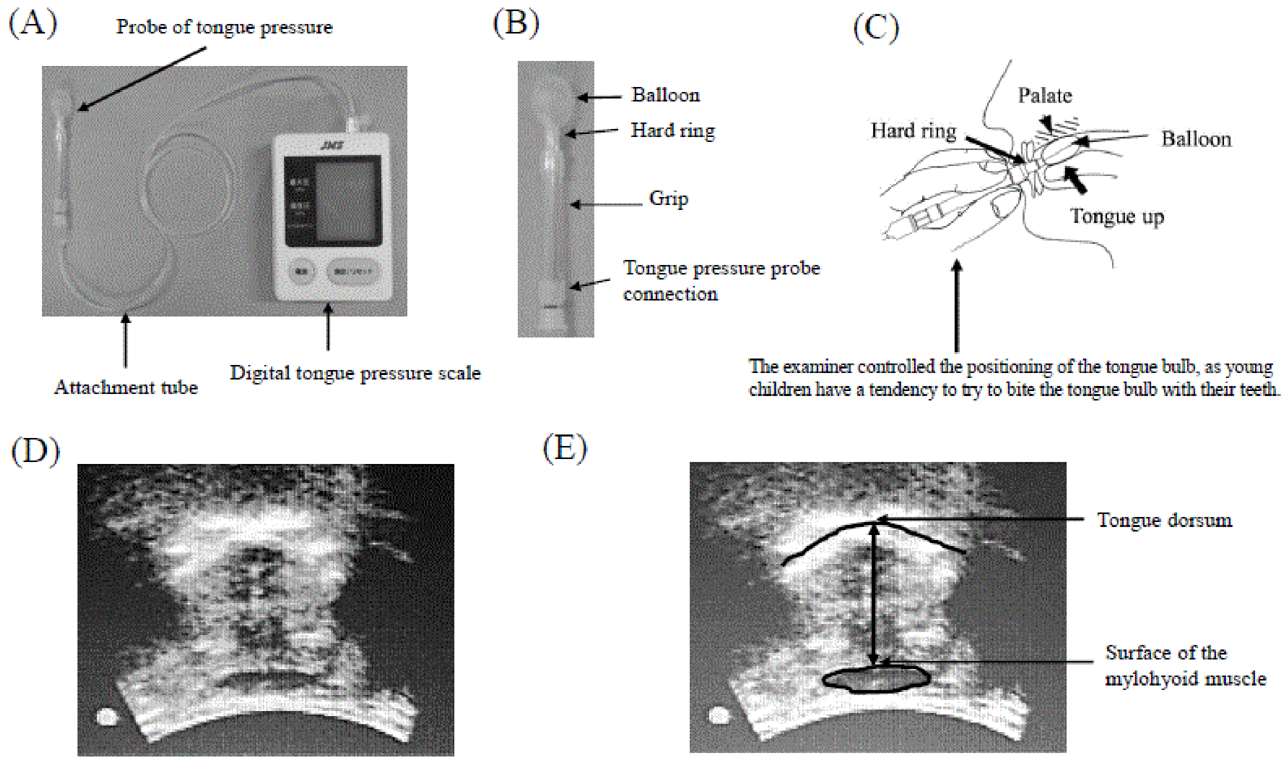


**Figure 2.** Tongue pressure device and tongue thickness measurement device [A: JMS tongue pressure measurement device®; B: Probe of tongue pressure; C: Method of tongue pressure measurement; D: Ultrasonographic image (tongue thickness of frontal section); E: Method of tongue thickness measurement]

### Statistical analysis

All data were analyzed with SPSS® version 23.0 software for Windows (IBM Japan, Inc., Tokyo, Japan). Correlations were identified using the Spearman's rank correlation coefficient, partial correlation coefficient, and t-test. A probability ($p$) value of <0.05 was considered statistically significant.

