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ABSTRACT

Background: The tongue plays an important role in oral functions. Reduced tongue strength is often noted among children with mouth-breathing behavior. **Objectives:** The purposes of this study were to measure the tongue pressure in children with mouth-breathing behavior, to compare these values to those of children with nasal-breathing behavior, and to analyze the relationship between age and tongue pressure in children with a mouth-breathing pattern and in children with a nasal-breathing pattern. **Methods:** In this cross-sectional analytical observational study, we enrolled 40 children aged 5–12 years who either exhibited mouth-breathing behavior (n=20) or nasal-breathing behavior (gender- and age-matched [±2 years] controls; n=20). Tongue pressure was evaluated using the Iowa Oral Performance Instrument; three measurements were recorded for each participant, with a 30-s rest interval. **Results:** The average tongue pressure in the mouth-breathing group was lower than that in the nasal-breathing group. There was no difference in tongue pressure between genders. There was a strong and direct correlation between tongue pressure and age in the nasal-breathing group. **Conclusion:** The breathing pattern impacts tongue pressure development.

Keywords: Tongue, Muscle Strength, Mouth Breathing, Child, Respiration, Myofunctional Therapy.

1. **Background**

Mouth breathing occurs when respiration through the nose is supplemented by oral respiration. The prevalence of this condition is reportedly 55% among children aged 6–9 years[1]. The most frequent causes of mouth breathing include allergic or non-allergic rhinitis, pharyngeal tonsil (adenoid) and/or palatine tonsil (amygdales) hypertrophy, turbinate hypertrophy, and septum deviations[2]. Mouth breathing may also persist as a habit even after the anatomical factor that obstructed nasal breathing has been removed[2].

Commonly noted signs and symptoms associated with mouth breathing include frequent tiredness, daytime sleepiness, decreased appetite, attention deficits, typical facial abnormalities (such as increased vertical height of the lower third of the face, narrow maxillary arch, and narrow palate), dental malocclusions, and orofacial myology alterations (including a short upper lip, everted lower lip, lip incompetence, weakness of orofacial muscles, changes in resting tongue posture, deglutition, speech and mastication), voice abnormalities[3], altered neck posture and decreased respiratory muscle strength[4]. Additionally, studies have indicated that children with mouth-breathing behavior are more likely to have learning difficulties[5].

Reduced tongue strength is often noted among individuals with mouth-breathing behavior[2]. Tongue strength is routinely evaluated by speech-language pathologists as an essential part of orofacial myology assessments. The evaluation can be performed in a qualitative manner by asking the patient to press the tip of the tongue against the finger of the professional, against a tongue blade while the examiner provides resistance[6], or against the inner cheek while the examiner's fingers rest outside[7]. Speech-language pathologists classify tongue strength as either normal or reduced[8], and further classify the reduced category as slightly weak, moderately weak, or severely weak[9]. However, such an assessment is based on subjective judgment and is associated with concerns regarding its reliability.

Over the previous two decades, new tools have been developed to measure the pressure or the force generated by the tongue; these new tools have offered speech-language pathologists an objective way to assess tongue strength. The most commonly used tool is the Iowa Oral Performance Instrument (IOPI), which measures the pressure the tongue exerts on the palate[7]. Several studies have adopted the IOPI as a method of measurement. In fact, researchers have measured tongue pressure and/or endurance in adults[10], children[11], and individuals with the following conditions: dysphagia[12], head or neck cancer[13], oculopharyngeal muscular dystrophy[14], Parkinson disease[15], traumatic brain injury[16], developmental apraxia of speech[17], developmental verbal dyspraxia[17], cleft lip and palate[18], obstructive sleep apnea[19], primary snoring[19] and others. In children without any orofacial myofunctional disorders, the tongue strength increases rapidly from the age of 3 to 8 years, continues to increase at a slower rate with age, and reaches the peak between late adolescence and young adulthood[11]. To our knowledge, no study has used the IOPI to measure the pressure exerted by the tongues of children with mouth-breathing behaviors.

Considering the important role of the tongue in oral functions such as mastication, deglutition, and speech, some authors have examined the tongue in patients with mouth-breathing behaviors and have reported that mouth breathing is associated with decreased tongue force[20]. Due to the lack of sufficient data on this topic, in the present study, we aimed to measure tongue pressure in children with mouth-breathing behaviors and to compare these values with those of children with nasal-breathing behaviors. Our secondary objective was to analyze the relationship between age and tongue pressure in children with a mouth-breathing pattern and those with a nasal-breathing pattern. We hypothesized that children with a mouth-breathing pattern would have a lower tongue pressure than those with a nasal-breathing pattern.

