CORRELATION BETWEEN NASALANCE AND NASALITY IN CHILDREN WITH HYPERNASALITY

Correlação entre nasalância e nasalidade em crianças com hipernasalidade

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ABSTRACT

Purpose: to correlate nasalance scores and speech nasality of operated unilateral cleft lip and palate children. **Methods:** this prospective study involved auditory perceptual identification of nasality by three experienced speech-language pathologists who judged recorded phrases produced by 79 children (mean age of 6y5m), all speakers of Brazilian Portuguese. Nasalance measures obtained simultaneously to audio recordings were also analyzed. The speech samples included two sentences, one with [p] and another with [b] sounds. Inter-judgment agreement for the total (N=158) phrases judged by the speech-language pathologists was obtained (78.5% for [p] and 93.5% for [b]). Intra-judgment agreement for duplicated sentences was 82% for [p] and 86% for b] sounds. The speech-language pathologists were then instructed to judge individually speech nasality of the 178 phrases using a 4 points scale. Nasalance scores for these 158 phrases were then obtained. Mean speech nasality and nasalance scores were correlated. **Results:** mean values of 1.53 and 1.52 (indicative of mild hypernasality) were obtained for the [p] and [b] phrases, respectively, from perceptual judgments. Mean nasalance scores were 32% ([p] phrase) e 39% ([b] phrase). Although significant, low correlation was found between speech nasality and nasalance scores for the two investigated phrases ([p]; r= 0,31; p=0,004; [b]; r= 0,37;p=0,0007). **Conclusion:** mild hypernasality as identified in the speech of children with cleft palate may disfavor correlation findings between speech nasality and nasalance scores. Longer speech stimuli and samples including higher degrees of hypernasalityare recommended for future studies.

KEY WORDS: Cleft Palate; Speech Disorders; Child

INTRODUCTION

Hypernasality is defined as the presence of excessive resonance in the nasal cavity during the production of oral speech when there should be an oral-nasal balance. This excessive resonance occurs due to the coupling of the oral and nasal cavities, while issuing the oral voiced sounds, due to the velopharyngeal dysfunction (VPD)[1] which in turn, may occur after the primary correction of the cleft palate. A recent survey reported the presence VPD after primary palatoplasty in 24% of patients enrolled in a clinical type study[2]. In these patients, the communication between the oral and nasal cavities remained even after the completion of primary surgery for the correction of the lip and palate. Such surgeries aimed, beyond the closure of the cleft itself, to establish the correct function of the velopharyngeal mechanism for speech production.

Traditionally, speech resonance is evaluated by a speech-language pathologist through the auditory perceptual assessment. Even though the literature

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agrees that the auditory-perceptual judgment is the gold standard procedure for the identification of the resonance disorder[3,4], it is proposed that this is not the only way to assess speech resonance. In general, it is observed that the correlation between the intra-and / or inter-evaluated speech judgments of individuals with hypernasality can vary due to its subjective nature, even among listeners trained in evaluations of speech in patients with cleft lip and palate. Moreover, the lack of standardization of clinical procedures used by evaluators make it difficult to compare the results derived from subjective reviews[5]. Such a fact led researchers to seek consistency between procedures for those used for evaluating the speech of individuals with hypernasality[3].

The use of objective instrumental measures, standardized and normalized for assessing the velopharyngeal function have been recommended in the literature, in order to complement the auditory perceptual assessment of speech, since they offer more accurate information to enable better therapeutic planning[6, 7]. For this reason, the instrumental acoustic analysis of the speech signal is proposed as a way of corroborating the results of perceptual tests of speech resonance. More specifically, the nasometer was developed to provide objective measures of nasality of speech involving no risk to the patient for not being invasive[8]. This equipment provides a score indicating the percentage of nasal acoustic energy added to the oral acoustic energy (nasalance). The value of nasalance obtained through the nasometer reflects the relative amount of nasal acoustic energy present in the speech of an individual, providing an acoustic correlate of speech nasality[6]. The combined use of auditory perception judgment and of the acoustic correlate of nasality (nasalance) can provide more accurate diagnosis and therapeutic procedures, since these have shown the validity of the clinical diagnosis of hypernasality[9].

