Research Article

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SPEECH-LANGUAGE PATHOLOGY FINDINGS IN PATIENTS WITH MOUTH BREATHING: MULTIDISCIPLINARY DIAGNOSIS ACCORDING TO ETIOLOGY

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ABSTRACT

The purpose of this study was to identify and compare the results of the findings from speech-language pathology evaluations for orofacial function including tongue and lip rest postures, tonus, articulation and speech, voice and language, chewing, and deglutition in children who had a history of mouth breathing. The diagnoses for mouth breathing included: allergic rhinitis, adenoidal hypertrophy, allergic rhinitis with adenoidal hypertrophy; and/or functional mouth breathing. This study was conducted with on 414 subjects of both genders, from 2 to 16-years old. A team consisting of 3 speech-language pathologists, 1 pediatrician, 1 allergist, and 1 otolaryngologist, evaluated the patients. Multidisciplinary clinical examinations were carried out (complete blood counting, X-rays, nasofibroscopy, audiometry). The two most commonly found etiologies were allergic rhinitis, followed by functional mouth breathing. Of the 414 patients in the study, 346 received a speech-language pathology evaluation. The most prevalent finding in this group of 346 subjects was the presence of orofacial myofunctional disorders. The most frequently orofacial myofunctional disorder identified in these subjects who also presented mouth breathing included: habitual open lips rest posture, low and forward tongue rest posture and lack of adequate muscle tone. There were also no statistically significant relationships identified between etiology and speech-language diagnosis. Therefore, the specific type of etiology of mouth breathing does not appear to contribute to the presence, type, or number of speech-language findings which may result from mouth breathing behavior.

KEYWORDS: mouth breathing; etiology; diagnosis; speech-language pathology, orofacial myofunctional disorders

INTRODUCTION

Mouth breathing (MB) is one of the most common symptoms in childhood and a great deal of the literature relates it directly to different etiologies (Cintra, Castro, Cintra, 2000; Motonaga, Berti, Anselmo-Lima, 2000; Rizzo, Hauache, Naspitz, 2002; Takahashi, Ono, Ishiwata, Kuroda, 2002; Paulo, Conceição, 2003; Di Francesco, Passeroti, Paulucci, Miniti, 2004; Andrade, Araújo, Ribeiro, Deccax, Nemr, 2005; Lessa, Enoki, Feres, Valera, Lima, Matsumoto, 2005; Bicalho, Motta, Vicente, 2006; Vera, Conde, Wajnsztein, Nemr, 2006). While the most common cause for mouth-breathing behavior is allergic rhinitis, there are other etiologies, which include: pharyngeal tonsil (adenoid) and/or palatine tonsils (amygdales)

hypertrophy, non-allergic rhinitis, turbinal bone hypertrophy, and septum deviations (Lund, 1988; Motonaga et al, 2000; Paulo et al, 2003; Di Francesco et al, 2004). In addition to etiological factors, which contribute to this behavior, MB may occur as an established habit pattern that persists without an obstructive anatomical factor that prevents nasal breathing (Cintra et al, 2000; Motonaga et al, 2000). Many authors refer to the 'mouth-breathing syndrome' to represent the characteristics found in individuals who use their mouths as their predominant manner of breathing. However, it is know that MB has various causes and characteristics, with distinct pathophysiologies. This makes it

difficult to include all MB patients within a homogeneous group (Brodsky, 1993).

It is not uncommon for some authors to claim that the following concerns are characteristic of children with MB: articulation disorders, impaired vocal quality, alterations in the orofacial structures and functions, as well as language difficulties (Rizzo et al., 2002; Di Francesco et al., 2004). Because MB is a symptom that frequently presents in association with multifactorial causes associated with various pathologies, it is necessary to clarify details of the clinical aspects of MB. This study aims to identify and compare the results of the findings from speech-language pathology evaluations in children from 2 to 16-years of age with a history of mouth breathing who were diagnosed by a multidisciplinary team with one or more of the following: allergic rhinitis; adenoidal hypertrophy; allergic rhinitis with adenoidal hypertrophy and/or functional MB.

METHODS

This study was conducted with 414 subjects of genders, 269 (65.0%) males and 145 (35.0%) females, from 2 to 16-years old, attending the Care Center for the Mouth-Breather at the Cefac Institute. A team of three speech-language pathologists, one pediatrician, one allergist, and one otolaryngologist, who are staff members at the Care Center for the Mouth-Breather, evaluated the patients over several years from March 2004 to April 2009. Multidisciplinary clinical examinations were carried out which included complete blood counting, cavum X-rays, nasofibroscopy, audiometry, with all subjects submitted to all the examinations. Additional examinations were required after the medical evaluation to determine the cause of MB. Then a speech-language evaluation was administered.

