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Axial force of the tongue in different age groups

Força axial de língua em diferentes faixas etárias

ABSTRACT

Purpose: To analyze the maximum axial force, the mean axial force, the amount of energy accumulated by the tongue, and the time taken to reach the maximum axial force, in different age ranges. **Methods:** The records of 92 individuals – students, staff and visitors at an university –, 29 (32.6%) men and 63 (67.4%) women, with ages between 14 and 53 years old, were analyzed. Subjects were divided into four age groups: 14 to 18 years, 19 to 23 years, 24 to 28 years, and 29 to 53 years. Each subject underwent clinical and instrumental assessment of the tongue. Instrumental assessment used FORLING. Data were statistically analyzed. **Results:** Regarding the maximum force, the mean force and the tongue's accumulated energy, no differences were observed between groups. Regarding the time taken to reach the maximum force, the greatest values were obtained at the age range from 14 to 18 years (4.5 s), and the shortest values, at the age range from 19 to 23 years (3.1 s), with significant difference between the groups ($p=0.001$). **Conclusion:** Only the time taken to reach the tongue's maximum force is influenced by age range, indicating that teenagers are not able to reach the maximum lingual force as fast as young adults.

RESUMO

Objetivo: Analisar a força axial máxima, força axial média, a energia acumulada pela língua e o tempo gasto para alcançar a força máxima de língua, em diferentes faixas etárias. **Métodos:** Foram analisados os prontuários referentes a 92 indivíduos, alunos, funcionários e visitantes de uma universidade, sendo 29 (32,6%) homens e 63 (67,4%) mulheres, com idades entre 14 e 53 anos de idade, que foram divididos em quatro grupos etários: 14 a 18 anos, 19 a 23 anos, 24 a 28 anos e 29 a 53 anos. Cada indivíduo foi submetido à avaliação clínica e instrumental de língua, sendo esta última realizada por meio do FORLING. Os dados foram analisados estatisticamente. **Resultados:** Em relação à força média, à força máxima e à energia acumulada pela língua não foram observadas diferenças entre os grupos. Quanto ao tempo empregado para alcançar a força máxima de língua, os maiores valores foram encontrados na faixa etária entre 14 e 18 anos (4,5 s) e os menores entre 19 e 23 anos (3,1 s), havendo diferença entre os grupos ($p=0,001$). **Conclusão:** Apenas o tempo médio gasto para se alcançar a força máxima da língua sofre influência da faixa etária, indicando que os adolescentes não são capazes de atingir a força máxima lingual de maneira tão rápida quanto os adultos jovens.

Study conducted at the Speech-Language Pathology and Audiology Department, Universidade Federal de São Paulo – UNIFESP – São Paulo (SP), Brazil.

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Conflicts of interest: There is conflict of interest by the first author of the article for being part of the group of inventors who requested patent register of the equipment used in the study.

INTRODUCTION

The tongue participates in many functions of the stomatognathic system such as mastication, swallowing and articulation. This organ assists in the formation and ejection of the bolus towards the pharynx, performs cleanup of the buccal vestibule, modifies the resonance of the oral cavity and vocal tract, and participates in speech production⁽¹⁾.

The axial force is defined as that one performed along the axis on which it is exercised⁽²⁾. Thus, it is characterized as a longitudinal force that, in the case of the tongue, refers to the protrusion force. The force of protrusion of the tongue against some resistance presumes the action, besides the genioglossus, the intrinsic lingual muscles⁽³⁾. The intrinsic muscles of the tongue are often altered in patients with orofacial myology disorders, being therefore of great interest for Speech-Language Pathology. Seeking a low-cost evaluation method that especially investigated the axial force of the tongue, the Biomechanical Engineering Group of the Universidade Federal de Minas Gerais, Brazil, developed FORLING^(4,5).

The first study using the device showed the capacity of the instrument in measuring and representing a profile of the axial forces of the human tongue. In studies with oral and nasal breathing children⁽⁶⁾, there was agreement between the results of the clinical and instrumental assessment of the axial force of the tongue. Thus, the instrument has been effective in complementing and confirming the clinical speech therapy findings. Reproducibility studies⁽⁷⁾ and with larger samples⁽⁸⁾ were also conducted, indicating a need for adjustments to the equipment. Such adjustments were made by Fundação Centro Tecnológico de Minas Gerais (CETEC), partner in the construction of the instrument. FORLING also was able to identify adults with normal lingual tonus and with severe impairment of the structure, considering the clinical evaluation⁽⁹⁾.