The relationship between nasalance and nasality was reported in several studies either by analyzing the correlation between these two measures[9,10] as much by estimating the effectiveness of the nasometer when determining their sensitivity and specificity[9]. With regard to the correlation between the measures of nasalance and the perceptual auditory judgment of nasality, results obtained in previous studies showed that this correspondence is not absolute, nor linear. While some of these studies reported high correlation between these two aspects with the use of oral stimulus[9,11-13] other reported moderate correlations[14, 15] and even lower correlations[16]. This wide variation in results has been attributed to methodological differences between studies, including differences in the speech stimuli and the scales used for perceptual judgments, the degree of experience of the judge to the perceptual ratings, the differences between the speech samples used for perceptual and nasometric reviews[17]. For example, a recent study indicated a correlation between the judgments of hypernasality and nasalance scores as higher for trained than for untrained speech-language pathologists. A correlation was also indicated between these two assessments when stimuli consisted of sentences with predominantly oral phonemes were used, which was not observed when oro-nasal stimuli were used[10].

In addition to information about the relationship between nasalance and nasality, previous data on the effectiveness of the nasometer[11] demonstrate that this instrument is effective to support judgments of the presence or absence of hypernasality reported by the judges, being of great value in assessing the speech of individuals with VPF. A recent study found high sensitivity and specificity of the method, confirming indications complementing the velopharyngeal evaluation[9], besides indicating similar sensitivity and specificity even when different perceptual scales are used[15].

Particularly with regard to studies involving Brazilian Portuguese language (PB), they initially prioritized the normalization of nasalance values for the population without cleft palate[6,18,19] and limits for normality[20] of nasalance, since the international literature indicates that nasalance values are dependent on the language[13,17,21] and dialect[10, 22]. Thus, when using nasometry as a diagnostic measure and a control (follow up) of treatment of the alterations in resonance, there is a need to provide normative data of nasalance of the language studied[22] in order to help distinguish between normal and altered speech nasality[23].

In addition to normative data, measures of nasalance for the population with operated cleft palate and with normal speech were presented[24]. Other studies reported measures of nasalance in patients with operated cleft palate in order to investigate the conditions of the velopharyngeal mechanism after the performed surgical procedures [25-28], even after adapting a palatal prosthesis[29]. While these studies have contributed greatly to information about nasalance in individual PB speakers, data on the correlation between the values of nasalance and perceptual findings in BP-speaking children are limited. A study[12], in particular, investigated the correlation between nasalance and nasality of 40 individuals (mean age 18 years) BP speakers who presented hypernasality, from the analysis of two speech stimuli ("*bebê*"/"baby" and "*O bebê babou*"/

"the baby drooled"). The results of this study showed a high correlation between nasality and nasalance scores for samples of speech (word *bebê*/"baby", r = 0.81 and sentence "*O bebê babou*"/"The baby drooled" r = 0.88) in which the judges had agreement regarding the speech nasality of 85% or higher. Also evidenced a high correlation for the studied samples (r = 0.80, r = 0.73) in which the judges had agreement regarding the speech nasality of 70% or higher. These results indicate that the correlation between judges in turn of around 70% can promote studies that aim to correlate speech nasality and the nasalance scores.

Additional information about the correlation between nasalance and nasality, specifically for the pediatric population with a history of cleft palate, with the use of specific speech samples are important for validating the use of the instrument in speakers of Brazilian Portuguese, since variables such as age, gender and complexity of speech samples can influence the measures of nasalance. The aim of this study was to establish the correlation between measures of nasalance and auditory perceptual judgment of nasality, by children with operated cleft palate.