## Results

### Characteristics of the children

A total of 209 nursery school children (113 boys, 96 girls) with an average age of 60.1 (range, 49.0–72.0) months participated in this study. The mean height and body weight of these children are shown in Table 1a. The height and body weight of the children (Kashima, Japan) were almost the same as the average values among Japanese children [23]. Hence, this was an average group in terms of general development.

### Excluded children

Of the 270 children for whom a consent form was completed, 23 were absent from school on the day of testing, 11 did not submit a completed questionnaire, and tongue pressure could not be measured in 27. Many children who had difficulty in tongue pressure measurement were younger than the average (Table 2). The reasons that the children had difficulty in measurement were (1) inability to understand the instructions, (2) willingness, (3) inability to compress the balloon, and (4) nausea.

### Maximum tongue pressure

MTP was moderately correlated with age ($r = 0.581$, $p < 0.01$). The average MTP value for each age was as follows: 3 years, 11.82 ± 7.68 kPa; 4 years, 16.67 ± 7.49 kPa; 5 years, 22.10 ± 9.50 kPa; and 6 years, 25.38 ± 8.15 kPa (Table 1a). Although there was a correlation between MTP and age ($p < 0.01$ and 0.05 for children aged 5 and 6 years, respectively), there was none between MTP and sex (not significant) (Figure 3).

### Relationship between maximum tongue pressure and other factors

MTP was moderately correlated with height, weight, maximum grip strength, and skeletal muscle mass (r = 0.506, 0.488, 0.596, and 0.497, respectively, all $p < 0.01$) (Table 3). However, MTP showed almost no correlation with occlusal force or average tongue thickness ($r = 0.087$ and $r = 0.145$, $p < 0.05$) (Table 3). In addition, regardless of age, MTP was weakly correlated with maximum grip strength ($r = 0.258$, $p < 0.01$) (Table 4).

### Other factors (average tongue thickness, height, weight, maximum grip strength, occlusal force, and skeletal muscle mass)

Table 1a shows the average of the measurement item according to age and Table 1b shows the average tongue pressure measurement according to age of the excluded children. All parameters, with the exception of the average tongue thickness, were strongly correlated with age (r = 0.873, 0.764, 0.767, 0.262, and 0,773, respectively, all $p < 0.01$) (Table 3). In addition, the average tongue thickness was weakly correlated with weight and skeletal muscle mass (r = 0.304 and 0.331, respectively, $p < 0.01$ for both) (Table 3).

## Discussion

### Changes in tongue pressure in childhood

The participants in this study were of normal development and of similar height and body weight as the average values in Japan.

**Table 1a.** Average of measurement items by age.

| | Height(cm) | Weight(kg) | Maximum grip strength(kg) | Skeletal muscle mass(kg) | Occlusal force(N) | Maximum tongue pressure(kPa) | Average tongue thickness(cm) |
|---|---|---|---|---|---|---|---|
| 3years (n=44) | 95.18±3.51 | 14.36±1.44 | 3.95±1.17 | 5.12±0.77 | 156.34±77.19 | 11.82±7.68 | 3.07±0.25 |
| 4years (n=49) | 102.93±4.89 | 16.69±1.78 | 5.28±1.00 | 6.29±0.82 | 206.87±96.64 | 16.67±7.49 | 3.18±0.29 |
| 5years (n=58) | 108.86±4.31 | 18.74±2.92 | 7.07±1.75 | 7.28±1.17 | 196.48±104.78 | 22.10±9.50 | 3.19±0.27 |
| 6years (n=58) | 114.20±4.00 | 20.64±2.56 | 8.12±1.41 | 8.12±1.24 | 237.89±100.94 | 25.38±8.15 | 3.20±0.24 |
| Total (n=209) | 106.07±8.10 | 17.87±3.25 | 6.28±2.10 | 6.83±1.51 | 201.96±100.01 | 19.57±9.69 | 3.16±0.27 |

