EFFECT OF EXPIRATORY MUSCLE STRENGTH TRAINING (EMST) ON SPEECH AND SWALLOW FUNCTIONS IN INDIAN ELDERLY

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(Speech -Language Pathology)

ALL INDIA INSTITUTE OF SPEECH AND HEARING MANASAGANGOTHRI,

MYSORE – 570006

JUNE - 2026

CERTIFICATE

This to certify that this dissertation entitled **"Effect of Expiratory Muscle Strength Training (EMST) on Speech and Swallow Functions in Indian Elderly"** is a bonafide work submitted in part fulfillment for the Degree of Master of Science (Speech-Language Pathology) of the student Registration Number P01II24S123031. This has been carried out under the guidance of the 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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DECLARATION

This is to certify that the dissertation entitled **“Effect of Expiratory Muscle Strength Training (EMST) on Speech and Swallow Functions in Indian Elderly”** is the result of my own study under the guidance of **Ms. Sindhusha Chandran**, Assistant Professor of Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech & Hearing, Mysuru. It has not been submitted earlier to any other University for another Diploma or Degree award.

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CHAPTER I

INTRODUCTION

Aging is a natural multi-dimensional biological process marked by a gradual build-up of physiological changes along with a diminishing capacity to respond to environmental insults culminating in the predisposition to chronic illnesses (Costa et al., 2016; Singh & Singh, 2024). According to the studies, the number of elderly will double constituting around 20% of the total population in India by 2050 (Madiwalappagol, 2025). A critical physiological contributor for the decline in speech and swallowing functions during aging is sarcopenia, which refers to the reduction in muscle mass and its strength affecting the function of respiratory and oropharyngeal muscles (Nishikawa et al., 2021; Walston, 2012). Sarcopenia is associated with reduced elasticity, thoracic compliance, expiratory muscle strength, leading to reduced subglottic air pressure necessary for speaking (Kim & Sapienza, 2005). Beyond speech, they also affects swallowing mechanism, causing difficulty in swallowing or dysphagia (Laciuga et al., 2014).

Literature has evidenced that the aging process induces significant alterations in the structure and physiology of the respiratory system, marked by the loss of elastic recoil and the increased rigidity of the chest wall (Campbell & Lefrak, 1978; Sharma & Goodwin, 2006). As a result, elderly people exhibit “senile emphysema” because the enlargement of air spaces decreases the total surface area of the lungs available for gaseous exchanges (Sharma & Goodwin, 2006). Critically, as the muscle strength of respiratory muscles declines with aging; there is a significant reduction in the strength of diaphragms, over 20% because of muscle atrophy associated with aging (Lee et al., 2016). As a result, the maximum inspiratory pressure decrease, which hinders generation of subglottic pressure required for effective speech and coughing (De Souza Pereira Gama et al., 2018; Sharma & Goodwin, 2006). The alterations in respiration thus impacts phonation as subglottal pressure are vital for voice.

The changes in the larynx with aging is commonly referred to as "presbylarynx," is found to significantly impact phonatory function in elderly adults (Devadas et al., 2022). The muscles of the larynx are prone to atrophy, and incomplete glottal contact during phonation results from the lamina propria's elastin fibres being thinner (Allen & Miles, 2019; Keerthiga & Shetty, 2023). These morphological changes result vocal fatigue, increased breathiness, decreased projection, and changes in fundamental frequency (Allen & Miles, 2019; Keerthiga & Shetty, 2023). These phonatory abnormalities, like tremulousness and hoarseness, can make it difficult for many elderly individuals to communicate effectively and have a detrimental influence on their quality of life (Allen & Miles, 2019; Devadas et al., 2022).

In addition to these phonatory changes, aging also is seen to influence the motor components of speech production, specifically the timing and coordination of articulatory movements. Age-related changes in the motor aspects of speech production also show a decline in the stability of speech motor control (Hu et al., 2023). According to research, elderly individuals often exhibit reduced speaking rates and a significantly higher variety of spatiotemporal organization during speech movements (Hu et al., 2023; Wohlert & Smith, 1998). In particular, articulatory movements characterized by longer deceleration phases and less steady tongue body movement tend to slow down significantly after the age of 60. Even in cognitively healthy adults, these alterations in articulation and timing suggest a gradual decline in speech movement planning and execution (Tremblay et al., 2018).

