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THE CORRELATION BETWEEN DERIVED NASALANCE MEASURES AND PERCEIVED NASALITY IN CHILDREN WITH REPAIRED CLEFT LIP AND PALATE

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ABSTRACT

***Context*:** Velopharyngeal dysfunction (VPD) is one of the associated condition reported in individuals with repaired cleft lip and palate (RCLP) leading to hypernasality. Nasality can be assessed by nasometer through nasalance values. But, mean nasalance values (N) found to be overlapping between individuals with RCLP and normals. To overcome these limitations Nasalance Distance (ND) and Nasalance Ratio (NR) are derived based on nasalance range.

***Aims*:** The study is aimed to evaluate, correlate and compare acoustical (N, ND & NR) and perceptual measures of nasality between the children with RCLP and control group.

***Settings and Design*:** Institutional setup and standard group comparison design

Methods and Material: The study included fifteen children with RCLP ranging from 6 to 11 years and the control group consists of age and gender matched 15 typically developing children. Four point standard rating scale was used to rate the hypernasality by three speech language pathologists (SLP's) and Nasometer was used to measure the mean and derived nasalance scores for vowels and sentences in Kannada.

***Statistical analysis*:** SPSS, Cronbach's Alpha test, multivariate analysis and Pearson's product movement correlation were used to analyze the data.

***Results*:** Significant increase in the mean nasalance value and NR was seen in children with RCLP than the control group, whereas ND was contrary. ND was highly correlated with perceived nasality than N. The NR of sentences shows high negative correlation.

***Conclusions*:** The measures based on range of nasalance can be adapted to the routine clinical examinations for better correlation with perceived nasality.

***Key-words*:** Nasalance distance, Nasalance ratio, Hypernasality.

Introduction

The speech is a product of coordinated function of the respiratory, phonatory and resonatory system. Any disruption in the coordination of any of these systems can result in disruption of speech. Cleft lip and palate (CLP) is a congenital condition, affecting the anatomical and physiological mechanism of the lip and palate characterised by incomplete closure of lip, hard and soft palate. The structural deformities of oral cavity and nasal cavity can result in hypernasality and misarticulation, dental problems, frequent flu leading to ear infections, and poor self image. Rehabilitation of these individuals requires multidisciplinary team consisting of plastic surgeon, orthodontist, prosthodontist, audiologist, ENT specialist, psychologist, and speech language pathologist. The speech language pathologist mainly deals with the assessment and management of communication disorders of these children.

The speech of individuals with cleft lip and palate is characterized by resonance disorder and unintelligible speech. The inappropriate balance between oral and nasal acoustic energy is perceived in the form of hypernasality, nasal emissions, and cul-de-sac resonance.[1] Hypernasality is defined as "unacceptable voice quality manifested due to inappropriate acoustic coupling of the nasal airway to the vocal tract." Whereas nasal air emission is abnormal escape of air through the nasal port. These characteristic features of "hyper nasality" and "nasal air emission" have detrimental effects on the speech and thereby affect the speech intelligibility and acceptability as perceived by a listener. In some cases even after surgical reconstruction of the soft and the hard palate and consequent logopaedic treatment, hypernasality remains. In order to make decisions about the need for modification of oral structures, planning and execution of therapeutic procedures an in-depth assessment of speech production is essential. The perceptual assessment of nasality constitutes an important aspect of a comprehensive assessment of the speech of individuals with repaired CLP.[2, 3]

The perceptual assessment is the gold standard for assessment of speech disorders related to cleft palate and velopharyngeal dysfunction,[4] but there are confounding problems with this approach related to type of speech sample and reliability of scales used.[5,6,7] To maintain similar evaluation procedures across the centers standardized perceptual evaluation protocol for reporting speech outcomes in individuals with CLP was developed.[8] This protocol used perceptual parameters that characterize cleft palate speech production behaviour regardless of the language spoken. However, the phonetic structure of the language can have differential effect on the perception of nasality in speech production. This has evidenced again the importance of objective measures of speech in relation to the perceived nasality. Due to variations in the interrater reliability, it is useful to augment the subjective assessment by an objective analysis of nasality.