An etiology of MB was determined by the physicians based on the following objective measurements: specific IgE (immunoglobulin E) serum, cavum X-ray and/or nasofibroscopy. Based on the identified etiology, the subjects were divided into four groups:

Group 1. Allergic Rhinitis: subjects were assigned to this group when signs and symptoms characteristic of allergic rhinitis was documented in their clinical history and was accompanied by specific IgE

results greater than or equal to Class 3, according ImmunoCAP - Phadia technique - level minimum 0.35 KU/ml - Class 0 (Lund, 1988).

Group 2. Adenoidal Hypertrophy:

subjects were assigned to this group when their X-rays indicated that the aerial column of the nasal cavity was decreased by $\frac{3}{4}$ (three quarters) or more, (i.e., obstruction of more than 80%); or when in the nasofibroscopy it was determined that the adenoids occupied over three quarters of the nasopharynx, (i.e., 80% or more, for adenoidal hypertrophy) (Lund, 1998.)

Group 3. Allergic Rhinitis and

Adenoidal Hypertrophy: subjects were assigned to this group when signs of both allergic rhinitis and adenoidal hypertrophy were diagnosed.

Group 4. Functional Mouth Breathing

(FMB): subjects were assigned to this group when mouth-breathing behavior was diagnosed with no signs of allergic rhinitis or obstruction (Di Francesco et al., 2004).

Of the 414 subjects in the total study, 346 subjects met the criteria to undergo the speech-language pathology evaluation. A speech-language pathologist trained in orofacial myofunctional disorders performed the speech-language evaluation. The assessment included a speech/articulation, voice, language, and orofacial myofunctional examination. A hearing evaluation was also administered. Subjects with hearing loss, neurological and / or motor disabilities and/or related problems were excluded from the speech evaluation. For the speech-language pathology evaluation, protocol established by Marchesan (2003) was used, which included specific observations concerning the subjects' usual position of the lips, tongue, orofacial tonicity, breathing, swallowing, speech, voice and spoken language. Based on the results of this evaluation, subjects diagnosed as mouth-breathers were classified into three groups:

Group 1 - Orofacial Myology: subjects were assigned to this group when orofacial myofunctional disorders were identified in one or more of the evaluated areas (for example: habitual position of lips and / or tongue, tonus, chewing and/or swallowing).

Group 2 – Alterations in Orofacial Myology with Speech and/or Voice and/or Language:

subjects were assigned to this group when orofacial myofunctional deficits were identified in conjunction with any other speech, voice and/or language impairments.

Group 3 - Normal: subjects were assigned to this group when no deficiencies were identified in either orofacial myofunctional areas or speech-language areas.

Ethical Committee approved the study (number 078/09). Data were statistically analyzed using the chi-square test ($p = 0.05$).

RESULTS

The study included 414 subjects, from 2 to 16-years of age, 269 (65.0%) males and 145 (35.0%) females. The subjects were divided according to their etiological mouth-breathing diagnosis. The most prevalent identified etiology was allergic rhinitis which was found in 148 (35.7%) subjects. This was followed by 102 (24.6%) subjects diagnosed with functional mouth breathing. The group of

subjects with the adenoidal hypertrophy, and the group of subjects with both allergic rhinitis and adenoidal hypertrophy were equally significant as they each had 82 (19.8%) subjects.

Of the 346 subjects receiving the speech-language evaluation, which included an orofacial myofunctional evaluation, 82.2% were found to have at least one disorder. Subjects were assigned to one of three groups: Group 1 only OMD; Group 2 - OMD in conjunction with another speech-language disorders such as speech articulation, voice and/or language; and Group 3 – Normal. The most prevalent finding was the presence of Orofacial Myofunctional Disorders in 216 (62.4%) subjects. There were no statistically significant associations found between the patients' etiology and their respective speech-language pathology diagnosis group ($p = 0.218$) (Table 1).

An analysis of results for all the patients who received a speech language evaluation was completed based on etiology. There were no statistically significant associations between the patients' etiology and the presence of any alteration, either OMD or others ($p = 0.202$) (Table 2.)