**Table 1b.** Average of measurement item by age of children excluded from tongue pressure measurement.

| | Height(cm) | Weight(kg) | Maximum grip strength(kg) | Skeletal muscle mass(kg) | Occlusal force(N) | Maximum tongue pressure(kPa) | Average tongue thickness(cm) |
|---|---|---|---|---|---|---|---|
| 3years (n=11) | 94.17±3.75 | 14.14±1.19 | 3.33±1.01 | 4.63±0.85 | 113.51±59.85 | Unmeasurable | 2.99±0.15 |
| 4years (n=11) | 102.95±3.40 | 16.82±2.62 | 4.97±1.00 | 6.08±0.91 | 154.66±100.65 | Unmeasurable | 3.10±0.40 |
| 5years (n=3) | 108.13±4.79 | 19.97±3.59 | 5.60±0.40 | 7.33±1.00 | 196.03±82.26 | Unmeasurable | 3.10±0.12 |
| 6years (n=2) | 112.65±1.77 | 19.72±1.86 | 10.00±2.26 | 7.80±0.85 | 61.70±87.26 | Unmeasurable | 3.13±0.19 |
| Total (n=27) | 100.00±6.86 | 16.20±3.00 | 4.74±2.01 | 5.74±1.38 | 133.32±87.64 | Unmeasurable | 3.05±0.28 |

(mean±SD)

**Table 2.** Characteristic of the children excluded from tongue pressure measurement.

| Number | Age (months) | Sex | occlusal force(N) | Exclusion reason |
|---|---|---|---|---|
| 1 | 36 | M | 58.1 | Introduction is not understood |
| 2 | 38 | F | Unmeasurable | Rejection |
| 3 | 40 | F | Unmeasurable | Can't be well compressed the balloon |
| 4 | 40 | M | 124.9 | Introduction is not understood |
| 5 | 41 | M | 203.3 | Can't be well compressed the balloon |
| 6 | 42 | F | 105.4 | Can't be well compressed the balloon |
| 7 | 42 | M | 100.2 | Introduction is not understood |
| 8 | 45 | M | 125.5 | Can't be well compressed the balloon |
| 9 | 45 | M | 128.2 | Can't be well compressed the balloon |
| 10 | 46 | F | 176 | Rejection |
| 11 | 47 | F | Unmeasurable | Can't be well compressed the balloon |
| 12 | 49 | M | 13.8 | Can't be well compressed the balloon |
| 13 | 49 | F | 340.6 | Can't be well compressed the balloon |
| 14 | 49 | M | 177.3 | Can't be well compressed the balloon |
| 15 | 51 | F | 64.4 | Can't be well compressed the balloon |
| 16 | 52 | M | 164.6 | Can't be well compressed the balloon |
| 17 | 54 | M | 62.5 | Can't be well compressed the balloon |
| 18 | 55 | M | 126.6 | Can't be well compressed the balloon |
| 19 | 57 | F | 74.4 | Can't be well compressed the balloon |
| 20 | 58 | M | 180.9 | Can't be well compressed the balloon |
| 21 | 59 | M | 294.2 | Can't be well compressed the balloon |
| 22 | 59 | M | 202 | Can't be well compressed the balloon |
| 23 | 60 | F | 271.9 | Can't be well compressed the balloon |
| 24 | 61 | F | 207.6 | Rejection |
| 25 | 66 | F | 108.6 | Introduction is not understood |
| 26 | 74 | M | 123.4 | Can't be well compressed the balloon |
| 27 | 80 | M | Unmeasurable | Nausea |

Therefore, that the results of the tongue pressure measurements were considered standard for Japanese children.