An instrumental measure associated with the perception of nasal resonance is nasalance. This measure is derived by calculating the proportion of the nasal energy in speech from separate measurements of nasal and oral sound pressure level.[9,10] The extensively used instrument for computerized measurement of nasalance is the Nasometer 6200 (Kay Elemetrics, Lincoln Park, NJ). It measures oral and nasal acoustic sound signals through calculating a score, which represents the ratio of the energy in two signals.[11] Nasometry measures are useful for supplementing the speech and language therapist's perception of hypernasal resonance in individuals with VPD.[12, 13] Results of previous studies indicated that factors such as language, dialect and the speech stimuli influence the scores obtained from the Nasometer.[14]

Several studies have reported a good relationship between perceptual ratings of hypernasality and nasalance scores, with correlation coefficients ranging from 0.70[13] to 0.82.[12] Sweeney and Sell found correlation coefficient ranging from 0.69 to 0.74 between perceptual and acoustic assessments of nasality with sensitivity ranging from 0.83 to 0.88 and specificity ranged from 0.78 to 0.95, while its overall efficiency was between 0.82 and 0.92.[15] Other studies have reported weaker relationships, with correlation coefficients ranging from 0.49[16] to 0.66.[17] Watterson[13] reported a correlation coefficient of 0.32 between perceptual ratings and nasalance scores on the Mouse Passage, while Keuning[18] reported a mean correlation coefficient of 0.57 between perceptual ratings of hypernasality and nasalance scores for a speech sample containing the normal distribution of phonemes in the Dutch language. The equivocal results of the above mentioned studies can be due to the overlap of mean nasalance value between normals and severe hypernasal subjects.

Bressmann reported range of mean nasalance values are 19% to 35% for perceptually normal individuals and 23% to 64% for individuals with severe hypernasality.[19] The variability in nasalance values of normals was attributed to the individual variations as well as dialectal aspects of speech. Bressmann[20] states that perceived nasality may not be represented always interms of mean nasalance values because hypernasality is not attributed solely to excessive hypernasality but to inappropriate oronasal sound balance. Hence he conducted a study to measure nasalance distance and ratio derived from the range of nasalance values obtained from *Nasal View*. They assumed that individual variability in nasalance can be better analyzed by measuring the individual variation in nasal resonance. The results reported sensitivity and specificity of derived measures ranged from 64.4% to 89.6% and from 91.2% to 94.1% respectively. The study concluded that two new measurements are valuable in routine clinical examinations. The study did not correlate the derived measures over mean nasalance values with the perceived nasality. Hence, the aim of the present study is to investigate the correlation of derived nasalance scores (Nasalance distance and ratio) and mean nasalance measures with the perceived nasality.

Objectives of the study

- To classify the children with RCLP based on perceived nasality.
- To measure and compare the mean and derived nasalance values (ND & NR) of vowels (/a/ & /i/) and oral sentences in children with RCLP and control group.
- To correlate mean and derived nasalance values (ND & NR) with perception of hypernasality in children with CLP and control group.

Methods

The present study considered fifteen children (6 male & 9 female) with RCLP ranging from six to eleven years. Children with unrepaired cleft and submucous cleft or any other associated issues were not considered for the study. The control group consisted of fifteen age and gender matched typically developing children. All the children included in the study had passed hearing screening, exhibited normal cognitive abilities without any neuromotor dysfunction. The Informed consent/assent was obtained from all the care takers/parents of the participants.

For perceptual evaluation of nasality, child's spontaneous speech sample was video recorded in a sound-treated room using a *Sony handycam with 60 optical zoom, bearing Model no. DCR-SR88.* The recording was done by placing the handy cam at a distance of 2 feet from the child. The speech sample consisted of 5 min spontaneous speech on self introduction, school, leisure activities, picture description and reading/repeating of the standard oral sentences in Kannada language. Standardized perceptual rating scale was considered for perceptual evaluation of hypernasality in the current study.[8] This rating scale was used to rate the severity of nasality perceived by three experienced judges (qualified speech language pathologist). Scale is defined as 0 = within normal limits (WNL), 1 = mild, 2 = moderate, 3 = severe. Three reference samples were used prior to the actual perception task to provide familiarity to the judges. These reference samples represented examples of scale points 0, 1, 2, 3 that ranged from normal nasal resonance at 0 to severe hypernasal at 3. The reference samples were selected from the 10 samples based on the 3 experienced listeners' agreement before the perceptual experiment. Written instructions were provided and reviewed orally at the beginning of the task.