The decline in swallowing function with aging, or "presbyphagia" undergoes a number of physiological changes making the elderly more susceptible to dysphagia. The risk of aspiration in elderly is increased by changes such as delayed bolus clearance, reduced hyolaryngeal excursion, slower and more variable tongue (Bennett et al., 2007; Troche et al., 2010). It is estimated that the elderly population is estimated to be 138 million in India by 2021 (Dodderi et al., 2024). The high prevalence of self-reported swallowing fatigue (41.5%) by community-dwelling older adults and requiring assistance with feeding, highlight the critical need for focused screening and intervention (Chilwan et al., 2025; Dodderi et al., 2024).

The interconnection among these three physiological functions underscored the need for a multisystem intervention approach. Expiratory Muscle Strength Training (EMST) is a promising intervention to reduce age-related declines by strengthening the muscles essential for both respiratory and non-respiratory functions, such as laryngeal elevation and pharyngeal constriction. The treatment modality relies on forced exhalation against resistance, leading to increased strength in the expiratory muscles (Hutcheson et al., 2017). EMST therapy is shown to enhance maximum expiratory pressure and intraoral pressure during speech even under high loads among healthy older adults (Kim & Sapienza, 2006). This increases airway protection and swallowing efficiency, especially in patients prone to dysphagia (Brooks et al., 2017). Studies involving clinical populations have demonstrated positive effects of EMST on swallowing function, including reductions in dysphagia severity among individuals with various neurological conditions, such as stroke. These improvements have been associated with increased activation of suprahyoid muscle activity and reduced risk of aspiration (Eom et al., 2017; Park et al., 2016). Given the significant high prevalence of aspiration-related complications, particularly, among individuals with neurodegenerative disorders, interventions that strengthen airway protection mechanisms are of important clinical relevance (Pitts et al., 2008).

Age-related changes across respiratory, phonatory, and swallowing systems shows the need to establish both accessible and effective rehabilitative intervention approaches for the elderly. In India, clinical practice among speech-language pathologists (SLPs) shows considerable variability, mainly due to limited access to instrumental assessments, and the absence of standardized national guidelines (Rangarathnam & Desai, 2020). Consequently, exploring EMST as a non-invasive, cost-effective intervention is of particular importance. Previous International studies have demonstrated its efficacy in enhancing swallowing-related muscle function and airway protection; however its specific applicability within India's unique demographic and clinical context remains underexplored (Brooks et al., 2017; Park et al., 2016). The current study, seeks to address this gap by evaluating the effect of EMST on speech and swallowing functions in Indian elderly, thereby supporting the development of evidence-based assessment and intervention protocols for geriatric care in India.

Need for the study

Though a substantial amount of research confirms the role of EMST on speech and swallowing abilities, very little work has been done to investigate the its impact on Indian elderly. Considering the differences in culture, language, and body structure, it is essential to have data that is applicable to the Indian geriatric population. This study is concerned with individuals 60 years and older, given that aging poses specific risks because of the gradual loss of respiratory muscle mass and strength, primarily due to sarcopenia and decreased neural activation of the respiratory muscles. Loss of respiratory muscle mass leads to decreased maximal expiratory pressure, diminished phonation stability, and impaired airway clearance. It is further noted that delayed initiation of the swallow, decreased airway protection, presbyphagia, and presbyphonia (characterized by reduced vocal loudness, breathy voice quality, and instability of the pitch) are often increased in older adults. Reduced laryngeal control and expiratory force are closely associated with these disorders (Ramig & Ringel, 1983). Prior research indicates that neuromuscular adaptation is still possible in older persons, and that specific therapies such as EMST can result in notable enhancements in phonatory and respiratory performance (Sapienza et al., 2011).

Therefore, research on the effects of EMST in healthy older people in India is critically needed. In order to provide comprehensive and functionally relevant insights into the efficacy of EMST as a prospective intervention for the aging population, the current study will investigate the effects of EMST on speech and swallowing function.

Aim of the study

This study aims to examine the impact of expiratory muscle strength training (EMST) on speech and swallow functions in individuals aged 60 or older.

