Original Article

Artigo Original

Nasalance scores of Brazilian Portuguese speakers at 5 years of age

Escores de nasalância de falantes do Português Brasileiro aos cinco anos de idade

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Keywords

Nasometry
Speech
Resonance
Velopharyngeal Insufficiency
Cleft Palate

ABSTRACT

Purpose: To determine nasalance scores of Brazilian Portuguese speaking children without evident speech disorders, language delay and orofacial deformities, at age 5 years, and analyze differences between types of speech samples and genders. **Methods:** Twenty children were analyzed, 11 males, age ranging from 4 years and 10 months to 5 years and 11 months. The Nasometer II 6450 (KayPENTAX) was used for nasalance assessment. Speech samples were eight consonant-vowel syllables and one sequence of nine words. The significance of differences between speech samples and genders were assessed by the Tukey test and Mann-Whitney test, respectively, at a significance level of 5%. **Results:** Mean nasalance scores were: /pa/= 10±4%, /pi/= 22±7%, /sa/= 11±5%, /si/= 24±11%, /ma/= 57±11%, /mi/= 73±13%, /la/= 14±9%, /li/= 25±11%, words (pipa, bis, burro, tatu, pilha, cuca, gui, fila, luz)= 20±6%. Nasalance scores of nasal syllables were significantly higher than those of oral syllables (with high or neutral vowels) and nasalance scores of oral syllables with high vowels were significantly higher than those of oral syllables with neutral vowels, for the majority of comparisons. There was no difference between genders. **Conclusion:** Normative nasalance scores for 5-year-old Brazilian children were determined. The methodology can serve as a standard for the early diagnosis of nasality deviations, such as hypernasality observed in cleft palate speech.

Descritores

Nasometria
Fala
Ressonância
Insuficiência Velofaríngea
Fissura Palatina

RESUMO

Objetivo: Determinar valores de nasalância de crianças falantes do Português Brasileiro sem alterações na produção da fala, atraso de linguagem e deformidades dentofaciais evidentes, aos 5 anos de idade, e verificar as diferenças entre tipos de emissão e entre gêneros. **Método:** A nasalância foi determinada em 20 crianças, 11 do gênero masculino e idade entre 4 anos e 10 meses e 5 anos e 11 meses, utilizando um nasômetro II 6450 (KayPENTAX), na produção de oito sílabas tipo consoante-vogal e uma sequência de nove vocábulos. A significância das diferenças entre os tipos de emissões foi verificada pelo Teste de Tukey e, entre os gêneros, pelo teste de Mann-Whitney, para um nível de 5%. **Resultados:** Os valores médios de nasalância foram os seguintes: /pa/= 10±4%, /pi/= 22±7%, /sa/= 11±5%, /si/= 24±11%, /ma/= 57±11%, /mi/= 73±13%, /la/= 14±9%, /li/= 25±11%, vocábulos (pipa, bis, burro, tatu, pilha, cuca, gui, fila, luz)= 20±6%. Na maioria das comparações, os valores de nasalância das sílabas nasais foram significantemente maiores do que os das sílabas orais (com vogal alta ou neutra) e os valores das sílabas orais com vogal alta foram significativamente maiores que os das sílabas orais com vogal neutra. Não houve diferença significante entre os gêneros. **Conclusão:** Foram definidos valores normais de nasalância de crianças falantes do Português Brasileiro, de 5 anos de idade, sendo que a metodologia empregada pode servir de padrão para o diagnóstico precoce de desvios de nasalidade, como a hipernasalidade observada na fala de crianças com fissura palatina.

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Received: September 27, 2016

Accepted: January 24, 2017

Study carried out at Laboratório de Fisiologia do Hospital de Reabilitação de Anomalias Craniofaciais, Universidade de São Paulo – USP - Bauru (SP), Brazil.

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Financial support: PIBIC, CNPq, process nº 144390/2014-0.

Conflict of interests: nothing to declare.

INTRODUCTION

The separation between the nasal and oral cavities during normal speech is achieved by the synchronized movement of the soft palate and the lateral and posterior pharyngeal walls. The joint action of these structures, which constitutes the velopharyngeal mechanism, is responsible for the distribution of expiratory airflow and acoustic vibrations to the oral cavity, in the production of oral sounds, and to the nasal cavity, in the production of nasal sounds[1].