The nasalance measures were obtained using Nasometer (Model 6400 II, Kay Pentax, and New Jersey) in a quiet environment in the speech lab. Nasometer II was calibrated each day prior to the data collection and headgear was adjusted according to the instructions provided by the manufacturer. Each child was instructed and demonstrated to phonate /a/, /i/ thrice and to read/repeat the standardized five oral and nasal sentences of six to ten syllable length in Kannada. The child was instructed to phonate and read/repeat at comfortable vocal pitch and loudness level. The standardized Kannada oral sentences (Jayakumar & Pushpavathi, 2005) were selected, where the oral sentences loaded with 90 % oral pressure consonants and nasal sentences with 85% of nasal consonants along with the vowels. Each stimulus was recorded and saved separately for further analysis. An interval of 2-3 minutes was given between two stimuli. The subject was asked to produce /a/ and the first trail was considered as practice trail, to make the child comfortable with the procedure. The child was asked to produce the speech sample separately with an interval of 2-3 minutes. Once the child produces, the speech sample was recorded and saved for further analysis. The cursors on the screen were dragged to select from onset to the offset of the stimulus for analysis. As the vowels were produced thrice, the average of the mean nasalance of two trails was calculated. Sentences were recorded only once, as the variability was reported to be more in case of production of phonemes and the reliability of nasalance value was more if the length of the stimulus is around six syllables[21] and mean nasalance value was noted.

After obtaining the nasalance values for the five oral and five nasal sentences separately, the mean of the nasalance values for both sets of sentences were considered. The two measures of ND and NR were derived from these mean values using the following formulas: ND (sentences) = N of nasal- N of oral sentences and NR (sentences) = N of oral/ N of nasal sentences. For vowels the Nasometer provides the mean, maximum and minimum values after analyzing the stimulus, from those values ND and NR for vowels were calculated using the following formulas: maximum - minimum = ND; maximum / minimum = NR.

Statistical Analysis

The mean and standard deviation (SD) were calculated and multivariate analysis was performed using SPSS software to obtain the significance level of the variables in differentiating the groups. Cronbach's Alpha test was administered to measure inter judge reliability of perceived hypernasality between three judges on four point rating scale. Pearson product movement correlation was used to correlate between perceived hypernasality with the derived and mean nasalance measures.

Results

a) *Perceptual evaluation of hypernasality across the stimuli and groups*

The study included thirty children, out of these; fifteen children with cleft lip and palate were exhibiting varying degrees of nasality in their speech. All these children were grouped on the basis of severity of nasality exhibited in the speech. The speech of these children was subjected to perceptual evaluation of hypernasality by three experienced judges. They were asked to rate for vowels and sentences separately. Perceptual evaluation of vowels revealed, three children with RCLP perceived to be normal, ten mild and two with moderate hypernasality. When grouping the children based on nasality exhibited in sentences majority (nine) were exhibiting moderate hypernasality, three were mild hypernasal and two were severely hypernasal. The average of the ratings was considered for further correlation with the objective measures of nasalance. The interjudge reliability of perceived nasality by three judges indicated high Cronbach's Alpha coefficient for vowel /a/ (.772) followed by /i/ (.647) and oral sentences (.612).

b) *The mean nasalance values were compared across the stimuli and group.*

The increased mean nasalance was found in children with RCLP than the control group for all the stimuli. Across the stimuli, mean nasalance was more for nasal sentences, followed by vowel /i/, oral sentence, and vowel /a/ for both the groups. The differences in nasalance values between the groups were found to be more for vowel /i/ followed by oral sentences, vowel /a/, and nasal sentences as shown in Figure 1.