Table 1. Association between Mouth-Breathing etiologies and Speech-Language Pathology diagnosis in 346 patients

	MOUTH BREATHING ETIOLOGY			
	Allergic rhinitis (n = 125)	Allergic rhinitis and adenoidal hypertrophy (n = 67)	Functional (n = 87)	Adenoidal hypertrophy (n = 67)
Normal	2 (1.6%)	0 (0.0)	1 (1.1%)	3 (4.5%)
With OM and other speech alteration	37 (29.6%)	27 (40.3%)	33 (37.9%)	27 (40.3%)
Only with OM alteration	86 (68.8%)	40 (59.7%)	53 (60.9%)	37 (55.2%)
p = 0.218				

Table 2. Overall association between Mouth Breathing etiologies and Speech-Language Pathology diagnosis (including OMD and other alterations) in 346 patients

	Mouth Breathing Etiology			
	Allergic rhinitis (n = 125)	Allergic rhinitis and Adenoidal hypertrophy (n = 67)	Functional (n = 87)	Adenoidal hypertrophy (n = 67)
Normal	2 (1.6%)	0 (0.0)	1 (1.1%)	3 (4.5%)
Altered	123 (98.4%)	67 (100%)	86 (98%9)	64 (95%)
p = 0.202				

DISCUSSION

The speech-language difficulties found in MB subjects have been widely reported in the last decade (Cintra et al., 2000; Rizzo et al., 2002; Paulo et al, 2003; Valera, Trawitzki, Mattar, Matsumoto, Elias, Anselmo-Lima, 2003; Valera Trawitzki, Anselmo-Lima, 2006). However, it should be emphasized that much of the published research is carried out with no data proof. Some authors repeat in their publications the reports of earlier authors who did not support their findings based on quantitative data analysis. In addition, other studies show an often-subjective criterion to define MB. The lack of objectivity in order to define nasal obstruction can lead to misdiagnosis and, consequently, to inappropriate treatment. Instrumental assessment of MB is of critical importance for accurate diagnosis.

This study sought to identify the causes of the MB behaviors presented by subjects through a multidisciplinary approach using instrumental assessments, which allowed the documentation of the presence or absence of an anatomical obstruction. Through the clinical evaluation and standardized complementary examinations, findings indicated that among the most prevalent causes of MB were: allergic rhinitis (35.7%), functional MB (24.6%), adenoidal obstruction (19.8%), and allergic rhinitis with adenoidal obstruction

(19.8 %). This last finding indicates an association of respiratory pathologies resulting in nasal obstruction in the same subject. This is consistent with findings in previous research studies that sought to identify the primary causes of MB (Motanaga et al., 2000; Valera et al., 2006).

Other authors have reported in their studies that the presence of MB may be habitual in nature, with subjects persisting in MB behavior even when the permeability of their upper airways were clear (Cintra et al., 2000; Motanaga et al., 2000; Di Francesco et al., 2004). The current results support this finding. Of the subjects who presented as mouth breathers, 24.6% were classified as functional mouth breathers who did not have obstructive causes as confirmed by instrumental multidisciplinary assessment. Attention should be called to this diagnosis of functional mouth breathing, because many children may present with MB behaviors even after a previous obstruction has been medically treated and is no longer present. Functional mouth breathing is a disorder that should be addressed using therapeutic measures.

Whatever the MB etiology, orofacial myofunctional disorders were almost always identified. These disorders are associated with the subject persisting in mouth breathing

behaviors either in an attempt to compensate for the deficiency of inspired air, or as a habit pattern. One of the consequences may be that the function of the tongue to shape the oral vestibule is greatly restricted when it is in a breathers may impact the interactions of the orofacial musculature. The end result of this incorrect and inefficient breathing pattern is the potential interactive effect on surrounding orofacial musculature, which may result in generating a functional deficiency. (Cintra et al., 2000; Motanaga et al., 2000; Rizzo et al., 2002; Paulo et al, 2003; Valera et al., 2003).

Disorders in voice quality, speech, and language, which may be related to the presence of MB, have also been reported by several authors (Cintra et al., 2000; Motanaga et al., 2000; Rizzo et al., 2002). In concurrence with the literature, a high incidence of orofacial myofunctional disorders was found in subjects who were mouth breathers. This study also identified a higher incidence of both orofacial myofunctional disorders and speech-language disorders among the participants identified as mouth breathers than previous studies. A significant number of subjects with isolated voice, speech and language disorders were not identified in this study.

