NASOMETER SCORES FOR BENGALI-SPEAKING ADULTS USING NASOMETER II 6500

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JUNE, 2026

CERTIFICATE

This is to certify that this dissertation entitled **"Nasometer scores for Bengali-speaking adults using Nasometer II 6500"** is a bonafide work submitted as part of fulfilment of the degree of Master of Science (Speech Language Pathology) of the student with Registration Number P01II24S123040. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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Registration Number

P01II24S123040

Mysuru
June, 2026

Dedicated to

My Family

And

My AYJ Girls

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LIST OF FREQUENTLY USED ABBREVIATIONS

CLP: Cleft Lip and Palate

RCLP: Repaired Cleft Lip and Palate

SLP: Speech-language Pathologist

C: Consonant

V: Vowel

M: Male

F: Female

OW: Oral Words

NW: Nasal Words

OS: Oral Sentences

NS: Nasal Sentences

SD: Standard Deviation

IPA: International Phonetic Alphabet

IRB: Institute Review Board

ABSTRACT

Background: Nasalance is defined as the ratio of nasal to oral-plus-nasal acoustic energy that is obtained from two microphones

Aims and Objectives: The objectives of the study included developing a set of oral and nasal stimuli (words and sentences) in Bengali language, establishing normative nasalance values in Bengali language for Bengali-speaking adults of 20-40 years of age using the Nasometer II 6500 model, and estimating effect of age and gender on nasalance values

Methods: The study was conducted in three phases. Phase 1 involved development of oral and nasal stimuli (words and sentences), in Bengali language; Phase 2, involved content validation of the developed stimuli and selection of the final stimuli; Phase 3, involved data collection from 60 healthy Bengali-speaking adults aged between 20-40 years with equal age and gender distribution using Nasometer II 6500 instrument acrosss three speech tasks. The data was analysed using SPSS software 26.0 version.

Results: Female participants generally demonstrated higher mean nasalance values across all stimuli. There was no significant effect of age across all stimuli. Larger gender differences were observed for the high vowel /i/ and nasal syllables, wheras gender differences were lesser for low vowel /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/. In words and sentences, nasal words and sentences showed higher gender differences than oral words and sentences.

Conclusions: The present study helped to develop words and sentences for the assessment of nasalance in Bengali language as well as in establishing normative nasalance values for Bengali-speaking adults using Nasometer II 6500.

CHAPTER I

INTRODUCTION

The process of speech production is highly complex, requiring the coordinated efforts of several physiological systems, often categorized into four functional units: respiratory, phonatory, articulatory, and resonatory. The resonatory system mainly consists of the nasal cavity, the oral cavity and the pharynx (Dang, 2018).

The velopharyngeal valving mechanism selectively couples or decouples the nasal and oral chambers to regulate speech resonance. Therefore, depending on their resonance, sounds can be classified as nasal or oral. During the production of oral sounds, the velopharyngeal port closes, causing oral resonance. In contrast, nasal sounds are generated when the velopharyngeal port opens, resulting in nasal resonance.

Assessment of nasal resonance or nasality includes both subjective or perceptual and objective methods. Perceptual analysis is considered as the gold standard in analysis of speech in subjects with cleft lip and palate (Kuehn & Moller, 2000). Perceptual methods of assessment are of fundamental importance in the assessment of Velopharyngeal Inadequacy because they are inexpensive and easy to use. Some of the most commonly used methods for perceptual analysis include sound prolongation tasks, syllable repetition tasks, counting tasks, sentence repetition tasks, connected speech, formal articulation tests like IOWA pressure articulation test, Deep test of articulation for cleft lip and cleft, Bzoch Error Pattern for diagnostic articulation test(1979), P-B articulation screening test (Van Demark & Swickand, 1980); as well as formal perceptual assessment scales, including the Pittsburgh Weighted Speech Scale (PWSS) (McWilliams and Philips 1979), the Great Ormand Street Speech Assessment (GOS.SP.ASS; Sell, Harding, Grunwell., 1994, 1998), the Cleft Audit Protocol for Speech (CAPS) (Harding, Harland, & Razzell, 1997), Cleft Audit Protocol for Speech-Augmented

(CAPS-A) (John, A., Sell, D., Sweeney, T., Harding-Bell, A., M'Orth., A.W., 2006). Objective assessment includes direct imaging techniques like videofluoroscopy and nasopharyngoscopy, that involve the direct visualisation of the velopharyngeal structures, as well as indirect measures like acoustic measures like nasometry and aerodynamic measures (Kummer, 2020)

Nasalance is an acoustic measure that has gained widespread acceptance as a diagnostic correlate of perceived oral nasal resonance balance (Dalston et al., 1991). Nasalance is defined as the ratio of nasal to oral-plus-nasal acoustic energy that is obtained from two microphones (Ruth et al., 2019). The nasometer is an acoustic device that uses two microphones to detect nasal sound energy in relation to oral sound energy produced during speech. Fletcher (1970, 1976) originally developed the concept for the nasometer and called early models Tonar (The Oral-Nasal Acoustic Ratio). The nasometer is commercially available from Kay Pentax Corporation (Lincoln Park, New Jersey). It consists of two microphones separated by a metal plate that provides 25 dB sound separation. Newer versions of the nasometer provide a handheld option that eliminates the need for a head harness required in earlier models. The outputs of each microphone are band-pass filtered at 350 to 650 Hz, digitized to a computer, and the per cent nasalance is displayed during running speech and the prolongation of vowels. Percent nasalance is calculated as nasal intensity divided by oral plus nasal intensity multiplied by 100.

Bengali is an Indo-Aryan language belonging to the Indo-Iranian branch of the Indo-European language family. It is native to the Bengal region of South Asia, including Bangladesh, India's West Bengal and Tripura) of South Asia. It is the official language of the Indian states of West Bengal, Tripura, and the Barak Valley of Assam, and the second official language of the Indian state of Jharkhand since September 2011. It is one of the twenty-three officially recognized languages in India.

Unlike English, Bengali vowels are distinguished by their lax pronunciation, giving the language's sound system a distinctive timbre. The three commonly accepted lengths of the vowels: short, half-long, and long, affect their acoustic quality. All seven vowels can be nasalized, which results in minute phonetic differences that affect their acoustic profile. The language's vowels are positioned in the vowel space close to the cardinal vowels, with /i/ tending to be slightly retracted and /u/ slightly advanced, affecting their acoustic tonal qualities. (Chatterji, 2009)

According to an online resource material developed of the Central Institute of Indian Languages (CIIL), Mysore (n.d.), Bengali monosyllabic words present a total of thirteen canonical forms , namely CV, CVC, V, VC, VV, CVV, CCV, CCVC, CVVC, CCVV, CCCV, CCCVC, and VVC forms, where V stands for Vowel, and C stands for Consonant. In polysyllabic words in addition to the above canonical forms, there are three more patterns, viz. CCVVCV, CVCCCCVCV, and CCCVVC, are also available.

1.1 NEED OF STUDY

Cleft of the lip and palate (CLP) is one of the most common congenital anomalies in the world, with an incidence of 1 in 1000 live births (Bhattacharya, 2021). Out of an estimated 24.5 million births in India annually, 27,000 to 33,000 babies are born with cleft lip, palate, or both (Mossey et al., 2009). In a retrospective study by Saha et al. (2022) to observe the clinical and epidemiological profile of non-syndromic cleft lip and/or palate patients admitted to a cleft care center in West Bengal from May 2021 to April 2022, out of a total of 276 non-syndromic cleft patients, 164 were male and 112 were female patients. The mean age of patients reporting to this hospital was 13-18 months. Cleft lip with palate patients (62%) predominated than any other type and was primarily seen in male patients (69.59%); isolated cleft lip (22%) cases were more in females (56.25%), whereas isolated cleft palate (16%) cases were seen more in

males (62.79%); unilateral (77%) and left-sided cleft (67%) were found predominantly than bilateral cases (23%) and seen mostly in females. In contrast, bilateral cleft cases were more common in males.

Structural differences like vocal tract length, nasal cavity volume, and velopharyngeal configuration significantly affect acoustic resonance. For example, compared to adults, children tend to have higher nasalance score variability and higher resonance frequencies (Seaver & Dalston, 1991). Likewise, research has consistently demonstrated that males and females differ, with males generally exhibiting lower nasalance values because of their larger resonating cavities (Van Doorn & Purcell, 1998). For this reason, normative databases must also be stratified according to age and gender.

Traditionally, nasometry has been done using standardised passages like Rainbow passage and Zoo passage to assess nasalance values. The Zoo Passage is 83 syllables in length and is sufficiently long to obtain valid and stable measures of nasalance (Dalston et al., 1991; Dalston & Seaver, 1992). Watterson et al. (1999) conducted a study on the effect of stimulus length on nasalance values. A standard 44-syllable passage was compared to a 17-syllable passage, a six-syllable sentence, and a two-syllable word. All stimuli were devoid of nasal consonants and were composed only of low pressure consonants and vowels.The subjects were twenty children at risk for velopharyngeal dysfunction and five children without history of communication disorder. The results showed that comparable measures of nasalance can be obtained using stimuli as short as a six-syllable sentence. Both the 17-syllable and the 6-syllable stimulus achieved high criterion validity, indicating that stimuli of that length could be substituted for the longer 44-syllable passage. Thus the authors concluded that valid assessment of nasalance can be achieved with speech samples as short as six syllables.

The phonemic systems of various languages have distinct acoustic patterns in speech production. The effect of language on nasalance has been studied by many researchers in the 21st century and found that native language influences the nasalance of normal speech (V. T. Nguyen et al., 2019). Normative nasalance values have been established in multiple languages in both non-Indian languages, including English (Seaver et al., 1991), Danish (Van de Weijer & Slis, 1991), Japanese (Tachimura et al., 2000), Flemish (Van Lierde et al., 2001), and Arabic (Natour et al., 2020), as well as Indian languages such as Marathi (Nandurkar, 2002), Tamil (Sunitha et al., 2005), Hindi (Meshram & Pushpavathi, 2012), and Kannada (Jazeera & Manasa, 2025).

Bengali is the official language of the Indian states of West Bengal, Tripura, and the Barak Valley of Assam, and is the second official language of the Indian state of Jharkhand since September 2011. According to the Ethnologue reports of 2025, Bengali is the seventh most spoken language globally, with an estimated 272.8 million speakers. Hence, it is essential to have a standardized objective measure like Nasalance that can be used in the objective assessment of patients with various resonance disorders in Bengali language.

1.2 Aims and objectives of the study

The study aims to estimate and establish normative scores of nasalence in Bengali language in native Bengali-speaking adults of 20-40 years of age using the Nasometer II 6500 model. The specific objectives of the study are as follows:

1. To develop and validate a set of oral and nasal stimuli (words and sentences) for the objective assessment of Nasalance in Bengali language.
2. To estimate the normative nasalance values using the Nasometer II 6500 model in adult Bengali speakers.
3. To compare nasalance values across age and gender.

CHAPTER II

REVIEW OF LITERATURE

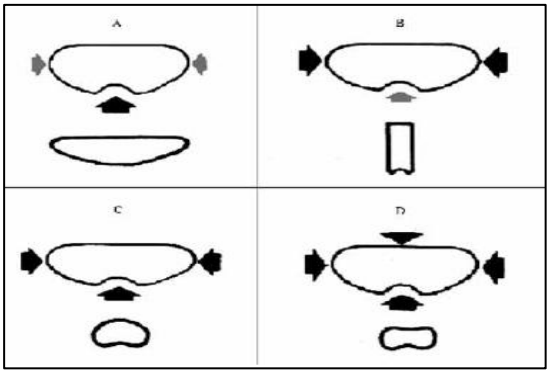
2. 1 Normal Velopharyngeal Mechanism in Adults

The velopharyngeal mechanism is a muscular valve that extends from the posterior margin of the bony hard palate to the posterior pharyngeal wall (Moon & Kuehn, 2004), that is bounded anteriorly by the velum (or soft palate), laterally by the lateral pharyngeal walls, and posteriorly by the posterior pharyngeal wall. The velum extends posteriorly from the horizontal plate of the palatine bone (hard palate) via the palatine aponeurosis. The three-dimensional space posterior to the relaxed velum is known as the "velopharyngeal port." The primary function of the velopharyngeal mechanism is to form a seal between the nasal and oral cavities to produce normal resonance and create a positive pressure during swallowing.

There are four main types of patterns of velopharyngeal closure, including Coronal, Sagittal, Circular, and Circular with Passavant´s ridge (Shadi, 2022) Figure 2.1 provides a representation of the four patterns of velopharyngeal closure.

Figure. 2.1.

Velopharyngeal Closure patterns. A. Coronal pattern; B. Sagittal pattern: ; C. Circular pattern; D. Circular with Passavant's ridge pattern (Desgain, 2006)



A retrospective three-dimensional analysis of velopharyngeal region in 31 healthy patients with dental implants and 29 patients with surgically repaired CLP (RCLP) by Miller et al. (2019) reveals mean airway area in clinically normal group of 201.29 mm^2, with an average airway volume of 5877.0 mm^3, and a minimum axial area of 155.94 mm^2. In the sagittal plane, the average distance between the posterior nasal spine and the posterior pharyngeal wall was found to be 19.36 mm, and the average distance between the velum and the posterior pharyngeal wall was 5.35 mm, wheras in the caudal plane, the average posterior pharyngeal wall length was found to be 20.69 mm in length and the anterior pharyngeal wall (corresponding to the velum) was found to be 27.65 mm in the normal group. These values were found to be relatively shorter in the normal adults group compared to the group with RCLP.

Shadi et al. (2022), in a study of velopharyngeal closure patterns during speech, studied 100 normal subjects of the age range between 15 to 60 years, and found Coronal closure pattern to be the most frequent (75%) among participants followed by circular pattern (25%). Jordan et al. (2017) studied three-dimensional magnetic resonance imaging on thirty-eight participants (18 females and 20 males) between 19 and 32 years of age to correlate velopharyngeal closure patterns with velopharyngeal anatomic structural characteristics. The authors found circular closure patterns occuring more frequently in females, and coronal closure patterns occuring more frequently in males. They also found variations in nasopharyngeal length, velar length, and nasopharyngeal width with sex, with males showing significantly larger values than females. These preliminary findings indicate that the length of the velum and thickness of the adenoids may have the greatest impact on velopharyngeal closure patterns.