METHODS

The study was developed in the Laboratory of Experimental Phonetics (LAFE), Hospital for Rehabilitation of Craniofacial Anomalies, USP (HRAC/USP), with the approval of the Research Ethics Committee (Protocol 89/2013-SVAPEPE-CEP). It is a prospective study of recorded audio speech samples and registered nasalance scores in the database belonging to the LAFE. All recordings were edited and submitted to professional judgment (speech-language pathologists) with experience in evaluation of speech disorders associated with cleft lip and palate. Subsequently, the auditory perceptual judgments were correlated with the nasalance scores. Emphasized audio recordings of speech samples were used in this study, since the literature[30] point out that recordings of this nature are the main system of documentation of speech because besides allowing for data recovery, recordings can be edited and presented for the auditory-perceptual judgment of multiple judges, allowing for calculations of intra and inter-rater evaluator reliability.

To keep a control variable of the type of cleft, only recordings of patients with operated unilateral complete cleft lip and palate were selected (OUCCLP). Speech samples included in the study were produced by 79 children aged between 4 and 9 years (mean = 6.5 ± 2.9 years), and at the age of recording all had received only primary procedures to correct the cleft. Of the recorded content, only the phrases *"Papai pediu pipoca*" ("Daddy asked for popcorn") and "*O bebê babou*" (The baby drooled") constituted the samples of interest, although the following inclusion criteria were considered: the audio samples should have been recorded simultaneously with the nasometric evaluation and such samples should have been classified as hypernasal, regardless of the grade (mild, moderate or severe), according to the recordings of the clinical evaluations of speech contained in each child´s file.

The speech samples were repeated for each child after the clinician and recorded in a silent and acoustically treated room, using a AKG C420 headset microphone. The selected recordings of each sentence were edited using a Sony Sound Forge software, version 7.0. In the editing, each phrase was repeated three times (with an interval of 3 seconds) consecutively, keeping an interval of 20 seconds between them. To calculate the reliability between judges, 35% of the samples were duplicated and all the recorded material was randomly ordered on a CD in order to allow the auditory perceptual judgments of the occurrence and the degree of hypernasality. The material presented for the speech-language pathologists (judges) was thus composed of a total of 213 speech samples (79 recordings X 2 phrases = 158 + 55 duplications. The three speech-language pathologists performed the individual judgments using the Windows Media Player (Microsoft Windows) program and Sennheiser HD 202 model headphones. All had extensive experience in the evaluation and treatment of cleft lip and palate. They were instructed to classify the speech resonance through a 4-point scale as follows; 1- normal, 2- mild hypernasality, 3- moderate hypernasality and 4- severe hypernasality. To promote such classification, the CD that each received also contained examples of speech samples representative of normal speech and hypernasal speech in mild, moderate and severe degrees. The judgments were made individually in a quiet room. During the judgments, all adjustments in audio volume were allowed as well as repeating the submission of samples to allow the judgment to be as accurate as possible. The order of presentation of the samples was identical for all the judges.

After analysis of the 213 samples by the judges, the degree of intra (55 duplicate phrases) and inter judgments (158 sentences) was calculated. Regarding the intra judge agreement, the measure of 86% was observed for the phrase *"O bebê babou"* ("The baby drooled") and 82% for the phrase *"Papai pediu pipoca*" ("Daddy asked for popcorn"). According to the categorization proposed in the literature[31], these findings indicate almost perfect

agreement for the auditory perceptual judgments made by the same examiner. Regarding the inter judge agreement, the judgments obtained with total (3 agreements / 3 judges) or partial (2 agreements /3 judges) agreements were considered. Thus, for the phrase *"Papai pediu pipoca*" ("Daddy asked for popcorn"), inter judge agreement found was 78.5% and the phrase *"O bebê babou" (*"The baby drooled") was 93.5%. According to the categorization proposed in the literature[31], these findings indicate substantial agreement (*"Papai pediu pipoca*"; "Daddy asked for popcorn") and almost perfect (*"O bebê babou";* "The baby drooled") for the auditory perceptual judgments and therefore were considered reliable for correlation with the nasalance scores.

