BREATH GROUP MEASUREMENT IN HEALTHY HINDI SPEAKERS USING A NOVEL METHOD FOR READING AND SPONTANEOUS SPEECH

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Registration Number: P01II22S123034

This dissertation is submitted as a part of fulfillment for the degree of Master of Science (Speech Language Pathology)

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July, 2024

CERTIFICATE

This is to certify that dissertation entitled "**Breath group measurement in healthy Hindi speakers using a novel method for reading and spontaneous speech**" is a bonafide work submitted as a part of the fulfillment for the degree of Master of Science (Speech Language Pathology) of the student registration number: P01II22S123034. It has been carried out under the guidance of a faculty of this institution and has not been submitted earlier to any other university for the award of any diploma or degree.

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CERTIFICATE

This is to certify that the dissertation entitled "**Breath group measurement in healthy Hindi speakers using a novel method for reading and spontaneous speech**" has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that the dissertation entitled "**Breath group measurement in healthy Hindi speakers using a novel method for reading and spontaneous speech**" is a result of my own study done under the guidance of Dr. T. Jayakumar, Professor, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysore. This dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore **Registration No.: P01II22S123034**

July, 2024

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to all those who have supported and guided me throughout the journey of completing this dissertation.

First and foremost, I would like to express my gratitude to the director of our institution, **Dr. M Pushpavathi**, for granting me the opportunity to conduct this research.
I am deeply thankful to **Dr. T. Jayakumar**, my guide for this dissertation, for their invaluable guidance and constant encouragement. Their insights and expertise have been instrumental in shaping the direction and quality of my research.

I am also deeply grateful to **Dr. Vasantha Laxmi** for her thoughtful feedback and constructive suggestions on statistics, which significantly enhanced the quality of this work.
Special thanks to my colleagues and friends Moksh for his immense assistance, Bhawna for their good-fellowship during challenging times and Varna, my dissertation partner for keeping up with me. Your support made this journey more enjoyable and less isolating. Special thanks to my junior Manoj for lending his laptop in need. Also, I would like to mention my dearest regards **to all my participants.**

I would also like to acknowledge the resources provided by the Department of clinical sciences which made this research possible. The administrative and technical staff at All India Institute of Speech & Hearing deserve recognition for their assistance and support.

On a personal note, I am eternally grateful to my family. To my parents for their unconditional love, patience, and encouragement. To my dearest V for their understanding and support throughout this endeavor.

Lastly, I thank all those who, in one way or another, contributed to the completion of this dissertation. Your contributions, though not mentioned individually, are deeply appreciated.

Thank you all

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ABSTRACT

Breath groups are discrete units of speech produced within a single expiratory phase, offering insights into the coordination of respiratory and articulatory processes. As fundamental units of speech breathing, characterized by duration and volume, they reveal much about an individual's respiratory and phonatory control. Traditionally, the Phonatory Aerodynamic System (PAS) has been used to estimate breath groups, but it is highly priced, high-maintenance, and requires sterilization after each use, posing an infection risk. This study introduces a novel, cost-effective method using Cervical Auscultation (CA) and aims to validate this method and establish normative data for breath groups in Hindi-speaking adults. Sixty participants, divided into two age groups (20-30 and 31-40 years) and by gender, were assessed using PAS and CA during spontaneous speech and reading tasks. Three temporal parameters were measured: Breath Group Duration (BGD), Inter-Breath Group Pause (IBP) and Inspiratory Duration (ID). Results showed that all breath group parameters were longer during spontaneous speech than reading for both genders and age groups, consistent with previous studies. No significant gender differences were observed for BGD, but males generally exhibited slightly higher IBP and ID, particularly during spontaneous speech, likely due to physiological differences such as larger lung volume and greater vital capacity. Comparison between PAS and CA revealed minimal differences for BGD and IBP, indicating both methods provided similar results. However, CA consistently recorded shorter ID values, suggesting it measures inspiratory duration more conservatively. Correlation analysis confirmed a strong relationship between the two methods, validating CA as an effective alternative to PAS. The study also highlighted the impact of linguistic and cognitive demands on breath group measurements, with

spontaneous speech requiring more cognitive resources and physiological adjustments, resulting in longer breath groups, pauses and inhalations compared to reading tasks.

CHAPTER 1

INTRODUCTION

The respiratory system serves as a consistent source of airflow energy and ensures a stable subglottal air pressure during speech production by effectively regulating the respiratory muscles (Hixon et al., 1976). The demands of speech are likely to impact the management of breathing while speaking. In the context of speech, inspiration typically accounts for only 9% to 19% of the entire breath cycle (Loudon, Lee, & Holcomb, 1988). The typical respiratory pattern observed in speech, involving a swift intake of breath followed by a gradual and controlled exhalation, naturally establishes a breath-related framework for vocal expression. This framework, commonly referred to as the "breath group", encompasses a series of syllables or words spoken within a single breath. The management of these breath groups is a critical element in facilitating efficient and effective communication and achieving optimal vocal performance for both individuals with healthy and disordered speech (Wang et al., 2012). Accumulated evidence underscores a robust link between respiratory mechanisms and cognitive capabilities (Morton and Braakhuis, 2021), physiological requirements (Russo et al., 2017), linguistic adjustments (Winkworth et al., 1995). These characteristics can vary when comparing different speaking tasks, such as reading passages and spontaneous conversation.

A study by Alan Henderson et al. (1965) examined the potential regulator of speech breathing by analysis focused on the sequential temporal arrangement of a spoken English passage, reported that in the reading, the proportion of gaps in speech in which breaths were taken was significantly higher than in spontaneous speech.

However, another study involved speaking activities with two distinct tasks that varied in cognitive-linguistic demands. The first task, called the "No-Outline Task," required spontaneous speaking on a designated topic for about 3 minutes. The second task, the "Outline Task," involved speaking on the same topic while using a prepared written outline, they concluded that the mechanics of speech breathing were generally consistent across different cognitive-linguistic demands, but fluency-related breathing behavior proved to be highly responsive to these demands (Heather et al., 1996).

The temporal aspects of breath groups are also potential parameters to analyze which are typically characterized by their duration, the pauses between breath groups, and the time taken for inspiration. Analyzing these parameters provides insights into the fundamental respiratory pattern involved in speech. Average values for Breath Group Duration (BGD) and Inspiratory duration (ID) for reading and spontaneous speech in healthy speakers in different age-groups and gender have been reported in some studies. For example; A study found the BGD value 3.36 s for reading and 3.84 s for spontaneous speech (Winkworth et al., 1994). The primary distinctions identified when comparing these two conditions were associated with extended breath durations, inappropriate loci of inhalations, and increased variability in breathing patterns during spontaneous speech (Winkworth et al., 1995). Spontaneous speech involves elevated cognitive demands compared to reading (Wang et al., 2010). The length and frequency of pauses during speech are influenced by both the speaking rate and the grammatical structure of the pause location. Non-breathing pauses exhibit a similar pattern of occurrence as breathing pauses but are consistently briefer and predominantly happen at minor constituent breaks (François & Maryann, 1979).

A comprehensive grasp of how these temporal parameters fluctuate depending on the speaking task is yet to be achieved and necessitates systematic exploration using appropriately sensitive techniques in the Indian context. This information can further be helpful in the evaluation and management of various voice and speech disorders such as Dysarthria, Stuttering etc. in both children and the adult population. Furthermore, comprehending the patterning of breath groups plays a crucial role in enhancing the authenticity of speech synthesis. On a broader scale, the arrangement of breath groups offers a wealth of segmental and prosodic signals that listeners rely on to perceive and grasp spoken language (Lieberman, 1967).

This study follows up on previous research regarding breath group detection during passage reading done in western literature. It aims to assess the performance of various detection methods in both spontaneous speech and passage reading, considering differences in breath group patterns between these primary speech production tasks.

Need of the study

There is a lack of evidence on the breath group measurement and various factors affecting these measurements in the Indian context. The measurement of breath groups can be a valuable addition to our therapeutic settings, supporting evidence-based therapy. Traditionally PAS has been used as one of the measurement techniques to estimate breath groups, however, this measurement technique is expensive and high maintenance expenses. Also, PAS requires sterilization after every use, putting the participants at risk of contracting infections from one another if not properly taken care of. Hence, in the present study we have devised the novel method (Cervical auscultation) which is simple, cost effective. Hence, the present study is trying to establish and validate the novel method for breath group and also aim to establish the normative for PAS and the novel method of breath group in the Indian languages.