Given these results, an analysis was completed to determine if there was any correlation between the MB etiology and the degree of severity in the subjects' speech and

low and forward rest posture which frequently occurs in mouth breathers, as it is difficult to breathe through one's mouth with the tongue in position against the palate. This low and forward tongue rest posture in mouth language deficits. No statistically significant relationship was identified between the subject's etiology and the presence or the number of their respective speech-language pathology disorder/s. However, MB regardless of its cause was a factor associated with speech-language/orofacial myofunctional impairments.

Since impairments in the orofacial myofunctional system were the most prevalent findings in this study population, regardless of the etiology, future studies could focus on identifying if there is any relationship between the severity of MB and the most common causes of nasal obstruction.

CONCLUSIONS

Impairments in oral function, tonus and habitual lips and tongue rest postures are frequently found in mouth breathers. Etiology does not contribute to the presence, severity and/or the number of disorders found by SLPs in mouth breathers. Mouth breathing and the associated OMD are factors that may lie at the very foundation of a variety of speech and language disorders

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QUANTITATIVE EVALUATION OF TONGUE PROTRUSION FORCE

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ABSTRACT

The tongue plays an important role in the functions of speech, mastication, swallowing, and breathing. The tongue helps in the maintenance of proper dental alignment and arch stability. Adequate strength is essential for the tongue to perform these tasks. Recently the Biomechanical Engineering Group from Universidade Federal de Minas Gerais, Brazil, developed a device to improve tongue strength evaluation. The purpose of this study is to describe and compare the main results obtained in tongue protrusion force measurements in different age groups using this new device. Fifteen healthy subjects were given a qualitative evaluation and determined to have normal tongue strength. They were separated by age in three groups: children, adults and elderly. They were then given a quantitative evaluation. Maximum and average forces were analyzed. The time taken to reach maximum force was also assessed. Higher values of maximum and average tongue force were obtained in the adult group, followed by the elderly group and the group of children. Older subjects had greater tongue force when compared to children. However, there were statistically significant differences in the average force and in the maximum force only between children and adults. Time taken to reach maximal isometric force was longer in the elderly group and shorter in the group of children than in the group of adults although no statistically significant difference was found between groups.

KEYWORDS: tongue, muscle strength, instrumentation

INTRODUCTION

The tongue plays an important role in the functions of speech (Dworkin, Aronson & Mulder, 1980), mastication, and in the oral and pharyngeal stages of swallowing (Stierwalt & Youmans, 2007). The tongue also aids in maintaining upper airway patency during sleep (Bu Sha, Strobel & England, 2002) helping in the maintenance of proper dental alignment and arch stability (Posen, 1972). Adequate strength is essential for the tongue to perform these tasks.

During the normal aging process, children's tongue strength increases with age, reaching its peak in late adolescence. In this late adolescence phase, tongue strength is very similar to adults (Potter, Kent & Lazarus, 2009; Potter & Short, 2009). After 60 years of age, there is a deficit in strength, and changes in skeletal muscles occur. During this period, loss of skeletal muscle mass occurs due to muscle atrophy caused by motor neuron loss (Berger & Doherty, 2010). Tongue

musculature also suffers from these age related changes (Crow & Ship, 1996).

Some studies have demonstrated a decrease in tongue strength in the elderly (Crow & Ship, 1996; Mortimore, Fiddes, Stephens & Douglas, 1999; Mortimore, Bennett & Douglas, 2000; Hayashi, Tsuga, Hosokawa, Yoshida, Sato & Akagawa, 2002). In contrast, other studies have not found differences between children and adults (Lambrechts, Baets, Fieuws & Willems, 2010), or between adults and elderly (Dworkin et al., 1980; Hartman, Dworkin & Keith, 1980; Stierwalt & Youmans, 2007). Protrusion tongue force was also measured by Mortimore et al. (1999) and Bu Sha, England, Parisi & Strobel (2000) in healthy adults. They found maximum tongue forces of 30 N and 28 N respectively. In the elderly, tongue protrusion force was measured by Dworkin et al. (1980) and Hartman et al. (1980) but the values for age groups were not presented. No study was found that measured tongue protrusion force in children.

The evaluation of tongue strength is a usual and important task in clinical Speech-Language Pathology practice. However, such assessment is usually carried out in a subjective way, and is influenced by the experience of the professional. This makes diagnosis and follow up harder to accomplish. The Biomechanical Engineering Group from Universidade Federal de Minas Gerais, Brazil, developed a measurement system to evaluate tongue protrusion force as an interdisciplinary project (Barroso, Costa, Saffar, Las Casas, Motta, Perilo, Batista & Brito, 2009). The purpose of this study is to describe and compare the main results obtained by the system in different age groups.