Anatomical abnormalities in this mechanism, a condition called velopharyngeal insufficiency (VPI), affect speech production, leading to hypernasality, nasal air emission (audible or not) and articulatory errors. Hypernasality, is the most striking clinical manifestation of VPI and corresponds to excessive nasal resonance accompanying sounds not normally nasalized[2].

Auditory-perceptual assessment performed by experienced speech-language pathologists is an essential tool for the diagnosis of hypernasality. However, in order to minimize the subjectivity of this type of approach and, mostly, to allow comparisons between studies, nasometry started to be used in recent decades.

The technique estimates speech resonance by measuring nasalance, a physical variable which corresponds to the relative amount of nasal acoustic energy in speech[3-5]. The technique assumes that an increased nasalance during the production of speech samples containing only oral sounds is suggestive of hypernasality[1]. Nasalance is calculated by the numerical ratio between the nasal acoustic energy and the total acoustic energy during speech (sum of nasal and oral acoustic energy), expressed as percentage. Studies have shown good correlation between nasalance and nasality[6,7]. In other words, nasalance corresponds to the acoustic correlate of nasality, which, in turn, corresponds to the subjective perception that a listener has of the nasal component of speech. Thus, nasometry complements what can be heard in the perceptual assessment of speech and what is seen in the direct instrumental methods.

The first Nasometer, called Tonar, was developed by Samuel Fletcher[8] in 1970 This was the first instrument to provide objective data on the acoustic product of speech in terms of resonance. Due to certain technical limitations, the *Tonar* was replaced in 1987 by the so-called *Nasometer* system, first produced by *Kay Elemetrics Corporation* and more recently by *Kay Pentax*. The use of nasometry in different countries soon has shown that nasalance varies according to the language spoken[9-13]. Studies with Brazilian Portuguese speakers, including children, have shown that nasalance can also vary according to age, gender or the type of emission (syllables and/or sentences)[14,15], confirming observations for other languages[13,16-22].

Since the nasometer has become an important tool in the assessment of the speech resonance of the general population and particularly of individuals with cleft palate, and that nasalance measures were shown to differ between different languages and genders, studies have been developed at the Laboratory of Physiology of the Hospital for the Rehabilitation of Craniofacial Anomalies, University of São Paulo (HRCA-USP), in order to establish normal scores of nasalance for the Brazilian Portuguese speaking population.

In the first study conducted in the 1990s in partnership with Rodger Dalston, speech-language pathologist of the Craniofacial Center at the University of North Carolina -USA and one of the pioneers in using nasometry in the craniofacial anomalies clinical practice of, nasalance scores were established for non-cleft children (6-10 years), adolescent (11-17 years) and adult (18-35 years) Brazilian Portuguese speakers during the reading of standardized sentences[14]. This was the first time that the *Kay Elemetrics* nasometer was employed in Brazil, and those nasalance scores have become national and also international normative references[12,22].

Knowing that nasalance varies according to the spoken language, researchers from different European countries, when investigating the speech outcomes of cleft palate repair (SCANDCLEFT project), proposed a new cross-linguistic speech assessment method, the A*nalysis of Consonants in Speech Units that are Phonetically Similar across Languages* in audio and video recordings. The purpose was not only to characterize and monitor changes in nasality caused by surgery in the five languages spoken by the participants, but also allow future comparisons between different studies[23]. The experience resulted in the development of an interactive website CLISPI (*Cleft Palate International Speech Issues*)[24] that offers training in the use of the method to speakers of different languages, including Brazilian Portuguese, as standardized by researchers of the HRCA-USP Laboratory of Physiology (APF, RPY and IEKT).

The CLISPI analysis has been used to evaluate speech in another international multicenter study called *Timing of Primary Surgery in Cleft Palate* (TOPS), which includes the HRAC-USP and the participation of authors of the present study (IEKT, APF, RPY). One of the primary outcomes will be the nasalance at 5 years of children who underwent surgery at 6 or 12 months of age, using speech samples standardized at CLISPI.

Therefore, considering the age of 5 as a key moment to evaluate nasality in children with or without cleft palate, this study had the primary objective of determining speech resonance in Brazilian Portuguese speaking children without cleft by nasometry assessment at age 5 years. A secondary objective was to verify whether nasalance differs between types of emission and genders.