Several studies indicate differences in lingual force in relation to the age⁽¹⁰⁻²⁰⁾. However, according to the literature, the force increases rapidly between three and eight years old, going through a small increasing rate by the end of the adolescence, when it is stabilized⁽²⁰⁾. The decline of the force in consequence of aging occurs after 60^(10,13,16-19) or 80 years old⁽¹¹⁾.

For the above reasons, the objective of this study was to analyze the maximum axial force, the average axial force, the energy accumulated by the tongue and the time spent to reach the maximum force of tongue, in different age groups.

METHODS

The research was developed at the Faculdade de Medicina da Universidade Federal de Minas Gerais (UFMG) after the approval of the Research Ethics Committee of UFMG, under number 496/09. Data from medical records belonging to 92 individuals (students, staff and visitors of UFMG) were collected, 29 (32.6%) of them were men and 63 (67.4%) were women, aged between 14 and 53 years (mean 23.3 years, SD=7.7). Of the total, 16 (17.4%) women and seven (7.6%) men had decreased lingual tonus, and 47 (51.1%) women and 22 (23.9%) men had normal lingual tonus in clinical evaluation.

The participants were divided into four age groups, considering the interval of five years between the previous and the next ones, except the last one, which was grouped as a result of the sample size in each stratum. Thus, the participants were grouped as follows: 28 (30.4%) people between 14 and 18 years, 29 (31.5%) between 19 and 23 years, 21 (22.8%) between 24 and 28 years and 14 (15.2%) between 29 and 53 years old.

The prior studies employing FORLING that originated the data of this research were conducted with convenience sample, in which participants applied for it. So it was not possible to provide a sample with balanced strata, with regard to gender, age and clinical assessment of the lingual tonus.

As an inclusion criterion, the records should contain data on the clinical assessment of the lingual tonus. The occlusal type and the presence of orofacial myology disorder were not considered as exclusion criteria because, according to the literature, there is no association between lingual force and oral habits, Angle classification and other occlusal characteristics⁽²¹⁾.

The clinical and instrumental assessments were performed by three different examiners, speech therapists, with experience in Orofacial Myology of at least three years, who were previously trained to standardize the used parameters. The lingual tonus was indirectly assessed by verifying the position and mobility of the structure. In the latter case it was verified the capacity to perform thinning and the movement and sound produced during the 'snap'. The direct evaluation of the tonus was conducted through the anteriority test of the structure against a resistance. It was asked to a person to push the tongue against the examiner's gloved finger and against a wooden spatula. An interval time of ten seconds was employed between the two last described tasks.

The instrumental assessment of the lingual force, on the other hand, was performed with the equipment developed by Grupo de Engenharia Biomecânica (Group of Biomechanical Engineering) from Universidade Federal de Minas and designed at Isaac Newton Laboratory of CETEC^(2,3).

The evaluation was performed with the individuals sitting with their back and feet supported and hands resting on the base of the equipment. After the proper fit of the oral protector in the dental arches, it was asked to the person to push the starting rod of the piston with the tongue, after the buzzer, with the greatest force that he/she were able to perform and to keep it until hear the other acoustic signal, scheduled to ring after ten seconds. Only in this training situation the individual was allowed to visualize the graph generated in real time. This procedure was performed three more times at intervals of one minute between the measurements and with verbal positive reinforcement at each measurement, disregarding the first one (training).

The following data of the original records were transcribed into a schedule for collecting data: age, gender, clinical result of the lingual tonus assessment, three measures of the average axial force of the tongue (which are equivalent to the average of the maximum forces that the individual employed), three measures of the maximum axial force of the tongue (which correspond to the greater value of performed force in any point of each of the three measurements) and the time spent until the individual has reached the maximum force in each of the

three measurements. From these data, the energy accumulated by the tongue was calculated (force x time), which represents the area under the curve of the graph for each accomplished measurement.