In this study, MTP was moderately correlated with age. According to a report by Utanohara et al. [3], MTP is relatively stable from the age of 20 to 50 years and then decreases over the age of 60 years. On the other hand, Nancy et al. [12] reported that MTP, as measured with the Iowa Oral Pressure Instrument (IOPI measurement device), increases from the age of 3 to 16 years. Therefore, it is considered that MTP increases with age, peaks in early adulthood, and decreases in old age [10]. The MTP of 27.15 ± 4.80 kPa for 6-year-old children with the JMS tongue pressure measurement as reported by Ichikawa et al. [10] was close to the measurement of 25.38 ± 8.15kPa in this study. In addition, considering that Nancy et al. [12] reported that the MTP increased from the age of 3 to 6 years, the tongue pressure measurement of children with the JMS tongue pressure measuring device in this study was appropriate.

In regard to, sex differences, MTP is considered to be significantly greater in males than in females aged 20 to 40 years and almost the same between sexes from the age of 50 to 70 years [3]. Furthermore, it is reported that there is no significant difference in MTP between males and females from the age of 3 to 16 years [12]. Moreover, the results of this study showed that there was no sex difference in MTP in childhood. Ogata et al. [24] reported a lower difference between males and females in the muscles used frequently in daily life (masseter muscle, leg muscle) in childhood than those used most frequently in adulthood (arm muscles) [24]. Since the tongue muscle is frequently used in daily life by both males and females, it was considered that no sex difference exists.

Tongue pressure measurement is currently used as an evaluation of oral function tests and rehabilitation in adults and the elderly [3-5]. In this study, since the JMS tongue pressure measurement device was shown to be appropriate for tongue pressure measurement in childhood, it might be useful for oral function tests [19] and evaluation of habilitation.

## Investigation of related factors

In this study, MTP showed a moderate correlation with age, height, weight, and skeletal muscle mass in children. Regardless of age, tongue pressure and grip strength were found to be weakly correlated. In elderly people, tongue pressure and grip strength are significantly correlated, although both parameters tend to decrease with increasing age [4,5,25]. As a possible explanation, as grip strength is related to skeletal muscle,

**Table 3.** Results of correlation.

| | Age (year) | Maximum tongue pressure (kPa) | Average tongue thickness (cm) | Height (cm) | Weight (kg) | Maximum grip strength (kg) | Occlusal force(N) | Skeletal muscle mass(kg) |
|---|---|---|---|---|---|---|---|---|
| Age (years) | - | 0.581** | 0.165* | 0.873** | 0.764** | 0.767** | 0.262** | 0.773** |
| Maximum tongue pressure (kPa) | | - | 0.145* | 0.506** | 0.488** | 0.596** | 0.087 | 0.497** |
| Average tongue thickness (cm) | | | - | 0.233** | 0.304** | 0.164* | -0.08 | 0.331** |
| Height (cm) | | | | - | 0.873** | 0.813** | 0.260** | 0.883** |
| Weight (kg) | | | | | - | 0.715** | 0.217** | 0.923** |
| Maximum grip strength (kg) | | | | | | - | 0.169* | 0.738** |
| Occlusal force (N) | | | | | | | - | 0.255** |
| Skeletal muscle mass (kg) | | | | | | | | - |

**p<0.01 *p<0.05
Spearman's correlation coefficient

**Table 4.** Correlations exclusive of age.

| Control variable number:Age (year) | Maximum tongue pressure (kPa) | Average tongue thickness (cm) | Height (cm) | Weight (kg) | Maximum grip strength (kg) | Occlusal force(N) | Skeletal muscle mass(kg) |
|---|---|---|---|---|---|---|---|
| Maximum tongue pressure (kPa) | - | 0.084 | 0.005 | 0.084 | 0.258** | -0.075 | 0.115 |
| Average tongue thickness (cm) | | - | 0.164* | 0.312** | 0.074 | -0.138 | 0.335** |
| Height (cm) | | | - | 0.603** | 0.400** | 0.115 | 0.648** |
| Weight (kg) | | | | - | 0.339** | 0.018 | 0.756** |
| Maximum grip strength (kg) | | | | | - | 0.002 | 0.364** |
| Occlusal force (N) | | | | | | - | 0.158 |
| Skeletal muscle mass (kg) | | | | | | | - |