2.2 Changes in resonance across adulthood:

Aging is a basic physiological process that affects the structure and function of all parts of the body, including the nasal cavity and velopharynx (Xu et al., 2018). The anatomical and physiological changes occuring in the nasal cavity, velopharynx, and oral cavituy from birth to adolescence has been extensively studied across literature.

A study by Shastri et al. (2021) examined the changes occuring in the nasal dimensions in 240 participants aged between 16-50 years, divided across four groups, Group 1 (16-20 years), Group 2 (21-30 years), Group 3 (31-40 years), and Group 4 (41-50 years), with each group consisting of 30 males and 30 females respectively. The parameters assessed included Nasal Height (NH) in milimetres (mm), Nasal Breadth (NB) (in mm), Nasal Index, calculated in percentage (%), as (Nasal breadth/Nasal height)x100, and the Nasolabial angle (in degrees). The results of the study revealed that nasal height and breadth increases with age, whereas there are non-consistent age-related patterns for nasal index in all groups. Nasolabial angle was found to decrease with age, as nasal height increases more with age, as compared to nasal breadth.

Another study by Xu et al. (2019) studied the changes in nasality occuring in Korean-speaking adults. A total of 180 native adult Korean speakers (90 male, 90 female), aged between 20-70 years were taken for this study, and divided into five age groups, of 20-29 years, 30-39 years, 40-49 years, 50-59 years, and over 60 years each, with equal number of participants across each group. Nasometry, Acoustic rhinometry (AR), and Rhinomanometry were performed for all participants. The results demonstrate that the nasal cavity volume increased significantly with age, while nasal resistance decreased significantly with age. Nasalance values for the nasal passage and oronasal passage were found to decrease with age,

while there were no age-related changes in nasalance values for the oral passage. No gender differences in nasal cavity volume or nasal resistance when compared within each age group, as well as between age groups. The authors hypothesized that velopharyngeal dysfunction with age may play a more critical role in the age-related reduction in nasality, rather than changes in nasal cavity dimensions.

Pereira et al (2024) conducted a systematic review to evaluate the effect of age and gender on Nasalance Across the Lifespan following PRISMA 2020 guidelines, on a total of 50 observational-analytic studies (N=1,884 participants). The results revealed that only 10 studies (20%) met high-quality criteria (low risk of bias), with moderate effect sizes for age differences: adults versus children (d=0.717) and adults versus adolescents (d=0.521) for oral text/passage, and clinically significant gender differences specifically between adolescent males and females with moderate effect size (d=0.545) for oronasal text/passage. The authors conclude that separate normative databases are needed for specific age subgroups across the lifespan and for gender, particularly during adolescence, to improve clinical diagnosis and outcome measurement using the Nasometer.

2. 3 History of Nasometer

The oral and nasal acoustic ratio (TONAR) was the first non-invasive method of determining objectively the nasality, or "Nasalance" of speech (Fletcher, 1970). Although previous studies had examined this aspect of speech analysis (Shelton et al., 1967), Fletcher's comprehensive work has determined the data processing criteria for maximum reliability and developed the concept into a commercial production instrument known as the Nasometer® (Kay Elemetrics Corporation, Pine Brook, NJ, USA).

In 1986, the first Nasometer was developed by Kay Elemetrics in order to measure nasality during speech in an objective, non-invasive manner. It consisted of a specialized headset with microphones positioned to record the acoustic energy from the nasal and oral cavities. The device measured the degree of nasality in speech by calculating a nasalance score and analyzing the ratio of these acoustic signals. The Nasometer 6200 was introduced in 1987, based on the original model. This model featured enhanced sensitivity and improved signal processing capabilities, allowing for more accurate measurement of nasalance values.

In 2002, the Nasometer II Model 6400 was developed, which was the first digital model of the Nasometer. This model had a USB interface, which made it easier to connect to personal computers for data storage and analysis. Following the Nasometer II 6400 model, the Nasometer II, Model 6450 was released in 2009. This model had a compact form and an integrated sound chip connected directly to a host PC via USB, and was the first portable version of the Nasometer.

The Nasometer II, model 6500, was developed in 2019, and it provides objective measures of nasalance and real-time processing and feedback, enabling immediate visual and auditory feedback of nasalance to measure and facilitate patients' acquisition of therapy goals. This version does not need calibration before each test, making it easier to handle and reducing the usage time. The new version has a handset separator plate with microphones mounted on each side. The nasometer interface design is also simplified compared to the previous model for ease of use, and it is a class II equipment where the protection against electric shock is improved.

Figure 2.2

Nasometer II 6500 model with a handheld separator plate

2.3 Nasometry Studies

Several studies have been conducted using the different models of the Nasometer since its development in 1986. These include several studies comparing the nasalance values across different models of the instrument, comparison studies between different aerodynamic and acoustic measures with nasalance, normative studies done in various languages across different populations, etc.

Awan & Virani (2013) compared the nasalance obtained using the Nasometer 6200 versus the Nasometer II 6400 in typically speaking young adult males and females for the standard nonnasal Zoo Passage, the phonetically balanced Rainbow Passage, and the Nasal Sentences. The participants (25 males, 25 females) had to read the passages at a comfortable pitch and loudness twice while wearing Nasometer 6200 or Nasometer II 6400 headgear. The order of Nasometer system was counterbalanced across participants, and the order of the reading passage was randomized. The Results showed that the Nasometer 6200 and the Nasometer II 6400 differed significantly on mean nasalance for the Zoo Passage (mean difference 1⁄47.15%) and the Rainbow Passage (mean difference 1⁄4 3.05%) but not for the Nasal Sentences (mean difference 1⁄4 0.77%). Intersystem correlations and measures of

predictive accuracy indicated that the ability to predict Nasometer 6200 nasalance values from Nasometer II 6400 scores was relatively weak. They concluded that intrasubject changes in nasalance can only be validly assessed when test versus retest measurements have been acquired using the same nasalance system.

Bressman & Tang (2024) performed a comparative study of the scores obtained from Frequency response characteristics of microphone pairs in a Nasometer model 6200, a model 6450 and two model 6500 headsets, and compared them using long-term average spectra of white noise and multi-speaker babble signals. A female speaker (24 years) and a male speaker (49 years) were made to wear the headset while producing the first two sentences of the non-nasal Zoo Passage (Fletcher, 1972), the first Nasal Sentence (Fletcher, 1978), and the second sentence of the phonetically balanced Rainbow Passage (Fairbanks, 1960). The three stimuli were repeated twice each by the two speakers, resulting in a total of 12 test stimuli, from which 144 nasalence scores were obtained. The results demonstrated that the cumulative absolute differences in microphone frequency response between 300–750 Hz ranged from 6.58 to 7.68 dB, and variations in nasalance values were observed within and between headsets. Hence, they concluded that it is important to maintain the same model of the instrument for repeated measures.

2.3.1 Indian Studies

2.3.1.1 Comparison with other acoustic measures

In the Indian context, Ankita & Pushpavathi in 2013 established the normative data for both on 40 native Kannada speaking adults within 18-25 years of age using Nasometer II Model 6450. The stimuli used was five nasal and oral sentences and nasal and oral passages in Kannada.The participants had to read the stimuli at their habitual rate and loudness. The stimuli were assessed for mean nasalance, nasalance distance (calculated as Maximum nasalance –

Minumum nasalance) and Nasalance ratio (calculated as Minimum nasalance /Maximum nasalance) Results revealed both derived measures to be effective and have a good correlation with mean nasalance values.

Reshma & Jayakumar in 2020 studied the correlation between Acoustic Voice Quality Index (AVQI) and nasalence scores using a clinical group having hypernasality secondary to CLP and a control group of individuals with no orofacial structural or motor anomalies using Nasometer II 6450 model. Pearson's moment correlation reveals weak correlation between AVQI and nasalance (r= 0.432), significant positive correlation between Cepstral Peak Prominence (CPP) and nasalance (r=0.567), weak negative correlation between Harmonic-Noise Ratio (HNR) and nasalance (r= -0.355), weak negative correlation between nasalance and both Shimmer local (r= -0.248) and Shimmer dB (r= -0.319), and no significant correlation between nasalence and both Slope and Tilt of Long Term Averaging Spectrum (LTAS) (r= -0.365 and -0.711 respectively).

Girish et al. (2021) conducted a study to investigate the effect of native language on Nasalance values on a total of 24 female participants (12 native Kannada speakers and 12 native Malayalam speakers) aged between 18-23 years. Nasalance was measured across vowels, voiced and unvoiced syllables, meaningful words, oral sentences, and nasal sentences in both English and Kannada. Consistently higher nasalance values were observed among Malayalam speakers than Kannada speakers across all speech stimuli. The authors concluded that linguistic background should be considered during the assessment and management of resonance disorders.

2.3.1.2 Normative Studies

Several normative studies have also been conducted using various Indian languages and different models of the Nasometer.

In Marathi, Nandurkar (2002) conducted nasalance measures in the Marathi language using Nasometer 6200 model. The subjects included were 10 typically developing children aged 5 -11 years. For this study, 8 monosyllabic words in the CVC pattern loaded with pressure consonants (plosives, fricatives, and affricates) were developed, and the results showed that the nasalance score was significantly higher for cleft palate children than for normal children (7 to 12%). The norm mean nasalance score for plosives, fricatives, and affricates were 8.6 (1.5), 7.9 (1.5), and 11.4 (3.0), respectively. The author concluded that the existing correlation between perceptual judgment and instrument measurement was reasonably accurate; however, the drawback of this study was that generalization was restricted due to the limited sample size.

In Tamil, Sunitha et al. (2005) established the normative nasalance data. As a first phase, the development of ten meaningful sentences with various sound classes in Tamil was established. The 120 participants (60 males and 60 females) with an age range of 5 to 15 years were asked to repeat the developed sentences to calculate the nasalance. The data was analyzed using the Nasometer II, and the results revealed that a higher nasalance score was observed in females than in males. The normative score for oral stimuli was 9 to 15%, nasal stimuli were 58 to 62% and the stimuli with predominant oral sounds were 20 to 40%. The cut-off of nasalance was between 13 and 17% across age and gender for the Tamil language.

In Kannada, Jayakumar and Pushpavathi (2005) conducted a normative study of nasalance in native Kannada speakers for both children and adult Kannada speakers using the Nasometer II 6400 model on 50 children in the age range of 5 to 10 years and 50 adults in the age range of 20-35 years. Syllable repetition (oral and nasal syllables) and sentences (oral and

nasal sentences) were used as stimuli to obtain nasalance values. in both populations. The mean nasalance score obtained in children for sentences: nasal sentences = 53.03% (7.02), oral sentences = 9.08% (3.49), and nasalance value for syllable repetition: nasal syllable = 66.44% (6.63), and for oral syllable 10.66% (4.07). No significant difference were found across genders while analyzing the effect of gender on the nasalance score for children, however, the nasalance score obtained in adults for sentences showed a significant difference across gender. In males, the nasalance score for nasal sentences = 48.27% (8.74), oral sentences = 8.77 % (4.76), and in females the nasalance value for nasal sentences = 58.22% (8.40), and for oral sentences 14.69 % (5.86). Whereas in adults' females had higher nasalance values compared to males. The nasalance cut-off found ranged between 13% to 30% across the age and gender for the Kannada language.

In Bengali, Shailat & Kumar (2008) developed and standardized test passages in Bengali for measuring Nasalance using the Nasometer II 6400 model in adult Bengali speakers. 100 native Bengali speakers (50 male and 50 female) between the age range 18-30 years were taken for the study. Three pasages were developed, one Oral passage, one Nasal passage, and one Phonetically Balanced passage, and the participants had to read the passages. Mean nasalance values for male and female speakers obtained for oral passage were 11.24 and 10.78 respectively; for phonetically balanced passage, mean nasalance values for male and female speakers obtained were 29.32 and 29.66 respectively; and for nasal passage, the mean nasalance values for male and female speakers obtained were 55.08 and 55.62 respectively. High correlation was obtained for all passages in test-retest conditions. Common mean nasalance values of 12.78, 27.58 and 52.58 were obtained for oral, phonetically balanced, and nasal passages respectively.

In Hindi, Meshram & Pushpavathi (2012) studied normative nasalance values in Hindi-speaking participants using Nasometer II 6450 model. A total of 50 participants (25 males and

25 females) in the age range of 17-30 years were considered for the study. The stimuli used were vowels /a/, /i/, and /u/, meaningful words, sentences (5- nasal and 5- oral), and a paragraph containing 6 sentences with oral-rich context and 6 with nasal sounds. The result revealed that increased nasalance was observed in females compared to male speakers. In females, the nasalance score for oral words was 24.24% (7.83), sentences 21.92% (6.89), and paragraphs 17.92% (6.69). and for nasal- words 59.76% (6.78), sentences 61.60% (7.12), and paragraph 63.32 % (7.25). In male speakers, the value for oral-words was 20.40% (6.17), sentences 16.12 % (5.75), and paragraph 13.64% (4.93), and for nasal-words 56.08% (6.20), sentences 57.44% (7.04), and paragraph 58.20% (8.01).

Kuppusamy et al. (2013) established normative data in the Malayalam language. 60 normal individuals with an age range of 18 to 25 were taken for the study. The stimuli used were two sets of Malayalam words and sentences, five in each, in that one set consists of nasal-rich content and the other set consists of predominantly oral sounds. The Nasometer II 6400 model was utilized to derive the mean nasalance values across speech stimuli. The results indicated that for oral stimuli in males, the mean nasalance values were 28.50 (9.27) for words and 24.58 (7.49) for sentences, and for females, it was 34.90 (7.88) and 28.85 (8.62) for oral words and sentences, respectively. For the nasal stimuli, the scores for words and sentences were 75.66 (4.65) and 77.95 (3.46) for males and 77.95 (3.46) and 71.83 (4.39) for females, respectively. The study further showed a significant difference across gender for all the stimuli at the 0.01 level.

Kadisonga & Jayakumar (2016) studied the normative nasalance values for adult Manipuri speakers using the Nasometer II 6450 model. 80 English-speaking native Manipuri adult speakers (40 males and 40 females) with an age range of 17-35 years were considered for the study. The stimuli used were 20 Manipuri sentences (10 nasal and 10 oral sentences) containing 6 to 10 syllables, and the Zoo passage (oral paragraph) and the Rainbow passage

(phonetically balanced stimuli). The nasalance score was derived by using Nasometer II 6450 (Kay Elemetrics, NJ), and the result revealed that no gender effect on nasalance in all stimuli used. The mean nasalance with standard deviation (S.D.) for oral sentences, nasal sentences, Zoo passage, and Rainbow passage were 21(10.44), 59.63(7.28), 18.70 (7.28), and 38.95 (7.37) respectively.