METHODS

The study was conducted after approval by the HRCA-USP Ethics Committee on Research with Human Beings (Opinion nº 768.206) in the HRCA-USP Laboratory of Physiology, and after parents or guardians have signed the Informed Consent form.

Participants

The sample was selected from a universe of 75 school children, and the final sample was defined by the number of consents obtained. Thus, 20 children were evaluated, regardless of ethnicity, among which 11 were males. The mean age was 5 years (minimum: 4 years and 10 months and maximum: 5 years and 11 months). All were Brazilian Portuguese speakers, residents in the State of São Paulo, and had the typical accent of the region according to the principal speech-language pathologist of the study. Children of a single private educational institution in the city of Bauru-SP were invited to participate in the study by means of a letter with explanatory information addressed to parents or guardians.

Children with a history or complaints of chronic nasal obstruction and voice, speech, hearing and language disorders, or undergoing speech therapy were excluded. To survey these information, parents or guardians answered a questionnaire specially designed for this purpose at the invitation to participate in the study. The identification of other disorders during the clinical examination performed by the principal speech-language pathologist not mentioned by parents or guardians, was also considered an exclusion criterion. The examination consisted in naming figures for the identification of evident speech disorders and in a morphofunctional assessment of the integrity of orofacial structures and the use of orthodontic appliance.

Procedures

Nasometry was carried out at the school, in a room exclusively used for this purpose, far from the noisiest place in the school, with appropriate conditions for equipment calibration and assessment.

Nasalance was determined using a portable nasometer (Nasometer II, 6450-KayPENTAX Model, Montvale, NJ, USA) coupled to a Dell Latitude *laptop*. The system is composed of two microphones, positioned one on each side of a sound separation plate which is positioned against the upper lip. The system is held in position by a headgear (Figure 1). During reading of the speech samples presented on the computer screen, the upper microphone captures signals of the nasal component of speech and the lower microphone, signals of the oral component, which are filtered, digitized and analyzed with specific *software*. Nasalance is then calculated by the numerical ratio between the amount of nasal acoustic energy and the total acoustic energy (sum of nasal and oral acoustic energy) multiplied by 100. It may vary from 0% (no sound through the nose) to 100% (all sound emerging through the nose). Calibration of the system was carried out before each examination period, using a sound generator of the equipment, keeping the microphone perpendicular to the nasometer at a distance of 30 cm, and adjusting the balance between the two microphones by 50%.

The examination was carried out in two different speech contexts: production of eight isolated syllables composed by occlusal, fricative, nasals and liquid consonants; and naming of nine words containing consonants and vowels in tonic position, phonetically equivalent to those used in the English language and in Scandinavian languages in the development of the TOPS project, as follows: 1) *Syllables: pa, pi, sa, si, la, li, ma, mi:* each syllable was repeated six times (for example, pa, pa, pa, pa, pa, pa) at the speed of approximately one syllable per second so that all syllables would fit in a single screen. The recording time was set to eight seconds, in order to standardize the emission speed among children. A series of six syllables /pa/ is shown in Figure 2. Each series of syllables /pa/ was repeated three times

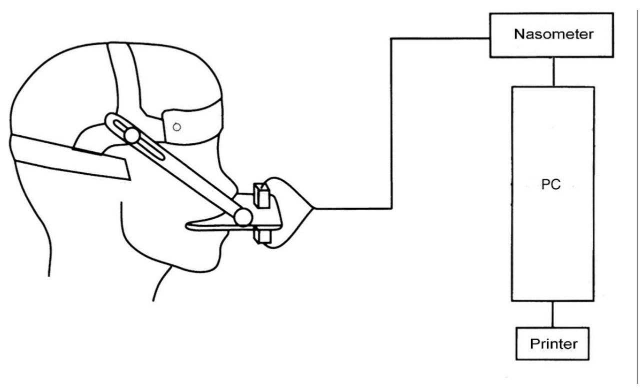

Figure 1. Scheme illustrating the instrumentation for assessment of nasalance. Source: Trindade et al.[1]