METHODS

Subjects

This study was conducted with the approval of the Ethics Committee of the University (authorizations 135/04 and 540/07). Fifteen healthy subjects were selected who had no speech or swallowing disorders and normal tongue strength as diagnosed by qualitative evaluation. Subjects were grouped by age in three groups: 5 children (range: 8-12 years; 4 female, 1 male), 5 adults (range: 19-53 years; 3 female, 2 male) and 5 elderly (range: 73-87 years; 1 female, 4 male).

Qualitative evaluation

Qualitative evaluation of tongue strength was obtained by having the participant press his/her tongue against a tongue blade, and against the examiner's finger for approximately 10 seconds with resistance provided by the examiner. This method was used to assess the force of both protrusion and lateralization. The examiners rated tongue strength as normal, slightly weak, moderately weak, or

severely weak (Clark, Henson, Barber, Stierwalt & Sherrill, 2003). Only those individuals who had obtained normal classification for tongue strength in the qualitative evaluation were submitted to the next stage - the quantitative evaluation.

Quantitative evaluation - equipment and procedure

The system used in this study was described by Motta, Perim, Perilo, Las Casas, Costa, Magalhães & Saffar (2004), Perilo, Motta, Las Casas, Saffar & Costa (2007) and Barroso et al. (2009). The authors of the current study labeled the device FORLING. It is composed of a piston/cylinder set, attached to a double protector mouth piece (like the one used by boxers), and coupled hydraulically to a pressure sensor. The values are transmitted by the digital acquisition system to a personal computer, as shown in Figure 1.

Before the test, the oral silicone double protector was disinfected using alcohol 70% and covered with a transparent non toxic PVC film (Doctor Film) so as to assure hygiene. For each trial the oral double protector was inserted and fitted in the mouth of the subject, who was given 15 seconds for accommodation.

After this period, the subject was instructed to push the cylinder head by protruding the tongue as hard as possible, holding it for 10 seconds (the same amount of time trial that was used for the qualitative evaluation). This procedure was repeated three times, with one minute intervals. Verbal reinforcement was provided at each repetition.

Figure 1. Diagram of the system (Motta et al., 2004)

The exerted tongue force was converted into a pressure measurement, Pascals, by the piston/cylinder assembly. After the acquisition of this data, the conversion of pressure to exerted force in newtons was calculated using the computer program MatLab®. Using this computer program the entire force time history was recorded for the duration of the application of tongue force. Figure 2. presents the graphic representation of this force in newtons as the vertical axis, while the amount of time in seconds is represented on the horizontal axis. Barroso et al. (2009) calculated the maximum uncertainty of the measurement system and found that it is about 0.18%.

Data analysis

Maximum and average forces were calculated for each individual and for each trial performed. Average force for each trial was defined as the average of the force signal throughout the 10 second period of sustained contraction. Average force for each individual was the average of force obtained in the three

trials. Maximum force for each trial refers to the peak force of the considered time interval. The maximum force of each subject was calculated by the average of the maximum force obtained in the three trials, because it better reflects the actual maximum performance of the individual. Average values for each age group were then calculated. Time taken to reach maximum force was also recorded during each trial, and the average value for each subject and for each age group was calculated. The coefficient of variation for each subject and for each group was calculated to verify the homogeneity of the results. Analysis of variance was used to determine if there was a difference in average force, maximum force, or time to reach maximum force between the age groups. The Tukey test was used for multiple comparisons. The Friedman test was used to verify if there were statistically significant differences between average forces obtained by the three trials. A p-value < 0.05 was considered statistically significant for all statistical procedures.

Figure 2. An example of the Force Time Series.

RESULTS

Average forces, maximum forces, time taken to reach maximum force, standard deviations and coefficients of variation for each subject are shown in Table 1. The three columns after the subjects are related to average force (value, standard deviation and coefficient of variation), the next three to maximum force and the last three columns are related to the time spent to reach maximum force.

Average forces, maximum forces, time taken to reach maximum force, standard deviations and coefficients of variation for each age group are shown in Table 2. The greatest values of maximum and average tongue force were obtained in the adult group followed by the elderly and children. Time taken to reach maximal isometric force was longer in the elderly group and shorter in children than in adults.