Jazeera & Manasa (2025) studied the normative nasalance values for native Kannada-speaking children using the Nasometer II 6500 model. Kannada using the Nasometer II 6500 model. A total of 100 Kannada-speaking children were considered with equal gender partition, aged between 5 to 10 years. To obtain nasalance values, three sets of speech stimuli were used, in which set 1 has phonemes and syllables, adapted from the SNAP test-R (Kummer, 2005); Set 2 contains simple and meaningful oral and nasal words, and Set 3 consists of oral and nasal sentences developed by Jayakumar & Pushpavathi (2005), which can be easily repeated by younger children. The handheld separator plate of the Nasometer II 6500 model was provided to ensure a comfortable placement on the prolabium of the subjects. The Nasogram was constantly monitored during recording. The study revealed that the percentage of mean nasalance values obtained for the oral and nasal stimuli in words and sentences shows greater differences, where the mean nasalance score for nasal stimuli is higher, i.e., for nasal words it is 63.10 (6.85) and for nasal sentences it is 49.33 (5.36) than the mean nasalance score for oral stimuli, i.e., for oral words it is 14.72 (4.89) and for the oral sentences it is 13.63 (4.29).

2.4 Bengali Language

Bengali is an Indo-Aryan language belonging to the Indo-Iranian branch of the Indo-European language family. It is native to the Bengal region of South Asia, including Bangladesh, India's West Bengal and Tripura) of South Asia. It is the official language of the Indian states of West Bengal, Tripura, and the Barak Valley of Assam, and the second official

language of the Indian state of Jharkhand since September 2011. It is one of the 23 officially recognized languages in India.

2.4.1 Bengali Phonemic Inventory

Bengali has thirty-seven phonemes, of which seven are vowels, and thirty are consonants (Barman, 2009). The vowels and consonants in Bengali language are listed in the table below.

Table 2.1

Vowel and Consonant inventory in Bengali language (Barman, 2009).

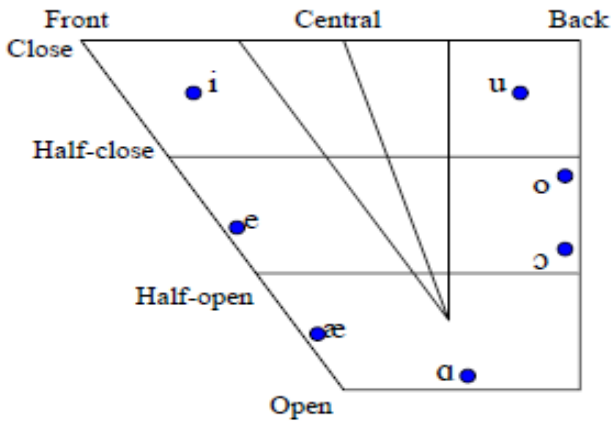
Vowels	*Consonants*
ɑ i e o u ɔ æ	p pʰ b bʰ t tʰ d dʰ ʈ ʈʰ ɖ ɖʰ c cʰ ɟ ɟʰ k kʰ g gʰ s ʃ m n ŋ l r h w j

2.4.1.1 Bengali Vowels

Bengali has seven pure vowels: /i/, /e/, /ɛ/, /o/, /ɔ/, /u/, /a/, positioned in a cardinal vowel diagram with front /i/, /e/, /ɛ/; central /a/; and back /o/, /ɔ/, /u/. Vowel length is not phonemically distinctive, though orthography marks short (hrasya) and long (dirgha) forms as a convention without meaning change. "vowel doubling" (e.g., /dii/ in "diyini") creates equivalents to long vowels. Nasalized counterparts exist for all vowels (/ĩ/, /ẽ/, /ɛ̃/, /õ/, /ɔ̃/, /ũ/, /ã/), but nasalization is debated as allophonic rather than phonemic in contemporary Bengali, with minimal meaning distinction. Reduced vowels like schwa are rare in Bengali phonology (Barman, 2009).

Figure 2.3

Cardinal Diagram for Bengali Vowels (Barman, 2009)



2.4.1.2 Bengali Diphthongs

Diphthongs are the combinations of two vowel sounds, one gliding towards the other. There are 25 diphthongs in Bengali, with both vowels of equal duration in 22 out of 25 diphthongs. Full vowels are of normal length and the half vowels only about half of it. The only half vowel that is found in Bengali is front-close /ɪ/. The diphthongs in which the half vowel is used are /ɑ ɪ ; ɔ ɪ ; æ ɪ / (Barman, 2009). A list of all Bengali diphthongs are included in Appendix-3.

2.4.1.3 Bengali Consonants

Bengali has a total of 30 consonants , which are classified by place (bilabial, dental, alveolar, post-alveolar, palatal, velar, glottal) and manner (plosives, fricatives, nasals, lateral, approximants). Aspiration/voicing distinctions are distinctive in Bengali, making it a four-fold language. The consonants are primarily classified on the basis of their place of articulation into bilabials (/p/, /pʰ/, /b/, /bʰ/); dental (/t̪/, /t̪ʰ/, /d̪/, /d̪ʰ/); alveolar/retroflex (/ʈ/, /ʈʰ/, /ɖ/, /ɖʰ/); post-alveolar (/tʃ/, /tʃʰ/, /dʒ/, /dʒʰ/); velar (/k/, /kʰ/, /g/, /gʰ/). On the basis of manner of articulation, additional classification include Fricatives: /s/, /ʃ/, /h/; nasals: /m/, /n/, /ŋ/; lateral: /l/;

approximants: /r/, /w/, /j/ (with flap/retroflex /ɽ/ variants). Bengali phonetic inventory lacks true labiodentals (/f/, /v/), which are replaced by the aspirated counterparts pf bilabial /p/ and /b/; as well as true dental fricatives /θ/, /ð/, which are replaced by the aspirated counterpart of the dental consonants /t̪/ and /d̪/ (Barman, 2009).

2.4.2 Bengali Syllabic Structure

According to an online information resource material from the Central Institute of Indian Languages (CIIL), Mysore (n.d.), Bengali monosyllabic words present total 13 canonical forms , namely CV, CVC, V, VC, VV, CVV, CCV, CCVC, CVVC, CCVV, CCCV, CCCVC, and VVC forms, where V stands for Vowel, and C stands for Consonant. In polysyllabic words in addition to the above 13 canonical forms, 3 more patterns, viz. CCVVCV, CVCCCCVCV, and CCCVVC, are also available.

CHAPTER III

METHODS

3.1 Type of research design: Normative research design

3.2 Participants

A total of sixty participants (30 male, 30 female) who were native speakers of Bengali, and without any speech, language, or hearing issues, aged between 20-40 years (30 aged between 20-30 years and 30 aged between 30-40 years) were selected for the study. Participants were native speakers of Bengali language, and were selected from in and around the institute, including students studying in the institute, families of clients who had come to the institute for treatment, as well as residents from the Bengali Association of Mysuru.

The inclusion and exclusion criteria for selecting the participants were as follows:

Inclusion Criteria

1. Participants should have Bengali as their mother tongue, i.e. L1
2. Participants with normal structure and functioning of their speech mechanism
3. Participants should not be having any viral infections like cold or cough that can affect their resonance
4. Participants should not have any linguistic-cognitive deficits

Exclusion Criteria

1. Participants having a different language as L1 and Bengali as a second language
2. Participants with structural and functional deficits in their speech mechanism
3. Participants who have linguistic cognitive deficits

The details of the participants selected for the main study are as given in Table 3.1. This study was approved by the Institute Review Board (IRB) for a bio behavioral study involving

human subjects at AIISH, Mysore (Ref. SH/IRB/M.5/SLP.38/2025-26).

Table 3.1

Participant details for study

Age range	Male	Female	Total
20-30 years	15	15	30
30-40 years	15	15	30
Total	**30**	**30**	**N=60**

Note. N = Total number of subjects

3.3 Stimuli

The stimuli used for this study consists of three sets, Set 1, Set 2 and Set 3. Set 1 consists of oral and nasal sounds and syllables, which was taken from the Simplified Nasometric Assessment Procedure- Revised (SNAP Test- R) developed by MacKay and Kummer in the year 2005, as given in Table 3.2.

Table 3.2

Set 1 : Prolonged Sounds and Syllable Repetition taken from SNAP Test-R by Kummer (2005)

Prolonged Sounds	Oral + /a/ syllables	Oral + /i/ Syllables	Nasal + /a/ Syllables	Nasal + /i/ Syllable
Prolonged /a/	/pa, pa, pa…/	/pi, pi, pi.../	/ma, ma, ma…/	/mi, mi, mi…/
Prolonged /i/	/ka. ka, ka…/	/ki, ki, ki…/	/na, na, na…/	/ni, ni, ni…/
Prolonged /s/	/sa, sa, sa…/	/si, si, si…/		
Prolonged /m/	/ʃa, ʃa, ʃa.../	/ʃi, ʃi, ʃi.../		

Set 2 consists of a total of ten meaningful words in Bengali, in which five are loaded with oral consonants (oral words) and five with nasal consonants (nasal words). Set 3 consists of oral and nasal loaded meaningful sentences in Bengali. The words and sentences were developed and finalised in two phases, Phase 1, involving the development of stimuli, and Phase 2, involving the content validation and finaliszation of the developed stimuli.

Procedure

The study was conducted in three phases:

Phase 1: Development of Stimuli in Bengali language

Phase 2: Content validation

Phase 3: Data collection and statistical analysis

Phase 1: Development of stimuli

A total of ten nasal rich words and sentences, and ten oral rich words and sentences of developed in Bengali after referring to standard Bengali textbooks for primary education, storybooks, novels, and other literature sources by a SLP, who is a native speaker of Bengali. The words developed were bisyllabic meaningful words of Consonant-Vowel-Consonant (CVC) and Consonant-Vowel-Consonant-Vowel (CVCV) combinations, and consonant blends were avoided. The sentences were meaningful, with a mean length 3-4 words. The words and sentences are included in Appendix-6.

Phase 2: Content Validation

The developed words and sentences were given for content validation through perceptual judgement. Each stimuli was rated on a Likert Scale ranging from 1 to 5 where 1 indicated “Very Poor” and 5 indicated “Excellent” by a group of five SLPs and three linguists who who had a minimum experience of five years in the field, and are proficient in Bengali

language. The rating was done through online as well as offline modes. Each stimuli was rated based on the following parameters as mentioned in Table 3.3.

Table 3.3

Parameters and ratings used for content validation

Parameter	Very Poor (1)	Poor (2)	Fair (3)	Good (4)	Excellent (5)
Simplicity					
Familiarity					
Relevance					
Neutrality					
Strength of pressure consonants used					
Nasal resonance strength					
Ease of reading (For sentences)					
Stimulability					

The stimuli that received the highest ratings for the above mentioned parameters were selected and finalised. A total of five oral words, five nasal words, six oral sentences, six nasal sentences were finalised for the testing procedure.

3.4 Instrumentation

The Nasometer II 6500 model (Kay Pentax, USA) software version was used for the study. The testing was carried out in a quiet environment. The model is portable, does not require prior calibration, and include a handheld separator plate (Figure 3.1) that rests on the

subject's upper lip. It consists of two microphones on either side of the plate that detect the nasal and oral energies, which are filtered individually and digitized by a customized electronic module in the interface box that is connected to a laptop via USB cable, and the output is observed from the display screen of the laptop.

Figure 3.1

Nasometer II 6500 Handheld nasal-oral separator plate

The nasalance score is then calculated using the following formula automatically, and the system-generated nasalance value is visualized in the display as output.

Nasalance =[Nasal Energy/(Nasal Energy + Oral Energy)]× 100%

3.5 Procedure

The Nasometer II 6500 model equipment was set up in a quiet room environment with minimal background noise for tresting. Informed consent was taken from all participants before data collection. The hygiene was well maintained by adequately sanitizing the seperator plate that comes in direct contact to the participant’s faces before and after each use. Each subject was assessed individually and was seated comfortably with his or her head in an upright position, and the test procedures were conducted in Bengali language. Participants were instructed to sit upright and look straight after placing the separator plate and repeat the stimulus one after the other, without moving/shaking their head. The hand-held separator plate

was then placed below the nostrils and above the subject's upper lip, and a seal was made in accordance with the manufacturer's instructions as demonstrated in Figure 3.2.

Figure 3.2

Positioning of the Nasometer II 6500 hand-held separator plate on participant's prolabium

The participants were asked to prolong the phonemes and repeat the syllables three times from the set-1 stimuli; followed by repeating the words from set-2, followed by the sentences in set-3 stimuli. At the end of each stimulus, an interval of two seconds was provided to ensure the differentiation for adequate analysis. A gap of 10-15 seconds was given between each set of stimuli, and participants were instructed again before recording the next set. Each stimuli was recorded thrice for greater accuracy of the measures obtained without making the task tedious for the participant. The time taken for each participant to complete all the speech tasks was approximately 15 minutes.

As the microphones picked up the oral and nasal energy, the nasalance traces were displayed on the screen called Nasogram, which was then stored in the computer database. Any off-task behavior, such as throat clearing or repeating the previous stimuli or shaking the head while speaking, was considered as extraneous, and was marked and deleted from the recorded trace immediately, and then the nasalance trace for each set was saved as a .nsp file on the PC laptop for each individual for later analysis. For reliability measures, 10% of the subjects were

asked to repeat the procedure after a 30-minute interval. The values of mean nasalance score, minimum, and maximum were displayed by using the Nasometer program and documented for data analysis.