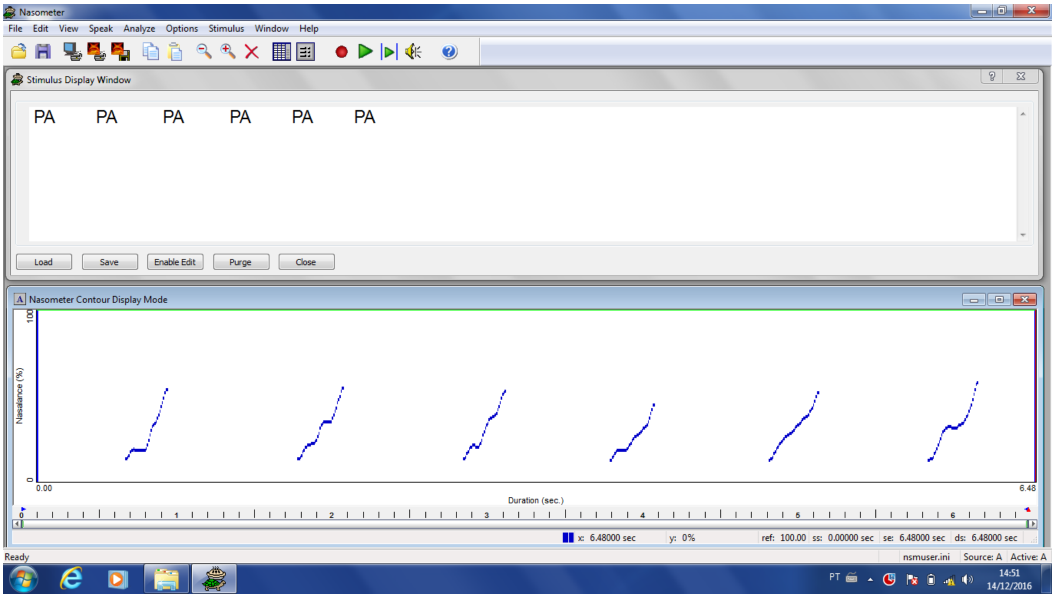

Figure 2. Illustration of a recording of nasalance in the production of six syllables /pa/ using the Nasometer II system, Model 6450. KayPENTAX 2010

on three different screens, and the mean nasalance of the three series was then calculated. This procedure was used for all studied syllables (/pa/, /pi/, /sa/, /si/, /ma/, /mi/, /la/, /li/); 2) *Words: pipa, bis, burro, tatu, pilha, cuca, gui, fila, luz (www.clispi.org)*: the nine words were produced in one sequence (one after another), at a rate of approximately one word every two seconds so that all words would fit in a single screen. The recording time was set to 16 seconds (nine words per screen, one screen). Each word was elicited by the presentation of a picture drawn in a card. When children did not recognize or did not correctly name the picture, they were instructed to repeat the word after the verbal model given by the examiner. The words used met the criterion defined by Lohmander et al.[23] for cross-linguistic comparisons, i.e., the use of a restricted number of speech units phonetically similar across languages and vulnerable to the presence of a palatal cleft.

During the examination, the positioning of the sound separation plate was systematically monitored to ensure reliable records. For analysis, only technically acceptable records, i.e. those produced without errors and within the acceptable limit of intensity of the instrument, were considered.

This protocol was established in order to standardize the production of speech samples among participants and for future comparisons with data from other studies.

Data analysis

Nasalance is expressed as percentage (%). Mean scores were calculated for each set of syllables and set of words. For statistical analysis, the SigmaPlot 12.0 program was used. The significance of differences between emission types was verified by the Friedman test (nonparametric ANOVA). In case of statistical significance, the Tukey test for multiple comparisons was used. The significance of the differences between genders for each type of emission was verified by the Mann-Whitney test. A significance level of $p<0.05$ was adopted.

RESULTS

Mean nasalance scores (± standard deviation) and minimum and maximum scores observed during the production of syllables and words are shown in Table 1. Nasal syllables had higher nasalance scores than oral syllables (with neutral or high vowel), and the high vowel oral syllables had higher nasalance scores than neutral vowel oral syllables. As shown in Table 2, differences were statistically significant between: 1) nasal syllables and high vowel oral syllables: /ma/>/pi/; /mi/>/pi/; /mi/>/si/; /mi/>/li/; 2) nasal syllables and neutral vowel oral syllables: /ma/>/pa/; /ma/>/sa/; /ma/>/la/; /mi/>/pa/; /mi/>/sa/; /mi/>/la/; 3) high vowel oral syllables and neutral vowel oral syllables: /li/>/pa/; /li/>/sa/; /li/>/la/; /si/>/pa/; /si/>/sa/; /pi/>/pa/; /pi/>/sa/.