Aim of the study

To validate novel method for breath group measures for Reading and Spontaneous speech in Healthy Hindi Speaking Individuals.

Objectives of the study

1. To establish normative of breath group parameters using PAS and Cervical auscultation method.
2. To compare the data obtained using both the measurement techniques.
3. To determine the effect of linguistic and cognitive demands on the measurement of the breath group using reading and spontaneous speech tasks.

CHAPTER 2

LITERATURE REVIEW

The Primary role of the respiratory system is to provide oxygen to the body and remove carbon dioxide, which is accomplished through the process of breathing. Whereas speech production is the overlaid function that utilizes the respiratory system to generate audible linguistic output (Connett & Thomas, 2018).

Role of the Respiratory System in Speech Production

Aerodynamic Source of Energy

Aerodynamic Energy Source for speech is provided by the respiratory system, which comprises the lungs, airways, and respiratory muscles (Herman, 2016; Yadav et al., 2023). Specifically, the respiratory muscles generate a pressure gradient that drives airflow through the vocal tract, providing the motive force for sound production (Herman, 2016). The respiratory muscles, including the skeletal muscles of the head and neck as well as the smooth muscles lining the trachea and bronchi, play a crucial role in controlling the caliber of the airway and regulating the flow of air into and out of the lungs (Sieck & Gransee, 2012; Bhat et al., 2021).

Maintenance of Subglottal Air Pressure

The system maintains a roughly constant subglottal air pressure during speech, which is crucial for the consistent production of speech sounds. This requires coordination between the respiratory muscles to provide adequate air flow and regulate laryngeal resistance, which in turn depends on the shape and position of the vocal folds. Proper breath support, characterized by efficient use of air from the lungs to generate adequate subglottic pressure and facilitate healthy, consistent vocal fold vibration, is a key component of effective vocal production (Kishbaugh et al., 2021).

Control of Respiratory Musculature

Precise and ongoing control of the respiratory muscles allows for the modulation of airflow and pressure, accommodating the demands of speech production. This control is achieved through the integration of neural signals from the central respiratory centers, sensory feedback from receptors in the lungs and airways, and voluntary cognitive input from cortical motor areas (Sieck & Gransee, 2012).

Structure and Function of Breath Groups in Speech

Breath Groups & its Importance

Measurement of breathing patterns during speech production can provide valuable insights into respiratory mechanics and control. Specifically, the concept of "breath groups" - discrete units of speech produced within a single expiratory phase offers a window into the coordination of respiratory and articulatory processes. Breath groups are the fundamental units of speech breathing and their characteristics (duration, volume, etc.) can reveal much about an individual’s respiratory and phonatory control (Bhat et al., 2021; Hakim & Usmani, 2014).

Influence of Respiratory and Grammatical Needs

The features of breath groups are governed by both respiratory needs (such as the necessity to breathe) and grammatical structure (such as phrase or sentence boundaries) (Rootberg, 2003). On the respiratory side, the need to replenish air and maintain adequate subglottal pressure influences the duration and frequency of breath groups. On the linguistic side, syntactic structure, phrase boundaries, and semantic considerations all play a role in shaping the placement and characteristics of breath groups. The interaction between these respiratory and linguistic factors results in the observed breath group patterns during connected speech (Rootberg, 2003). Analyzing the characteristics of breath groups is essential, as it can shed light on an individual's respiratory support for speech production and provide insights into the prosodic features, such as phrasing and timing that are integral to natural and effective speech.

Variability across Speaking Tasks

Variability of breath groups across different speaking tasks and contexts further underscores their importance as a window into speech production. The location and duration of breath groups can vary depending on the speaking task. For instance, the demands of reading a passage differ from those of spontaneous speech, leading to variations in breath group patterns.

A study by Alan Henderson et al. (1965) investigated the regulation of speech breathing by analyzing the sequential temporal arrangement of spoken English passages. Their findings indicated a notable difference between reading and spontaneous speech in terms of the proportion of gaps where breaths were taken. Specifically, Henderson et al. reported that during reading tasks, speakers tended to take breaths at a significantly higher rate compared to spontaneous speech. This observation suggests that the structure and demands of the task influence how breaths are strategically integrated into speech. In reading aloud, speakers may take more frequent and controlled breaths, potentially influenced by grammatical pauses, punctuation, and other textual cues present in written passages. In contrast, spontaneous speech often involves more fluid and continuous speech production, where speakers may pause or breathe at different points influenced by immediate communicative needs rather than predetermined structural cues. This distinction highlights the dynamic nature of speech breathing regulation, influenced by both external linguistic factors and internal physiological demands. Understanding these differences is crucial for various applications, including speech pathology, language processing research and the development of natural-sounding speech synthesis systems.

Another study investigated the effects of cognitive-linguistic demands on speech breathing mechanics by examining two distinct speaking tasks. In the first task, referred to as the "No-Outline Task," participants engaged in spontaneous speaking for approximately three minutes on a designated topic without any preparatory material. The second task, known as the "Outline Task," required participants to speak on the same topic but with the assistance of a prepared written outline.

Heather et al. (1996) found that while the fundamental mechanics of speech breathing such as breath group duration and respiratory muscle control remained generally consistent regardless of the cognitive-linguistic demands of the tasks, the fluency-related aspects of breathing behavior were significantly affected. Specifically, the use of a written outline in the Outline Task led to more fluent speech patterns, which in turn influenced breathing behavior, making it more responsive to the cognitive-linguistic demands of the speaking activity.

Characteristics for reading and spontaneous speech breath groups may differ (Rootberg & Kelso, 1984). Breath group length, frequency and temporal features are influenced by both respiratory and linguistic factors (Rootberg, 2003; Kishbaugh et al., 2021). Some studies have explored the impact of postural changes and vocal demands on breath group patterns. For example, teachers who spend long periods lecturing in a standing position may exhibit different breath group patterns than those working from home in a seated position (Kishbaugh et al., 2021). Similarly, the increased vocal demands of teaching compared to casual conversation may lead to distinct breath group profiles.

A study by Winkworth et al. (1995) found that breath group characteristics differed significantly between reading and spontaneous speech, with breath groups being longer and less frequent during reading. The distinct breath group strategies observed in these two tasks can be attributed to the differences in the linguistic and respiratory demands, as the cognitive and physiological requirements for reading aloud versus spontaneous speech production vary considerably.

The temporal characteristics of breath groups, such as their duration, the intervals between them, and the time taken for inhalation, are important parameters to analyze. The temporal aspects of breath groups, comprises three major parameters such as Breath group duration, Inter-breath pause and Inspiratory duration (Wang et al., 2010). Examining these aspects can provide valuable insights into the basic respiratory patterns involved in speech. Certain studies have reported average values for Breath Group Duration (BGD) and Inspiratory Duration (ID) during reading and spontaneous speech in healthy speakers across different age groups and genders.

Table 2.1: *Values of temporal parameters of Breath group across studies*

Study	Age range	Language	Parameter Analyzed	Reading Values	Spontaneous Speech Values	Key Findings
Winkworth et al. (1994)	19-22 yrs	English	Breath Group Duration (BGD)	3.36 seconds	3.84 seconds	BGD for spontaneous speech is longer than for reading.
Winkworth et al. (1995)	19-22 yrs	English	Breath Group Duration, Inhalation Locations, Breathing Pattern Variability	Not specified	Not specified	Spontaneous speech shows extended breath durations, inappropriate inhalation loci, and increased variability in breathing patterns.
Wang et al. (2010)	20-64 yrs	English	Cognitive Demands on Speech	BGD: 4.05 seconds. IBP: 0.64 seconds. ID: 0.54 seconds.	BGD: 4.88 seconds. IBP: 0.69 seconds. ID: 0.57 seconds.	Spontaneous speech task showed significantly more grammatically inappropriate breath group locations and had longer breath group durations compared to the passage reading task.