3.6 Data Analysis

The obtained data for each set of stimuli were assessed to ensure that the approximate data were included for necessary calculations. Extraneous data like throat clearing or mistakes in stimuli repetition were removed by selecting the unsteady portion of the sample and selecting the 'delete between cursors' option in the Nasometer software. For the nasalance values, the needed portion of speech sample was selected using the cursor in the Nasogram and by clicking 'statistics' option in the software, the mean, minimum, and maximum percentage of nasalance were obtained. Figures 3.3 and 3.4 show a typical nasogram and the automatically generated nasalance values by the nasometer software respectively

Figure 3.3

Nasogram for three repetitions of nasal sentence

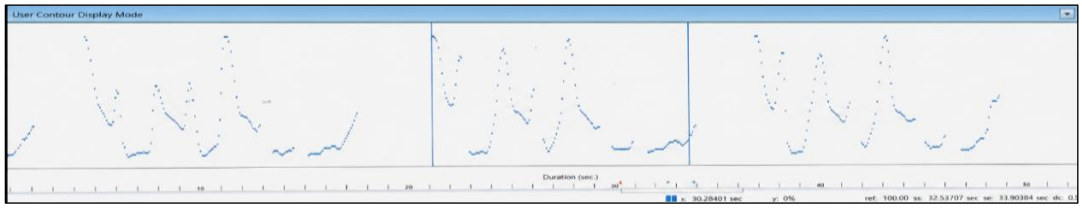
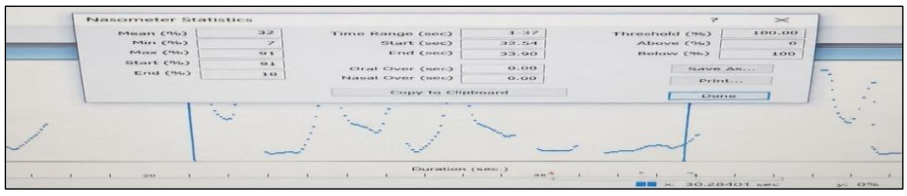


Figure 3.4

Nasalance statistics for nasal sentence



The data were collected and compiled in a MS Excel file and transferred into a separate sheet for analysis using appropriate statistical methods using the SPSS software program (version 26.0 package).

CHAPTER IV

RESULTS

The present study aimed to establish the normative values of nasalance for Bengali language for 20-40 year old Bengali-speaking adults. A set of ten oral and nasal words and ten oral and nasal sentences in Bengali were developed by the student researcher, who is a native speaker of Bengali. The developed words and sentences were given for content validation based on perceptual judgement on the parameters mentioned in Table 3.2 to five experienced SLPs and three linguists proficient in Bengali. Based on the responses from the content validators, five oral words, five oral sentences, six oral words and five nasal sentences that received the highest perceptual ratings were selected for data collection.

The compiled data was analysed through IBM SPSS software 26.0 package to fulfil the objectives of the study. The mean nasalance obtained through the software was considered for analysis, and tests performed included descriptive statistics, Cronbach's alpha for testing reliability, Mann-Whitney U test, one-way analysis of variance (ANOVA) two-way multivariate analysis of variance (MANOVA).

The results of the present study are compiled along the following sub-headings:

4.1 Test-retest reliability of data

4.2 Normative nasalance values for Bengali-speaking adults of 20-40 years of age

4.3 Effect of age and gender on mean nasalance values on various stimuli

4.1 Test-retest reliability of data

The test-retest reliability of the data was assessed by including 10% of the participants performing all the repetition tasks twice after a gap of half an hour. The Cronbach's alpha (α) value was calculated for all stimuli, and the values ranged from 0.832. to 0.997, indicating very good to excellent reliability (Hair et al., 2003)

4.2 Normative nasalance values for Bengali-speaking adults of 20-40 years of age

Descriptive statistics was performed on mean nasalance values for all of the compiled data. Phoneme /s/ was not considered for analysis as it is an unvoiced consonant, and the average nasalance score was approximately zero for all participants across both age and gender groups. Table 4.1 includes percentage of mean nasalance along with standard deviation, lower and upper boundary values for all sets of stimuli from phoneme prolongation to sentences for ages between 20-30 years across gender.

Table 4.1

Normative values of nasalance for 20-30 year old Bengali speaking adults across gender

Variable	Gender	Mean	SD	Lower bound	Upper bound
/a/	**M**	15.06	6.31	8.00	26.00
	F	16.80	5.07	6.00	27.00
/i/	**M**	16.00	5.86	5.00	28.00
	F	22.26	6.71	6.00	33.00
/m/	**M**	90.80	7.81	65.00	96.00
	F	91.13	5.78	72.00	95.00
/pa/	**M**	12.93	4.02	9.00	21.00
	F	11.06	2.57	6.00	18.00
/ka/	**M**	11.13	2.61	6.00	15.00
	F	11.20	4.31	7.00	24.00
/sa/	**M**	11.00	2.75	7.00	16.00
	F	10.26	3.01	5.00	15.00
/ʃa/	**M**	9.46	2.69	5.00	14.00
	F	9.53	3.06	4.00	15.00
/pi/	**M**	12.60	2.94	8.00	19.00
	F	17.40	7.04	4.00	29.00
/ki/	**M**	13.86	3.22	9.00	20.00

Variable	Gender	Mean	SD	Lower bound	Upper bound
	F	19.80	7.72	5.00	33.00
/si/	**M**	13.40	4.17	9.00	24.00
	F	18.60	6.95	5.00	28.00
/ʃi/	**M**	11.26	3.32	5.00	17.00
	F	17.26	7.304	4.00	27.00
/ma/	**M**	54.46	13.62	12.00	66.00
	F	59.53	11.08	41.00	78.00
/na/	**M**	59.66	7.85	46.00	73.00
	F	61.93	10.97	39.00	76.00
/mi/	**M**	74.93	9.67	44.00	85.00
	F	80.60	7.41	63.00	91.00
/ni/	**M**	76.93	7.34	57.00	87.00
	F	82.00	7.68	65.00	93.00
OW	**M**	10.72	2.34	6.40	13.60
	F	10.98	3.33	6.20	18.20
NW	**M**	56.77	8.27	32.80	66.40
	F	60.60	6.35	46.40	68.40
OS	**M**	12.15	2.38	7.33	15.67
	F	15.53	7.91	5.50	32.17
NS	**M**	39.74	7.16	26.60	51.60
	F	42.38	4.54	30.00	46.60

Note: OW- Oral words, NW- Nasal words, OS- Oral sentences, NS- Nasal sentences, SD- Standard Deviation, M- Male, F- Female

Table 4.2 includes percentage of mean nasalance along with standard deviation, lower and upper boundary values for all sets of stimuli from phoneme prolongation to sentences for ages between 30-40 years across gender.

Table 4.2

Normative values of nasalance for 30-40 year old Bengali speaking adults across gender

Variable	Gender	Mean	SD	Lower Bound	Upper Bound
/a/	**M**	14.20	4.69	8.00	22.00
	F	18.53	7.27	10.00	35.00
/i/	**M**	16.66	6.21	3.00	26.00
	F	23.93	9.09	6.00	42.00
/m/	**M**	90.26	6.92	78.00	96.00
	F	89.53	10.45	61.00	96.00
/pa/	**M**	13.53	3.06	8.00	18.00
	F	11.20	3.58	5.00	18.00
/ka/	**M**	13.53	2.72	9.00	20.00
	F	11.86	3.70	6.00	19.00
/sa/	**M**	11.33	3.33	7.00	19.00
	F	10.60	3.06	5.00	17.00
/ʃa/	**M**	10.46	3.44	5.00	18.00
	F	9.86	2.85	5.00	14.00
/pi/	**M**	11.00	5.15	5.00	22.00
	F	16.93	7.12	5.00	28.00
/ki/	**M**	12.93	5.13	6.00	24.00
	F	17.93	5.65	5.00	26.00
/si/	**M**	12.26	4.84	5.00	22.00
	F	17.60	6.63	4.00	27.00
/ʃi/	**M**	10.46	5.33	4.00	21.00
	F	16.66	6.11	4.00	25.00
/ma/	**M**	52.93	6.39	44.00	69.00
	F	55.20	8.30	42.00	70.00
/na/	**M**	55.60	7.13	47.00	72.00
	F	60.40	6.86	48.00	70.00
/mi/	**M**	74.93	8.87	61.00	89.00
	F	76.80	9.22	60.00	88.00

Variable	Gender	Mean	SD	Lower Bound	Upper Bound
/ni/	**M**	76.06	8.93	60.00	90.00
	F	78.13	9.76	59.00	90.00
OW	**M**	11.58	2.73	7.40	17.00
	F	10.88	3.07	6.20	17.40
NW	**M**	58.29	4.15	50.40	62.80
	F	61.29	5.37	48.20	68.40
OS	**M**	12.40	1.80	8.17	16.17
	F	12.72	3.59	6.00	19.67
NS	**M**	37.17	4.46	27.00	45.20
	F	42.25	5.02	32.60	52.20

Note: OW- Oral words, NW- Nasal words, OS- Oral sentences, NS- Nasal sentences, SD- Standard Deviation, M- Male, F- Female

4.3 Effect of age and gender on nasalance values

Shapiro-Wilk test of normality was performed on the collected data and the results showed normal distribution for oral stimuli for typical adults of 20-40 years age range ($p > 0.05$), and non-normal distribution for nasal stimuli including prolongation of nasal phoneme /m/ and syllable repetitions for nasal syllables /ma/, /mi/, /na/, /ni/ repetitions. Hence non-parametric test Mann-Whitney U-test was performed to test for the effect of age and gender on the aforementioned nasal stimuli for Bengali language, and two-way Multivariate ANOVA was performed to test for the effect of age and gender on the oral stimuli as well as for oral and nasal words and sentences for Bengali language.

4.3.1 Effect of age and gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

The results in this section are further subclassified into three subcategories:

4.3.1.1 Effect of age on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

4.3.1.2 Effect of gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

4.3.1.3 Effect of age and gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

4. 3.1.1 Effect of age on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

One-way analysis of variance (ANOVA) was conducted to investigate the effect of age on nasalance for phoneme /a/ and oral syllables pa/, /ka/, /sa/, /ʃa/. (Table no. 4.3) The results reveal no statistically significant effect of age on nasalance values for /a/ prolongation and syllable repetition for oral syllables containing /a/ vowel ($p > 0.05$).

Table 4.3

Effect of age on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

Variable	dF	Error	F(1, 56)	p	Partial η^2
/a/	1	56	0.08	.778	.001
/pa/	1	56	0.18	.674	.003
/ka/	1	56	3.03	.087	.051
/sa/	1	56	0.18	.673	.003
/ʃa/	1	56	0.73	.397	.013

4.3.1.2 Effect of gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

One-way analysis of variance (ANOVA) was conducted to investigate the effect of gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/. (Table 4.4)

The results reveal no statistically significant effect of gender on nasalance values for /a/ prolongation and syllable repetition for oral syllables containing /a/ vowel (p> 0.05), except syllable /pa/, with a p value of 0.019 (p< 0.05), which showed a statistically significant difference between the two genders.

Table 4.4

Effect of gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

Variable	dF	Error	F(1, 56)	p	Partial η²
/a/	1	56	3.92	.053	.065
/pa/	1	56	5.86	.019*	.095
/ka/	1	56	0.83	.368	.015
/sa/	1	56	0.87	.355	.015
/ʃa/	1	56	0.12	.734	.002

*Note: * indicates statistically significant at 95% confidence interval*

4.3.1.3 Effect of age and gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/.

Two-way multivariate analysis of variance (MANOVA) was conducted to investigate the effect of age and gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/. (Table 4.5) The results reveal no statistically significant effect of age on nasalance values for /a/ prolongation and syllable repetition for oral syllables containing /a/ vowel (p > 0.05). Statistically significant effect of gender was observed for nasalance values for /a/ prolongation and syllable repetition for oral syllables containing /a/ vowel (p value 0.021, p < 0.05) No statistically significant effect of interaction of age and gender on nasalance values for was observed for /a/ prolongation and syllable repetition for oral syllables containing /a/ vowel (p > 0.05).

Table 4.5

Comparison of effect of age and gender on nasalance for phoneme /a/ and oral syllables /pa/, /ka/, /sa/, /ʃa/

Effect	**Statistical Measure**	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Age	Wilks' Lambda	.891	1.271	5.000	52.00	.290
Gender	Wilks' Lambda	.780	2.936	5.000	52.00	.021*
Age*Gender	Wilks' Lambda	.089	.924	5.000	52.00	.473

*Note: * indicates statistically significant at 95% confidence interval, Sig. indicates Significance*

4.3.2 Effect of age and gender on nasalance for phoneme /i/ and oral syllables containing /i/

The results in this section are further subclassified into three subcategories:

4.3.2.1 Effect of age on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/

4.3.2.2 Effect of gender on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/

4.3.2.3 Effect of age and gender on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/

4. 3.2.1 Effect of age on nasalance for phoneme /i/ and oral syllables containing /i/

One-way analysis of variance (ANOVA) was conducted to investigate the effect of age on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/ (Table 4.6) . The results reveal no statistically significant effect of age on nasalance values for /i/ prolongation and syllable repetition for oral syllables containing /i/ vowel ($p > 0.05$).

Table 4.6

Effect of age on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/

Variable	dF	Error	F(1, 56)	p	Partial η²
/i/	1	56	0.406	.526	.007
/pi/	1	56	0.472	.495	.008
/ki/	1	56	0.916	.343	.016
/si/	1	56	0.512	.477	.009
/ʃi/	1	56	0.226	.637	.004

4.3.2.2 Effect of gender on nasalance for phoneme /i/ and oral syllables containing /i/

One-way analysis of variance (ANOVA) was conducted to investigate the effect of age on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/. (Table 4.7) The results reveal statistically significant effect of age on nasalance values for /i/ prolongation as well as syllable repetition for oral syllables containing /i/ vowel ($p < 0.05$).

Table 4.7

Effect of gender on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/

Variable	dF	Error	F(1, 56)	p	Partial η²
/**i**/	1	56	13.672	< .001*	.196
/**pi**/	1	56	12.732	.001*	.185
/**ki**/	1	56	13.962	< .001*	.200
/**si**/	1	56	12.488	.001*	.182
/ʃi/	1	56	17.146	< .001*	.234

*Note: * indicates statistically significant at 95% confidence interval*

4.3.2.3 Effect of age and gender on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/

Two-way multivariate analysis of variance (MANOVA) was conducted to investigate the effect of age and gender on nasalance for phoneme /i/ and oral syllables /pi/, /ki/, /si/, /ʃi/. (Table 4.8). The results reveal no statistically significant effect age on nasalance values for /i/ prolongation and syllable repetition for oral syllables containing /i/ vowel ($p > 0.05$). Statistically significant effect of gender was observed for nasalance values for /i/ prolongation and syllable repetition for oral syllables containing /i/ vowel ($p = 0.04$, $p < 0.05$) No statistically significant effect of interaction of age and gender on nasalance values for was observed for /i/ prolongation and syllable repetition for oral syllables containing /i/ vowel ($p > 0.05$).