Information on tongue pressure values in children with mouth and nasal breathing behaviors will enable speech-language pathologists to make a more accurate evaluation of tongue force and may also help to prove the effectiveness of the orofacial myofunctional therapy.

2. Methods

This analytical observational cross-sectional study conformed to the Helsinki Declaration and was approved by the University Research Ethics Committee (process 36663614.8.0000.5149).

2.1 Participants

The study included 40 participants aged 5–12 years who were assigned to two groups. The study group included 20 Portuguese-speaking children (13 boys and seven girls) with a mean age of 7.65±2.23 years. These participants were recruited from among the patients referred to the Mouth Breathing Outpatient Clinic of a university hospital, where they were diagnosed with mouth-breathing behavior of various etiologies (tonsil or palatine hypertrophy, allergic rhinitis, and other causes).

The control group included 20 Portuguese-speaking children (13 boys and seven girls), with a mean age of 8.25±1.97 years; these children were matched by sex and age (±2 years) with the study group and were recruited from a public school.

The inclusion criteria were as follows: age of 5–12 years, being a native Portuguese speaker, and provision of informed consent from the participant and the parents. In the study group, the patients also had to have received a diagnosis of mouth breathing by the multidisciplinary staff of the Mouth Breathing Outpatient Clinic of the Hospital between the dates of March 2015 and April 2015 and must not have initiated treatment. For the control group, the patients received a diagnosis of nasal breathing based on tests administered by the authors.

We did not include children aged <5 years of age because adenoids reach peak growth between 4 and 5 years of age[1], and very young children may find it difficult to follow orders and tolerate the bulb within the oral cavity.

The exclusion criteria for both groups were systemic disorders, craniofacial malformations and syndromes, coexistence of cognitive problems that affect language comprehension, inability to fulfil the tasks required for tongue pressure measurement, and other problems that could compromise the tests.

Two authors evaluated the control group participants using a protocol for the clinical diagnosis of mouth breathing[1]. The protocol involves patient history evaluation. Mouth breathing is characterized by the presence of certain major and minor signs. The authors considered the participants to be mouth breathers if they had two major signs or one major sign along with two or more minor signs.

The authors have considered snoring, open position of the mouth during sleep, drooling on the pillow, and a frequent blocked nose as the major signs of mouth breathing. The minor signs were itchiness of the nose, sporadic nasal congestion, nocturnal breathing difficulty, agitated sleep, diurnal sleepiness, irritability, difficulty swallowing food, more than three episodes of ear, nose, or throat infection (confirmed by a physician) during the previous 12 months, and problems at school.

Participants who were not diagnosed with mouth breathing in this test were subjected to another examination wherein their sealed lips were observed for 5 minutes during classes. If the child was able to maintain the lips sealed, we included him or her in the control group.

2.2 Tongue pressure measurement

Two speech-language pathology graduate students, directly supervised by a speech-language pathologist with more than 20 years of experience with orofacial myology disorders, accomplished tongue pressure measurements using the IOPI[7] (Figure 1). The measurements were performed at the Mouth Breathing Outpatient Clinic for the study group and at the school for the control group.

During the tests, the participants were placed in a seated position with their backs and feet supported. The bulb was positioned immediately posterior to the central incisors. The examiner held the bulb stem at a point immediately anterior to the participant's central incisors for consistent positioning of the bulb. The participants' mandibles were not restrained. The children were asked to raise their tongues and squeeze the bulb against the palate as hard as they could for approximately 3 s. The examiner then removed the bulb from the participant's mouth and attempted another measurement after a 30-s rest interval. The maximum value of three trials was recorded as the maximum tongue pressure for each participant.

2.3 Data analysis

Descriptive statistics were performed using frequency analysis for categorical variables, and central tendency and variability were used for continuous variables.

As the variables were normal (per the Shapiro-Wilk test), the t-test was applied to compare the tongue pressure between groups and genders. In all the analyses, a significance level of 5% and a confidence interval of 95% were adopted.

To analyze the relationship between age and tongue pressure, the patients in each group were further categorized into 3 groups based on age (5–6 years, 7–8 years, and ≥9 years), and analysis of variance was performed. To identify the differences between the measurements, multiple comparisons were performed using the Bonferroni method. Moreover, Pearson correlation analysis was used to measure the correlation between two variables.