François & Maryann (1979)	-	French	Non-breathing Pauses	Not specified	Not specified	Non-breathing pauses are shorter and occur mainly at minor constituent breaks, similar in pattern to breathing pauses but consistently briefer

Changes in the temporal characteristics of breath groups, such as shorter breath group durations, longer inter-breath pauses, and decreased inspiratory durations, are commonly observed in individuals with speech and language disorders, such as dysarthria. These breath group alterations can negatively impact speech intelligibility, prosody, and overall communication effectiveness.

Abnormalities in breath group patterns, such as premature termination of breath groups and increased breath group variability, have been documented in individuals who stutter. These disruptions in the coordination of respiratory-phonatory processes can contribute to the characteristic disfluencies and interruptions in the speech flow observed in stuttering. A study by Parkes (2005) found that some individuals with stuttering were able to extend their breath-hold durations through various maneuvers, suggesting a potential avenue for intervention.

Individuals with hearing impairment may also exhibit atypical breath group patterns, potentially due to the disruption of auditory feedback mechanisms that normally guide the coordination of respiration and phonation (Hitos et al., 2013). Another study by Keller et al. (2001) examined the speech characteristics of individuals with Parkinson's disease, finding that deficits in the respiratory, phonatory and articulatory systems resulted in altered breath group patterns, imprecise consonant articulation and a lack of expected variation in pitch and loudness levels.

Individuals with Parkinson’s disease often exhibit respiratory and laryngeal changes that impact speech production, including reduced respiratory support, decreased vocal intensity and impaired velopharyngeal function. These impairments can lead to alterations in breath group characteristics, such as shorter breath group durations, longer pauses between breaths, and decreased variation in breath group timing. One study found that individuals with Parkinson’s disease showed reduced range of velar movement during speech production, which was reflected in the temporal characteristics of their breath groups (Chenery et al., 1988).

Bunton K. et al., (2005) did a study on patients with parkinsonism, examining lung volume use in speakers with Parkinson disease (PD) during extemporaneous speaking, compared to a control group. Differences were found in breath group duration, lung volume initiation and termination. Control speakers alternated between longer and shorter breath groups, with higher lung volumes for longer groups and lower for shorter ones, terminating speech before reaching tidal end expiratory level (EEL). Four of the seven PD speakers showed a similar pattern, while the other three started at low lung volumes and spoke below EEL, ending breath groups at agrammatical boundaries unlike the control group.

There have been a few studies that have compared the breath group characteristics of older children and younger children who stutter to their fluent peers. The researchers found that young children who stuttered had shorter breath groups and longer pauses between them, compared to their fluent peers. For older children who stuttered, no significant differences were found in breath group characteristics. The researchers suggested that the younger stuttering children's breath group alterations may reflect an underlying respiratory control deficit that contributes to their fluency problems (Howell et al., 1995).

CHAPTER 3

METHODS

Study design

Normative and standard group comparison research

Participants

A total of 60 participants were enrolled for the present study. They were divided into two age groups. Group I is in the age range of 20-30 years and Group II is in the age range of 31-40 years (30 participants in each age group). All the participants underwent breath group measurements using both Cervical Auscultation method (CA) and Phonatory Aerodynamic System (PAS).

Inclusion criteria

- All the participants were native Hindi speakers.
- Subjects having adequate speech, language and cognitive skills to read passages and answer questions.

Exclusion criteria

- Participants with significant medical and surgical history.
- Participants with any history of smoking, pulmonary disease, neurological disease, structural disorders, language disorders, hearing disorders, speech disorders, and/or voice problems will not be included.
- Subjects suffering from colds or seasonal allergies on the day of testing were not included.
- The female participants who were menstruating at the time of data collection were not included.

Ethical consideration

- Before conducting the study, informed consent was obtained from each participant.

Stimuli

Task 1

For the purpose of speech samples collection from each participant, the 'Standard Hindi reading passage (Source: AYJNIHH)' was used at a comfortable pace, pitch and loudness. This passage is specifically chosen to emphasize voiced consonants at word and phrase boundaries, aiding in the identification of speech pauses.

Task 2

For the purpose of spontaneous speech samples, instructed the participants to discuss any one of the four topics chosen by the participant: about themselves and their family, India, their favorite hobby, cricket. The response lasted at least 1 minute and contained a minimum of 6 breath groups (as tracked by an airflow transducer).

Procedure

Speech samples, including Hindi reading passages and spontaneous speech, were obtained from each participant using both procedures i.e. PAS and Cervical Auscultation. The procedures were given below in detail.

Phonatory Aerodynamic System (PAS) recording procedure

Participants were seated in a comfortable, upright position and were directed to perform each speaking task using their preferred vocal pitch and volume for the sake of obtaining natural speech samples.

- The researcher demonstrated each speaking task, and a brief practice session was held before recording to capture the desired speech samples accurately.

- To maintain a proper seal, participants were instructed to securely hold the mask against their face.
- The screening and data collection process took approximately 20 minutes per participant.

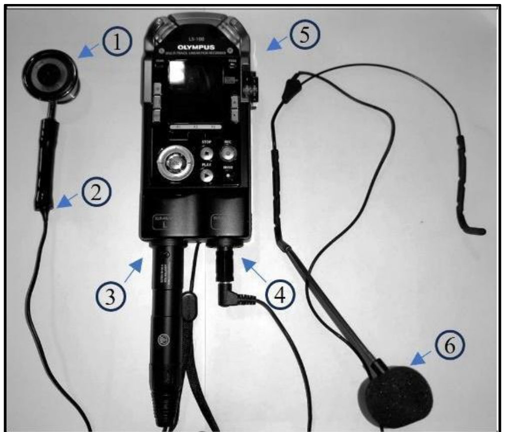
Cervical Auscultation (CA) recording procedure

Further participants were subjected for the evaluation of breath grouping using a cervical auscultation method. The inspiration for this has been drawn from the cervical auscultation used in clinical dysphagia evaluation. It entails the use of following measurement techniques: a pediatric stethoscope, two lavalier microphones, a dual channel recorder and PRAAT software installed in a computer system.

Figure 3.1 and 3.2 shows the details of the novel measurement technique with various parts and placement. The procedure involves the following steps:

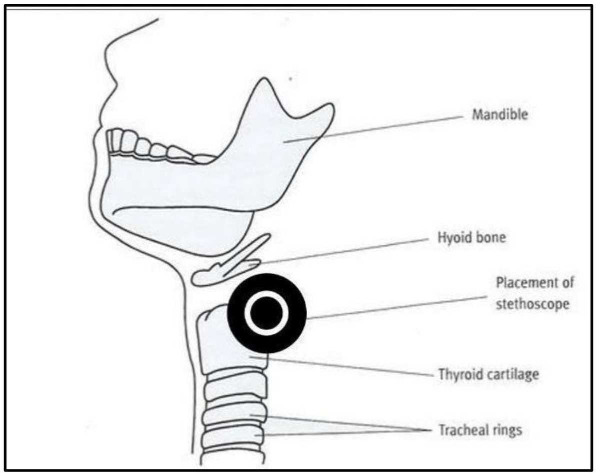
a. Placing one microphone near the mouth of the participant (that records the radiated speech signal)
b. Attaching the other microphone piece to a stethoscope (Steth-mic) as shown in figure 1 and placing the diaphragm of the stethoscope on the thyroid lamina as shown in figure 2.
c. Connecting both the microphones to a dual channel audio recorder.
d. Giving the reading and spontaneous speech task to the participant as described under the group.
e. Saving the recording in the audio recorder and transfer of the recorded file into the computer system.
f. Analysis of the recorded file in the PRAAT software.