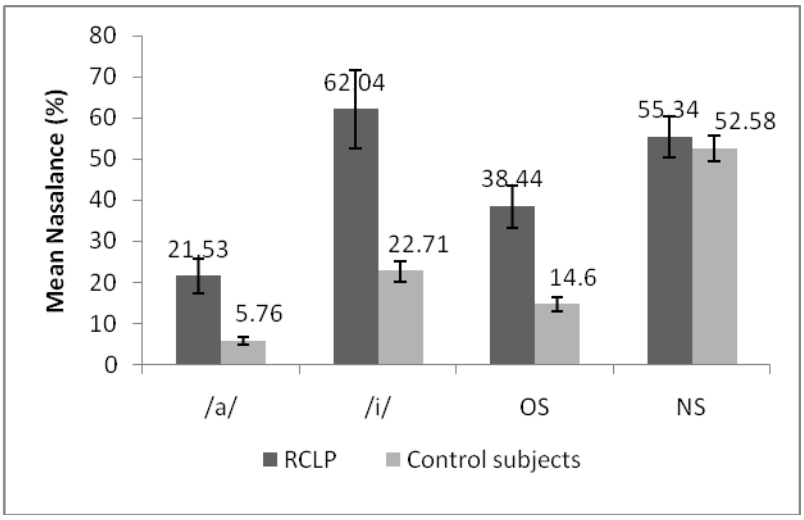

Figure 1: Mean and SD of nasalance values in children with RCLP and controls.

*RCLP- Repaired cleft lip and palate, OS-oral sentences, NS-nasal sentences.

c) *Mean and SD of ND and NR across the stimuli and groups*

From the range of the nasalance, nasalance distance (ND) was measured by calculating the difference between the maximum nasalance to minimum nasalance. ND was more for control group than RCLP across the stimuli. The higher nasalance distance was seen in sentences followed by vowel /i/ and /a/ for both the groups. However, ND of sentences and vowel /i/ were similar in both the groups exhibiting high ND than vowel /a/. The difference between the groups was more for sentences, followed by vowel /i/ and /a/ as shown in Figure 2.

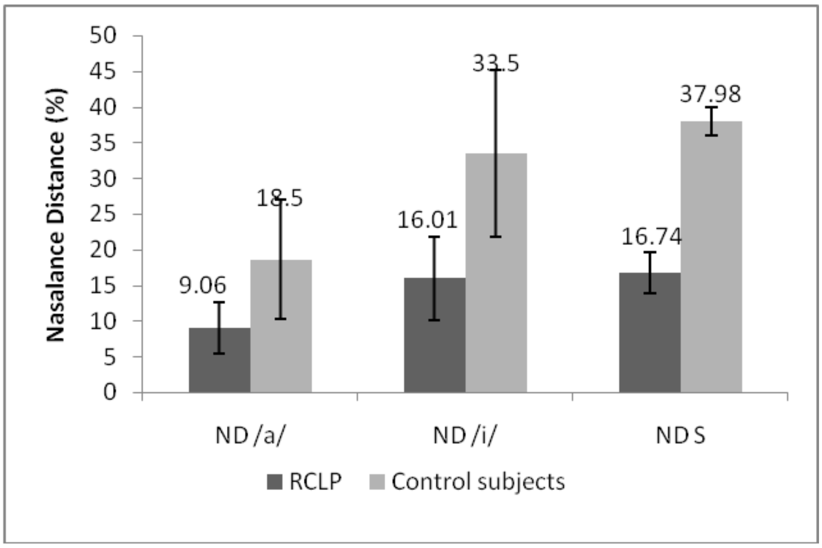

Figure 2: Mean and SD of nasalance distance in children with RCLP and controls

* RCLP- Repaired cleft lip and palate, ND-Nasalance Distance, S-sentences

From the nasalance range, nasalance ratio (NR) was measured as it is the ratio of minimum nasalance to maximum nasalance. The NR was high across the entire stimulus for group with RCLP than control group. Within the stimuli, increased NR was observed for /i/ followed by sentences and vowels in group with RCLP. Control group also exhibited high NR for /i/ and no difference was reported between /a/ and sentences. However, the differences in NR were predominant only between the groups but not across the stimuli as shown in Figure 3. The difference in NR across the groups was more for sentences followed by vowel /a/ and /i/.