**$p < 0.01$ *$p < 0.05$
Partial correlation coefficient

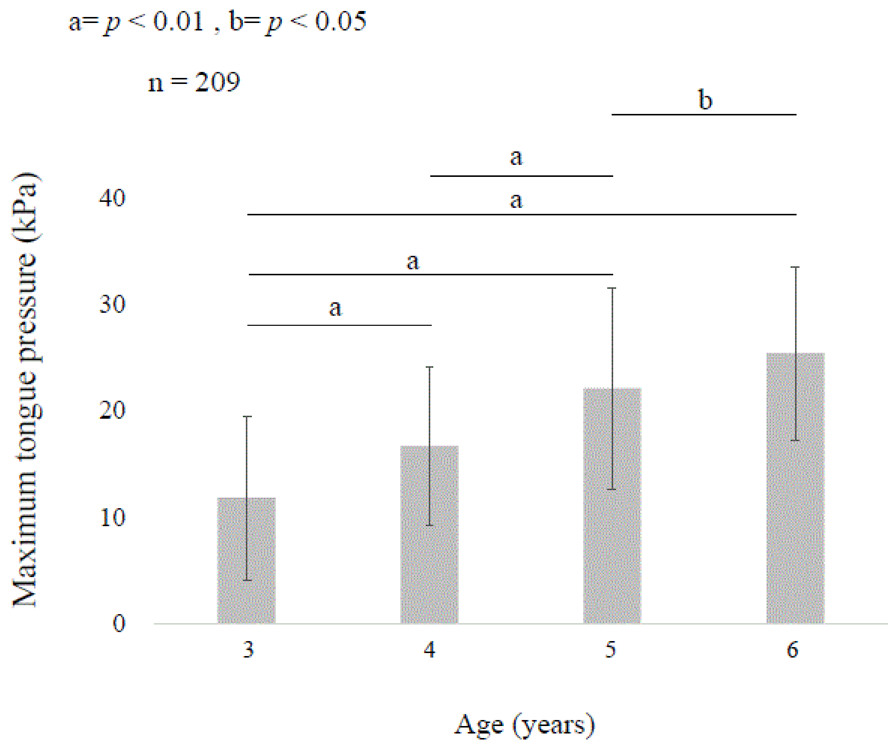


**Figure 3.** Comparison between maximum tongue pressure and age. No sex difference in MTP in childhood (t-test, not significant).

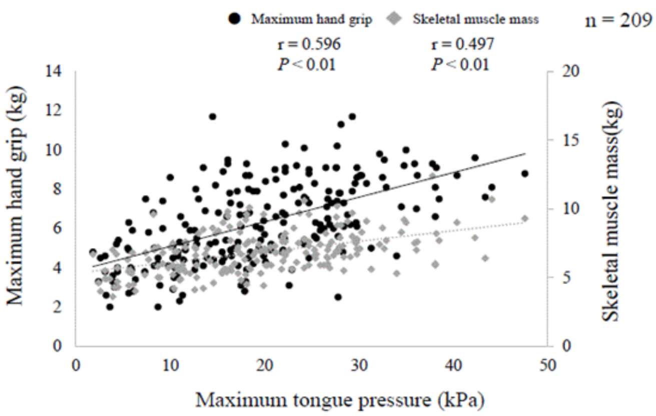


**Figure 4.** Comparison between maximum tongue pressure and maximum hand grip and skeletal muscle mass.

the extrinsic and intrinsic tongue muscles are composed of skeletal muscle fibers, so the muscle mass is reduced in older adults [3-5,25]. In this study, tongue pressure and grip strength were also weakly correlated in children, and grip strength increased as tongue pressure increased. Just as grip strength is a measure of muscular strength, MTP is representative of tongue muscle strength by using the pressure between the tongue and palate. Since the brachial muscles and tongue muscle are also cross-striated muscles, it is considered that the muscle strength of the tongue increases with grip strength. In addition, grip strength is regarded as a standard of physical function and general muscle strength [8,26]. Therefore, tongue pressure may be related to physical function and muscle strength of the whole body in childhood.