Figure 3.1: *Details of the novel measurement technique with various parts*



1: Diaphragm of pediatric stethoscope
2: Microphone piece connected to stethoscope tubing
3: Connection of the stethoscope microphone (marked as '2') to the Channel 1 of the Audio Recorder
4: Connection of the second microphone marked as '6' to the second channel of audio recorder
5: Dual channel digital audio recorder
6: Microphone with head clip that'll be placed near the participants mouth anchored with the head clip

Figure 3.2: *Details of the novel measurement technique placement on neck*

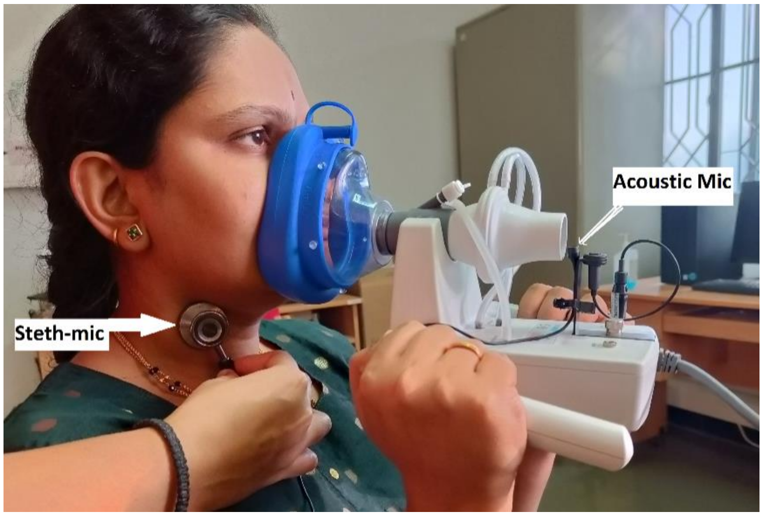


- This method lies on the premise that inhalatory bursts are easily identified using cervical auscultation audibly as well as visually on a spectrogram where the inhalatory bursts are seen as a patch of noise showing rise in frequency across time domain.
- The total number of incidences of inhalation within the sample were identified by counting the number of such spectrographic representations within the entire duration of the sample.
- Since a double channel recording was done, comparison with the radiated speech output recorded from the other mic (the one placed near the mouth) also allowed interpretation of the time synced speech output with that recorded using the cervical auscultation and also calculation of the number of syllables actually spoken by the participant.

Simultaneous recording of PAS and Cervical Auscultation recording

During the process of simultaneous recording, the same PAS setup was maintained along with the acoustic mic for the novel method was placed near the mouthpiece of the PAS transducer and another Steth- mic was placed above the thyroid lamina of Right or Left side of the larynx. The same is illustrated in figure 3.3. Ten percentages of the participants were re-recorded for the Cervical Auscultation procedure for the purpose of reliability.

Figure 3.3: *Picture of simultaneous recording of PAS and Cervical Auscultation*



Analysis of speech samples

The obtained speech samples were subjected to the following analysis.

1. Breath Group Duration (BGD), which is the duration of groups of speech events produced on a single breath, was measured from the start to the end of the speech signal produced on a breath group based on the acoustic waveform.
2. The Inter-Breath-Group Pause (IBP) was calculated as the time elapsed between consecutive Breath Group Durations (BGDs).
3. Inspiration Duration (ID) was determined by manual measurement, involving the width of dark band within the duration of IBP.

The Screenshot of Praat software with depiction of measures of BGD, IBP and ID based on recording done by the cervical auscultation method. The same is illustrated in figure 3.4.

The results were validated by comparing the data obtained by the Cervical Auscultation procedure to the universally used aerodynamic measurement technique PAS. The values obtained using the novel method will be compared with the measurements made through the Phonatory Aerodynamic System.

Figure 3.4: *Screenshot of Praat software with depiction of measures of BGD, IBP and ID based on recording done by the cervical auscultation method.*

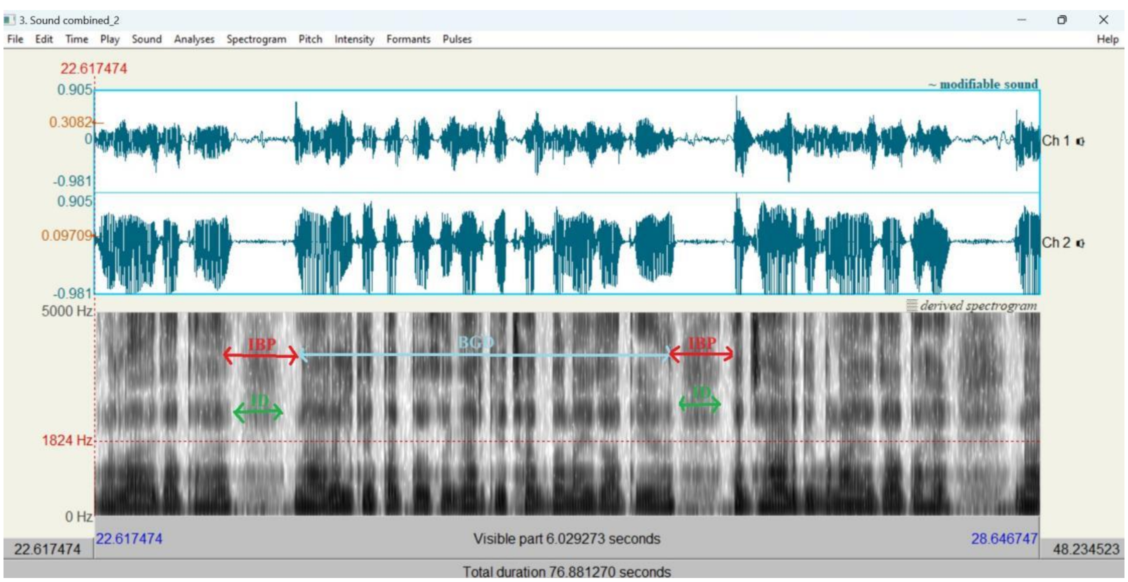
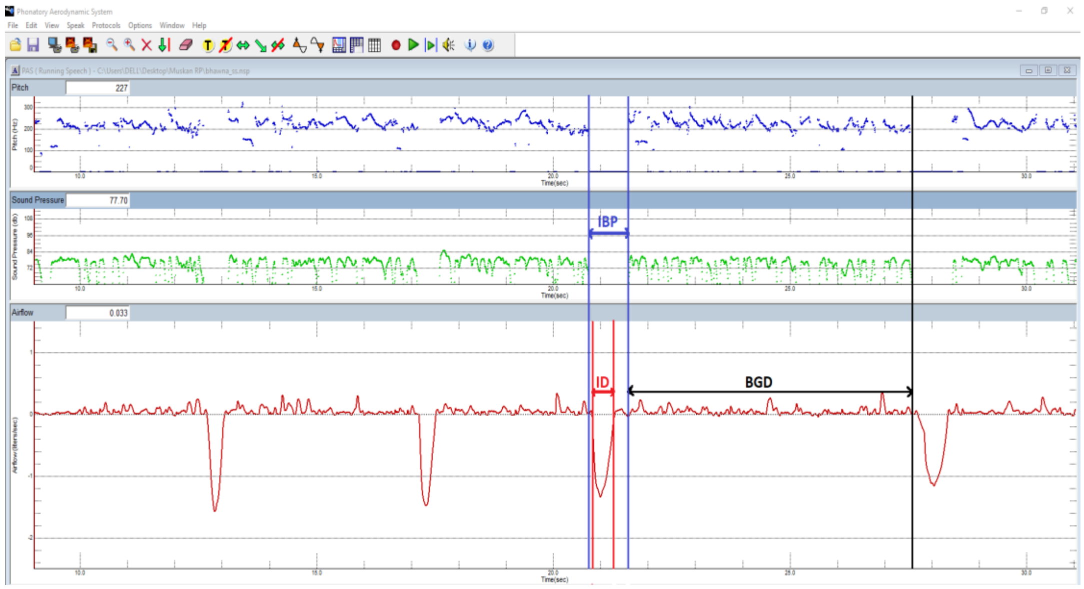


Figure 3.5: *Screenshot of PAS with depiction of measures of BGD, IBP and ID*



Statistical analyses

All the statistical analysis was carried out in SPSS statistical analysis software (Version 27).

Descriptive statistics were used to calculate the mean, median, standard deviation, 95% Confidence Interval for the mean and interquartile range. Shapiro Wilk's test of normality was estimated for the entire data set. The data set for BGD & ID were found to be normally distributed thus indicating the use of parametric tests for the inferential statistics. Whereas, data was non-normally distributed for IBP parameter. Hence, non-parametric tests were utilized.

Four-way ANOVA was run to analyze the comparison in BGD & ID values between tasks, measurement techniques for both male and female subgroups.