Table 4.8

Comparison of effect of age and gender on nasalance for phoneme /i/ and oral syllables containing /i/

Effect	Statistical Measure	Value	F	Hypothesis df	Error df	Sig.
Age	Wilks' Lambda	.940	.669	5.000	52.000	.648
Gender	Wilks' Lambda	.725	3.952	5.000	52.000	.004*
Age+Gender	Wilks' Lambda	.945	.605	5.000	52.000	.696

*Note: * indicates statistically significant at 95% confidence interval, Sig. indicates Significance*

4. 3.3 Effect of age and gender on nasalance for oral and nasal words

The results in this section are further subclassified into three subcategories:

4.3.3.1 Effect of age on nasalance for oral and nasal words

4.3.3.2 Effect of gender on nasalance for oral and nasal words

4.3.3.3 Effect of age on nasalance for oral and nasal words

4.3.3.1 Effect of age on nasalance for oral and nasal words

One-way analysis of variance (ANOVA) was conducted to investigate the effect of age on nasalance for oral words (OW) and nasal words (NW) (Table no. 4.9) The results reveal no statistically significant effect of age on nasalance values for oral words (OW) and nasal words (NW) ($p > 0.05$).

Table 4.9

Effect of age on nasalance for oral and nasal words

Variable	dF	Error	F(1, 56)	p	Partial η^2
OW	1	56	0.258	.613	.005
NW	1	56	0.474	.494	.008

Note: OW- Oral words, NW- Nasal words

4.3.3.2 Effect of gender on nasalance for oral and nasal words

One-way analysis of variance (ANOVA) was conducted to investigate the effect of age on nasalance for oral words (OW) and nasal words (NW) (Table no. 4.10) The results reveal no statistically significant effect of gender on oral words (OW) ($p >0.05$) and a statistically significant effect of gender on nasal words (NW) ($p = 0.038$, $p <0.05$).

Table 4.10

Effect of gender on nasalance for oral and nasal words

Variable	dF	Error	F(1, 56)	p	Partial η²
OW	1	56	0.087	.770	.002
NW	1	56	4.511	.038*	.075

*Note: OW- Oral words, NW- Nasal words, * indicates statistically significant at 95% confidence interval*

4.3.3.3 Effect of age and gender on nasalance for oral and nasal words

Two-way multivariate analysis of variance (MANOVA) was done to investigate the effect of age and gender on nasalance for oral and nasal words (Table 4.11). The results reveal no statistically significant effect age on nasalance values for age for oral words and nasal words ($p > 0.05$). Statistically significant effect of gender was observed for nasalance values for nasal words ($p = 0.038$, $p < 0.05$) No statistically significant effect of interaction of age and gender on nasalance values for was observed for oral and nasal words ($p > 0.05$).

Table 4.11

Comparison of effect of age and gender on nasalance for oral and nasal words

Effect	Variable	df	Error	F (1, 56)	Sig.	Partial η²
Age	**OW**	1	56	.258	.613	.005
	NW	1	56	.474	.494	.008
Gender	**OW**	1	56	.087	.770	.002
	NW	1	56	4.511	.038*	.075
Age+ Gender	**OW**	1	56	.423	.518	.008
	NW	1	56	.066	.798	.001

*Note: OW- Oral words, NW- Nasal words, Sig. Significance, * indicates statistically significant at 95% confidence interval*

4. 3.4 Effect of age and gender on nasalance for oral and nasal words

The results in this section are further subclassified into three subcategories:

4.3.4.1 Effect of age on nasalance for oral and nasal sentences

4.3.4.2 Effect of gender on nasalance for oral and nasal sentences

4.3.4.3 Effect of age on nasalance for oral and nasal sentences

4.3.4.1 Effect of age on nasalance for oral and nasal sentences

One-way analysis of variance (ANOVA) was conducted to investigate the effect of age on nasalance for oral words (OS) and nasal sentences (NS) (Table no. 4.12) The results reveal no statistically significant effect of age on nasalance values for oral words (OS) and nasal words (NS) ($p > 0.05$).

Table 4.12

Effect of age on nasalance for oral and nasal sentences

Variable	df	Error	F (1,56)	p	Partial η^2
OS	1	56	1.169	.284	.020
NS	1	56	.939	.337	.016

Note: OS- Oral sentences, NS- Nasal sentences

4.3.4.2 Effect of gender on nasalance for oral and nasal sentences

One-way analysis of variance (ANOVA) was conducted to investigate the effect of gender on nasalance for oral sentences (OS) and nasal sentences (NS) (Table no. 4.13) The results reveal no statistically significant effect of gender on oral sentences (OS) ($p >0.05$) and a statistically significant effect of gender on nasal sentences (NS) ($p = 0.008$, $p <0.05$).

Table 4.13

Effect of gender on nasalance for oral and nasal sentences

Variable	dF	Error	F(1, 56)	p	Partial η²
OS	1	56	2.429	.125	.042
NS	1	56	7.637	.008*	.120

*Note: OS- Oral sentences, NS- Nasal sentences, * indicates statistically significant at 95% confidence interval*

4.3.4.3 Effect of age and gender on nasalance for oral and nasal sentences

Two-way multivariate analysis of variance (MANOVA) was conducted to investigate the effect of age and gender on nasalance for oral and nasal sentences (Table 4.14). The results reveal no statistically significant effect age on nasalance values for age for oral sentences and nasal sentences ($p > 0.05$). Statistically significant effect of gender was observed for nasalance values for nasal sentences ($p = 0.008$, $p < 0.05$) No statistically significant effect of interaction of age and gender on nasalance values for was observed for oral and nasal sentences ($p > 0.05$).

Table 4.14

Comparison of effect of age and gender on nasalance for oral and nasal sentences

Effect	Variable	dF	Error	F(1, 56)	p	Partial η²
Age	**OS**	1	56	1.169	.284	.020
	NS	1	56	.939	.337	.016
Gender	**OS**	1	56	2.429	.125	.042
	NS	1	56	7.637	.008*	.120
Age*Gender	**OS**	1	56	1.657	.203	.029
	NS	1	56	.763	.386	.013

Note: OS- Oral sentences, NS- Nasal sentences, indicates statistically significant at 95% confidence interval*

4.3.5 Effect of age and gender on nasalance for nasal phoneme /m/ and nasal syllables

Non-parametric test Mann-Whitney U-test was performed to test for the effect of age and gender on the aforementioned nasal stimuli for Bengali language.

The results in this section are further subclassified into four subcategories:

4.3.5.1 Comparison between gender within 20-30 age group

4.3.5.2 Comparison between gender within 30-40 age group

4.3.5.3 Comparison between age within male participants

4.3.5.4 Comparison between age within female participants

4.3.5.1 Comparison between gender within 20-30 age group

Mann-Whitney U test was conducted to examine gender differences among participants aged between 20-30 years (N=30) (Table 4.15). The results indicated no significant gender differences in parameters /m/, /ma/, and /na/ parameters ($p > 0.05$) Significant gender differences were observed in parameters /mi/ ($p = 0.041$, <0.05) and /ni/ ($p = 0.040$, <0.05).

Table 4.15

Comparison between gender within 20-30 age group

Comparison	Variable	Mann-Whitney U	|Z|	p
Gender within age 20-30 years (N= 30)	/m/	108.00	0.19	.851
	/ma/	93.50	0.79	.430
	/na/	87.50	1.04	.299
	/mi/	63.50	2.04	.041*
	/ni/	63.00	2.06	.040*

*Note: * indicates statistically significant at 95% confidence interval*

4.3.5.2 Comparison between gender within 30-40 age group

Mann-Whitney U test was conducted to examine gender differences among participants aged between 30-40 years (N=30) (Table 4.16). The results indicated no significant gender differences in all parameters ($p > 0.05$)

Table 4.16

Comparison between gender within 30-40 age group

Comparison	Variable	Mann-Whitney U	|Z|	p
Gender within age 30-40 years (N= 30)	/m/	107.00	0.23	.818
	/ma/	90.00	0.94	.349
	/na/	71.00	1.73	.084
	/mi/	94.50	0.75	.455
	/ni/	91.50	0.87	.382

4.3.5.3 Comparison between age within male participants

Mann-Whitney U test was conducted to examine age differences among male participants (N=30) (Table 4.17). The results indicated no significant age differences in all parameters ($p > 0.05$)

Table 4.17

Comparison between age within male participants

Comparison	Variable	Mann-Whitney U	|Z|	p
Age within male participants (N= 30)	/m/	111.000	0.063	0.950
	/ma/	72.000	1.682	0.093
	/na/	76.500	1.495	0.135
	/mi/	104.000	0.354	0.723
	/ni/	111.500	0.042	0.967

4.3.5.4 Comparison between age within female participants

Mann-Whitney U test was conducted to examine age differences among male participants (N=30) (Table 4.18). The results indicated no significant age differences in all parameters ($p > 0.05$)

Table 4.18

Comparison between age within female participants

Comparison	Variable	Mann-Whitney U	|Z|	p
Age within female participants (N= 30)	/m/	98.500	0.588	0.556
	/ma/	82.500	1.246	0.213
	/na/	93.000	0.810	0.418
	/mi/	83.500	1.206	0.228
	/ni/	85.500	1.124	0.261

4.4 Summary Table

Table 4.19 provides a complete summary of the overall normative nasalance values for Bengali language for 20-40 year old adults (N= 60 participants).

Table 4.19

Normative nasalance values for Bengali language for 20-40 year old adults (N= 60)

Variable	Gender	Mean	SD	Lower Bound	Upper Bound
/a/	**M**	14.63	5.50	8.00	24.00
	F	17.67	6.17	8.00	31.00
/i/	**M**	16.33	6.04	4.00	27.00
	F	23.10	7.90	6.00	37.50
/m/	**M**	90.53	7.37	71.50	96.00
	F	90.33	8.12	66.50	95.50
/pa/	**M**	13.23	3.54	8.50	19.50
	F	11.13	3.08	5.50	18.00
/ka/	**M**	12.33	2.67	7.50	17.50
	F	11.53	4.01	6.50	21.50
/sa/	**M**	11.17	3.04	7.00	17.50
	F	10.43	3.04	5.00	16.00
/ʃa/	**M**	9.96	3.07	5.00	16.00
	F	9.70	2.96	4.50	14.50
/pi/	**M**	11.80	4.05	6.50	20.50
	F	17.17	7.08	4.50	28.50

Variable	Gender	Mean	SD	Lower Bound	Upper Bound
/ki/	**M**	13.40	4.18	7.50	22.00
	F	18.87	6.69	5.00	29.50
/si/	**M**	12.83	4.51	7.00	23.00
	F	18.10	6.79	4.50	27.50
/ʃi/	**M**	10.86	4.33	4.50	19.00
	F	16.96	6.71	4.00	26.00
/ma/	**M**	53.70	10.01	28.00	67.50
	F	57.37	9.69	41.50	74.00
/na/	**M**	57.63	7.49	46.50	72.50
	F	61.17	8.92	43.50	73.00
/mi/	**M**	74.93	9.27	52.50	87.00
	F	78.70	8.32	61.50	89.50
/ni/	**M**	76.50	8.14	58.50	88.50
	F	80.07	8.72	62.00	91.50
OW	**M**	11.15	2.54	6.90	15.30
	F	10.93	3.20	6.20	17.80
NW	**M**	57.53	6.21	41.60	64.60
	F	60.95	5.86	47.30	68.40
OS	**M**	12.28	2.09	7.75	15.92
	F	14.13	5.75	5.75	25.92
NS	**M**	38.46	5.81	26.80	48.40
	F	42.32	4.78	31.30	49.40

Note: OW- Oral words, NW- Nasal words, OS- Oral sentences, NS- Nasal sentences, SD- Standard Deviation, M- Male, F- Female

CHAPTER V

DISCUSSION

Nasalance is defined as the ratio of nasal to oral-plus-nasal acoustic energy that is obtained from two microphones (Ruth et al., 2019). Girish et al. (2021) emphasised on the importance of language background during the assessment and management of resonance disorders. Multiple normative studies have been conducted in various languages across the world, including including English (Seaver et al., 1991), Danish (Van de Weijer & Slis, 1991), Japanese (Tachimura et al., 2000), Flemish (Van Lierde et al., 2001), and Arabic (Natour et al., 2020), as well as Indian languages such as Marathi (Nandurkar, 2002), Tamil (Sunitha et al., 2005), Hindi (Meshram & Pushpavathi, 2012), and Kannada (Jazeera & Manasa, 2025). The present study aimed to establish normative nasalance values for Bengali language for Bengali speaking adults aged between 20-40 years.

The primary objectives of the study are discussed under the following objectives:

5.1 Establishing nasalance norms for Bengali-speaking children using the Nasometer II 6500 model

5.2 Evaluating the effect of age on nasalance values for Bengali-speaking adults aged between 20-30 years and 30-40 year adults

5.3 Evaluating the effect of gender on nasalance values for Bengali-speaking adults aged between 20-40 years

5.4 Evaluating the effect of vowel context for nasalance values of oral and nasal syllables

5.1 Establishing nasalance norms for Bengali-speaking children using the Nasometer II 6500 model

The present study aimed to establishing normative nasalance values for various speech tasks for Bengali-speaking adults aged between 20-40 years, including phoneme prolongation tasks, syllable repetition tasks, word and sentence repetition tasks. A total of 60 Bengali-speaking adults (30 Male, 30 Female) aged between 20-40 years were considered for this study. Table 4.19 gives a summarised account for the mean nasalance values along with the standard deviations for each speech task for males and females for the age group for Bengali language, including both oral and nasal stimuli.

Table 4.19 reveals a greater difference between upper and lower boundary values occuring for nasal stimuli compared to oral stimuli. This finding is supported by Girish et al. (2021), where broader score ranges were observed for nasal sentences (54.68±6.74 for native Kannada speakers, and 60.53±5.45 for native Malayalam speakers) than oral sentences (15.22 ±5.73 for native Kannada speakers and 20.03±7.53 for native Malayalam speakers), as well as by Bessman et al (2014), who compared nasalance values for nasometer models 6200 and 6450, and found variability in scores increased with the proportion of nasal consonants in the sentence. A possible reason for this could be the fact that the nasal phonemes in nasal stimuli create a stronger anticipatory coarticulatory effect on the preceding oral phonemes due to anticipatory opening of velopharyngeal port during the preceding vowels (Kent et al., 1974) as well as a stronger perseveratory coarticulatory effect on the adjacent phoneme compared to oral phonemes, as observed by Ali et al.,1979, who observed Nasal airflow was found on fricatives that followed nasal consonants, which is theorised to occur due to greater inertia of velopharyngeal muscles. Hence it supports the findings of the study that there is more variability in nasalance values for nasal stimuli and syllables with high vowel /i/.