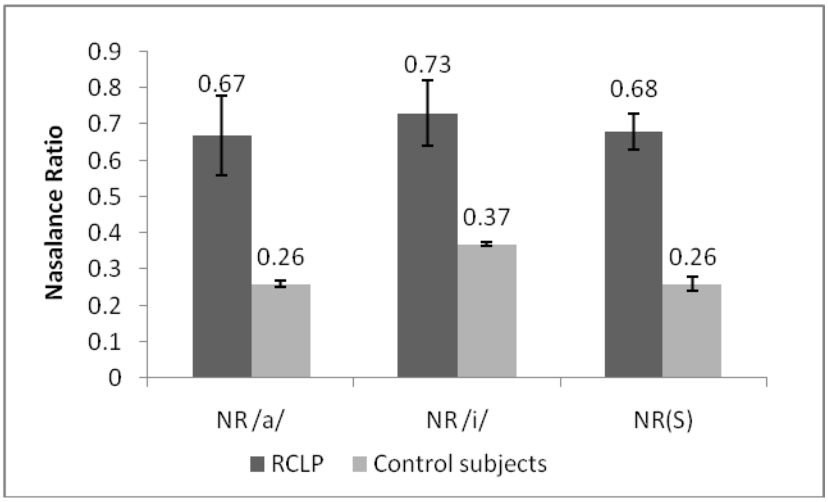

Figure 3: Mean and SD of nasalance ratio in children with RCLP and controls

* RCLP- Repaired cleft lip and palate, NR-Nasalance Ratio, S-sentences

d) *Significant parameters differentiating the groups in terms of nasalance measures*

The mean nasalance, nasalance distance and nasalance ratio measured for entire stimuli were subjected to multivariate analysis to find the significant parameters varying across the groups. The group with RCLP and controls were significantly differentiated by mean nasalance, ND and NR for all the stimuli except ND of /a/ and mean nasalance of nasal sentences. However, there found to be differences in scores of nasalance distance of /a/ between the groups, the difference was not statistically significant. Whereas the mean of nasalance scores were almost similar between the groups as mentioned earlier in table 1.

Table 1

Nasalance measures significantly discriminating children with RCLP and control group.

Parameters	F-value	Significance
M_N /a/	42.585	.000
M_ND /a/	2.813	.108
M_NR /a/	28.620	.000
M_N /i/	51.613	.000
M_ND /i/	4.629	.043
M_NR /i/	19.032	.000
MO	60.332	.000
MN	.622	.439
MNDs	105.998	.000
MNRs	9.698	.005

*M_N= Mean of mean nasalance, M_ND=Mean of nasalance distance, M_NR=Mean of nasalance ratio, MO= Mean of mean nasalance of oral sentences, MN= Mean of mean nasalance of nasal sentences, MNDs= Mean of nasalance distance of sentences, MNRs= Mean of nasalance ration of sentences.

e) Correlation of mean nasalance, ND and NR with perceived nasality.

The mean nasalance and the derived nasalance measures (ND & NR) were correlated with the perceived nasality of vowels and sentences. Pearson’s product movement correlation revealed positive correlation of nasalance distance, mean nasalance and negative correlation of NR with the perceived nasality for the entire stimuli as depicted in table 2. The correlation coefficient of ND was more than mean nasalance for vowels as well as sentences. However, correlation coefficient of ND for sentences was significantly more than the correlation coefficient of mean nasalance for sentences, and significant negative correlation was also exhibited by NR for sentence. For vowels the negative correlation was not statistically significant.

Table 2

Perceptual evaluation scores correlated with the Nasalance mean, ND and NR.

<table>
<tr><th></th><th colspan="2">Mean Nasalance</th><th>Nasal Distance</th><th>Nasal Ratio</th></tr>
<tr><td>Corr.Coefficient(r) for /a/ (P-value)</td><td colspan="2">.561 (.052)</td><td>.684 (.032)</td><td>-.142 (.061)</td></tr>
<tr><td>Corr.Coefficient(r) for /i/ (P-value)</td><td colspan="2">.512 (.049)</td><td>.591 (.057)</td><td>-.143 (.067)</td></tr>
<tr><td rowspan="2">Corr.Coefficient(r) for sentences (P-value)</td><td>Oral</td><td>Nasal</td><td rowspan="2">.794 (.031)</td><td rowspan="2">-.593 (.043)</td></tr>
<tr><td>.438 (.039)</td><td>.482 (.041)</td></tr>
</table>