Mann-Whitney was carried out to find the significance between the tasks, measurement techniques for both male and female subgroups. Further, Wilcoxon Signed Ranks Test was run to infer the significance within IBP values obtained from PAS and CA across tasks. Pearson correlation and Spearman's rho was calculated to find the correlation in BGD & ID values and IBP values respectively obtained from PAS and CA across tasks.

CHAPTER 4

RESULTS

The study aims to determine the normative values of the Breath group in the healthy Hindi speakers. A total of 60 participants were enrolled for the present study. They were divided into two age groups. Group I is in the age range of 20-30 years and Group II is in the age range of 31-40 years, 30 participants in each age group. Three parameters were investigated in this study: Breath Group Duration (BGD), Inter Breath- group Pause (IBP) and Inspiratory Duration (ID). Speech samples were collected from each participant for two tasks i.e. Reading and Spontaneous Speech which were analyzed using both Phonatory Aerodynamic System (PAS) and Cervical Auscultation method. Normative values of each parameter were recorded and statistical analysis was done using the software SPSS (Version 27). Descriptive statistics were used to calculate the mean, median, standard deviation, 95% Confidence Interval for the mean, and interquartile range. Three subjects (two males, one female) from the 20-30 years age group and one female subject from the 31-40 years age group were outliers, so they were removed and a total of fifty six participants were taken for the statistical analysis. Inferential statistics were utilized to find the age group and gender effect across measurement techniques and tasks. The results of the present study are discussed under the following headings:

- Test of Normality
- Descriptive statistics of BGD, ID and IBP
- Tests of Between-Subjects Effects for BGD and ID
- Tests of Within-Subjects Effects for BGD and ID
- Correlation between Measurement Techniques

- Test retest Reliability

Test of Normality

Shapiro Wilk's test of Normality was estimated for the entire data set. The data set for BGD & ID were found to be normally distributed thus parametric tests were used for the inferential statistics. Whereas, data was non-normal for IBP parameter. Hence, non-parametric tests were utilized.

Descriptive Statistics

Table 4.1 and figure 4.1 & 4.2 provides insights into how Breath Group Duration (BGD) and Inspiratory Duration (ID) variations by age, gender, and task (spontaneous speech vs. reading) using two measurement techniques: PAS and CA.

Age and Gender Differences:

- Younger females (20-30 years) have slightly higher BGD during spontaneous speech than males, while males have slightly higher BGD during reading.
- In the older group (31-40 years), the differences in BGD between males and females are less pronounced.
- ID values tend to be slightly higher in males than females across all age groups and tasks.

It was found that BGD is generally longer during spontaneous speech compared to reading for all groups. The difference between PAS and CA measures for BGD is minimal. ID is generally shorter for reading tasks compared to spontaneous speech. CA consistently shows shorter ID values compared to PAS across all groups and tasks.

Table 4.1: *Mean and SD values of BGD and ID measures using PAS and CA across age and gender groups*

			Female		**Male**	
			PAS	**CA**	**PAS**	**CA**
Group	**Parameter**	**Task**	**Mean (SD)**			
20 – 30 years	Breath Group Duration (BGD)	Spontaneous Speech	3.45 (0.85)	3.48 (0.83)	3.08 (0.85)	3.09 (0.86)
		Reading	2.79 (0.54)	2.82 (0.54)	2.90 (0.76)	2.91 (0.75)
	Inspiratory Duration (ID)	Spontaneous Speech	0.47 (0.07)	0.39 (0.06)	0.49 (0.09)	0.43 (0.07)
		Reading	0.39 (0.06)	0.34 (0.07)	0.43 (0.07)	0.35 (0.06)
31 – 40 years	Breath Group Duration (BGD)	Spontaneous Speech	3.25 (0.61)	3.25 (0.63)	3.12 (0.56)	3.13 (0.57)
		Reading	2.99 (0.59)	2.99 (0.59)	2.79 (0.59)	2.80 (0.57)
	Inspiratory Duration (ID)	Spontaneous Speech	0.43 (0.08)	0.35 (0.08)	0.48 (0.07)	0.39 (0.06)
		Reading	0.37 (0.05)	0.30 (0.04)	0.48 (0.07)	0.39 (0.05)

Figure 4.1: *Mean BGD & ID values across tasks for 20-30 years age group*

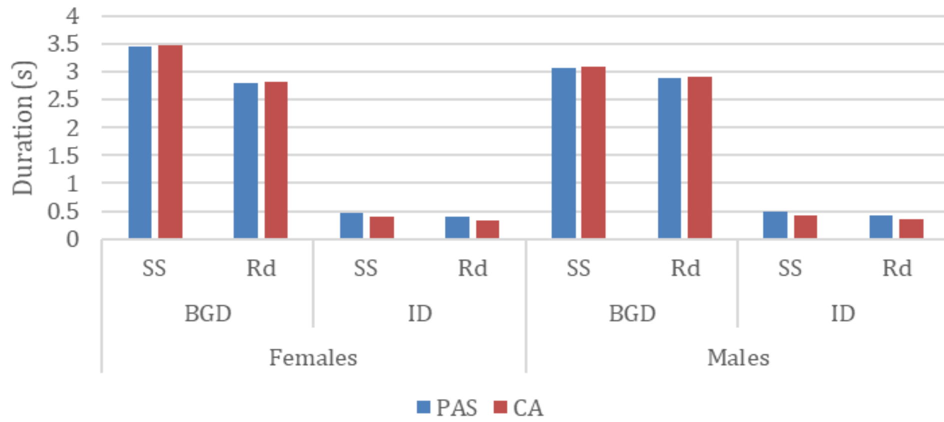
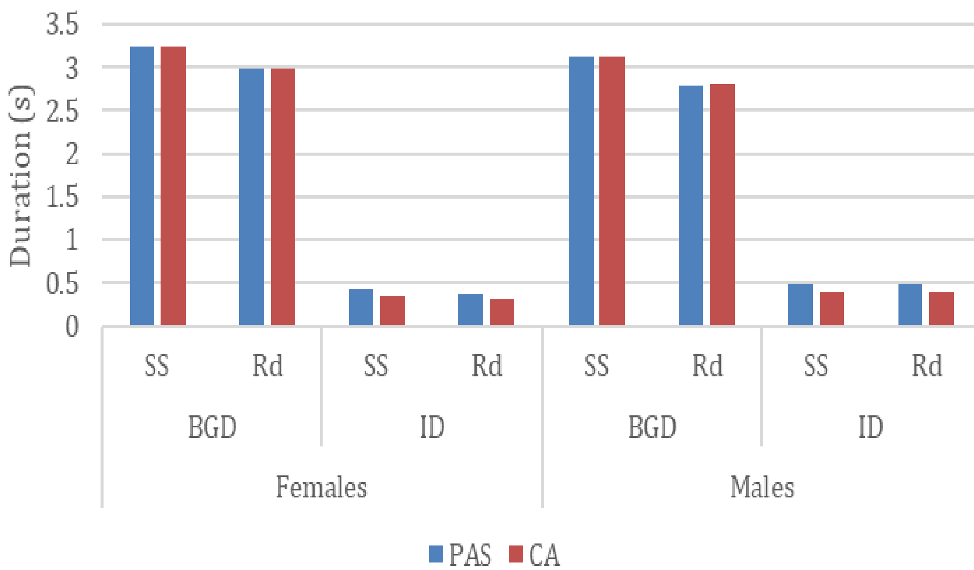


Figure 4.2: *Mean BGD & ID values across tasks for 31-40 years age group*



Descriptive statistics for IBP

Table 4.2 and figure 4.3 & 4.4 presents the median and interquartile range (IQR) values for Inspiratory Breath Pressure (IBP) during spontaneous speech and reading tasks, categorized by age group and gender, using two measurement techniques: PAS and CA.

Age & Gender Differences:

- Age group did not show major difference in median values
- Males tend to have a slightly higher median IBP than females in the 20-30 age group, especially during spontaneous speech.
- In the 31-40 age group, the differences in IBP between males and females are less pronounced, with males showing higher IBP during reading.

IBP is generally higher during spontaneous speech compared to reading. This trend is observed across both age groups and genders. The difference between PAS and CA measures for IBP is minimal, indicating both measurement technique provides similar result for this parameter.