The descriptive analysis was conducted using measures of central tendency (average and median) and dispersion (standard deviation and coefficient of variation). For comparison of variables according to age groups, the nonparametric Kruskal-Wallis test was used, since there are more than two comparison groups, adopting a significance level of 5%. As long as it was observed significant result in the Kruskal-Wallis test, multiple comparisons were performed using Bonferroni method⁽²²⁾ to identify where the difference between groups of different ages were. This method compares all pairs of means using individual tests (in this case, the nonparametric Mann-Whitney test for independent samples), considering a lower significance level than the level of global significance in each individual comparison. It was established an overall significance level (α) and for each individual comparison and it was used a significance level (α^*) that is obtained by dividing the overall significance level by the number of comparisons (k), i.e., $\alpha^* = \alpha/k$. In this case, $\alpha^* = 0.05/4 = 0.0125$

The data on the time used to reach the maximum force were stratified according to gender and the result of clinical evaluation in order to exclude the interference of these variables in the results. This analysis was performed by Mann-Whitney test at a significance level of 5%.

The energy accumulated by the tongue was defined as the area under the curve of the graph Time (seconds) versus Lingual Force (Newtons) for each evaluated moment. To calculate this area it was used the trapezoidal rule. The calculation was obtained from the *trapz* (Trapezoid Rule Numerical Integration) function. To calculate this function the number of subintervals was equal to the number of observations for each individual.

RESULTS

The data analysis of the average force, maximum force and energy accumulated by the tongue, according to age groups, indicated no differences between groups (Tables 1, 2 and 3).

The data referred to the time to reach the maximum force of the tongue indicated a difference only between the age groups 14 to 18 and 19 to 23 years (Tables 4 and 5). Thus, only among the youngest ones it is possible to verify differences in the speed of the tongue to reach the maximum force.

It is noteworthy that in the Bonferroni method⁽²⁰⁾ the value of significance in this case is 1.25%. To exclude the possibility of genre interference or strain classification in the results, the Mann-Whitney test was applied, which showed no differences in the two cases ($p=0.462$ and $p=0.567$, respectively). Thus, the sample was not stratified according to gender or the result of the lingual tonus classification, since these data did not interfere in the result.

Table 1. Distribution of the sample, measures of central tendency and dispersion, and comparison of the average force of tongue according to age group

Age group	Mean	SD	Minimum	Maximum	Q1	Median	Q3	p-value
14-18 years	12.7	2.9	7.7	19.4	10.3	12.7	15.0	0.707
19-23 years	12.7	5.2	4.6	31.4	10.2	12.0	13.9	
24-28 years	13.8	4.6	6.0	24.6	10.5	14.2	15.8	
29-53 years	13.3	4.5	7.6	21.5	9.4	12.8	15.7	

* Significant values ($p \leq 0.05$) – Kruskal-Wallis test

Note: SD = standard deviation; Q1 = 1st quartile; Q3 = 3rd quartile

Table 2. Distribution of central tendency and dispersion measures, and comparison of the maximum force of tongue according to age group

Age group	Mean	SD	Minimum	Maximum	Q1	Median	Q3	p-value
14-18 years	18.6	4.2	12.1	30.3	15.4	19.0	21.6	0.445
19-23 years	17.4	6.0	6.9	35.6	14.5	16.6	19.6	
24-28 years	19.4	5.8	9.2	31.5	14.7	19.8	22.2	
29-53 years	18.2	6.0	11.1	28.8	12.7	17.3	21.6	

* Significant values ($p \leq 0.05$) – Kruskal-Wallis test

Note: SD = standard deviation; Q1 = 1st quartile; Q3 = 3rd quartile

Table 3. Distribution of central tendency and dispersion measures, and comparison of the accumulated energy by the tongue according to age group

Age group	Mean	SD	Minimum	Maximum	Q1	Median	Q3	p-value
14-18 years	127.5	29.2	77.5	195.8	103.4	127.4	151.3	0.740
19-23 years	127.9	52.2	46.7	314.2	101.9	120.4	139.9	
24-28 years	138.8	46.4	59.9	248.1	105.0	138.0	159.3	
29-53 years	133.1	44.9	76.2	216.8	95.0	128.2	154.2	

* Significant values ($p \leq 0.05$) – Kruskal-Wallis test

Note: SD = standard deviation; Q1 = 1st quartile; Q3 = 3rd quartile

Table 4. Distribution of central tendency and dispersion measures, and comparison of the time to reach the maximum force of the tongue according to age group