Objectives of the study

The study aims to achieve the following:

1. To compare respiratory measures pre-, post-, and four weeks after EMST intervention in Indian elderly.
2. To compare phonatory measures pre-, post-, and four weeks after EMST intervention in Indian elderly.
3. To compare articulatory measures pre-, post-, and four weeks after EMST intervention in Indian elderly.
4. To compare the swallow measures pre-, post-, and four weeks after EMST intervention in Indian elderly.

CHAPTER II

REVIEW OF LITERATURE

Ageing is a biological and inevitable process characterized by progressive deterioration in structural strength and functional efficiency across various organ systems (Kirkwood, 2005). These processes are complex in nature, caused by a variety of factors including behaviours, environmental conditions, and genetic predisposition. As people age, physiological reserve becomes depleted, resulting in reduced capacity of the body to withstand internal and external stimulations.

The support systems for speech and swallowing, namely the respiratory, phonatory, articulatory, and swallowing systems are also impacted by aging affecting communication and nutrition. These systems are integrated in function, and any alterations in the function of one system can have an impact on the other systems. For instance, inadequate respiratory support can impair phonation which affects speech intelligibility and also compromise airway protection during swallowing.

Presbyphonia and presbyphagia refer to age-related changes associated with speech and swallowing, respectively. Presbyphagia refers to the age-related differences observed in swallowing physiology that allow safe deglutition in healthy individuals. Presbyphonia includes both structural and functional changes in the laryngeal mechanism and manifests in altered vocal performance. While not being pathological conditions per se, presbyphonia and presbyphagia characterise decreased reserve functions and therefore increase the risk of swallowing disorders and communication problems.

The aging population is growing rapidly on a global scale. According to the United Nations World Population Prospects (2019), by 2050 one out of six people in the world will be aged 65 or older. The World Health Organization (WHO) projects that by 2050, there will be three times more individuals aged 60 years or older and 400 million people aged 80 years or above. Such demographic trends have become evident in India where there is a health crisis amongst its elderly population. These demographic trends arise out of the decline in the quality of life, the increased prevalence of chronic illnesses, and reduced socialization. However, the process of aging varies from person to person based on factors such as lifestyle, genetics, and overall health (Orimo et al., 2006). In view of that, to provide adequate care for elderly population, the United Nations and WHO categorised them into three subgroup: young-old (age 65-74 years), middle-old (age 75-84 years), and old-old (age 85 years and above) (WHO, 2015; United Nations, 2019).

Aging is a diverse process, which manifests considerable inter-individual variation in terms of how it affects an individual's body. Functional deterioration is greatly influenced by various factors like physical activity, presence of other disorders, nutrition, and cultural effects. Therefore, understanding the impact of ageing on integrated systems such as speech and swallowing is essential for developing appropriate, population-specific and effective intervention strategies.

2.1 Ageing and its impact on the respiratory system

The respiratory system plays an important role in ensuring both speech production and swallow safety. It is important to create subglottic pressure, which is needed for vocal cord vibration; besides, it provides the main source of airflow for voicing. In addition, the respiratory system ensures that the airways are protected from aspirated materials because the mechanism of coughing enables clearing the airway from such aspirants.

In aging adults, various structural and functional changes occur in the lungs, respiratory muscles, and chest wall resulting in decreased efficiency of respiration. Consequently, low subglottic pressure develops, leading to speech and voice disorders. In particular, expiratory muscle strength decreases and therefore affects speech intelligibility, vocal intensity, and endurance (Langmore et al., 1998).

In terms of structure, calcification of costal cartilages reduces elasticity of the thoracic cage and age-related kyphotic changes in the spine cause decreased chest wall compliance. These changes limit the ability of the lungs to expand fully during inspiration (Janssens et al., 1999). At the pulmonary level, ageing results in reduced elastic lung recoil due to modifications in elastin and collagen fibres within the lung tissue. These changes result in an increase in residual lung volume and a decrease in vital capacity. Even though the total lung capacity is still intact, breathing might not be as efficient.

Respiratory sarcopenia is one of the leading causes of decreased breathing efficiency; it involves the decline in the strength and size of the muscles that are used for exhaling (the intercostal muscles, diaphragm, and abdominals) (Kim & Sapienza, 2005).This condition results in reduced force generation during expiration, an essential process involved in the act of speech production and coughing. Among individuals who are above 60 years, the prevalence of sarcopenia typically varies between 6 and 30 %, depending on the individual's gender, diagnostic method and criteria (Baumgartner et al., 1998; Melton et al., 2000; Tankó et al., 2002). However, the prevalence rate for this age group can increase over 50% when they exceed 80 years of age (Baumgartner et al., 1998; Melton et al., 2000; Tankó et al., 2002; Iannuzzi-Sucich et al., 2002).