Discussion

The present study was aimed to investigate the correlation of ND and NR along with mean nasalance measures with the perceived hypernasality in children with RCLP. Nasalance is an objective measure of perceived nasality and compared with the perceived nasality. The four point rating scale ranging from normal to severe hypernasal (0 to 3) was used by three experienced judges to rate the perceived nasality of children with RCLP. The results showed high interjudge reliability for /a/ (0.77) followed by /i/ (0.64) and oral sentences (0.61). The similar results were obtained on reliability ranging from 0.4 to 0.6 indicating fair to good inter-judge reliability by two judges (One experienced speech language pathologist not specializing in cleft palate and another one an inexperienced therapist).[15] Another study reported 0.46 interjudge reliability by the judges after undergoing practice (ten judges, studying graduate in speech language pathology).[22] The differences in interjudge reliability scores (good interjudge reliability in the present study) can be attributed to the variations across the judges, the present study included research scholars working in the area of cleft as judges. The studies have indicated that perceptual ratings can differ with respect to the type of speech samples, phonetic context, and expertise of judges, scale terms used for grading the severity. [23, 13, 24, 25]

The second aim of the present study was to measure the mean nasalance of both the groups. Dalston reported significant differences in mean nasalance values across the individuals with RCLP.[12] The nasalance measures were varying widely withrespect to stimuli and the clinical setups leading to ambiguity in the results while correlating with the perceptual evaluation of nasality.[16, 15] The results of the present study indicated increased mean nasalance scores across the stimuli for children with RCLP than control group. This could be because of inadequate velopharyngeal closure exhibited by children with RCLP. Fletcher[10] suggests that the degree of nasal resonance in speech was controlled by the magnitude of contact between the velum and the pharyngeal was as well as by the size of the VP gap when contact was not achieved.

Among the entire stimuli nasalance was more for vowel /i/ followed by nasal sentence, oral sentence and vowel /a/ in children with RCLP. However, the same pattern was observed across the stimuli in control group indicating high nasalance for high vowel /i/ followed by sentences and low vowel /a/. The results were in accordance with the study by Lewis[26] on effect of high to low vowel and sentences on perception of nasalance. They reported high nasalance scores for vowel /i/ followed by sentence (consisting mixed vowels) and vowel /a/. The result can be attributed to the articulatory pattern while producing /i/ contributing for increased nasal energy by reducing area in the oral cavity. During the production of /i/ tongue is placed high and front in the oral cavity leaving less space for resonating the sound in the oral cavity, leading the air to travel through the nasal cavity. During the production of vowel /a/ the tongue is placed low and back of the oral cavity providing relatively more space in the oral cavity for resonating the sound. This results in more oral resonance reducing the perception of nasality during the production. The sentences are combination of various words consisting low to high vowels, hence the perceived nasalance will be more than vowel /a/ and less than vowel /i/. The results supports the previous findings[26] indicating high vowels are characterized by lower oral intensity and higher nasal intensity than low vowels. The nasalance is nothing but ratio of nasal energy to the sum of nasal and oral or total energy.

The study also aimed to measure derived nasal measures (ND & NR) from the range of nasalance. The study indicated increased ND for sentences and vowel /i/ than /a/ for both the groups. The ND varies withrespect to the range of nasalance exhibited. There is a close correspondence between the degree of nasalance and the range of velopharyngeal (VP) closure. VP closure requires the movements of the pharyngeal wall along with the posterior backward movement of the velum. Fletcher[27] reported that greater forward positioning of the pharyngeal wall and greater retraction of the palate during production of the /i/ vowel was in general identified with increased nasalance. The production of /a/ requires relatively less articulatory movements than /i/ leading to reduced variability in the perceived nasality. Hence the ND of /a/ was less than /i/ across the groups. The ND of sentences was more due to various phonetic contexts leading to changes in tongue position and configuration of the transmission channels exert a major influence on the proportion of the phonic stream that transcourses the nasal cavities when the VP port is open or relatively open.

The nasalance ratio was computed for the same measures, the relationship found to be inverted i.e., children with RCLP exhibited high NR than controls. The differences across the stimulus were minimal. The results were inaccordance with the study[20] who reported an inverted relationship between NR and ND. They hypothesized that increase in NR is due to reduced distance between the oral and nasal sentences exhibiting high nasalance values for oral sentences, the corresponding quotient of oral sentence/nasal sentences was comparatively higher than the controls. Whereas the nasalance scores for oral sentences were less in controls increasing the denominator (nasalance of nasal sentences) reduces the value of NR. The variability in the mean nasalance and derived nasalance measures (ND & NR) were more in children with RCLP than control group, as reflected in terms of standard deviation across the entire stimulus. The variability present could therefore be interpreted as likely arising primarily from the speaker to speaker differences in velopharyngeal competency which overshadowed the specific influence of phonetic content.