The comparison between genders (Table 3) showed no statistically significant difference between the mean scores obtained from groups of girls (n=9) and boys (n=11), for any stimuli used.

Table 1. Nasalance scores in the production of syllables and words by children without craniofacial abnormalities and speech disorders

Consonants	Speech samples	Mean ± SD	Minimum	Maximum
Nasal	**/ma/**	57±11	34	78
	/mi/	73±13	42	86
Oral	**/pa/**	10±4	5	24
	/pi/	22±7	14	43
	/sa/	11±5	5	29
	/si/	24±11	14	55
	/la/	14±9	8	41
	/li/	25±11	11	52
	Words	20±6	11	35

Table 2. Comparison between the speech samples

	/pa/	/pi/	/sa/	/si/	/ma/	/mi/	/la/	/li/
/pa/								
/pi/	S							
/sa/	NS	S						
/si/	S	NS	S					
/ma/	S	S	S	NS				
/mi/	S	S	S	S	NS			
/la/	NS	NS	NS	NS	S	S		
/li/	S	NS	S	NS	NS	S	S	

Tukey test ($p<0.05$)
Caption: S - Statistically significant difference, NS - Non-significant difference

Table 3. Comparison of mean nasalance scores of female and male children

Speech samples	Mean ± SD		p
	Female (n=9)	Male (n=11)	
/ma/	55±10	58±12	0.761
/mi/	74±12	71±14	0.649
/pa/	11±5	9±2	0.761
/pi/	23±8	21±6	0.447
/sa/	11±7	11±3	0.517
/si/	27±12	22±9	0.305
/la/	14±9	14±9	0.879
/li/	25±11	24 ±11	0.704
Words	20±6	20±7	0.493

Mann-Whitney test

DISCUSSION

This study determined nasalance scores in 5-year-olds without craniofacial anomalies, speech disorders, orthodontic appliances and evidences of nasal obstruction that could compromise speech resonance during the examination. This approach was proposed to set normal parameters, not only for systematic assessment of speech outcomes of primary palate repair in children with cleft lip and palate but also for other purposes related to the investigation of speech resonance[25]. The normative nasalance scores established in the present study allows the interpretation of scores obtained in populations with suspected nasality deviations. One strategy to be used is the comparison between means of the two populations (children under investigation *versus* normal children). Another one is the comparison with the minimum and maximum scores obtained in the present sample. A third strategy is discussed later.

As demonstrated, the nasometry consists in an instrumental technique which indirectly estimates the velopharyngeal function by measuring nasalance, a variable that represents the relative amount (percentage) of acoustic energy emerging from the nasal cavity during speech. It is considered an indirect method because it does not allow visualizing velopharyngeal structures[2]. Yet, it is a valuable tool to assess hypernasality, especially in children, as they can show an uncooperative behavior during the perceptual assessment[18].

The present sample of twenty 5-year-old children showed higher nasalance scores for nasal syllables than oral syllables with neutral or high vowel, and higher scores for oral syllables with high vowel than oral syllables with neutral vowel. This result is expected and confirms the effectiveness of nasometry in the indirect assessment of nasality.

Similar results were found in a previous study[14], in which nasometry was performed in Brazilian Portuguese speaking children aged 6-10 years, with accent typical of the region of São Paulo, in a different context from the present study. In that study, four texts were used: ZOO-BR, consisting of five sentences with oral high-pressure consonants; ZOO2-BR, consisting of five sentences with liquid low-pressure consonants; NASAL-BR, consisting of five nasal sentences with high-pressure consonants; and NASAL2-BR, composed of five nasal sentences without high-pressure consonants. As in the present study, mean nasalance scores (Nasal-BR = 48 ± 7% and Nasal2-BR = 51 ± 7%) were higher in the nasal texts than those observed in the oral texts containing high-pressure consonants (ZOO-BR = 10 ± 6%) and liquid consonants (ZOO2-BR = 12 ± 9%). These scores are similar to the observed in the present study in equivalent syllabic emissions. For example, the nasal syllable /ma/ had a nasalance mean of 57% in the present study, while the corresponding nasal sentences in the previous study[14] had a score of 51%. It is noteworthy that differences smaller than 8% are not considered significant for the method[1]. Study in which nasometry was held in 70 Irish children, among 36 girls and 34 boys aged between 4 and 13 years and without speech, articulation, resonance and voice disorders, also aimed to obtain normative scores of nasalance. The authors used a set of high-pressure consonant sentences, another set of low-pressure consonant sentences, a third set with nasal consonants and a fourth set with all types of stimuli. Although language was different from Brazilian Portuguese, the authors also observed that nasalance in sentences with nasal consonants was higher than in the other sentences, and that there was no significant difference between high-pressure and low-pressure consonant sentences[17].