In order to obtain a correlation between the auditory perceptual and nasometric findings, it was necessary to first establish a criterion for the interpretation of the results of the auditory perceptual judgments. For that the arithmetic mean of nasality judgments made by the three judges obtained for each sentence was used. It was considered an average of 1.5 on a scale of 1 to 4, as a value of the auditory perception cut, i.e. values below 1.5 were interpreted as indicating normal nasality and values of 1.5 or higher were interpreted as indicative of hypernasality.

The nasalance scores were also collected from the database, as previously mentioned. At the time of data collection, the nasometric evaluation was performed using a Model 6200-2 Nasometer (KayElemetrics). The system comprises two microphones placed one on each side of a sound separation plate, placed above the upper lip of the patient. The upper microphone picks up signals from the nasal component of speech and the bottom picks up the signals from the oral component. These signals are filtered, digitized and processed by electronic modules in the microcomputer through specific software. The nasalance (expressed in percentage) corresponds to the relative amount of acoustic nasal speech energy, ie, the numerical ratio between the amount of nasal acoustic energy and the amount of the sum of the nasal and oral acoustic energy, multiplied by the 100th calibration of the nasometer. The procedures for recording and the calculation of the measures of nasalance for each child were performed according to the procedures described in the Nasometric Instruction Manual[32].

An adaptation of the nasometer plate microphones was also used, as previously proposed in the literature[12]. While performing the nasometry, the child sat in a comfortable chair in an acoustically isolated room. Each one was asked to repeat after the clinician, the two phrases of interest. Considered for the analysis were the values of nasalance (average) of the first technically acceptable emission of each sentence, ie produced without errors (pauses or hesitations) and within the limits of the accepted speech intensity of the instrument[32]. The nasometer calibration was performed daily before the begining of the examinations. Having obtained the samples, they were stored in individual files on the computer connected to the nasometer and the nasalance values for each sample were calculated for each child.

To interpret the nasalance scores, the cutoff value of 27% was used based on previous descriptions of the literature[33]. Thus, nasalance values higher than 27% were considered indicative of excessive amount of acoustic nasal energy or hypernasality. Values below 27% were considered indicative of normal speech resonance. As reported in the literature[33], this score is the value that maximized sensitivity and specificity of the nasometry in identifying the presence or absence of hypernasality.

Mean values (and standard deviation) of the perceptual findings (indicative of nasality of speech) and nasometric values were obtained. The Spearman correlation coefficient was used to obtain the correlation between nasalance and nasality. Results with p-values less than 0.05 ($p < 0.05$) were considered statistically significant.

RESULTS

Mean values attributed to auditory perceptual judgments obtained by three speech-language pathologists ranged between 1.52 and 1.53, which indicated hypernasality (mild), taking into account the cutoff value of 1.5 established for the interpretation of data. These results agree with the initial preliminary assessment (contained in the records) used for the selection of children, which should present hypernasal speech for inclusion in the study.

The mean nasalance values obtained for each of the sentences also indicated hypernasality (using a cutoff value of 27%) (Table 1).

The Spearman test revealed low correlation, but statistically significant between the values of nasalance and nasality, according to auditory perception judgment trial by three speech-language pathologists. More specifically, a coefficient correlation $r = 0.31$ were found for the phrase *"Papai pediu pipoca*" ("Daddy asked for popcorn") ($p = 0.004$) and $r = 0.37$ for the phrase *"O bebê babou"* ("The baby drooled") ($p = 0.0007$), as shown in Table 2.