Functionally, these structural changes result in measurable reductions in respiratory function indices such as Forced vital capacity (FVC), Slow vital capacity (SVC), Maximum expiratory pressure (MEP) and Peak expiratory flow rate (PEFR) (Janssens et al., 1999). Forced vital capacity (FVC) and one-second forced expiratory volume (FEV1) are correlated with appendicular skeletal muscle mass (Jeon et al., 2015) and skeletal muscle area at the level of third lumbar vertebra, respectively, indicating whole-body muscle mass and respiratory function. Previous studies showed that aging was related to the increase in residual lung values by nearly 50%, which caused the decrease in overall vital capacity, FVC and FEV_1, with total lung volume remaining relatively constant (Kim & Sapienza, 2005). These declines have also been recorded in Indian populations. In a normative study conducted by Annapurana (2009) with South Indian adults, it was noted that spirometric measures of FVC, FEV_1, and PEFR decline significantly with age, and are affected by height and body composition. According to this study, the spirometric measures in South Indian populations were generally lower than western norms, indicative of both age-related declines and physiological differences in the populations surveyed. Similar study done by Mankar et al. (2021) in Indian population reported age-related declines in both FVC and FEV1. The changes are closely associated not only with structural lung changes, but also with weakening of the respiratory muscles. Saleem et al. (2005) investigated the effects of EMST in neurological populations with a specific focus on cough effectiveness and swallowing functions. Tidal Volume (TV) was neither measured nor reported in this study, reflecting the broader trend in the literature where TV falls outside the expected scope of EMST outcome measures. The clinical implications of age-related respiratory decline are substantial. Reduced cough strength is a significant predictor of aspiration; where food, liquid or secretions enter the airway during swallowing. Aspiration pneumonia is one of the most significant forms of morbidity and mortality for the elderly population (Hammond et al., 2008). Thus, age-related respiratory decline forms the physiological foundation for further changes in both speech production and swallowing function.

2.2 Ageing and its impact on the phonatory system

The respiratory, phonatory, and articulatory subsystems must coordinate with one another precisely during the process of speech production. Among these, the respiratory system provides the necessary air pressure required for the onset and sustenance of vibration of vocal folds. Respiratory lung volume and subglottal pressure at the initiation of speech sounds will be directly proportional to lung capacity and subglottic pressure. In addition, the expiratory flow of air creates intraoral pressures that facilitate proper pronunciation of pressure consonants influencing clarity and intelligibility (Tong & Sataloff, 2022; Hegland et al., 2019).

Histological changes in the vocal folds and surrounding musculature causes age-related changes in larynx commonly referred to as presbyphonia. Thyroarytenoid muscle that provides tension and adduction of vocal folds will start to atrophy as a result of degenerative changes in vocal fold mucosa characterised by decreased thickness and loss of elastic fibres and overall collagen (Sato et al., 1997). Poor glottal closure resulting from poor elasticity of vocal fold will cause a breathy weak voice. Breathy voice quality and poor glottal closure will be caused by changes in vocal fold shape as stated by Kendall (2007).

Phonatory instability, which manifests as hoarseness, voice cracks, tremor and/or breathiness, is more common in older voices (Gorham-Rowan & Laures-Gore, 2006). These phonatory characteristics may be reflected through acoustic perturbation measures such as amplitude perturbation quotient and F0 standard deviation. According to Xue and Deliyski (2001), these characteristics help listeners establish the age of a talker since both decrease as the person grows older. The noise in the voice signal, which can be quantified as a harmonics-to-noise ratio, is also probably linked to the perceived breathiness and/or hoarseness of aging voices (Spazzapan et al., 2018). According to Ferrand (2002), elderly population have a much lower harmonics-to-noise ratio than younger population (Ferrand, 2002). This ratio is linked to partial vocal cord closure and reduced periodicity of vocal folds, both of which have been seen in elderly speakers (Gorham-Rowan & Laures-Gore, 2006).