5.2 Evaluating the effect of age on nasalance values for Bengali-speaking adults aged between 20-30 years and 30-40 year adults

Normative nasalance studies on adults (participants aged above 18 years) rarely evaluate the effect of age on nasalance values. A study by Xu et al. (2019) evaluated nasality changes with age in 180 healthy adult Korean speakers for oral, oronasal and nasal passages, and found no significant correlation ($p > 0.05$) between nasalance score for oral passage without nasal consonants and age, whereas nasalance scores for oronasal passage and nasal passage containing nasal consonants decreased with age. The authors postulated these changes as occuring primarily due to the decreasing opening function of the velopharyngeal sphincter with age, thus resulting in reduced nasality during production of nasal consonants in the ≥60 years age range (59.03±6.12) compared to the 20-29 age range (65.67±5.04).

The present study finds no significant difference in nasalance values for Bengali-speaking adults in age ranges 20-30 years and 30-40 years for oral stimuli ($p > 0.05$ for all categories of oral stimuli) as well as for nasal stimuli ($p > 0.05$ for all categories of nasal stimuli). A possible reason for this finding could be because the age related anatomical changes in nasal and velopharyngeal mechanism are often much less during the age range of 20-40 years, as supported by Shastri et al. (2021), who found just significant difference in nasal breadth ($p = 0.031$, $p < 0.05$) and nasal index ($p = 0.024$, $p < 0.05$) for only males of age 20-30 years and 30-40 years, while all nasal dimensions assessed in the study (nasal height, nasolabial angle) revealed non-significant differences for males and females between the two age groups ($p > 0.05$), in addition to no significant differences being observed for nasal height ($p = 0.453$, $p > 0.05$) and nasal index ($p = 0.034$, $p \sim 0.05$) in females of age groups 20-30 years and 30-40 years. Both these studies support the findings of the current study that there is no significant effect of age on nasalance between the ages of 20-40 years.

5.3 Evaluating the effect of gender on nasalance values for Bengali-speaking adults aged between 20-40 years

The present study reveals mixed findings on comparing the mean nasalance scores across both genders. Stimuli like /a/ prolongation and oral syllables with /a/ vowel show no significant difference across both genders ($p > 0.05$), except for /pa/ repetition, which shows a significant difference across both genders ($p = 0.021$, $p < 0.05$). Significant gender difference is observed for nasal words ($p = 0.038$, $p < 0.05$) and nasal sentences ($p = 0.008$, $p < 0.05$), however no significant gender differences are found for oral words and oral sentences ($p > 0.05$). Also, statistically significant effect of gender on nasalance values for /i/ prolongation as well as syllable repetition for oral syllables containing /i/ vowel ($p < 0.05$). For nasal stimuli, no significant difference was found for prolongation of /m/ as well as repetition of syllables /ma/ and /na/, wheras significant gender differences were observed for repetition of syllables /mi/ ($p = 0.041$, $p < 0.05$) and /ni/ ($p = 0.040$, $p < 0.05$). These findings are in agreement with several other normative nasometry studies, where significant differences have been observed in nasalance occuring across gender for adults, including Jayakumar & Pushpavathi (2005), McKerns & Bzoch (1970), Seaver et al. (1991), Leeper et al. (1992), Nichols (1999), Van Lierde et al. (2001), Prathanee et al. (2003), Sunitha et al. (2005), Devi & Pushpavathi (2009), Kuppusamy et al. (2013), and Maturo et al. (2017) . In most of these studies, the nasalance scores were higher for females than for males.

A probable reason for the same could be the underlying anatomical and physiological differences related to velopharyngeal closure across gender (Jayakumar & Pushpavathi, 2005). Jordan et al. (2017) performed magnetic Resonance Imaging (MRI) studies on 38 participants (20 male, 18 female) aged between 19-32 years in order to investigate differences between velopharyngeal closure patterns, and their associated anatomical causes between the two genders. They found significant differences in nasopharyngeal length ($p = 0.010$, $p < 0.05$), velar

length (p= 0.013, p <0.05), adenoid thickness (p= 0.004, p <0.05) and nasopharyngeal width (p= 0.003, p <0.05), with males demonstrating significantly larger values compared to females across most values except adenoid thickness, where females demonstrated larger thickness values (3.83 ± 2.28 mm) compared to males (1.57 ± 2.15 mm). Both these studies support the findings of the present study that gender has a significant effect on nasalance values for adults aged between 20-40 years.

5.4 Evaluating the effect of vowel context for nasalance values of oral and nasal syllables

The present study reveals oral syllables with /i/ vowel combinations having mean nasalance values that are consistently higher than oral syllables with /a/ vowel combinations, with values ranging from 9.86± 2.85 (/ʃa/ repetition, males) to 13.23±3.54 (/pa/ repetition, females) for /a/ combinations, to values ranging from 10.86±4.33 (/ʃi/ repetition, males) to 17.17±7.08 (/pi/ repetition, females) for /i/ combinations. Similarly, higher mean nasalnce values have also been observed for nasal syllables with /i/ combinations compared to nasal syllables with /a/ combinations, with values ranging from 53.70±10.01 (/ma/ repetition, males) to 61.17±8.92 (/na/ repetition, females) for /a/ combinations, to values ranging from 74.93±9.27 (/mi/ repetition, males) to 80.07±8.72 (/ni/ repetition, females) for /i/ combinations.

Lewis et al. (2000) studied 19 children with velopharyngeal dysfunction (VPD) and 19 children without history of communication disorder, where the participants had to produce vowels /i/, /u/, /æ/, and /a/ in isolation, as well as five sentences, out of which four were loaded with High Front, High Back, Low Front, or Low Back vowels, and the fifth sentence contained a mixture of vowel types. The results revealed mean nasalance score for the High Front vowel stimulus was significantly greater (20±9.40 for non-VPD group) than that obtained from the High Back (10±7.04), Low Front (10±7.01), and Low Back vowel (10±10.27) stimuli.

However, the authors did not provide any possible explanation for this observation (Lewis et al., 2000).

Ha & Cho (2015) studied the effect of age, vowel context and stimulus length on nasalance scores for normal Korean-speaking children and adults. A total of 57 children aged between four to six years, as well as 17 adults were considered for the study, and the mean nasalance scores were ontained for eight oral sentences with vowel /a/ and /i/ contexts, with their lengths ranging from 4-31 syllables. Results revealed higher nasalance scores for the vowel /i/ contexts than for the vowel /a/contexts for all speakers, irrespective of age or length of sentence. The authors attributed that to acoustic characteristics of high vowels, which show lower oral intensity and higher nasal intensity compared to low vowels (Stevens, 1961). Therefore, high vowels induced an increased ratio of nasal acoustic energy and ultimately increased nasalance scores (Ha & Cho, 2015). These studies support the findings of the current study that the vowel context, whether low vowel like /a/ or high vowel like /i/ has an effect on the nasalance values.

CHAPTER VI

SUMMARY AND CONCLUSION

Nasalance is defined as the ratio of nasal to oral-plus-nasal acoustic energy that is obtained from two microphones (Ruth et al., 2019). Girish et al. (2021) emphasised on the importance of language background during the assessment and management of resonance disorders. The present study aimed to develop and validate a set of oral and nasal stimuli including words and phrases and to use them to estimate normative nasalance values for Bengali-speaking adults aged between 20-40 years.

The first objective of the present study was to develop and validate a set of oral and nasal stimuli including words and phrases and to use them to estimate normative nasalance values for Bengali-speaking adults aged between 20-40 years. For this purpose, a set of 10 oral words, 10 nasal words, 10 oral sentences and 10 nasal sentences were developed in Bengali language. The developed stimuli were given to a group of five experienced SLPs and three linguists who are proficient in Bengali language for content validation. For oral stimuli (words and sentences), the stimuli that received the highest perceptual ratings by the content validators in terms of strength of pressure consonants were selected, and for nasal stimuli the stimuli that received highest ratings in terms of strength of nasal resonance were selected. A total of five oral words, five nasal words, six oral sentences, and five nasal sentences were selected for final test administration. The list of all developed words and sentences as well as the finalised list of words and sentences are given in Tables 7 to 14 in Appendix 5.

The second objective of the study was to establish normative nasalance values for Bengali-speaking adults aged between 20-40 years. For this purpose, 60 healthy bengali speaking adults (30 males, 30 females) without any speech or language complaints were taken across two age groups (20-30 years and 30-40 years), with equal distribution of age and gender.

The participants had to perform phoneme prolongation tasks, syllable repetition tasks, followed by word and sentence repetition tasks for both oral and nasal stimuli. The consolidated results of mean nasalance along with the standard deviations for each stimuli are summarised in Table 4.19 in Results section. Overall mean nasalance values were observed to be higher for females than for male participants, a fact that can be attributed to anatomical differences in the velopharyngeal mechanisms between the two genders (Jordan et al., 2017)

The third objective of the study was to estimate the effect of age and gender on nasalance scores for bengali-speaking adults of 20-40 years age. For this purpose, Shapiro-Wilk's test of normality was performed for all data using SPSS software version 26.0. Two-way multivariate ANOVA was conducted for oral phonemes, oral syllables as well as oral and nasal words and sentences as the data was normally distributed for these parameters. The oral parameters were compared for effect of age and effect of gender seperately using one-way ANOVA, and the interaction effect of age and gender was analysed using two-way multivariate ANOVA. The data for nasal phoneme /m/ and nasal syllables were found to be non-normally distributed, hence non-parametric test Mann-Whitney U test was performed to compare the effect of age across both genders and the effect of gender across both age groups. The results reveal no significant differences due to age for all the stimuli ($p > 0.05$) . Significant differences were observed across gender for oral as well as nasal syllables with /i/ context ($p = 0.041$ and $p = 0.040$ for /mi/ and /ni/ respectively), as well as in nasal words ($p = 0.038$) and nasal sentences ($p = 0.008$), whereas no significant differences were observed across age groups for oral and nasal syllables with /a/ context. The findings are in agreement to Ha & Cho (2015), who found higher nasalance scores for the vowel /i/ contexts than for the vowel /a/contexts for all speakers, irrespective of age or length of sentence, and attributed this to high vowels inducng an increased ratio of nasal acoustic energy and ultimately increased nasalance scores.

Overall, the present study added to the evidence base for age and language specific normatives for nasalance values for Bengali-speaking adults aged between 20-40 years. The findings of the study add to the existing evidence bases supporting the fact that no significant differences occur in nasalance for adults across 20-30 years and 30-40 years age group, as well as supporting the need for gender-specific norms for adults. The findings of the study also highlight the effect of the adjacent vowel context on the nasalance values for syllable repetitions.

6.1 Implications of the study

The implications of the present study are as follows:

- The present study resulted in the development of a set of language-specific oral and nasal stimuli (words and sentences) for Bengali language
- The established data is crucial for the objective assessment of resonance Bengali-speaking adults in the 20-40 years age range having resonance disorders, and can be used for the purposes of calculation of percentage of speech disability for Bengali-speaking adults with obligatory hypernasality due to CLP.
- The results of the present study can aid in clinical decision making regarding further treatment for Bengali-speaking adults with obligatory hypernasality
- The present study establishes norms in Bengali language for nasalance literature, filling the research gap of eighteen years since last study on Bengali population
- The present study provides nasalance norms for Bengali language with the latest model of the nasometer, Nasometer II 6500, making the results more relevant according to technological advancements.
- It provides a baseline for future research on the disordered population or on comparative studies in Bengali language.

6.2 Limitations of the study

The present study has a few limitations, including the following:

- As the present study was done outside West Bengal, fewer participants could be recruited for the study, which might have led to more variability in nasalance for a few parameters.
- Due to limited availabilty of Bengali-speaking adult participants in and around the institution area, the effect of dialectal variations could not be controlled in the present study.
- Comparison could not be done for typical versus disordered population due to limited availabilty of Bengali-speaking adult participants in and around the institution area.
- The present study leaves a research gap in the normatives for children speaking Bengali language, who are more likely to seek treatment for resonance disorders.

6.3 Future directions

The following areas could be explored in the future:

- Nasalance normatives can be explored for Bengali-speaking children
- Nasalance normatives can be explored for Bengali-speaking adults over the age of 60 years, to explore the changes occuring in nasal and oral resonance due to advanced age.
- Comparative studies can be done exploring the differences of nasalance values for Bengali-speaking children and adults
- Normative values of nasalance can be compared across different models of the Nasometer for the same participants
- Comparative studies can be done exploring nasalance for different populations with resonance disorders, including CLP, dysarthria, hearing impairment

REFERENCES

Awan, S. N., & Virani, A. (2013). Nasometer 6200 versus nasometer ii 6400: Effect on measures of nasalance. *The Cleft Palate Craniofacial Journal*, *50*(3), 268–274. https://doi.org/10.1597/11-219

Banerjee, S. & Sarkar, M. (2010). Development of pressure consonant articulation drill material in Bengali (DRILART-B) for children with repaired CLP (Dissertation No. 2629) [Master's dissertation, West Bengal University of Health Sciences]

Barman, B. (2009). A contrastive analysis of English and Bengali phonemics. *Dhaka University Journal of Linguistics*, *2*(4), 19–42. https://doi.org/10.3329/dujl.v2i4.6898

Bengali Structure. (n.d.). http://lisindia.ciil.org/Bengali/Beng_struct.html

Bhattacharya, N. (2021). CLP-will India ever be able to resolve the problem? *IP Indian Journal of Anatomy and Surgery of Head, Neck and Brain*, *7*(3), 71–72. https://doi.org/10.18231/j.ijashnb.2021.018

Bressmann, T., & Tang, B. H. Y. (2024). Differences in nasalance values obtained with different Nasometer headsets. *Clinical Linguistics & Phonetics*, 1–11. https://doi.org/10.1080/02699206.2024.2305118

Chatterji, S. K. (1921). Bengali phonetics. *Bulletin of SOAS*, *2*(1), 1–25. https://doi.org/10.1017/S0041977X0010179X

Das, M., Saha, N., Zahir, S., & Santra, A. (2023). A retrospective study on clinical and epidemiological profile of nonsyndromic CLP patients admitted in a large Comprehensive Cleft Care Centre in West Bengal, India. *Journal of Cleft Lip Palate and Craniofacial Anomalies*, *10*(1), 9 https://doi.org/10.4103/jclpca.jclpca_19_22

Das, S. & Manasa, A.S. (2024). Comparison of nasalance in native and non-native Kannada speakers (Dissertation No. 1793) [Master's dissertation, University of Mysore]. All India Institute of Speech and Hearing Institutional Repository

Dash, N. S. (2015). *A descriptive study of Bengali words*. Cambridge University Press.