Age group	Mean	SD	Minimum	Maximum	Q1	Median	Q3	p-value
14-18 years	4.5	2.0	0.8	8.4	2.7	4.7	6.3	0.040*
19-23 years	3.1	1.7	0.7	6.5	1.4	2.8	4.4	
24-28 years	3.4	2.0	0.6	7.8	1.5	3.1	4.8	
29-53 years	4.2	2.2	0.8	7.5	2.4	4.5	6.3	

* Significant values ($p \leq 0.05$) – Kruskal-Wallis test

Note: SD = standard deviation; Q1 = 1st quartile; Q3 = 3rd quartile

Table 5. Multiple comparison of the time to reach the maximum force of tongue according to age group

Age group (years)	p-value
14-18 x 19-23	0.001*
14-18 x 24-28	0.043
14-18 x 29-53	0.820
19-23 x 24-28	0.778
19-23 x 29-53	0.114
24-28 x 29-53	0.288

* Significant values ($p \leq 0.05$) – Kruskal-Wallis test

DISCUSSION

Orofacial Myology has been considerably highlighted in the recent years by taking possession of tools of facial, muscular and skeletal assessment, not only qualitative but mainly quantitative. This contributes to the training of professionals, because it allows the calibration during a therapeutic procedure. As for the many physical and muscular varieties of the human being, especially in Brazil due to the large presence of miscegenation, it is necessary to know with more details the forces exerted by different muscular groups. Of these, the tongue is one of the main ones, because it is crucial to the process of nutrition, human communication and occlusion stability.

Unlike the results of average and maximum force of tongue and the stored energy by the tongue, the data of the time to reach the maximum axial force indicated differences with respect to the age group variable. The differences were only found between the age groups 14 to 18 years and 19 to 23 years, indicating that, in the sample surveyed, adolescents cannot reach the maximum lingual force as fast as young adults can.

According to previous study, the force of tongue increases rapidly between 3 and 8 years old, reaching its peak in late adolescence (at the age of 16 the values are close to those ones found in adults)⁽²⁰⁾. Children have a lower value of lingual force due to the development of incomplete muscular morphology and the immaturity of the central nervous system^(20,23). These same reasons may explain the fact that the group which included individuals younger than 16 years required a longer time to reach the force peak. In the study that compared the time to reach the maximum pressure peak in adults between 48 and 55 years old and elderly between 69 and 91 years old, it was found differences between the groups, with higher values presented by the elderly.

Although some studies found differences between age groups in the analysis of maximum force^(12,14,15), other studies showed no differences between the values achieved by adults and the elderly^(24,25). However, according to the literature, the difference between age groups tends to occur after 60^(10,13,16,18,19) or 80 years old⁽¹¹⁾, a fact that supports the lack of association observed in most of the variables investigated in this study.

The decrease in lingual force due to age can be explained by a decrease of the muscular mass that occurs throughout the years^(10,14), such as reduction of motor units^(10,11), changes in the fiber densities, and central mechanisms⁽¹⁰⁾. In addition, there is the reduction of the lingual thickness and the increase of lipofuscin in the lingual muscles of the elderly⁽¹⁷⁾.

According to previous study⁽¹⁰⁾, the maximum pressure during isometric contraction is greater in young individuals when compared to the elderly, considering the lingual middle region (between the apex and back). But during the swallowing no differences between groups were observed, indicating that elderly perform compensation to maintain the functionality even with a reduction in maximum pressure. Similar work⁽¹³⁾ also observed a difference only in relation to the maximum pressure, although the fact has occurred only in the bulb positioned in the transition region between the hard palate and soft palate.

Two studies were carried out using FORLING for data analysis by age group^(8,9). However, as the distribution of ages in this study did not follow to the same interval for the constitution of studied age groups, it was not possible to compare the findings.

Some limitations could be verified during the development of this work, especially on the small sample size and its distribution in different age groups. It is also suggested to include clinical assessment by three independent examiners, with concordance analysis, which makes the data more reliable. Another problem concerns the impossibility to directly confront the values found in this study with results of other studies, due to methodological differences of the equipment used.

CONCLUSION

The maximum axial force, the average axial force and the energy stored by the tongue are similar in individuals between 14 and 53 years. In relation to the time needed to reach the maximum force of the tongue it was found that teenagers cannot reach the maximum lingual force as fast as the young adults can.

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