Physiological changes due to aging are related to measures that evaluate the acoustic characteristics of phonatory function. The older population usually have either low or unstable fundamental frequencies, short phonation length, and higher measures of perturbation such as jitter and shimmer (Kost et al., 2018). These results align with extensive normative datasets, which showed the relationship between increased shimmers in males due to age and differences between jitter and shimmer in terms of sex (Goy et al., 2013). Although it was shown earlier that MPT decreased as individuals aged (Ptacek et al. 1966; Kreul 1972), more recent studies revealed that this measure did not show a statistically significant difference between younger and older adults (Maslan et al. 2011). One study even found that older females demonstrated longer MPT values than younger females (Goy et al. 2013). However, the inconsistencies observed might indicate the compensation mechanism used by individuals in order to cope with their phonatory changes. Changes in phonatory function significantly affect the effectiveness of communication and speech intelligibility, especially in cases where sustained vocal effort or increased loudness are required.

2.3 Ageing and its impact on the articulatory system

Articulation requires the coordinated and precise movements of the jaw, lips, tongue, and soft palate to produce speech sounds. In addition to the respiratory and phonatory alterations, aging exerts a significant influence on speech production at the articulatory level. Age-related alterations in neuromuscular function led to reduced speed, strength, and coordination of these structures.

Research consistently indicates that older adults have slower speech rates, less precise articulation, and less intelligibility than younger speakers (Benjamin, 1982). Age has a strong effect on diadochokinetic (DDK) performance, with older adults performing at slower rates across all speech stimuli. There was no effect of gender, and the task type was also a significant effect. Participants produced trisyllabic non-words at the slowest rate, while they produced disyllabic non-word answers faster, but disyllabic real words were faster than both the disyllabic non-words and trisyllabic real words. This suggests a possible role of both motor complexity and aging in articulatory speed (Tafiadis et al., 2022). A preliminary study with older Shanghainese speakers investigated eight speech acoustic parameters that are related to swallowing and found that Maximum Phonation Time (MPT) and DDK (AMR and SMR) had significant age-related differences, such that mean values of these measures declined across age groups. The elderly speakers (65 years and above) produced significantly lower MPT, DDK (AMR and SMR) than the younger and middle-aged adults, suggesting that phonatory endurance and articulatory coordination are impaired with age, which may compromise communicative effectiveness and swallow safety (Sun et al., 2024).

Speech acoustic analysis indicates that elderly speakers exhibit greater variations in duration of longer segments and fundamental frequency, which is lower compared to the younger speakers; hence, their speech sounds unnatural (Ramig, 1983). Elderly patients often have reductions in vocal loudness, prosodic modifications, and difficulties maintaining fluent speech due to a decrease in respiratory support and physiological alterations associated with larynx functioning (Duffy, 2013). Sensory feedback is another aspect of speech functions that gets affected by aging. Indian studies on age-related alterations in speech functions indicate differences in articulation among people speaking different languages. Aging can significantly limit the abilities of elderly people to effectively communicate, thus reducing the quality of their social interaction and their ability to live an active life.

2.4 Effects of ageing on swallowing

Swallowing is an intricate sensorimotor process that requires precise coordination among multiple anatomical structures, including the oral cavity, pharynx, larynx, and esophagus. The successful execution of this system relies upon an extensive and highly integrated neural network including brainstem, subcortical, and cortical regions. The mechanisms responsible for maintaining airway protection during swallowing are, however, susceptible to the effects of aging, particularly the gradual declination of neuromuscular control and muscle strength (Robbins et al., 1999). Even in the absence of an overt pathology, the efficiency and coordination of these systems reduce progressively with advancing age, giving rise to a condition known as presbyphagia.

Presbyphagia is conceptually distinct from dysphagia in that it does not represent a pathological impairment, but rather represents the natural, age-related changes that occur in swallowing physiology. Its defining characteristic is a reduced physiological reserve a state in which swallowing function remains adequate under normal conditions, yet becomes increasingly vulnerable when the individual is exposed to physiological or environmental stressors, such as dehydration, acute illness, or physical fatigue.

During the oral preparatory and oral phases of swallowing, the aging process is associated with a combination of physiological changes that collectively compromise bolus management. These include a reduction in oral sensation, reduced salivary secretion, and reduced tongue strength and pressure generation. Such alterations in aging impair the efficiency of bolus preparation and intraoral control of bolus, often resulting in a prolonged oral transit time and an elevated risk of premature bolus spillage into the pharynx before the initiation of the pharyngeal swallow. Along with these effects, age-related dental deterioration and a decline in masticatory efficiency may further affect the adequate mechanical breakdown of food, particularly when solid food consistencies are consumed.