There was almost no correlation between MTP and tongue thickness or occlusal force. As a possible reason, although tongue pressure is a measurement of the muscle strength of the tongue, the occlusal force is strongly influenced by anatomical factors, such as dentition and occlusal morphology, rather than muscle strength. Therefore, it is considered necessary to measure not only tongue pressure but also occlusal force to comprehensively evaluate oral function in children. On the other hand, tongue thickness was weakly correlated with skeletal muscle mass and weight. In elderly people, tongue thickness is regarded to be related to physical constitution, age, and midarm muscle mass [20,21]. The thickness of skeletal muscle fibers, including facial muscles, can be approximated at birth but then increases from childhood to adulthood [27]. Since the tongue muscle is also a cross-striated muscle, which composes skeletal muscles, the tongue thickness and the skeletal muscle mass show a weak correlation. Therefore, it was supposed that tongue thickness is related to the muscle mass of the whole body.

These findings suggest that it is important to examine systemic growth and development when measuring tongue pressure.

This study did not include external evaluation of eating, speech intelligibility testing, or labial pressure measurements. The relationship between these evaluations and tongue pressure has been reported previously [5,7,8,11,28-32]. In future, we plan to explore the relationship with these evaluations and tongue pressure measurement to consider the usefulness and practicability of oral function tests in children.

## The measurement of tongue pressure in children

The size of the balloon of the JMS tongue pressure measurement device is based on the size of the bolus of adults and the elderly [1], not children. Although tongue pressure measurements are also possible in children, there exists the possibility that the volume of the balloon may be larger than the oral volume of children. Nancy et al. reported that although it was an IOPI measurement device, it was possible to obtain measurements in adults as well as in children using the same balloon size (2.8 mL) [12,33]. In this study, there exists the possibility that the balloon size (3.2 mL) of the JMS tongue pressure measurement device [34] may be larger than the oral volume of children. However, after re-examining the balloon size of the JMS tongue pressure measurement device, it was considered that it was not too big compared with a spoon for children. In addition, comparing the average value of mouthful weights reported by Kazuko Yagi et al. [35] with the balloon size of JMS, the balloon size of JMS was considered not to be too big during childhood. In addition, since it was difficult for younger children to understand the instructions of the measurement method, an explanation was given with the use of pictures of animals and illustrations. Since many of the younger children bit the balloon at the time of measurement, the examiner had to control the positioning of the probe and guide the hard ring part to the position of the upper and lower front teeth. The examinations were conducted at nursery schools to prevent the children from becoming nervous. In accordance with the method described by Nancy et al. [12], even though tongue pressure measurement was not practiced beforehand, many children had no problem with compliance with the protocol.

The ratio of children who had difficulty in measuring tongue pressure was 20% for 3 year olds, 18% for 4 year olds, 5% for 5 year olds, and 3% for 6 year olds, showing a higher ratio among younger children. The reasons why it was difficult to measure with 20% of children at 3 and 4 years were ① inability to understand the instructions, ② willingness, and ③ inability to compress the balloon. Therefore, these causes occurred owing to the fact that the ability to concentrate was not sustained due to the linguistic comprehension problem and that there were many measurement items at the time of survey and not because of the measuring equipment being a problem. In future, when measuring the tongue pressure in the group, it was suggested that it was necessary to narrow down the measurement items using a small number of people. To improve the accuracy of the measurement, it may be necessary to practice before taking measurements.

One limitation to this study is that it is a cross-sectional study. Longitudinal studies are warranted in the future for more detailed effectiveness of tongue pressure. Also, there was a possibility that some children had oral habits (not just related to the tongue) before the survey but did not admit. Therefore, it was added that it was not possible to state based on this research as to how having oral habits before the survey affected tongue pressure

## Conclusion

MTP increased from the age of 3 to 6 year; thus, it was considered that the use of tongue pressure measurement of children with the JMS tongue pressure measuring device was appropriate in this study. In addition, tongue pressure and grip strength were found to be correlated. It was suggesting that both parameters can be measured at about the cross-striated muscles force.