Table 4.2: *Median and IQR values of IBP measures using PAS and CA across age and gender groups* served across both age groups and genders. The difference between PAS and CA measures for IBP is minimal, indicating both methods provide similar results for this parameter.

		Female		**Male**	
		PAS	**CA**	**PAS**	**CA**
Group	**Task**	**Median (Interquartile range)**			
20 – 30 years	**Spontaneous Speech**	0.60 (0.26)	0.59 (0.26)	0.64 (0.23)	0.63 (0.25)
	Reading	0.47 (0.13)	0.47 (0.13)	0.55 (0.10)	0.54 (0.12)
31 – 40 years	**Spontaneous Speech**	0.60 (0.18)	0.61 (0.19)	0.62 (0.13)	0.63 (0.13)
	Reading	0.50 (0.10)	0.50 (0.10)	0.63 (0.16)	0.63 (0.16)

Figure 4.3: *Median and IQR values of IBP measures using PAS and CA across 20-30*

years age group

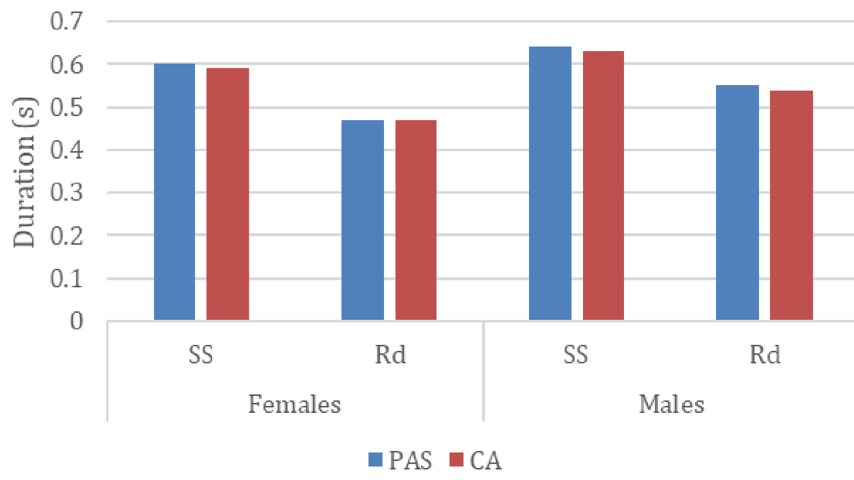
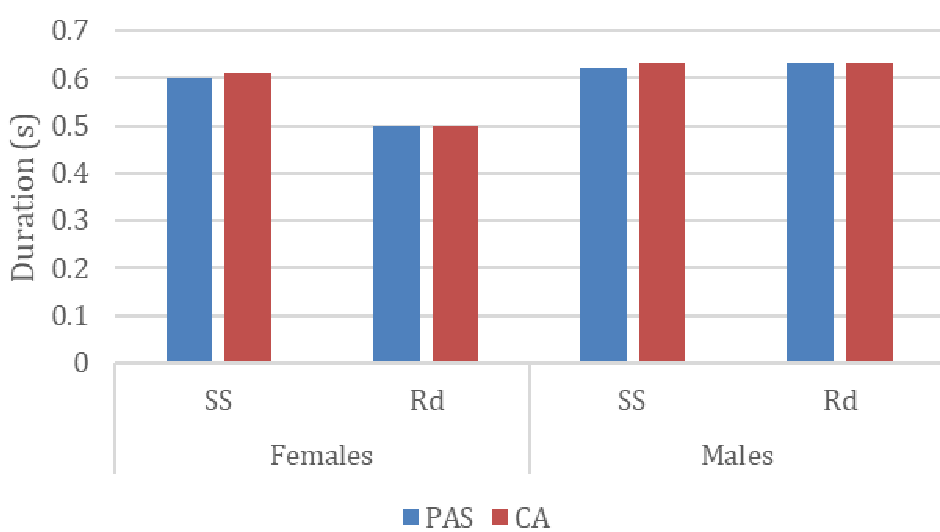


Figure 4.4: *Median and IQR values of IBP measures using PAS and CA across 31-40 years age group*



Inferential statistics

Tests of Between-Subjects Effects for BGD and ID

Table 4.3 depicts the results from the statistical test (Four-way ANOVA) to determine the effects of age group and gender on Breath Group Duration (BGD) and Inspiratory Duration (ID).

Breath Group Duration (BGD):

Age group or gender has a statistically significant effect on BGD, suggesting that BGD is consistent across different age groups and genders.

Inspiratory Duration (ID):

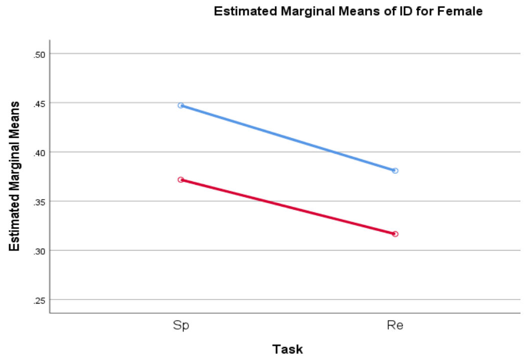
Gender showed a statistically significant effect on ID, meaning that Inspiratory Duration varies between males and females. Gender differences can be noticed with a graph in figure 4.5. However, no interaction between age group and gender was shown in four-way ANOVA.

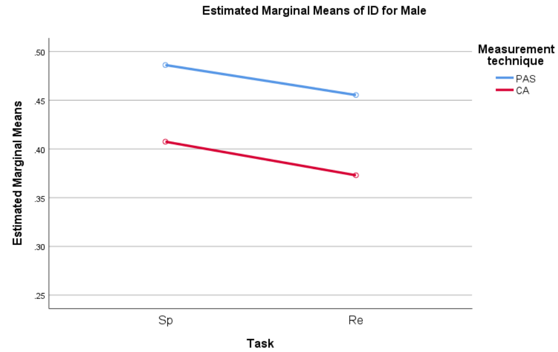
Table 4.3: *Results of four-way ANOVA for gender and age group*

Tests of Between-Subjects Effects				
	BGD		**ID**	
	F-value	**Sig.**	**F-value**	**Sig.**
Age group	0.04	0.85	0.84	0.36
Gender	0.99	0.33	11.82	0.00**
Age group*gender	0.001	0.973	2.49	0.12

**P<0.01

Figure 4.5: *Gender comparison of ID Across task and measurement technique*





Tests of Within-Subjects Effects for BGD and ID

Table 4.4 shows the results from four-way ANOVA to determine the effects of within-subject factors (task and measurement technique) on Breath Group Duration (BGD) and Inspiratory Duration (ID).

Breath Group Duration (BGD):

Task: There is a statistically significant effect of the task on BGD implying that BGD varies significantly between spontaneous speech and reading tasks.

Inspiratory Duration (ID):

- **Task:** There is a statistically significant effect of the task on ID implying that ID varies significantly between spontaneous speech and reading tasks.
- **Measurement technique:** There is a statistically significant effect of the measurement technique on ID. This suggests that the measurements of ID differ significantly between the two measurement techniques (PAS and CA). Also there is an interaction effect between measurement technique and age group. These differences can be seen in Figure 4.1 and 4.2

Table 4.4: *Results of four-way ANOVA of within subject's effects for age group, gender, task and measurement technique.*

Tests of Within-Subjects Effects				
	BGD		**ID**	
	F-value	**Sig.**	**F-value**	**Sig.**
Task	14.07	0.00**	23.92	0.00**
Task* Age grp	0.50	0.48	3.97	0.05
Task* Gender	1.15	0.29	2.18	0.15
Task* Age grp* Gender	2.13	0.15	2.28	0.14
Measurement technique	3.23	0.08	754.47	0.00**
Measurement technique * Age grp	0.15	0.69	6.51	0.01*
Measurement technique * Gender	0.23	0.63	3.77	0.06
Measurement technique * Age grp* Gender	0.18	0.67	0.82	0.37
Task* Measurement technique	2.37	0.13	1.14	0.29
Task* Measurement technique* Age grp	0.05	0.83	0.71	0.41
Task* Measurement technique* Gender	2.83	0.09	4.51	0.04*
Task* Measurement technique* Age grp* Gender	0.95	0.34	1.37	0.25

**P<0.05, **P<0.01*

Inferential statistics for IBP

As the result of normality test revealed non-normal distribution for IBP measures, a non-parametric test for comparison between two independent categories i.e. Mann-Whitney test was utilized for comparing the values of Inspiratory Breath Pressure (IBP) measures across two age groups (20-30 years and 31-40 years) for two tasks across gender and two measurement techniques. The results from table 4.5 revealed the age group effect for the reading task and for both the measurement technique.