The pharyngeal phase of swallowing is also affected by a number of age-associated physiological alterations. A frequently noted change is the delayed initiation of the pharyngeal swallowing reflex, which is due to slowed neural processing and a reduction in oropharyngeal sensory input. This delay extends the temporal window during which the airway remains unprotected, thereby increasing the susceptibility to laryngeal penetration or aspiration. Furthermore, a reduction in the muscular strength of the pharyngeal constrictor musculature may compromise the generation of adequate pharyngeal driving pressure, leading to the accumulation of post-swallow residue within the pyriform sinuses and valleculae.

Aging is further associated with a reduction in both the velocity and amplitude of hyolaryngeal elevation, a biomechanical movement that is critically important for airway protection and for facilitating adequate opening of the upper esophageal sphincter (UES). Diminished hyolaryngeal excursion consequently compromises both bolus clearance through the pharynx and the effectiveness of laryngeal airway closure during swallowing. These deficits may be further compounded by a reduction in UES compliance and opening duration, which collectively affect the efficient passage of the bolus into the esophagus.

At the level of the larynx, incomplete or delayed glottal closure during swallowing substantially elevates the risk of laryngeal penetration and aspiration. Age-related atrophy of the intrinsic laryngeal musculature, a process similar to that observed in presbyphonia, may additionally reduce the efficacy of airway protective mechanisms, making the aging larynx increasingly vulnerable during the pharyngeal phase of swallowing.

The disruption of respiratory-swallowing coordination represents another significant age-related concern. Hiss and Treole (2001) reported that impairments in the temporal coordination between respiration and swallowing markedly increase aspiration risk in the elderly population. In relation to clinical screening, the Repetitive Saliva Swallow Test (RSST) is widely recognised as a reliable and clinically accessible bedside measure for the identification of swallowing dysfunction. In the early study conducted by Oguchi et al. (2000), older adults with a mean age of approximately 68 years produced significantly less saliva swallows within a 30-second interval (mean of 5.9 swallows) in comparison to their younger counterparts (mean of 7.4 swallows), supporting the presence of an age-related decline in swallowing frequency. Furthermore, Oguchi et al. (2000) established that an RSST score of less than three swallows per 30 seconds requires referral for more comprehensive swallowing assessment, including instrumental evaluation such as videofluoroscopic examination.

In the geriatric age group, the weakened condition of the expiratory muscles often leads to the development of inadequate cough reflexes, which are incapable of clearing the airway and hence increasing the incidence of aspiration. Strength of the cough reflex, quantified using peak expiratory flow rate (PEFR), has been shown to be a strong predictor of aspiration risk in the elderly population (Hammond et al., 2008). The clinical usefulness of voluntary cough as a predictor of aspiration risk has been comprehensively established by Hammond et al. (2001), where cough airflow parameters were studied in a stroke population, and it was observed that decreased voluntary cough production was strongly correlated with increased risk of aspiration, as determined by videofluoroscopy of the swallowing function. This pivotal work has led to the use of PEFR as a valid measure of airway protection integrity, paving the way for further studies involving PEFR as the main outcome variable (Hammond et al., 2008).

Within the context of aging, where expiratory muscle weakness reduces the forceful expiratory effort required for an effective cough, PEFR has emerged as a practical bedside indicator of aspiration risk that does not necessitate instrumental assessment. Reduced cough peak flow values have been associated with impaired airway clearance and elevated rates of aspiration pneumonia, particularly in the presence of concurrent neurological disease. From a clinical threshold perspective, a PEFR of less than 60 L/min or a Standardised Cough Secretion Score (SCSS) of three or below has been linked to an increased risk of extubation failure and aspiration pneumonia (Smina et al., 2003). Research conducted within neurological populations, including individuals with stroke and Parkinson's disease, has further demonstrated that reduced cough strength is predictive of dysphagia severity and the frequency of aspiration events (Troche et al., 2010; Pitts et al., 2009). It is important to acknowledge, however, that cough efficacy may be meaningfully compromised as a consequence of the normal aging process alone, independent of any underlying pathology.