Table 1 – Mean values of auditory-perceptual judgments of nasality and nasalance scores for the two sentences of interest

	Nasality		Nasalance	
	Mean (judges)	Interpretation (cutoff value = 1,5)	Score Mean % (SD)	Interpretation (cutoff value = 27%)
Papai pediu pipoca (*Daddy asked for popcorn*)	1,53	Hipernasal	32% (16)	Hipernasal
O bebê babou *(The baby drooled)*	1,52	Hipernasal	39% (17)	Hipernasal

Table 2 - Correlation ("r") between perceptual judgment of nasality and nasalance measures for the two sentences of interest

	Correlation ("r")
	Nasalance/Nasality
Papai pediu pipoca *(Daddy asked for popcorn)*	0,31**(p = 0,004)*
O bebê babou *(The baby drooled)*	0,37**(p = 0,0007)*

*Spearman correlation coefficient: p ≤ 0,05**

DISCUSSION

In general, the literature indicates that the correspondence between auditory perception judgment and nasometry is not absolute[14]. In the present study, by correlating the nasalance scores with the auditory perceptual judgments, the results showed that, although statistically significant, the correlation was low (between 0.31 and 0.37). These results corroborate with previous findings[16] which also found a low correlation between the two variables, differing, however, with studies that found high [9,11-13] or moderate[14, 15] correlations between speech nasality and the nasalance scores.

The low correlation found in this study can be explained,in part, by the difficulty found by the judges to judge hipernasality in speech recordings involving short stimuli (short sentences).

When this study was designed, it was considered that the evaluators may have difficulty judging the speech samples because such samples include short extension stimuli. To minimize this potential difficulty, it was decided to edit the recording of each sentence three times consecutively. This measure, in order to facilitate the judgment of nasality, since the judges had more time to judge the sample, seems to have been enough to encourage a closer correlation between the nasalance and nasality of speech.

The guidelines offered to the judges who were instructed to judge the hypernasality (when present) should still be considered as mild, moderate and severe, using for this purpose, sentences consisting of words with predominance of the same consonants (plosives [p] or [b]). This may have hampered the task of evaluating, considering that the speech resonance of the patients included in this study varied between normal and mild hypernasality. If however, the judges had been instructed to judge only the "presence" or "absence" of hypernasality, the correlations between the nasalance and nasality could be better. According to discussions presented in the literature[14] the high correlation between nasalance and nasality judgments previously reported in other studies[9,11] for example, may be explained by the fact that the hypernasality of the patients investigated have varied from mild to severe. This argument leads us to think that a possible explanation for the low correlation between the nasalance and nasality in the present study is due to the fact that most of the children included in the study had mild hypernasality, according to the auditory perceptual judgment of the three judges. These findings, however, suggest the existence of a sample with a tendency for light hypernasality values. That is, even considered as eligible all patients with OUCCLP and hypernasality, only 79 individuals were found in the database who had audio speech samples recorded simultaneously in the nasometric review.

Future studies involving multicenter partnerships can promote the establishment of a representative data bank of varying degrees of hypernasality.

Regarding the nasalance scores, it is stressed that the studies that found a high[9,11,13] or moderate[14, 15] correlation between the nasalance and nasality used texts such as speech stimulus or set of phrases[9]. Some authors[34] investigated the minimum extent that the speech stimuli might have to keep the same result of nasalance of the original stimulus

(text) and suggested that speech stimuli with at least six syllables would be indicated to obtain valid measures of nasalance. Another study[35] justified that it is possible to use even smaller speech stimuli since it will regulate its nasalance value, and can be significantly affected by their phonetic composition. The speech stimuli used in this study understood the phrase *"Papai pediu pipoca*" ("Daddy asked for popcorn") and *"O bebê babou"* ("The baby drooled"). Although nasometry is generally performed using longer stimuli (text), data involving shorter segments were published in several studies[12,19,34]. The MacKay-Kummer SNAP Test-R[1], for example, consists of appropriate stimuli for children, being embedded especially in the nasometer software. Considering that this test was unsuitable and/ or standardized for Brazilian Portuguese, short sentences with controlled phonetic-phonological context have been used in research conducted at the LAFE-HRAC/USP[12,19]. It is noteworthy that a single sentence can be more easily produced by children and a few collaborators, as well as being easier to control the use of compensatory articulation (eg, glottal plosive) typically associated with velopharyngeal dysfunction. Thus, in the present study, short extension sentences were selected to provide the nasometric measures that were subsequently correlated with the auditory-perceptual judgment of the presence or absence of nasality. Such stimuli have controlled the phonetic context, consisting predominantly of occlusive consonants [p] and [b], which favors the control effect of the presence of possible articulatory changes as well as improves the performance of children with incomplete phonological acquisition[1].