Another aim of the study is to compare the mean and derived nasalance measures (ND & NR) across the groups. The nasalance values of vowels and oral sentences were significantly different between the groups. The RCLP and control groups became increasingly similar as the proportion of nasal consonants increased in the stimuli. This was indicated by reduced difference in mean nasalance values of nasal sentences between the groups. Thus, in speaking the sentences with a high density of nasal consonants, many normal subjects apparently simply overlaid their articulatory gestures onto a generally nasalized sound stream.

The third aim of the present study is to correlate the objective measures of nasalance with the perceived nasality. On correlating the mean and derived nasalance values with the perceived nasality, the correlation coefficient (r) of mean nasalance was high for vowel /a/ (0.56) followed by /i/ (0.51), oral sentences (0.43), and nasal sentences (0.48). Similar (r) value 0.43 was reported by Keuning et al., and Watterson et al. (1996) who reported a (r) of 0.32. The obtained (r) values for the mean nasalance scores are in comparable with the above mentioned studies. However, the (r) values obtained for mean nasalance values in the present study are considerably less than the overall correlation coefficient 0.73 for speech samples with normal distribution of phonemes and speech sample free of nasal consonants.[28] The variations across the studies can be attributed to the methodological differences between the studies such as stimulus variations with respect to language, subjects included in the study, and perceptual judgements of judges. Whereas, the (r) of ND for oral sentences in the present study is (0.79) and comparable with (r) of mean nasalance indicated in study by Dalston.[23] The nasalance distance exhibited high (r) values even for vowels (/a/ - 0.68 & /i/ 0.59) along with sentences than the mean nasalance scores. However, NR exhibited negative correlation coefficient with the perceived nasality for entire stimuli. The negative correlation for sentence (-0.59) stimuli was high and statistically significant than vowels (-0.14). The increased (r) values of ND and NR for sentences than vowels can be attributed to the increase in better perception of hypernasality and judgment abilities as the length of the stimulus increases. These results are similar to findings of Watterson[21] on comparison of nasalance scores with the length of the stimuli, they found that longer the stimulus, the stronger the correlation with the perceived nasality.

Conclusion

The present study is aimed to investigate the correlation of derived nasalance scores (Nasalance distance and ratio) and mean nasalance measures with the perceived nasality. Results revealed significantly high correlation coefficient of nasalance distance (ND) than the mean nasalance scores with the perceived nasality. The nasalance ratio (NR) revealed significant negative correlation with the perceptual measures of nasality. Hence the derived nasalance measures (ND & NR) can be used as diagnostic measures in the clinical scenario. However, the study need to be performed in a large sample size to generalize the results.

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References

1. Bressmann T, Sader R, Whitehill TL, Awan SN, Zeilhofer H, Horch H. Nasalance distance and ratio: Two new measures. Cleft Palate Craniofac J. 2000;37:248-256.
2. McWilliams BJ, Morris HL, Shelton RL. Cleft Palate Speech. 2nd ed. Philadelphia: BC Decker. 1990.
3. Sell D, Harding A, Grunwell P. GOS.SP.ASS'98: an assessment for speech disorders associated with cleft palate and/or velopharyngeal dysfunction (revised). Int J Lang Comm Disord. 1999;34:17-33.
4. Kuehn D, Moller KT. Speech and language issues in the cleft palate population: The state of the art. Cleft Palate Craniofac J. 2000;37:348-348.
5. Kent RD. Hearing and believing: some limits to the auditory – perceptual assessment of speech and voice disorders. Am J Speech-Lang Pat. 1996;5:7-23.
6. Sell D, Harding A, Grunwell P. GOS.SP.ASS.'98: An assessment for speech disorders associated with cleft palate and/or velopharyngeal dysfunction (revised). Int J Lang Comm Dis. 1999;34,17-33.
7. John A, Sell D, Sweeney T, Harding-Bell A, Williams A. The cleft audit protocol for speech – augmented: a validated and reliable measure for auditing cleft speech. Cleft Palate Craniofac J. 2006;32:145-8.
8. Henningsson G, Kuehn DP, Sell D, Sweeny T, Trost-Cardamone JE, Whitehill TL. Universal parameters for reporting speech outcomes in individuals with cleft palate. Cleft Palate Craniofac J. 2007;45:1-17.
9. Fletcher SG. Theory and instrumentation for quantitative measurement of nasality. Cleft Palate Journal. 1970;7:601-609.