Collectively, the age-related variations described across the oral, pharyngeal, laryngeal, and respiratory domains contribute to a progressive reduction in swallowing efficiency, increased post-swallow residue, and a increased risk of airway compromise. Although such changes may manifest subtly in otherwise healthy elderly, they represent a significant reduction in physiological reserve that makes the aging swallowing system substantially more vulnerable to the development of clinically significant dysphagia when compounded by acute illness, physical deconditioning, or neurological impairment.

2.4.1 Respiratory-swallowing coordination

The coordination between respiration and swallowing is an important physiological mechanism that ensures airway protection during swallowing. Swallowing usually occurs during the expiratory phase of respiration in healthy adults, with an exhale-swallow-exhale pattern. This pattern provides a protective advantage by helping in clearance of any residual material from the airway immediately after swallowing. For post-swallow airway clearance, this provides the ideal subglottic pressure and expiratory airflow (Martin-Harris et al., 2008; Valenzano et al., 2020). The central pattern generators in the Brainstem, which combine information from the swallowing and respiratory networks, control this coordination. Age-related breakdown of this coordination is caused by both central and peripheral mechanisms.

From a neurological perspective, aging is linked to decreased central pattern generator responsiveness and decreased neural transmission efficiency. The timing and sequencing of respiratory and swallowing events become more variable as a result. Reduced respiratory muscle strength restricts the capacity to produce sufficient expiratory airflow from a peripheral standpoint. Because of this, older people frequently have different respiratory-swallow rhythms, such as more inspiration before or after swallowing. This is especially dangerous because residual material may be drawn into the lower airway by inspiratory airflow after swallowing, raising the possibility of aspiration.

The lung volume at swallow onset is another significant component. Swallowing usually happens at mid-to-high lung volumes in younger people, which offers the optimal subglottic pressure for airway protection. In contrast, because of reduced respiratory capacity, elderly individuals frequently start swallowing at lower lung volumes. As a result, the efficiency of airway closure is compromised by a decrease in subglottic pressure.

The efficiency of coughing, a secondary defensive mechanism against aspiration, is strongly correlated with the strength of the expiratory muscles. Cough peak flow is reduced as a result of age-related decreases in Maximum Expiratory Pressure (MEP) and Peak Expiratory Flow Rate (PEFR), which restricts the capacity to evacuate inhaled material. Clinical research has shown a substantial correlation between a lower PEFR and a higher risk of aspiration pneumonia.

Dai et al. (2024) published a systematic review and meta-analysis to investigate the effects of respiratory training on swallowing function in individuals with swallowing disorders. The results demonstrated that respiratory training, including both inspiratory muscle training (IMT) and expiratory muscle training (EMT), can enhance swallowing safety and efficiency through strengthening the shared neuromuscular mechanisms that control respiration and swallowing. In the systematic review and meta-analysis done by Su et al. (2025) evaluated the effectiveness of respiratory exercise on swallowing dysfunction in elderly patients with dysphagia. The findings indicated that respiratory exercise had a positive effect on enhancing respiratory and swallowing function among elderly patients with dysphagia (> = 65 years), which was associated with decreased risk of aspiration, in comparison with standard medical therapy. Based on the recent research, the current study is the most contemporary evidence regarding the efficacy of respiratory training among elderly patients with dysphagia. Therefore, respiratory swallowing impairment can be considered as an essential mechanism that causes aspiration in elderly people.

Martin et al. (2005) described how reduced respiratory and vocal ability in the elderly is associated with a delayed swallow response and failure of the larynx to assume a closed position. Because of these connections, instead of depending only on compensatory techniques, researchers and clinicians have looked for focused, rehabilitative methods that directly enhance expiratory musculature (Sapienza, C. M. 2008).

2.5 Impact of aging on quality of life

The functional impact of presbyphonia and presbyphagia extend beyond physiological limitations and significantly affect the quality of life of elderly individuals. These changes impact multiple domains, including physical health, psychological well-being, and social participation.

From a communication perspective, decreased vocal intensity, reduced speech intelligibility, and vocal fatigue can lead to frequent communication breakdowns. This may result in reduced frustration, confidence, and withdrawal from social interactions. Over time, such limitations can lead to reduced participation in daily activities and social isolation. From a swallowing perspective, eating and drinking difficulties might result in dietary changes, decreased nutrient intake, and a higher risk of malnourishment and dehydration. People may be further hindered from participating in communal dining situations by ambition or fear of choking.