Table 1. Force Time By Group

Subjects	Favg (N)	SD	CV	Fmax (N)	SD	CV	Time (s)	SD	CV
Child 1	5.8	1.50	0.26	10.9	0.83	0.08	1.1	0.17	0.16
Child 2	8.1	1.15	0.02	10.1	0.65	0.06	3.1	1.68	0.54
Child 3	10.2	0.46	0.04	14.1	0.38	0.03	4.3	1.36	0.31
Child 4	6.8	0.81	0.12	9.7	0.06	0.01	1.5	0.89	0.59
Child 5	5.8	1.66	0.29	7.0	1.93	0.27	3.8	2.70	0.71
Adult 1	14.5	0.40	0.03	20.6	1.88	0.09	5.1	1.04	0.20
Adult 2	18.7	1.83	0.10	28.7	2.58	0.09	1.3	0.17	0.13
Adult 3	11.1	1.56	0.14	17.1	3.45	0.20	5.4	4.41	0.82
Adult 4	15.1	1.15	0.08	19.7	1.80	0.09	5.3	3.85	0.73
Adult 5	20.3	2.88	0.14	28.0	3.75	0.13	1.7	0.10	0.06
Elderly 1	21.5	2.85	0.13	29.6	1.91	0.06	6.2	2.55	0.41
Elderly 2	7.8	0.56	0.07	11.8	1.40	0.12	3.9	1.73	0.44
Elderly 3	5.1	1.11	0.22	10.3	2.90	0.28	4.4	2.05	0.47
Elderly 4	15.6	2.54	0.16	22.7	3.38	0.15	4.7	1.99	0.42
Elderly 5	4.5	0.50	0.11	6.4	0.74	0.11	9.5	0.15	0.02

Favg – average force in newtons, SD – standard deviation, CV – coefficient of variation, Fmax – maximum force in newtons, time – time in seconds taken to reach maximum force.

Table 2. Average force, maximum force, time taken to reach maximum force, standard deviation and coefficient of variation in different age groups

Group	Favg (N)	SD	CV	Fmax (N)	SD	CV	Time to peak (s)	SD	CV
Children	7.34	1.86	0.25	10.36	2.55	0.25	2.76	1.37	0.54
Adults	15.96	3.63	0.23	22.84	5.21	0.23	3.76	2.22	0.59
Elderly	10.91	4.44	0.52	16.17	6.03	0.47	5.75	2.27	0.40

Favg – average force, Fmax – maximum force, time to peak – time taken to reach maximum force, SD – standard deviation, CV – coefficient of variation.

The scatter plot with error bars of average force, maximum force and time to reach maximum force, in each age group is shown in Figure 3. for Children, Figure 4. for Adults, and Figure 5. for Elderly. Figure 6. show the scatter plot with error bars of average force, maximum force and time to reach maximum force, for the three age groups with an analysis of variance. The differences between the groups for maximum and average forces were considered significant. When groups were compared in pairs, there were statistically significant differences in average force ($p = 0.040$) and in maximum force ($p =$

0.016) only between children and adults. No statistically significant difference was found in average force comparisons between children and elderly ($p = 0.499$) nor between adults and elderly ($p = 0.269$). Neither was a statistically significant difference found in maximum force comparing children and elderly ($p = 0.365$), nor between adults and elderly ($p = 0.274$). There was no statistically significant difference between the groups for the length of time to reach maximum force. Table 3. shows the comparison of average and maximum forces for the three trials. There was no significant difference in the trials for either parameter.

Figure 3. Average force, maximum force and time taken to reach maximum force for each child.

Figure 4. Average force, maximum force and time taken to reach maximum force for each adult.

Figure 5. Average force, maximum force and time taken to reach maximum force for each elderly subject.

Figure 6. Average force, maximum force and time taken to reach maximum force in different age groups with analysis of variance. *p-value < 0.05.

Table 3. Average force and maximum force on the three trials for each group and statistic for comparison of the average values of the three trials.

Subjects	Trial 1		Trial 2		Trial 3		P-value ¹
	Average	SD	Average	SD	Average	SD	
Average Force (N)							
Children	6.9	2.2	8.0	1.2	7.0	2.4	0.247
Adult	16.7	4.1	16.4	4.1	14.7	3.3	0.35
Elderly	11.1	8.4	10.2	5.9	11.3	8.2	0.549
Maximum Force (N)							
Children	10.1	3.5	10.5	2.1	10.3	2.6	0.951
Adult	24.1	3.8	23.4	7.1	21.0	5.5	0.247
Elderly	15.3	10.6	16.4	9.0	16.8	9.9	0.549

SD – Standard deviation, ¹ Friedman test.

DISCUSSION

There are few published studies on tongue strength among healthy children. Consequently, values of musculature strength during the grown phase still remains vague.