Table 4.5: *Results of Mann-Whitney test for age group effect for two measurement techniques across two tasks.*

Comparison of IBP for the two age groups				
	PAS		**CA**	
	IZI	**P-Value**	**IZI**	**P-Value**
Spontaneous Speech	0.788	0.431	0.624	0.533
Reading	1.34	0.178	1.44	0.148

The results from table 4.6 revealed that no age group effect was observed across measurement technique and task.

Table 4.6: *Results of Mann-Whitney test for gender effect for the two age groups.*

Gender comparison of IBP for the two age groups				
	20-30 years		**31- 40 years**	
	IZI	**P-Value**	**IZI**	**P-Value**
PAS_Sp_ IBP	0.32	0.75	1.18	0.24
CA_Sp_ IBP	0.27	0.79	1.18	0.24
PAS_Re_ IBP	1.09	0.27	3.66	0.00**
CA_Re_ IBP	1.14	0.25	3.78	0.00**

[Sp-spontaneous speech, Re-Reading]**P<0.01

Table 4.7 shows the comparison in Inter-Breath group pause (IBP) measures between PAS and CA across tasks.

Measuring technique comparison

There was no significant difference observed for measurement technique and task for both age group and gender.

Task comparison

In the 20-30 years age group there is a significant difference obtained between tasks in both male and females. However, in the 31-40 years age group significant difference is observed only for females.

Table 4.7: *Results of Wilcoxon Signed Ranks Test for IBP measures across age group and gender between measurement technique and task.*

Parameters	**20-30 years**				**31-40 years**			
	Female		**Male**		**Female**		**Male**	
	|Z|	**P Value**	**|Z|**	**P Value**	**|Z|**	**P Value**	**|Z|**	**P Value**
	Measuring technique comparison							
CA_Sp_IBP Vs PAS_Sp_IBP	0.66	0.51	0.46	0.64	1.16	0.25	0.82	0.41
CA_Re_IBP Vs PAS_Re_IBP	0.37	0.71	0.86	0.39	0.33	0.74	0.45	0.66
	Task comparison							
PAS_Re_IBP Vs PAS_Sp_IBP	3.18	**0.00****	2.29	**0.02***	2.56	**0.01***	0.12	0.91
CA_Re_IBP Vs CA_Sp_IBP	3.18	**0.00****	2.20	**0.03***	2.51	**0.01***	0.00	1.00

[Sp- spontaneous speech, Re-Reading]**P<0.01

Correlation between Measurement Techniques

Correlation analysis was carried out between measures obtained from Cervical Auscultation (CA) and PAS across tasks. The correlation coefficients were computed using Pearson correlation for BGD and ID, and Spearman's rho for IBP displayed in Table 4.8 and 4.9.

Breath Group Duration (BGD):

- Across all age and gender groups, there is a very strong and statistically significant positive correlation between measurements obtained from CA and PAS for BGD in both spontaneous speech and reading tasks.

Inter Breath Group Pause (IBP):

- There is a very strong and statistically significant positive correlation between CA and PAS measurements for IBP in both tasks across all age and gender groups.

Inspiratory Duration (ID):

- There is a very strong and statistically significant positive correlation between CA and PAS measurements for ID in both tasks across all age and gender groups. However, the correlation is slightly lower (though still strong) for reading tasks in 31-40 years males.

Table 4.8: *Correlation between parameters obtained from Cervical Auscultation and PAS across tasks for the age group of 20-30 years.*

Parameter	Task	Female Correlation coefficient	Sig. (2 tailed)	Male Correlation coefficient	Sig. (2 tailed)
Breath Group Duration (BGD)	**Spontaneous Speech**	0.99	0.00**	0.99	0.00**
	Reading	0.99	0.00**	0.99	0.00**
Inter Breath group pause (IBP)	**Spontaneous Speech**	0.99	0.00**	0.99	0.00**
	Reading	0.98	0.00**	0.98	0.00**
Inspiratory Duration (ID)	**Spontaneous Speech**	0.92	0.00**	0.98	0.00**
	Reading	0.93	0.00**	0.98	0.00**

*(BGD, ID – Pearson correlation, IBP- Spearman correlation), ** p<0.01*

Table 4.9: *Correlation between parameters obtained from Cervical Auscultation and PAS across tasks for age group 31-40 years.*

Parameter	Task	Correlation coefficient	Sig. (2 tailed)	Correlation coefficient	Sig. (2 tailed)
Breath Group Duration (BGD)	**Spontaneous Speech**	0.99	0.00**	0.99	0.00**
	Reading	0.99	0.00**	0.99	0.00**
Inter Breath group pause (IBP)	**Spontaneous Speech**	0.99	0.00**	0.99	0.00**
	Reading	0.99	0.00**	0.99	0.00**
Inspiratory Duration (ID)	**Spontaneous Speech**	0.97	0.00**	0.97	0.00**
	Reading	0.95	0.00**	0.88	0.00**

*(BGD, ID – Pearson correlation, IBP- Spearman correlation), ** p<0.01*

Test retest reliability

Test retest reliability was carried out for 10% of the participants for the novel measurement technique (CA) only. Test retest reliability was not carried out for PAS as it is a well-established and validated measurement technique. Cronbach's alpha test showed good reliability as given in table 4.10. The Cronbach's alpha coefficient values for all the parameters were >0.90 indicating high test retest reliability.

Table 4.10: *Cronbach's alpha coefficient value for various parameters across task*

Parameter	Cronbach's Alpha
BGD_Sp	0.93
BGD_Re	0.96
IBP_Sp	0.96
IBP_Re	0.99
ID_Sp	0.89
ID_Re	0.96

CHAPTER 5

DISCUSSION

The aim of the study was to determine the normative breath group in healthy Hindi speaking adults. A total of 60 participants (both males and females) were selected for the study, 30 native Hindi speaking participants in each age group of 20-30 years and 31-40 years. Information content was taken from the participants for their participation. The breath group was measured under three major temporal parameters, which are Breath Group Duration (BGD), Inter-Breath group Pause (IBP) and Inspiratory Duration (ID) across two tasks i.e. Spontaneous speech and Reading simultaneously using the gold standard measurement technique Phonatory Aerodynamic System (PAS) and a novel method comprising Cervical Auscultation (CA).

The first objective of this study was to establish the normative of breath group parameters using PAS and Cervical auscultation method.

Normative score for PAS

The present study estimated that the mean value for BGD, IBP and ID for both female and male, grouped under 20-30 years and 31-40 years for PAS as depicted in table 5.1, 5.2. In congruence with the previous studies (Winkworth et al., 1994; Wang et al., 2010) we found that all the temporal measures of breath group i.e. BGD, IBP and ID values are longer for spontaneous speech than in reading for both males and females. However, there is scarcity of evidence showing the difference of the breath group variation across gender. Wang (2010) examined the temporal and fundamental frequency (F0) aspects of breath groups in reading versus spontaneous speech in which sixteen native English speakers under the age 20-60 years were taken, who performed both tasks while wearing a pneumotach mask, inspiratory locations and an audio signal for breath group analysis was carried, values observed for all the temporal parameters were longer than in the current study but the trend across the tasks is comparable. Differences among studies are probably due to the variations in the methods used to elicit spontaneous speech samples; also the differences might be due to linguistic, cultural and physiological differences among the participants. No significant difference was observed for BGD across gender in both the age groups. Also, it is observed that males in both the age groups generally exhibit a slightly higher IBP and ID than females, particularly during spontaneous speech, which can be due to various factors including larger lung volume, on average male have larger lungs than females (Lufti, 2017). This larger lung volume allows for greater air intake, which can result in higher inspiratory breath pressure. Also, males typically have a higher vital capacity (the maximum amount of air a person can expel from the lungs after a maximum inhalation) compared to females. This greater capacity enables longer and more forceful expirations, contributing to higher inspiratory pressure and duration. Additionally, males generally have a larger thoracic cavity, which accommodates larger lungs and allows for more significant expansion during inhalation (Harms & Rosenkranz, 2008). The muscles involved in respiration, such as the diaphragm and intercostal muscles, tend to be stronger in males. This increased muscle strength can also lead to higher inspiratory pressure and a longer duration of breath. Moreover, males often have a higher aerobic capacity than females, which means their bodies are more efficient at utilizing oxygen. This efficiency can contribute to better overall respiratory function and higher inspiratory pressure and duration in males.