3. Results

The comparison between the groups indicated that the mean tongue pressure of the study group (32.4 kPa) was lower ($p < 0.001$) than that of the control group (51.4 kPa) (Figure 2).

A significant difference in tongue pressure was observed among the age groups only for the patients in the control group, as shown in Table I.

Post hoc tests for the control group revealed differences in tongue pressure between 5-6-year-old children and those 9 years or older, as well as difference between 7-8-year-old children and those 9 years or older.

There was a strong and direct correlation between tongue pressure and age in the control group, as indicated by Figure 3.

There was no difference in tongue pressure between genders, as shown by Table II.

4. Discussion

Based on the current findings, children with mouth-breathing behavior had lower tongue pressure than those with nasal-breathing behavior. This finding confirms our hypothesis and is consistent with the findings in the literature, which suggest that the lack of adequate muscle strength is one of the most frequent orofacial myofunctional disorders in children with mouth-breathing behaviors[2].

Perilo and coworkers[20] measured tongue protrusion force in three groups: children with nasal-breathing behavior, children with mouth-breathing behavior before surgery, and children with mouth-breathing behavior who underwent surgery and were receiving orofacial myology treatment. Tongue force was greatest in the children with nasal-breathing behavior, followed by those receiving orofacial myology treatment and was lowest in the children with mouth-breathing behavior before surgery. The findings of our study are consistent with those of Perilo[20].

Previous studies suggest that mouth breathing can cause several orofacial disturbances, such as habitual open mouth posture, low and forward tongue rest posture, and muscular weakness[2]. Tongue weakness may primarily be due to the low and forward rest posture that requires less muscular activation, compared to the position of the tongue against the palate in individuals with nasal-breathing behavior. The forward head position commonly adopted by individuals with mouth-breathing behavior also influences tongue force. This position is characterized by the forward projection of the head, positioned anterior to the trunk in the sagittal plane[21] in order to facilitate air flow through the mouth[4]. Researchers observed a difference in genioglossus muscle activation in the same subjects who assumed normal and forward head posture[22]. Other researchers have found that the forward head posture requires greater effort for suprahyoid muscle recruitment[23].

Felício and coworkers[19] measured anterior tongue elevation pressure using the IOPI in 39 Portuguese-speaking children aged 7-10 years. Of those, 27 were diagnosed with obstructive sleep apnea and 12 with primary snoring. Obstructive sleep apnea is characterized by intermittent complete or partial obstruction of the upper airway, and the most common consequence of upper airway obstruction is mouth breathing. In both groups, anterior tongue elevation was lower than those reported for healthy children.

In the present study, the tongue pressure increased with age in the control group but not in the study group. As noted in previous studies, tongue strength increases rapidly from ages 3 to 8 years, and then it continues to develop at a slower rate with increasing age until it peaks during late adolescence[11]. The tongue strength at the age of 16 years is very similar to that of adulthood[11]. Our findings are consistent with the theory that nasal breathing is needed for the suitable development of craniofacial structures, whereas mouth breathing negatively interferes in the development of stomatognathic structures[20,24]. In the present study, there was highly significant positive correlation between tongue pressure and age in the control group. Moreover, there was a significant difference in tongue pressure between age ranges only in the control group, as showed by analyzing the variance test and the Bonferroni correlation.

There was no difference in tongue pressure values between genders in either the study or the control groups. In a previous study of tongue pressure in 150 children, the authors found no significant difference related to gender, but they did observe a trend toward greater tongue strength in girls than in boys at 10 years of age. However, the tongue strength was greater in boys than in girls at ages 14 and 16 years[11].

In the present study, the number of boys with mouth-breathing behavior was greater than the number of girls with such behavior. This is consistent with other studies[1,2], wherein mouth breathing was more commonly noted in boys; however, no scientific explanation regarding the cause of this gender difference has been proposed in the literature.

This study was limited by its sample size. Therefore, caution must be exercised during interpretation of the analyses used in this study, especially those involving age and gender, since the subgroups have a small number of individuals. In future studies, the number of participants for both groups should be increased, and a more homogeneous distribution of participants according to gender and age should be ensured. The evaluation of tongue function in pediatric populations is also limited due to concerns regarding the reliability of a child's performance in the objective measurement of tongue strength. Moreover, there is a lack of available data for comparison regarding tongue pressure in both typically developing children and children with mouth-breathing behavior.