Although the speech stimuli used in this study are generally considered to be relatively short stimuli, the phrase "*O bebê babou*" ("The baby drooled") was used in a previous study[12] which found a high correlation between the nasalance and nasality when these two same speech sounds were used. The high correlation reported in a previous study[12] can be due to the fact the population of the study is composed of adults and children with varying degrees of hypernasality (ranging from mild to severe), unlike the present study which was limited to children, predominantly with mild hypernasality values.

Based on this information, it is found that variables such as the degree of hypernasality and extent of stimulation may influence the correlation between the data of speech nasalance and. nasality, resulting in lower values of correlation, although significant. Information obtained from studies involving a correlation between the nasalance and perceptual findings should therefore be interpreted carefully when proposing conducts and treatment plans. Although the correspondence between nasometry and perceptual judgment of nasality is not exact, nasometry is considered effective in detecting patients with clinical judgment of hypernasality[14]. For clinical and research purposes, it is suggested that future studies be carried out that verify the correlation between speech nasality and nasalance involving longer speech stimuli and include representative samples of higher degrees of hypernasality in order to provide a better understanding of the relationship between nasality and nasalance .

CONCLUSION

The results obtained in the present study leads to conclude that the correlation between nasalance and nasality in children with speech resonance ranging between normal and mild hypernasality is low when using short extension sentences. Therefore, future studies are suggested that aim to correlate nasalance and nasality with the use of longer speech stimuli (provided appropriate for the age range to be investigated). Moreover, the control variables that may affect the auditory perceptual judgment of nasality, nasal snoring, nasal air emission, and the presence of compensatory articulations should also be considered.

RESUMO

Objetivo: estabelecer a correlação entre medidas de nasalância e de nasalidade de fala apresentada por crianças com fissura labiopalatina operada. **Métodos:** estudo prospectivo, em que as gravações de áudio de frases produzidas por 79 crianças (idade média 6,5 anos) falantes do português brasileiro foram julgadas auditivamente por três fonoaudiólogas. Medidas de nasalância obtidas simultaneamente às gravações áudio também foram analisadas. As amostras de fala incluíram duas frases, uma constituída por [p] e outra por [b], em recorrência. A concordância interjuízes foi obtida para as 158 frases (78,5% para [p] e 93,5% para [b]). A concordância intrajuízes também foi verificada para as frases duplicadas (82% para [p] e 86% para [b]). Os fonoaudiólogos classificaram individualmente a nasalidade de fala das 158 frases utilizando uma escala de 4 pontos. Valores de nasalância destas mesmas frases foram calculados. Os valores médios da nasalidade de fala foram correlacionados como os escores de nasalância. **Resultados**: valores médios de 1,53 e 1,52 (indicativo de hipernasalidade leve) foram obtidos para as frases [p] e [b], a partir dos julgamentos perceptivos. Os valores médios de nasalânciaforam 32% (frase [p]) e 39% (frase [b]). Embora significantes, houve correlação baixa entre nasalidade e nasalância paraas duas frases (/p/;r= 0,31 p=0,004e /b/; r= 0,37 p=0,0007). **Conclusão:** quando classificada como leve, a hipernasalidade de fala apresentada por crianças com fissura labiopalatinapode desfavorecer entre nasalância e nasalidade. Estímulos de fala mais longos e amostras representativas de graus mais elevados de hipernasalidade são recomendados para futuros estudos.

DESCRITORES: Fissura Palatina;Distúrbio da Fala;Criança

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