Table 5.1: *Mean values for BGD, IBP and ID in the spontaneous speech and reading samples using PAS*

		Female	**Male**
Parameter	Task	Mean (SD)	
BGD	Spontaneous Speech	3.23 (0.72)	
	Reading	2.87 (0.61)	
IBP	Spontaneous Speech	0.45 (0.13)	0.65 (0.14)
	Reading	0.49 (0.07)	0.58 (0.11)
ID	Spontaneous Speech	0.44 (0.07)	0.49 (0.08)
	Reading	0.38 (0.06)	0.45 (0.07)

Normative score for Cervical Auscultation (CA)

Table 5.2: *Mean values for BGD, IBP and ID in the spontaneous speech and reading samples using Cervical auscultation*

		Female	Male
Parameter	Task	Mean (SD)	
BGD	Spontaneous Speech	3.24 (0.73)	
	Reading	2.89 (0.61)	
IBP	Spontaneous Speech	0.62 (0.14)	0.65 (0.14)
	Reading	0.49 (0.07)	0.58 (0.11)
ID	Spontaneous Speech	0.37 (0.07)	0.49 (0.07)
	Reading	0.31 (0.06)	0.37 (0.06)

It has been observed that all the parameters of breath group measure BGD, IBP and ID are generally longer during spontaneous speech compared to reading across all groups. This trend is consistent for both age groups and genders. ID values are generally slightly higher in males than in females across all age groups and tasks, suggesting that males may take longer breaths on average. The same reason as mentioned for the normative score using PAS holds good for CA.

The second objective of this study was to compare the data obtained using both the measurement techniques. It was observed that the difference between PAS and CA measures for BGD and IBP was minimal, indicating both methods provide similar results for this parameter. CA consistently showed shorter ID values compared to PAS across all groups and tasks, suggesting CA may measure inspiratory duration more conservatively. Also, Correlation analysis was carried out for the values obtained by both the measurement techniques across tasks. The correlation coefficients were computed using Pearson correlation for BGD and ID, and Spearman's rho for IBP. All correlations were statistically significant, with p-values of 0.00, indicating a very strong relationship between the measurements obtained from the two methods (CA and PAS). Suggesting that the novel method proposed in the current study is equally efficient as the gold standard method PAS in measuring for BGD and IBP. However, the ID parameter can be measured with a correction factor as it has a linear relationship with each other measurement technique.

The third and final objective of this study was to examine how linguistic and cognitive demands impact breath group measurements by comparing reading and spontaneous speech tasks. Specifically, the study aimed to determine if the complexity of language use and cognitive load in different speech tasks affect breath group duration (BGD), inter-breath group pause (IBP), and inspiratory duration (ID). The findings revealed that BGD, IBP, and ID are generally longer during spontaneous speech than reading tasks across all participant groups. These observations align with previous research (Winkworth et al., 1994, 1995; Wang et al., 2010; François & Maryann, 1979).

The longer breath group measurements during spontaneous speech highlight the impact of higher linguistic and cognitive demands on speech production. Spontaneous speech's unpredictable and dynamic nature requires more cognitive resources and physiological adjustments, resulting in longer breath groups, pauses, and inhalations. In contrast, reading tasks, which are more controlled and predictable, involve shorter and more segmented utterances.

This finding emphasizes the importance of considering these variables when evaluating breath group metrics, providing insight into how different speech contexts affect respiratory patterns. Conrad and Schonle (1979) studied air volume changes during various speech tasks compared to resting respiration. They concluded that speech respiration involves faster inspirations and slower expirations than resting respiration. Tasks performed aloud, sub-vocally, and silently showed increasing respiratory changes from reading to arithmetic, suggesting a gradual shift from resting to speech respiration which can be likely due to increased cognitive-linguistic processing demands.

Understanding these differences allows researchers and clinicians to better interpret breath group measurements and their implications for speech and respiratory disorders, potentially enhancing diagnostic and therapeutic approaches. Further, more studies should be carried out to show that integrated acoustic and aerodynamic measurements are necessary to test the above speculations specifically by including participants with speech motor disorders or cognitive deficits.

Conclusion: The present study gives normative score for both PAS and CA methods. It can be concluded that the novel measurement technique can be used to measure BGD, IBP whereas ID with a correction factor and the present study also confirms that cognitive demand has an influence on breath group measurement.

CHAPTER 6

SUMMARY AND CONCLUSION

Breath groups are the discrete units of speech produced within a single expiratory phase, providing a window into the coordination of respiratory and articulatory processes. As fundamental units of speech breathing, breath groups are characterized by their duration and volume, which can reveal much about an individual's respiratory and phonatory control. These characteristics of the breath group are influenced by the physiological, linguistic and cognitive requirements of communication. Incorporating breath group measurement into therapeutic settings can enhance evidence-based practices. Traditionally, the Phonatory Aerodynamic System (PAS) has been used to estimate breath groups. However, PAS is highly priced hence limiting its availability especially in Indian scenarios and also requires sterilization after each use, posing a risk of infection if not properly managed. Therefore, this study introduces a novel method i.e., Cervical Auscultation (CA) that is simple and cost-effective. This study aims to establish and validate this new method for measuring breath groups and to establish normative data along with the traditional measurement technique PAS for breath groups in Hindi language.

The normative of breath group parameters were estimated in healthy Hindi-speaking adults, involving 60 participants divided into two age groups (20-30 years and 31-40 years) split between both males and females. Breath groups were measured simultaneously using the Phonatory Aerodynamic System (PAS) and the novel method, Cervical Auscultation (CA), across two tasks: spontaneous speech and reading. Three temporal parameters were assessed: Breath Group Duration (BGD), Inter-Breath Group Pause (IBP), and Inspiratory Duration (ID).

Results showed that all breath group parameters were longer during spontaneous speech than reading for both genders and age groups, which was consistent with previous studies. Also, no significant gender differences were observed for BGD, but males generally exhibited slightly higher IBP and ID, particularly during spontaneous speech, likely due to physiological differences such as larger lung volume and greater vital capacity in males.

Moreover, when PAS and CA were compared, minimal differences were found for BGD and IBP parameters, indicating both methods provided similar results. However, CA consistently showed shorter ID values, suggesting it measures inspiratory duration more conservatively. Additionally, correlation analysis revealed strong relationships between the two methods, supporting CA's efficacy as an alternative to PAS.

The study also highlighted the impact of linguistic and cognitive demands on breath group measurements. It was found that spontaneous speech requires more cognitive resources and physiological adjustments, resulting in longer breath groups, pauses and inhalations compared to the more controlled reading tasks. This aligns with previous research indicating that higher linguistic and cognitive demands extend breath group parameters. These insights are valuable for interpreting breath group metrics and can enhance diagnostic and therapeutic approaches in speech and respiratory disorders.

Clinical Implications

a. Normative values will have clinical significance for assessing respiratory function in speech therapy and as intervention guidelines.

b. Can be used in the clinical assessment battery used to evaluate dysarthria and other disorders of speech and voice.

c. It helps in estimating the coordination between laryngeal function and the respiratory patterns.

d. Comprehending breath group patterns can be helpful for enhancing the naturalness of synthesized speech.

Limitations and Future scope

This study was conducted exclusively on adults aged 20-40 years, limiting its generalizability to other age groups. Future studies should include younger and older participants to broaden the applicability of the findings. Additionally, further research is needed, particularly with participants who have speech motor disorders or cognitive deficits, to explore the integration of acoustic and aerodynamic measurements in greater detail. Longitudinal studies are also necessary to observe changes in breath group parameters over time or in response to interventions. Moreover, similar research should be conducted in other Indian languages across various age groups to enhance the understanding of breath group measurements in diverse linguistic contexts.