It is known that, at the stage of the preprimary dentition, the tongue fills the oral cavity and that suction is its main function. With the expansion of the jaws, enlargement of the oral cavity and eruption of teeth, the swallowing pattern changes and the orofacial muscle function becomes stronger due to mastication (Ruan, Chen, Gu, Lu, Su & Guo, 2005). Tongue strength increases rapidly through ages 3–8 years and then continues to develop at a slower rate with age, until its peak in late adolescence. At the age of 16, tongue strength is very similar to adults (Potter & Short, 2009).

The population of children for this study was between 8 and 12 years of age. It was expected that they would have lower tongue strength values than adults, due to their stage of developmental maturation in muscle morphology and the central nervous system (Potter et al., 2009; Potter & Short, 2009). As expected, statistically significant differences were found in maximum and average tongue force between children and adults. The group of adults had higher tongue force than the group of children.

Posen (1972) measured maximum tongue protrusion force in a population aged between 8 and 12. The measures ranged between 600 g to 2350 g and the average value was 1534.83 g (approximately 15 N). In the present study, the children group obtained lower values (approximately 10 N). This difference may be due to differences in the instrument used to measure tongue force.

Potter et al. (2009) also measured tongue strength in children between 8 and 12. The average force value obtained was 53.47 kPa. In the present study, pressure was calculated by the division of force by area. An average tongue pressure for children was obtained which was approximately 63.83 kPa. This value is higher than that obtained in Potter's study. This difference may be explained by the difference in the direction of the measured force as Potter et al. (2009) measured tongue force in a cranial direction toward the palate.

Maximum force values obtained in the present study from adults and older individuals were also higher than those described in literature by Robbins, Levine, Wood, Roecker & Luschei, (1995); Crow & Ship, (1996); Stierwalt & Youmans, (2007). This difference in the values is possibly explained by the difference in the direction of tongue displacement during the measurement. Each tongue displacement involves different muscles, extrinsic and/or intrinsic. The weakness of a specific muscle can affect one direction more than the others, results can be different for each direction (Weijnen, Kuks, Van Der Bilt, Van Der Glas, Wassenberg & Bosman, 2000). Studies with protrusive tongue force (Mortimore et al., 1999; Bu Sha et al., 2000) also reported higher results than the present study. This may possibly have happened because the devices used for measurement were different, and this study was conducted with Brazilians who may have different facial characteristics than other populations.

When comparing the elderly group with the adult group a decrease in tongue strength was observed, although this decrease was not statistically significant. This decline, resulting from sarcopenia, produces a decrease in the size and number of muscle fibers, reduction in fiber density, in functional motor units, increase in non-contractile tissue and changes in central mechanisms. This age related change appears to have no clinical significance in normal aging, but in association with other pathologies, it could potentially cause a problem (Nicosia, Hind, Roecker, Carnes, Doyle, Dengel & Robbins, 2000).

The hypothesis raised by Motta and co-workers (2004) is that, knowing the capability of an individual to exert protrusion force with the tongue, it is possible to infer his/her capacity to accomplish other tasks. That presumably happens because the muscles responsible for tongue protrusion, including the genioglossus, verticalis and transversus (Pittman & Bailey, 2008) actively take part in swallowing, mastication, speech and other tasks.

Tongue pressure in cranial direction, elevated up toward the palate was recorded in a study by Robbins et al. (1995) during a maximal isometric task and during saliva swallows in young and older people. They found that, while isometric maximum pressure declined

with age, swallowing pressure did not. They linked this finding to the fact that for healthy individuals, regardless of age, swallowing pressures are sub-maximal with regard to those generated isometrically. Swallowing does not demand ~~tongue~~ maximum tongue force, leading to the conclusion that healthy elderly subjects manage to achieve the necessary pressures to successfully swallow.

Nicosia et al. (2000) found that, as tongue pressure is reduced in the elderly population, the available "pressure reserve", or difference between isometric and swallowing pressures, is also reduced. This reduction may leave aged individuals more vulnerable to suffer from dysphagia, as they have to work harder to achieve the necessary pressure to accomplish these functions.

Another important factor observed in results of the present study was ~~is~~ that in the older population, coefficients of variation related to maximum and average force, were greater than in the other groups (see figure 6), demonstrating that this population is less homogeneous than the groups of either children or adults, even though all participants were classified as having normal tongue strength during qualitative evaluation. This heterogeneity is presumably related to the biological variability of the subjects, especially older subjects, as they may have less muscular control than adults and children (Sosnoff & Voudrie, 2009). It is important to note that qualitative evaluation is accomplished according to the judgment of the examiner, who may have subconsciously had lower expectations for the elderly group and so clinically rated them as 'normal'. This is a limitation of the study. That is why the quantitative evaluation is an important complement to the clinical evaluation, This makes the diagnosis of tongue force more reliable, especially in the subjects with slight strength deficits, which are difficult to identify by clinical evaluation alone.