Regarding the differences between types of emissions containing high vowel /i/ and neutral vowel /a/, higher nasalance scores were observed for the former. Similar results were seen for Hungarian and Korean speaking children[26,27] and for a normal Brazilian Portuguese speaking population, including children, adolescents, young adults and adults[15]. The lower nasalance scores seen in the production of the neutral vowel is related to the position of the tongue (lower) and the size of the oral cavity (larger). In other words, these factors lessen the contribution of the nasal cavity to resonance during the production of the neutral vowel compared to the production of the high vowel[15].

Particularly with regard to the words, which had not been used in Portuguese language studies so far, their use demonstrated the importance of using specific and controlled stimuli. This is because, if we compare the nasalance score (10 ± 6%) of the set of oral sentences used in the previous study (ZOO-US text)[14] and the nasalance score obtained in the production of the word series in this study (20 ± 6%), with equivalent content of consonants, there is a significantly higher mean score for the words. This may be explained by the fact that high vowels predominate in the word series while neutral vowels predominate in the ZOO-US text.

Regarding gender, there were no statistically significant differences between girls and boys for any stimuli used in the present study. In a study[28] determining normal nasalance scores in Australian children aged 4-9 years, nasal sentences and the *Zoo Passage*, devoid of nasal sounds, were used as speech samples. Like in our present findings, no significant difference between genders for the two stimuli were found. The same has been observed by several other authors[16-19]. This result may be related to the fact that fundamental frequency of girls and boys are similar until puberty[29]. On the other hand, unlike the results found here, differences between genders have been found for languages spoken in Malaysia, Turkey and Arabia, and, in general, nasalance was shown to be higher in girls[13,20,21]. Taken together, these data suggest that gender differences may be present in some languages but not in others. Differences between languages will be better explored in subsequent studies.

Although it is not the scope of the present study, a final comment on nasalance scores in the present 5-year-old children as compared to those observed in children aged 6-10 years in a pilot study conducted in the HRCA-USP Laboratory of Physiology[30]. This comparison indicates that there are no age differences in Brazilian Portuguese, within the age group studied, when it comes to comparisons between syllables. This is in line with the findings of a study conducted in the Swedish language[16]. In-depth evaluation of age related differences in nasalance is being addressed in an ongoing study at our laboratory with a large sample of participants. This study will even make possible the use of strategies such as the calculation of the normal limits of nasalance for different types of emissions, adding 1.654 standard deviations to the mean of the "normal" group.

Finally, this study has three limitations that must be mentioned: the small number of participants, the inclusion of children living in a single city of the São Paulo state, and also the uncontrolled dialectal differences. All these factors may limit the use of nasalance scores reported here as normative data; however, they can serve as reference to studies of this same nature, provided due caution at interpreting the findings is taken.

CONCLUSION

In this study, normal nasalance scores for Brazilian Portuguese at the age of five years were established, for comparison in clinical evaluations of suspected velopharyngeal dysfunction and for monitoring therapy. There was no difference between genders, in the 5-year-olds analyzed, and the type of emission had influence on nasalance scores measured by nasometry. This must be taken into consideration when this technique is used as diagnostic tool for nasality deviations determined by a palatal cleft and other conditions.

ACKNOWLEDGEMENTS

To the staff of the Laboratório de Fisiologia do Hospital de Reabilitação de Anomalias Craniofaciais da Universidade de São Paulo and to Colégio São José, Sagrado Rede de Educação de Bauru for providing perfect conditions for the execution of the study. To the Programa Institucional de Bolsas de Iniciação Científica (PIBIC) - Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support provided for executing the project.

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Author contributions

DNO participated as undergraduate Scientific Initiation student in the study design, literature review, project drafting, collection, analysis and interpretation of data, article writing; ACMST participated in the study design and data collection; BGA participated in the literature review and data collection; APF and RPY participated in the interpretation of data, IEKT participated as advisor of the study design, project drafting, analysis and interpretation of data, article writing.