10. Fletcher SG. “Nasalence” versus listener judgements of nasality. Cleft Palate Journal. 1976;13:31-44.

11. Fletcher SG, Adams LE, McCutcheon MJ. Cleft palate speech assessment through oral nasal acoustic measures. In Communication Disorders Related to Cleft Lip and Palate, K. R. Bxoch, Boston, MA; Little-Brown. 1989;246-257.

12. Daltston RM, Warren DW, Dalston ET. Use of nasometry as a diagnostic tool for identifying patients with velopharyngeal impairment. Cleft Palate Craniofac J. 1991;28:184-9.

13. Watterson T, Hinton J, McFarlane S. Novel stimuli for obtaining nasalance measures from young children. Cleft Palate Craniofac J. 1996;33:67–73.

14. Seaver EJ, Dalston RM, Leeper HA, Adams LE. A study of Nasometric values for normal nasal resonance. J Speech Hear Res. 1991;34:715-21.

15. Sweeney T, Sell D. Relationship between perceptual ratings of nasality and nasometry in children/adolescents with cleft palate and / or velopharyngeal dysfunction. Int J Lang Comm Dis. 2008;43:265-282.

16. Watterson T, McFarlane S, Wright DS. The relationship between nasalance and nasality in children with cleft palate. J Commun Disord. 1993;26:13-28.

17. Paynter ET, Watterson TL, Boose WT. The relationship between nasalance and listener judgements. Paper presented at the American Cleft Palate – Craniofacial Association Convention, Hilton Head, DC, USA, 1991.

18. Keuning KHDM, Wieneke GH, Van Wijngaarden HA, Dejonckere PH. The correlation between nasalance and a differentiated perceptual rating of speech in Dutch patients with velopharyngeal insufficiency. Cleft Palate Craniofac J. 2002;39:277-83.

19. Bressmann T, Sader R, Awan SN, Horch HH. Objektive Hypernasalitatsdiagnostik bei Patienten mit Lippen-Kuefer-Gaumenspalte. In Beeintrachtigungen des Mediums Sprache : Aktuelle Untersuchungen in der Neurolinguistik, M. Hielscher, P. Clahrenbach, S. Elsner, W. Huber, and B. Simons, Tubingen, Stauffenburg Verlag, 1998;83-93.

20. Bressmann T, Sader R, Whitehill TL, Awan SN, Zeilhofer H, Horch H. Nasalance distance and ratio: Two new measures. Cleft Palate Craniofac J. 2000;37:248-56.

21. Watterson, Lewis, Foley-Homan. Effect of stimulus length on nasalance scores. Cleft Palate Craniofac J. 1999;36:243-7

22. Lee SYA, Whitehill TL, Ciocca V. Effect of listener training on perceptual judgment of hypernasality. Clin Linguist Phonet. 2009;23:319-334.

23. Carney PJ, Sherman D. Severity of nasality in three selected speech tasks. J Speech Hear Res. 1971;14:396-401.

24. Schmelzeisen R, Hausamen JE, Loebell E, Hacki T. Long term results following velopharyngoplasty with a cranially based pharyngeal flap. Plast Reconstr Surg. 1992;90:774-778.

25. Kreiman J, Gerratt BR, Kempster, GB, Erman A, Berke GS. Perceptual evaluation of voice quality: review, tutorial, and a framework for future research. J Speech Hear Res. 1993;36:21-40.

26. Lewis KE, Watterson T, Wuint T. The effect of vowels on nasalance scores. Cleft Palate Craniofac J. 2000;37:584-589.

27. Fletcher S. (1978). Diagnosing Speech Disorders From Cleft Palate. New York: Grune & Stratton; 1978.

28. Dalston, R, Neiman G, Gonzalez-Landa G. Nasometric sensitivity and specificity: a cross dialect and cross culture study. Cleft Palate Craniofac J. 1993;30:285-291.