The coefficient of variation for each subject was calculated to verify the homogeneity of the results for average force and maximum force. Values of coefficient of variation up to 0.3% were considered as homogeneous. Table 1. shows that maximum force and average force were homogeneous for all subjects. With respect to whether maximum or average force provides a better operational definition of

tongue strength, studies have shown that both measures indicated results similar to the qualitative evaluation of tongue strength. In this study we verified that maximum force was more homogeneous than average force for most of the subjects (57%). From a practical standpoint, using maximum force may be more efficient in a clinical setting because no calculation is required (Clark et al., 2003).

Three trials were done for each participant. The maximum force of each trial refers to the peak force of the considered time interval, while the maximum force of each subject was calculated by the average of the maximum force obtained in the three trials. The average force of each trial was the average of the force signal throughout the 10 second period of sustained contraction while average force of the subject is the average of the 3 trials. There was no consistent pattern in which trials produced the maximum tongue strength or average tongue strength (see Table 3.), although most of the subjects produced the highest values on their first attempt. Forty percent of the subjects reached the highest value of maximum force on the first trial, 33.3 % on the second trial, and 26.7% on the third trial. In relation to average force, 46.7 % of the subjects reached the highest value on the first trial, 33.3% on the second, and 20% on the third. The tendency of the subjects to produce the highest values on the first trials is probably related to tongue fatigue in second, and, especially, on third trial.

Lambert, Dyck (1978) apud by Dworkin et al. (1980) observed tongue force in subjects with degenerative diseases, and found that normal individuals produce maximum force in the first seconds of contraction whereas subjects with decreased tongue strength need at least seven seconds to reach peak force values. In thee current study, the sample was composed of healthy individuals and only one, from the elderly group, needed more than 7 seconds to reach maximum force. Although the time taken to reach maximum isometric force was longer among the elderly than for adults and children, there was no statistically significant difference between groups. Thus, it is important to consider requesting a shorter length of time for muscle contraction when evaluating tongue maximum force in healthy individuals. This could avoid the confounding variable of muscular fatigue. In this research, it was observed that although not statistically significant, there was a decrease of the force

values measured during the second and third assessments for most participating subjects.

The elderly presented more homogeneous results than adults or children for the parameter of time taken to reach maximum force. This may have happened because, unlike the latter two, the elderly maximum force was not reached on the first peak. Among older people, voluntary muscle responses become progressively slower due to an increased latency evoked primarily by changes of excitability in the central nervous system (Price & Darvell, 1981). Children reached peak forces faster than adults. A possible explanation would be that adults strictly try to adhere to maintaining a consistent force, being able to produce longer peaks of force than the initial one while children lose interest for the task, producing their maximum force only in the beginning of the test.

Endurance can be 'operationally defined' as the length of time for which an individual can maintain 50% of his maximum strength. It appears to be also important to characterize and differentiate tongue strength in different age groups. Additional research is needed to determine this parameter for each age group.

The Forling instrument used in this quantitative evaluation is able to reproduce qualitative evaluation results because the movements involved in both qualitative and quantitative strength measurements are the same (Barroso et al., 2009). Previous studies with the same instrument also indicated that both types of

evaluations produced concurring results (Perilo et al., 2007). It proved to be a reliable tool to measure tongue strength in all age groups. The double protector mouthpiece is soft and easily adaptable to several sizes of teeth and different dentition without discomfort to the patient. Another advantage is that the mechanism is simple to operate and to understand.

CONCLUSIONS

Adults had both higher average tongue force and maximum tongue force than that obtained in the elderly or children. There were statistically significant differences in average force and in maximum force only between children and adults. Time taken to reach maximal isometric force was longer in the elderly group and shorter among children when compared to adults, although no statistically significant difference was found between groups. The results of this study agree with other studies from literature and reaffirms that tongue force increases with age until reaching a peak at the adult stage, then declines with age.

The use of the Forling tool in research and in clinical orofacial myology practice can help speech-language pathologists with the quantification of tongue force. This would allow pre- and post-treatment assessment which would provide measurable gain, without a large amount of time required for the calculation.

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