With regard to the reliability of tongue strength measurement in children across trials, Potter and Short[11] found that children and adolescents aged 3–16 years demonstrated some variability across trials. However, overall, the children performed reliably in terms of multiple measurements of tongue strength. Moreover, the authors found less variability in older children, which can be explained by the maturation of the central nervous system. The axon diameter and myelination in the corticobulbar tract, which controls tongue elevation, increases conspicuously and nonlinearly during early childhood, and it continues to increase gradually throughout childhood and adolescence; this could contribute to greater interparticipant variability in younger children[25].

Another concern was the ability of 5-year-old children to tolerate the IOPI standard tongue bulb. However, we did not believe that this would be a problem, as the study of Potter and Short[11] involved children who were 3 years of age and could tolerate the bulb without any problems. As in previous research, children of this study were able to tolerate the standard tongue bulb from the IOPI.

In the clinical setting, tongue strength is typically assessed in a qualitative manner. However, objective measurements are important to complement this evaluation, rather than to replace it, as the professional's subjective judgement is important in making a diagnosis. Nevertheless, qualitative evaluation is not as sensitive as objective evaluation to small changes in tongue strength following treatment. Hence, both objective and subjective measures of tongue strength should be employed in clinical practice[11,20].

This study shows the impact of breathing patterns on tongue pressure, and it reinforces the importance of early diagnosis. This study also provides information on tongue pressure values of children with mouth-breathing patterns, which is scarce in the literature. It also shows that the speech-language pathologists have to pay special attention to the tongue force of mouth breathers in order to make accurate diagnoses in orofacial myology clinical practice.

5. Conclusion

Tongue pressure was lower in children with mouth-breathing behavior than in children with nasal-breathing behavior. In children with nasal-breathing behavior, the tongue pressure increased with age; however, this was not observed among children with mouth-breathing behavior. Moreover, there was no difference in tongue pressure between genders in either group. These data suggest the important role of the respiratory pattern in the development of tongue strength.

6. Ethical Approval

This study conformed to the Helsinki Declaration and was approved by the Research Ethics Committee of Universidade Federal de Minas Gerais (process 36663614.8.0000.5149).

7. Source of funding: None

8. Conflicts of interest: The authors have stated explicitly that there are no conflicts of interest in connection with this article.

9. Disclosure Statement

The authors have nothing to disclose.

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Table I. Comparison of tongue pressures according to age group

Group	n	Age range (yrs)	Mean age (yrs)	SD	Mean tongue pressure (kPa)	SD	p value*
Control group	3	5–6^{A}	5.4	0.53	37.88	7.18	0.001
	9	7–8^{A}	7.2	0.41	48.37	6.41	
	8	≥9^{B}	10.3	1.11	59.9	5.27	
Study group	7	5–6	5.3	0.58	28.57	5.62	0.085
	6	7–8	7.4	0.53	35.66	3.77	
	7	≥9	10.2	1.03	33.33	6.47	

SD: standard deviation; yrs: years; *analysis of variance

Different letters indicate statistically significant differences between age groups.

Table II. Tongue pressure according to gender

Group	Gender	N	Mean tongue pressure (kPa)	SD	p value*
Control group	Female	7	49.76	9.23	0.866
	Male	13	50.48	8.96	
Study group	Female	7	30.38	7.23	0.291
	Male	13	33.43	5.23	