## Conflicts of interest

The authors declare no conflict of interest.

## Acknowledgement

We are very grateful to the children, parents, and staff in the nursery schools who participated and supported our survey. We also thank our colleagues of the division of hygiene and oral health, Showa University, Tokyo. This work was supported by JSPS KAKENHI (grant nos. JP15K20649 and JP16K11869).

## References

1. Hayashi R, Tsuga K, Hosokawa R, Yoshida M, Sato Y, et al. (2002) A novel handy probe for tongue pressure measurement. *Int J Prosthodont* 15: 385-388. [Crossref]

2. Ono T, Hori K, Nokubi T (2004) Pattern of tongue pressure on hard palate during swallowing. *Dysphagia* 19: 259-264. [Crossref]

3. Utanohara Y, Hayashi R, Yoshikawa M, Yoshida M, Tsuga K, Akagawa Y (2008) Standard values of maximum tongue pressure taken using newly developed disposable tongue pressure measurement device. *Dysphagia* 23: 286-290. [Crossref]

4. Mendes AE, Nascimento L, Mansur LL, Callegaro D, Jacob Filho W (2015) Tongue forces and handgrip strength in normal individuals: association with swallowing. *Clinics* 70: 41-45. [Crossref]

5. Yoshida M, Kikutani T, Tsuga K, Utanohara Y, Hayashi R, et al. (2006) Decreased tongue pressure reflects symptom of dysphagia. *Dysphagia* 21: 61-65. [Crossref]

6. Butler SG, Stuart A, Leng X, Wilhelm E, Rees C, et al. (2011) The relationship of aspiration status with tongue and handgrip strength in healthy older adults. *J Gerontol A Biol Sci Med Sci* 66: 452-458. [Crossref]

7. Sakai K, Nakayama E, Tohara H, Maeda T, Sugimoto M, et al. (2017) Tongue strength is associated with grip strength and nutritional status in older adult inpatients of a rehabilitation hospital. *Dysphagia* 32: 241-249. [Crossref]

8. Crow HC, Ship JA (1996) Tongue strength and endurance in different aged individuals. *J Gerontol A Biol Sci Med Sci* 51: M247-250. [Crossref]

9. Takeuchi K, Ozawa Y, Hasegawa J, et al. (2012) Usability of maximum tongue pressure measurement in patients with dysphagia or dysarthria-Using newly developed measurement device. *JJDR* 16: 165-174.

10. Ichikawa M, Fujita Y, Hamaguchi A, Chaweewannakorn W, Maki K (2016) Association of tongue pressure with masticatory performance and dental conditions in Japanese children. *Ped Dent J* 26: 51-59.

11. Shiono Y, Morikawa K, Maki K (2015) Comparative clinical study evaluating lip-closure forces in association with tongue pressure in children. *Ped Dent J* 25: 19-25.

12. Potter NL, Short R (2009) Maximal tongue strength in typically developing children and adolescents. *Dysphagia* 24: 391-397. [Crossref]

13. Mathiowetz V, Weber K, Volland G, Kashman N (1984) Reliability and validity of grip and pinch strength evaluations. *J Hand Surg Am* 9: 222-226. [Crossref]

14. Incel NA, Ceceli E, Durukan PB, Erdem HR, Yorgancioglu ZR (2002) Grip strength: effect of hand dominance. *Singapore Med J* 43: 234-237. [Crossref]

15. Wind AE, Takken T, Helders PJ, Engelbert RH (2010) Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *Eur J Ped* 169: 281-287. [Crossref]

16. Jensky-Squires NE, Dieli-Conwright CM, Rossuello A, Erceg DN, McCauley S, et al. (2008) Validity and reliability of body composition analysers in children and adults. *Br J Nutr* 100: 859-865. [Crossref]

17. Fujii K, Ishizaki A, Ogawa A, Asami T, Kwon K, et al. (2017) Validity of using multi-frequency bioelectrical impedance analysis to measure skeletal muscle mass in preschool children. *Physical Therapy Science* 29: 863-868. [Crossref]

18. Koko C, Yuriko Y, Yuko M, Kochi S, Mayanagiet H, et al. (2008) Comparison of occlusal function in children with and without cleft lip and/or palate. *Ped Dent J* 18: 131-136.