De Boer, G., & Bressmann, T. (2014). Comparison of nasalance scores obtained with the nasometers 6200 and 6450. *The Cleft Palate Craniofacial Journal*, *51*(1), 90–97. https://doi.org/10.1597/12-202

Girish, K. S., Pushpavathi, M., & Satish, H. V. (2021). Influence of native language on Nasalance values in Kannada and Malayalam speakers. *Journal of Cleft Lip Palate and Craniofacial Anomalies*, *8*(2), 111–118. https://doi.org/10.4103/jclpca.jclpca_33_20

Ha, S., & Cho, S. (2015). Nasalance scores for normal Korean-speaking adults and children: Effects of age, vowel context, and stimulus length. *International Journal of Pediatric Otorhinolaryngology*, *79*(8), 1235–1239. https://doi.org/10.1016/j.ijporl.2015.05.019

Jayakumar, T. & Pushpavathi, M. (2005). Normative score for nasometer in Kannada (Dissertation No. 540) [Master's dissertation, University of Mysore]. All India Institute of Speech and Hearing Institutional Repository

Jordan, H. N., Schenck, G. C., Ellis, C., Rangarathnam, B., Fang, X., & Perry, J. L. (2017). Examining velopharyngeal closure patterns based on anatomic variables. *Journal of Craniofacial Surgery*, *28*(1), 270–274. https://doi.org/10.1097/SCS.0000000000003284

Kadisonga, P. & Jayakumar, T. (2016). Norms for nasalance score in adult Manipuri speakers (Dissertation No. 1161) [Master's dissertation, University of Mysore]. All India Institute of Speech and Hearing Institutional Repository

Kar, Somdev and Truckenbrodt, Hubert. "Syllable structure and stratification in Bengali " *Journal of South Asian Languages and Linguistics*, vol. 6, no. 1, 2019, pp. 1-25. https://doi.org/10.1515/jsall-2019-2008

Kummer, A. W. (2005). *(PDF) The MacKay-Kummer SNAP Test-R Simplified Nasometric Assessment Procedures Revised 2005*

Kummer, A. W. (2020). Cleft palate and craniofacial conditions: A comprehensive guide to clinical management. *Cleft Palate and Craniofacial Conditions: A Comprehensive Guide to Clinical Management*, 51-72,94-96,454-70.

Kuppusamy, G., Sankar, G. & Mariswamy, P. (2013). NORMATIVE NASALANCE VALUES ACROSS STIMULI AND GENDER IN MALAYALAM SPEAKING INDIVIDUALS. Otolaryngology Online Journal. 3. 85-98.

Lewis, K. E., Watterson, T., & Quint, T. (2000). The effect of vowels on nasalance scores. *The Cleft Palate Craniofacial Journal*, *37*(6), 584–589. https://doi.org/10.1597/1545-1569_2000_037_0584_teovon_2.0.co_2

Meshram, N. & Pushpavathi, M. (2012). Normative nasalance in Hindi language (Dissertation No. 906) [Master's dissertation, University of Mysore]. All India Institute of Speech and Hearing Institutional Repository

Murlidhar, B. & Pushpavathi, M. (2013). Correlation and reliability of nasalance distance, nasalance ratio, mean nasalance value (Dissertation No. 962) [Master's dissertation, University of Mysore]. All India Institute of Speech and Hearing Institutional Repository

Parker, Andrew J., Clarke, P. M., Dawes, P. J., & Maw, A. R. (1990). A comparison of active anterior rhinomanometry and nasometry in the objective assessment of nasal obstruction. *Rhinology*.

Pereira, V. J., Ching, E. S.-M., She, J. H.-M., Yu, W. S., Lau, K., Tong, M. C.-F., & Lee, K. Y.-S. (2025). Effect of age and gender on nasalance across the lifespan: A systematic review. *The Cleft Palate Craniofacial Journal*, *62*(10), 1774–1801. https://doi.org/10.1177/10556656241276675

Reshma, O. & Jayakumar, T. (2020). Relationship between nasalance and acoustic voice quality index (Dissertation No. 1460) [Master's dissertation, University of Mysore]. All India Institute of Speech and Hearing Institutional Repository

Shailat, R. & Kumar, S. (2008). Development and standardization if test materials in Bengali for measurement of nasalance (Dissertation No. 1659) [Master's dissertation, West Bengal University of Health Sciences]

Saha, S. N., & Mandal, S. K. D. (2018). Phonetic realization of English lexical stress by native (L1) Bengali speakers compared to native (L1) English speakers. *Computer Speech & Language*, *47*, 1–15. https://doi.org/10.1016/j.csl.2017.06.006

Sameer ud Dowla Khan (2010). Bengali (Bangladeshi Standard). Journal of the International Phonetic Association, 40, pp 221-225 doi:10.1017/S0025100310000071

Shadi, M. S., Hegazi, M. A., Ghandour, H. H., Othman, N. M., & Khaled, D. M. (2022). Patterns of velopharyngeal closure during speech in individuals with normal habitual resonance: A nasoendoscopic analysis. *Auris Nasus Larynx*, *49*(6), 995–1002. https://doi.org/10.1016/j.anl.2022.04.002

Shastri, D., Tandon, P., & Singh, A. (2021). Nasal changes in different age groups. *National Journal of Maxillofacial Surgery*, *12*(3), 367–371. https://doi.org/10.4103/njms.NJMS_246_20

She, J. H.-M., Ching, E. S.-M., Yu, W. S., Lee, K. Y.-S., Tong, M. C.-F., & Pereira, V. J. (2024). Cross-linguistic nasalance comparisons: A review of speech sample sets and preliminary consideration of effect of lexical tone. *Folia Phoniatrica et Logopaedica*, 1–21. https://doi.org/10.1159/000541513

Teena, P. & Pushpavathi, M. (2007). Protocol for the assessment of speech in individuals with CLP (Dissertation No. 610) [Master's dissertation, University of Mysore]. All India Institute of Speech and Hearing Institutional Repository

Xu, J., Kang, Y.-A., Park, S.-K., Yoon, Y. H., Bai, S. J., Jin, Y. D., Kim, Y. M., & Rha, K.-S. (2019). Nasality changes with age in normal korean-speaking adults. *Clinical and Experimental Otorhinolaryngology*, *12*(1), 95-99 https://doi.org/10.21053/ceo.2018.00717

Watterson, T., Lewis, K. E., & Foley-Homan, N. (1999). Effect of stimulus length on nasalance values. *The Cleft Palate Craniofacial Journal*, *36*(3), 243–247. https://doi.org/10.1597/1545-1569_1999_036_0243_eoslon_2.3.co_2

Watterson, T. (2020). The use of the nasometer and interpretation of nasalance values. *Perspectives of the ASHA Special Interest Groups*, *5*(1), 155–163. https://doi.org/10.1044/2019_PERSP-19-00029

APPENDIX- 1

Ethical Clearance from AIISH-IRB

All India Institute of Speech and Hearing
(An autonomous Institute under the
Ministry of Health and Family Welfare, Govt. of India)
Center of Excellence - Assessed & Accredited by NAAC with 'A' Grade
ISO 9001:2015 Implemented Institute
Manasagangothri, Mysuru-570006

ಅಖಿಲ ಭಾರತ ವಾಕ್ ಮತ್ತು ಶ್ರವಣ ಸಂಸ್ಥೆ
ಮಾನಸಗಂಗೋತ್ರಿ, ಮೈಸೂರು-570006
अखिल भारतीय वाक् श्रवण संस्थान
मानसगंगोत्री, मैसूरु - 570 006

INSTITUTE REVIEW BOARD (IRB) APPROVAL FOR BIO-BEHAVIOURAL RESEARCH PROPOSAL INVOLVING HUMAN SUBJECTS AT AIISH

AIISH Institute Review Board (IRB)

Ref: SH/IRB/M.5/SLP.38/2025-26 **Date: 11.03.2026**

Title of the Dissertation	: Nasometer scores for Bengali-speaking adults using Nasometer II 6500
Name of the Student	: Ms. Srijita Bhattacharjee
Guide	: Ms. Manasa A. S.
Co-Guide (if any)	: Nil
Proposed Duration of the Project	: 06 months
Source of funding	: Non-funded Master's dissertation
Estimated budget	: Nil
Reference Number of the Project	: Nil
Date on which the IRB meeting was held	: 05.03.2026
A clear statement of the decision reached IRB meeting (In the vent of the proposal is not APPROVED, a statement of reasons for the same must be indicated)	**: APPROVED**
Advice & suggestions (if any)	: Nil

Signature & Name of the Member Secretary-IRB
Dr. Animesh Barman
Professor of Audiology
All India Institute of Speech and Hearing, Mysore-570006

सदस्य सचिव / Member Secretary
संस्थागत समीक्षा बोर्ड
Institutional Review Board
अखिल भारतीय वाक् श्रवण संस्थान
All India Institute of Speech and Hearing
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APPENDIX- 2

Informed Consent Form

All India Institute of Speech & Hearing

Manasagangothri, Mysuru-570006

Informed Consent

Title of the Study: Nasalance values for Bengali Speaking Adults using Nasometer II 6500

Investigator: Srijita Bhattacharjee, MSc Speech-Language Pathology (SLP) Student, doing under the guidance of Ms. Manasa A S, Assistant professor in Speech Pathology at All India Institute of Speech and Hearing (AIISH), Manasagangothiri, Mysore -570006.

Purpose of the Study:

To establish normative nasalance data for Bengali-speaking adults using the Nasometer II 6500. This data will aid SLPs in assessing resonance disorders and improving clinical outcomes.

Participant inclusion criteria:

- Native Bengali speaker aged between 20-40 years
- Normal oral structure and function and scores normal intelligibility in AYJNIHH rating scale.
- Able to comfortably read standard Bengali script

Participant exclusion criteria:

- Participants with structural or functional deficits to their speech mechanism
- Participants with linguistic or cognitive deficits

Proccdures:

The data collection of nasalance values will be done using the Nasometer II 6500 model, a device that measures nasal and oral energy in speech. It is a **non-invasive procedure** to measure the nasalance in the individual's speech which will further be analysed and standardized as normative scores for clinical purposes.

To assess the nasalance, you will be seated comfortably in a quiet room and placed with a nasal-oral separator plate above the upper lip, where the microphones are mounted to capture the sound energy. You will be asked to follow the clinician's instruction that is to prolong a few sounds and repeat the words and sentences one after the other following the clinician. The testing may take approximately 15-30 minutes. All collected data will remain confidential and used only for research purposes.

পদ্ধতি :

Nasometer II 6500 মডেল ব্যবহার করে Nasalance স্কোরের ডেটা সংগ্রহ করা হবে, একটি ডিভাইস যা বক্তৃতায় অনুনাসিক (Nasal) এবং মৌখিক (Oral) শক্তি পরিমাপ করে। এটি ব্যক্তির বক্তৃতায় অনুনাসিকতা পরিমাপ করার জন্য একটি **non-invasive** পদ্ধতি যা আরও বিশ্লেষণ করা হবে এবং ক্লিনিকাল উদ্দেশ্যে আদর্শ স্কোর হিসাবে মানক করা হবে।

Nasalance মূল্যায়ন করার জন্য আপনাকে একটি শান্ত ঘরে আরামে বসতে হবে এবং উপরের ঠোঁটের উপরে একটি অনুনাসিক-মৌখিক বিভাজক প্লেট দিয়ে রাখা হবে, যেখানে শব্দ শক্তি ক্যাপচার করার জন্য মাইক্রোফোনগুলি মাউন্ট করা হয়েছে। আপনাকে চিকিত্সকের নির্দেশ অনুসরণ করতে বলা হবে যা হল কয়েকটি শব্দ দীর্ঘায়িত করা এবং চিকিত্সকের অনুসরণ করে একের পর এক শব্দ এবং বাক্য পুনরাবৃত্তি করা। পরীক্ষায় প্রায় 15-30 মিনিট সময় লাগতে পারে। সমস্ত সংগৃহীত তথ্য গোপন থাকবে এবং শুধুমাত্র গবেষণার উদ্দেশ্যে ব্যবহার করা হবে।

Voluntary Participation and Right to Withdraw:

Your participation in this study is completely voluntary, and you can choose to withdraw at any point of the study without any consequences.

এই অধ্যয়নে আপনার অংশগ্রহণ সম্পূর্ণরূপে স্বেচ্ছাসেবী, এবং আপনি অধ্যয়নের যে কোন সময়ে প্রত্যাহার করতে পারেন।

Potential Benefits and Risks:

There are no direct benefits to the participants. This study aims to contribute valuable data that could improve clinical purpose in the field of speech sciences, assessment and management of children with resonance disorders. There are no anticipated risks associated with participation in this study.

অংশগ্রহণকারীদের সরাসরি কোন সুবিধা নেই। এই অধ্যয়নের লক্ষ্য মূল্যবান ডেটা প্রদান করা যা বক্তৃতা বিজ্ঞান, অনুরণন ব্যাধিযুক্ত শিশুদের মূল্যায়ন এবং পরিচালনার ক্ষেত্রে ক্লিনিকাল উদ্দেশ্যকে উন্নত করতে পারে। এই গবেষণায় অংশগ্রহণের সাথে সম্পর্কিত কোন প্রত্যাশিত ঝুঁকি নেই।

Consent Statement

I acknowledge that I have read and understood the information provided about the study and I was clearly informed about the procedure of the study. I give my voluntary consent to participate for data collection which will be analysed to meet the objectives of the study. I am acknowledging it is a risk-free procedure and the data collected will be utilized for future publishing of the study in respective journals and also to be utilized for paper presentations and conferences. I understand that the participation of the study is entirely voluntary and participation can be withdrawn at any time. I am aware that this study does not involve any monetary benefits only research purpose.