SD: standard deviation *t-test

Figure 1

Figure 2

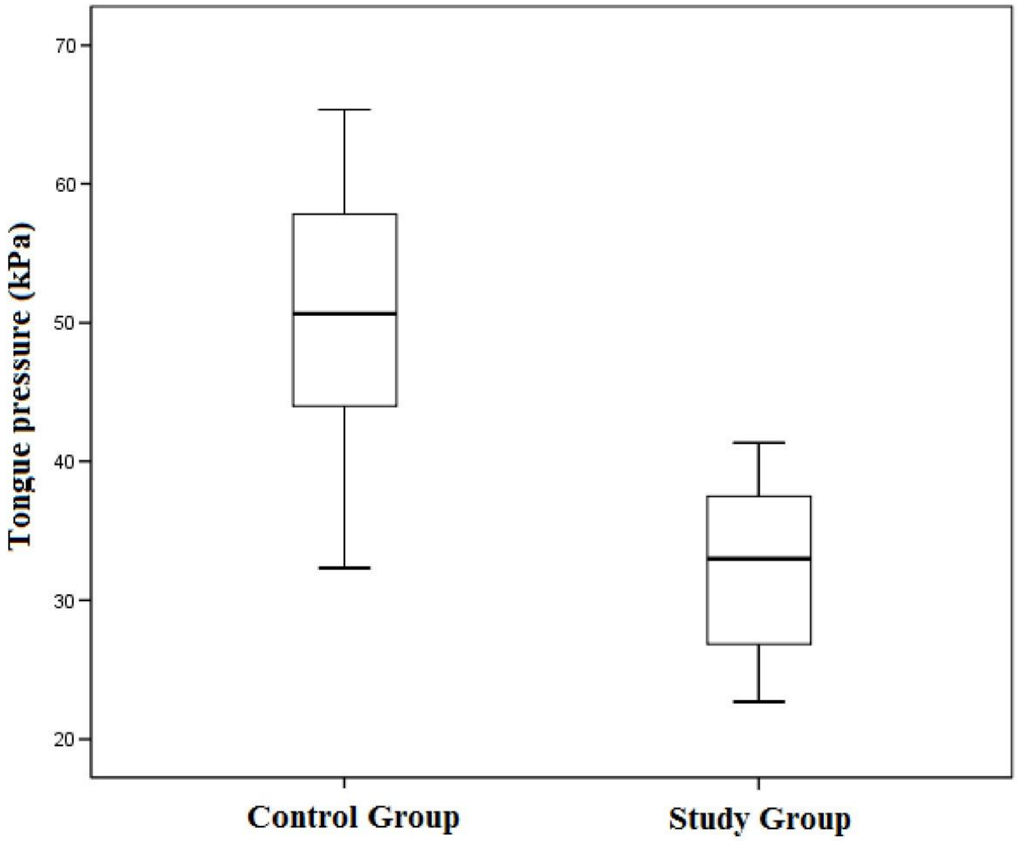
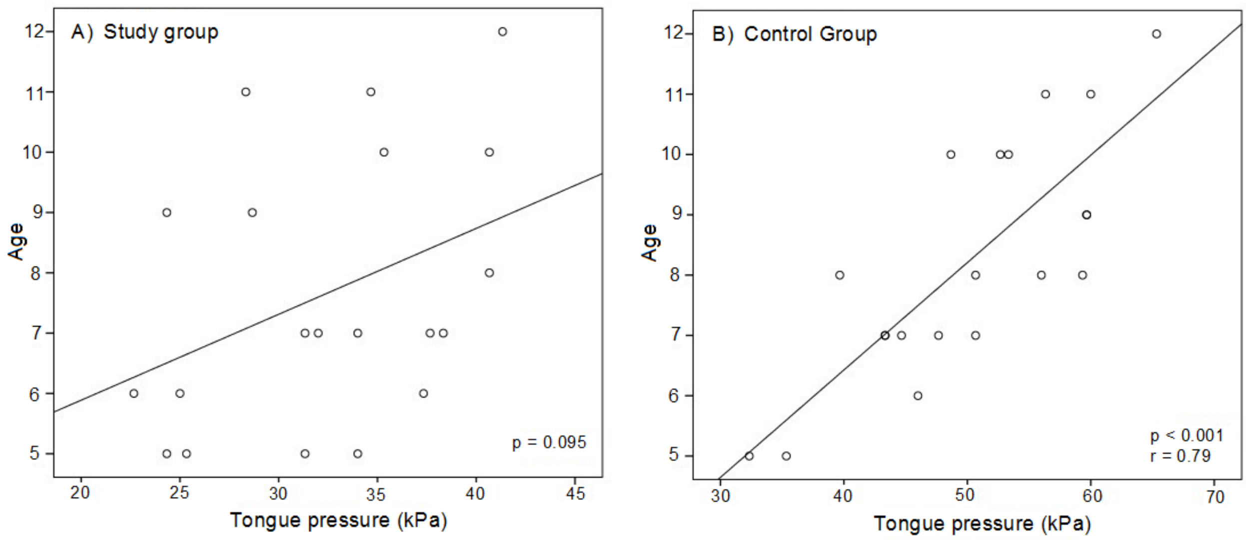

Tongue pressure (kPa)
70
60
50
40
30
20
Control Group
Study Group

Figure 3



Pearson correlation test

Figure Captions

Figure 1. Iowa Oral Performance Instrument

Figure 2. Comparison of tongue pressures between the groups

Figure 3. Correlation between tongue pressure and age: A) Study group B) Control group