19. Ogawa A, Ishizaki A, Asami T, Kwon K, Fujii K, et al. (2017) Effectiveness of a mouth rinsing function test for evaluating the oral function of children. *Ped Dent J* 27: 85-93.

20. Watanabe S, Ayano R, Ohtsuka Y, et al. (1995) Ultrasound analysis in cornal section of tongue surface movements during swallowing. *J Jpn Soc Disabil Oral Health* 16: 24-37.

21. Okayama H, Tamura F, Tohara T, et al. A study on the tongue thickness of the elderly with care needs. *JJSDH* 31: 723-729.

22. Tamura F, Kikutani T, Tohara T, Yoshida M, Yaegaki K (2012) Tongue thickness relates to nutritional status in the elderly. *Dysphagia* 27: 556-561. [Crossref]

23. Report of Infants body growth investigation in 2011, Ministry of Health, Labour and Welfare, Japan.

24. Ogata K, Karibe H, Kikuchi S (1996) Assessment of the occlusal force in children utilizing the "Dental Prescale". *Jpn J Ped Dent* 34: 856-864.

25. Buehring B, Hind J, Fidler E, Krueger D, Binkley N, Robbins J (2013) Tongue strength is associated with jumping mechanography performance and handgrip strength but not with classic functional tests in older adults. *J Am Geriatr Soc* 61: 418-422. [Crossref]

26. Wind AE, Takken T, Helders PJ, Engelbert RH (2010) Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *Eur J Pediatr* 169: 281-287. [Crossref]

27. Bowden DH, Goyer RA (1960) The size of muscle fibers in infants and children. *Arch Pathol* 69: 188-189. [Crossref]

28. Honjyo T, Morikawa K, Saeki K, Nagao S, Hideshima O, et al. (2015) A study of the relationship between lip closing force and tongue presser in children. *Jpn J Ped Dent* 53: 60-68.

29. Lambrechts H, De Baets E, Fieuws S, Willems G (2010) Lip and tongue pressure in orthodontic patients. *Eur J Orthod* 32: 466-471. [Crossref]

30. Fukami A, Saitoh I, Inada E, Oku T, Iwase Y, et al. (2010) A reproducibility method to test lip-closing strength in preschool children. *Cranio* 28: 232-237. [Crossref]

31. Kikutani T, Tamura F, Nishiwaki K, Kodama M, Suda M, et al. (2009) Oral motor function and masticatory performance in the community-dwelling elderly. *Odontology* 97: 38-42. [Crossref]

32. Kikutani T, Tamura F, Nishiwaki K, Suda M, Kayanaka H, et al. (2009) The degree of tongue-coating reflects lingual motor function in the elderly. *Gerodontology* 26: 291-296. [Crossref]

33. Clark HM, Solomon NP (2012) Age and sex differences in orofacial strength. *Dysphagia* 27: 2-9. [Crossref]

34. Tsuga K, Yoshida M, Urabe H, Hayashi R, Yoshikawa M, et al. (2004) Effect of general condition and tongue pressure on meal form selection for elderly care recipient. *Journal of Japanese Society for Mastication Science and Health Promotion* 14: 62-67.

35. Kazuko Y, Junko M, Tomoe M, Taguchi Y, Noda T (2006) Changes in the mouthful weights of familiar foods with age of five years, eight years and adults. *Ped Dent J* 16: 17-22.