আমি স্বীকার করি যে আমি অধ্যয়ন সম্পর্কে প্রদত্ত তথ্য পড়েছি এবং বুঝেছি এবং অধ্যয়নের পদ্ধতি সম্পর্কে আমাকে স্পষ্টভাবে অবহিত করা হয়েছিল। আমি ডেটা সংগ্রহের জন্য অংশগ্রহণ করার জন্য আমার স্বেচ্ছায় সম্মতি দিই যা অধ্যয়নের উদ্দেশ্য পূরণের জন্য বিশ্লেষণ করা হবে। আমি স্বীকার করছি যে এটি একটি ঝুঁকি-মুক্ত পদ্ধতি এবং সংগৃহীত ডেটা সংশ্লিষ্ট জার্নালে অধ্যয়নের ভবিষ্যতে প্রকাশের জন্য ব্যবহার করা হবে এবং কাগজের উপস্থাপনা এবং সম্মেলনের জন্যও ব্যবহার করা হবে। আমি বুঝতে পারি যে অধ্যয়নের অংশগ্রহণ সম্পূর্ণরূপে স্বেচ্ছাসেবী এবং যে কোনো সময় অংশগ্রহণ প্রত্যাহার করা যেতে পারে। আমি সচেতন যে এই গবেষণায় কোনো আর্থিক সুবিধা জড়িত নয় শুধুমাত্র গবেষণার উদ্দেশ্য।

Date:

Participant’s Name:

Signature:

Investigator's Name: Srijita Bhattacharjee

Signature:

Guide's Name: Ms. Manasa A.S.

Signature:

APPENDIX- 3

Bengali Phonemic Inventory

Figure 1:

Bengali Alphabet Chart

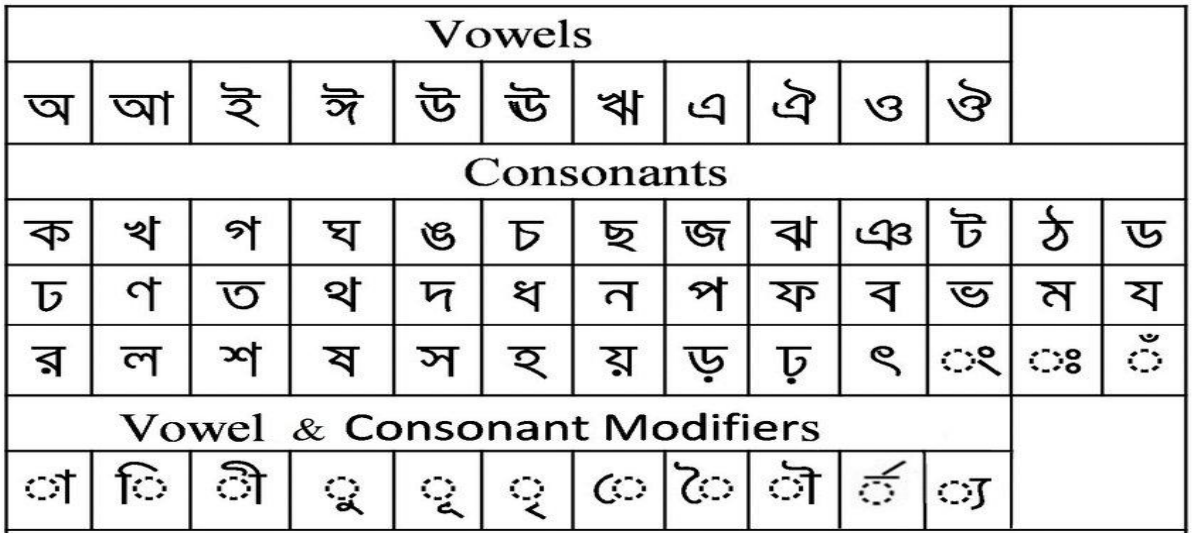

Table 1:

Bengali pure vowels and IPA

Phoneme	Bengali Word	IPA	Meaning
/a/	কান	/ka:n/	ear
/i/	মিল	/mil/	similarity
/e/	পেট	/pet/	stomach
/o/	গোল	/gol/	round
/u/	বুক	/buk/	chest
/ɔ/	বক	/bɔk/	stork
/æ/	ব্যাঙ	/bæŋ/	frog

Table 2:

Bengali Diphthongs with IPA

Glide Direction	Diphthong	Word	Meaning
Towards central-open	/iɑ /	/bɪɑ /	marriage
	/eɑ /	/kʰeɑ /	boat
	/uə/	/bʱuə/	false
	/oə/	/doə/	blessing
Towards back-open	/iɔ/	/ʃiɔr/	head
	/uɔ/	/ʃuɔr/	pig
Towards front-close	/ei/	/nei/	missing
	/ai/	/bʱai/	brother
	/oi/	/moi/	ladder
	/oi/	/oi/	that
	/ui/	/dui/	two
Towards back-close	/ou/	/bou/	bride
	/au/	/lau/	pumpkin
	/eu/	/keu/	someone
	/iu/	/ʃiuli/	a flower
Towards back-middle	/io/	/dio/	give
	/æo/	/næo/	take (imperative)
	/ao/	/dao/	give
	/ɔo/	/kɔo/	tell (imperative)
	/uo/	/kuo/	well / pit
Towards front-middle	/ie/	/bie/	marriage
	/ue/	/ʃue/	sleeping

Table 3:

Bengali consonants with IPA

Manner of Articulation	**Bilabial**	**Dental**	**Alveolar**	**Post-alveolar**	**Palatal**	**Velar**	**Glottal**
Plosive	p, pʰ, b, bʰ	t̪, t̪ʰ, d̪, d̪ʰ	t, d	ʧ, ʤ		k, kʰ, g, gʰ	
Fricative			s	ʃ			h
Nasal	m		n			ŋ	
Lateral			l				
Approximant			r		j		

APPENDIX- 4

Bengali syllabic structures

Table 4

Monosyllabic words in Bengali with light canonical forms

Syllable Structure	Word	IPA	Meaning
CV	কী	/ki:/	'what'
CVC	নীল	/ni:l/	'blue'
V	ও	/o/	'she/he'
VC	আজ	/a:ʤ/	'today'
VV	উই	/ui:/	'termite'

Note: C- Consonant, V- Vowel

Table 5

Monosyllabic words in Bengali with heavy canonical forms

Syllable Structure	Word	IPA	Meaning
CVV	কই	/koi:/	'where'
CCV	শ্রী	/ʃri/	'Mr.'
CCVC	প্রেম	/prem/	'love'
CVVC	বাইশ	/bai:ʃ/	twenty two'

Syllable Structure	Word	IPA	Meaning
CCVV	প্রায়	/prae/	'almost'
CCCV	স্ত্রী	/st̪ri/	'wife'
CCCVC	স্ত্রীর	/st̪rir/	'wife's'
VVC	আইন	/aɪ̯n/	'law'

Note: C- Consonant, V- Vowel

Table 6

Canonical forms in polysyllabic Bengali words

Syllable Structure	Word	IPA	Meaning
CCVVCV	ক্লৈব	/kloɪ̯b.bo/	'timidity'
CVCCCCVCV	সংস্কৃত	/ʃɔŋʃ.krito/	'Sanskrit'
CCCVVC	স্ত্রৈন	/st̪roɪ̯.no/	'henpecked'

Note: C- Consonant, V- Vowel

APPENDIX- 5

ORAL AND NASAL STIMULI

i) Oral Words

A total of ten words in Bengali language loaded with oral pressure consonants were selected and given to a group of five experienced SLPs and three linguists who are proficient in Bengali language for content validation. The following words were shortlisted for the purpose of content validation:

Table 7

List of shortlisted oral words for content validation

Word	IPA representation	Meaning
পাতা	/pa:ʈa:/	Leaf
কলা	/kɔla:/	Banana
টক	/tɔk/	Sour
চাকা	/ʧa:ka:/	Wheel
ঘাট	/gʰa:t/	River bank
কাক	/ka:k/	Crow
গীতা	/gi:ʈa:/	A name
বক	/bɔk/	Crane (bird)
খুশি	/kʰu:ʃi:/	Happy
ধুতি	/ɖʱu:ʈi:/	Dhoti

Out of these ten words, the five words that received the best ratings in majority of parameters were selected for the study. The selected words are given in Table 8.

Table 8

Selected oral words

Word	**IPA representation**	**Meaning**
কলা	/kɔla:/	Banana
টক	/tɔk/	Sour
চাকা	/ʧa:ka:/	Wheel
ঘাট	/gʰa:t/	River bank
কাক	/ka:k/	Crow

ii) Nasal Words

A total of ten words in Bengali language loaded with nasal consonants were selected and given to a group of five experienced SLPs and three linguists who are proficient in Bengali language for content validation. The following words were shortlisted for the purpose of content validation:

Table 9

List of shortlisted nasal words for content validation

Word	IPA representation	Meaning
নুন	/nu:n/	Salt
মায়া	/ma:ja:/	Illusion
মানা	/ma:na:/	Refuse
মুলো	/mu:lo/	Radish
মীন	/mi:n/	Fish
মালি	/ma:li:/	Gardener
নলি	/noli:/	Pipe
মই	/moi:/	Ladder
মণি	/moɳi:/	Gem
নীল	/ni:l/	Blue

Out of these ten words, the five words that received the best ratings in majority of parameters were selected for the study. The selected words are given in Table 10.

Table 10

Selected nasal words

Word	**IPA representation**	**Meaning**
নুন	/nu:n/	Salt
মায়া	/ma:ja:/	Illusion
মানা	/ma:na:/	Refuse
মীন	/mi:n/	Fish
নলি	/noli:/	Pipe

iii) Oral Sentences

A total of ten sentences in Bengali language loaded with oral pressure consonants were developed and given to a group of five experienced SLPs and three linguists who are proficient in Bengali language for content validation. Each sentence had a mean length of utterance of three to four words, amd each sentences has no more than six to ten syllables. Table 11 lists the oral sentences were given for the purpose of content validation.

Table 11

Oral sentences given for the purpose of content validation:

Bengali	IPA	Meaning
বাঘ গুহার ভেতরে থাকে।	/bagʱ guɦar bʱe̪t̪ore t̪ʰake/	The tiger stays inside the cave
ছাগল কচি ঘাস খায়।	ʧʰagol kɔʧi gʱas kʰae/	The goat eats tender grass
গীতা রোজ বই পরে।	/gi/t̪a: rodʒ boi pɔre/	Gita reads books daily
টবে গোলাপ ফুল ফুটেছে	/tɔbe gola:p pʰul pʰuteʧʰe/	A rose has bloomed in the pot
পাখি পাকা ফল পাড়ে।	/pa:kʰi: pa:ka: pʰɔl pa:ɽe/	The bird plucks ripe fruit
টোটা টিটাগড়ে টোটো দেখে।	/tota: ti:ta:gɔɽe toto d̪ækʰe/	Tota (a name) sees a toto (a vehicle) in Titagarh (a town)
কাকু কলা কাটে।	/ka:ku: kɔla: ka:te/	Uncle cuts a banana
বাবা বই বাছে।	/ba:ba: boji: ba:ʧʰe/	Father selects books
চাচা চারটে চা চায়।	/ʧa:ʧa: ʧa:rte ʧa: ʧa:je/	Uncle wants four cups of tea
গীতা গাছ লাগায়।	/gi:t̪a: ga:ʧʰ la:ga:je/	Gita plants trees

Out of these ten sentences, the six sentences that received the best ratings in majority of parameters Strength of pressure consonants and were selected for the study. The selected sentences are listed in Table 12.

Table 12

Selected oral sentences

Bengali	IPA	Meaning
পাখি পাকা ফল পাড়ে।	/pa:kʰi: pa:ka: pʰɔl pa:ɽe/	The bird plucks ripe fruit
টোটা টিটাগড়ে টোটো দেখে।	/tota: ti:ta:gɔɽe toto d̪ækʰe/	Tota (a name) sees a toto (a vehicle) in Titagarh (a town)
কাকু কলা কাটে।	/ka:ku: kɔla: ka:te:/	Uncle cuts a banana
বাবা বই বাছে।	/ba:ba: boji: ba:ʧʰe/	Father selects books
চাচা চারটে চা চায়ে।	/ʧa:ʧa: ʧa:rte ʧa: ʧa:je/	Uncle wants four cups of tea
গীতা গাছ্ লাগায়ে।	/gi:t̪a: ga:ʧʰ la:ga:je/	Gita plants trees

iv) Nasal sentences

A total of ten sentences in Bengali language loaded with nasal consonants were developed and given to a group of five experienced SLPs and three linguists who are proficient in Bengali language for content validation. Each sentence had a mean length of utterance of three to four words, amd each sentences has no more than six to ten syllables. Table 13 gives a list of the ten nasal sentences given for the purpose of content validation

Table 13

Nasal sentences given for the purpose of content validation

Bengali	IPA	Meaning
আমরা মামার বাড়ি যাবো।	/a:mra: ma:ma:r b:aɽi ʤa:bo/	We will go to uncle's house
মামার মাথায় চুল নাই।	/ma:ma:r ma:ʈʰa:je ʧul na:i/	Uncle has no hair on his head
মঙ্গলবার মাঠে মেলা বসবে।	/moŋgolba:r ma:tʰe mela: boʃbe/	On Tuesday a fair will be held in the field
মোহন নাগরদোলায় চড়বে।	/mohon na:gorɖola:je ʧoɽbe/	Mohan will ride on the Ferris wheel
মেয়েটি রোজ নাচ করে।	/mejɛti rodʒ na:ʧ kɔre/	The girl dances everyday
নদীর মাঝে নৌকা চলে।	/nodir ma:dʒe nouka: ʧɔle/	A boat moves in the middle of the river
মামা আম নিয়ে আসবে	/ma:ma: a:m nije a:ʃbe/	Uncle will bring mangoes
নমিতা নাচ করে।	/nomiʈa: na:ʧ kɔre/	Nomita dances
মামা মালদা যাবে।	/ma:ma: ma:lɖa: ʤa:be/	Uncle will go to Malda (a district)
নকুল নদীতে নৌকা চালায়ে।	/nokul noɖiʈe nouka: ʧa:la:je/	Nokul rows a boat in the river

Out of these ten sentences, the five sentences that received the best ratings in majority of parameters were selected for the study. The selected sentences are listed in Table 14.

Table 14

Selected nasal sentences

Bengali	IPA	Meaning
নদীর মাঝে নৌকা চলে।	/nod̪i:r ma:dʒʰe nou:ka: ʧɔle/	A boat moves in the middle of the river
মামা আম নিয়ে আসবে।	/ma:ma: a:m nije a:ʃbe/	Uncle will bring mangoes
নমিতা নাচ করে।	/nomit̪a: na:ʧ kɔre/	Nomita dances
মামা মালদা যাবে।	/ma:ma: ma:ld̪a: ʤa:be/	Uncle will go to Malda (district)
নকুল নদীতে নৌকা চালায়ে।	/noku:l nod̪i:t̪e nou:ka: ʧa:la:je/	Nokul rows a boat in the river