These functional limitations align with the activity limitation and participation restriction components of the International Classification of Functioning (ICF) framework. Individuals may experience reduced independence in daily activities and decreased engagement in social roles. In a recent cross-sectional study, Gascon et al. (2024) found that older adults experiencing voice and swallowing problems reported significant negative effects on their health-related quality of life and these issues are often not identified by healthcare providers. Pereira et al. (2025) found that risk for dysphagia was associated with lower quality of life and increased psychological distress. These findings highlight how limitations in speech and voice can have far-reaching effects on both physical functioning and mental health.

Psychologically, these alterations are linked to elevated anxiety, depression, and low self-esteem. Elderly people with speech and swallowing problems report much lower health-related quality of life than their healthier peers, according to studies.

In order to improve physiological function as well as the general well-being and quality of life of the aged population, it is crucial to address age-related changes in speech and swallowing.

2.6 Expiratory Muscle Strength Training (EMST): Mechanisms and Physiological basis

Expiratory Muscle Strength Training (EMST) is a task-specific intervention applying threshold resistive loading during forceful expiration to strengthen the expiratory muscles, primarily, the internal intercostals and abdominal wall. Training is performed using repeated maximal expiratory efforts representing 60–80% of a person's baseline maximum expiratory pressure (MEP). The objective is to overload the muscles to create a neuromuscular adaptation for improved functional performance (e.g., coughing, speaking, and swallowing). From a motor learning perspective, the neuromuscular gain produced by resistive expiratory training do not always manifest immediately at the end of a training protocol. According to Schmidt and Lee (2011), motor learning follows a trajectory in which newly acquired movement patterns may temporarily affect established coordination before strengthening at a higher performance level. This transitional disruption phase is relevant to EMST outcomes, as short-term post-intervention assessments may underestimate functional gains that continue to emerge during a post-intervention retention period. Structural changes in muscle fibre composition and neural drive, particularly adaptations in motor unit recruitment patterns, may take several weeks beyond the active training phase to fully strengthen. Consequently, follow-up assessments conducted weeks after training termination often reveal continued improvement or delayed emergence of gains not detected immediately post-intervention. This principle has direct implications for interpreting both spirometric and articulatory outcomes following EMST in healthy elderly individuals.

Resistance training leads to muscle hypertrophy and increased force generating capacity. EMST also improves neural drive to the respiratory muscles improving timing and coordination between inspiratory and expiratory efforts. This results in increased subglottic pressure which is necessary for effective phonation, cough and airway protection during swallowing. Studies have shown that EMST has positive effects on respiratory function, speech and swallowing. Studies have demonstrated that a brief program (approximately 4 weeks) can increase MEP considerably. While results from EMST studies are encouraging, they should be compared with those from other forms of exercise. One such approach is Inspiratory Muscle Strength Training (IMST), which apparently can increase lung volumes but, unlike cough, does not guarantee effective cough or airway protection. More traditional speech training can enhance vocal quality and speech articulation but is inadequate for managing respiratory muscle weakness. In contrast, EMST, by strengthening the expiratory muscles that are responsible for subglottic pressure, can increase cough strength and swallowing safety. Adding EMST to other interventions, however, may result in better patient outcomes.

Over the past 20 years, EMST has widely been investigated in Western populations in particularly healthy older adults and individuals with neurological disorders. For example, Kim and Sapienza (2005) noted increased MEP and vocal intensity in healthy older adults who participated in 4 weeks of EMST. Troche et al. (2010, 2014) demonstrated safety when swallowing was improved in Parkinson’s disease, while Pitts et al. (2009) showed that EMST improved voluntary cough. EMST also increased cough effectiveness in patients following stroke (Moon et al., 2017), improved swallowing safety in individuals with multiple sclerosis (Chiara et al., 2006), and included larger neurogenic populations (Claus et al., 2021; Wang et al., 2019). More recent EMST studies showed benefit to pre-frail elderly (Sari et al., 2023) and EMST improved intraoral pressure and vocal intensity in healthy older adults (Kim et al., 2021).

These studies confirm the findings of systematic reviews. Mancopes et al. (2021) found EMST has an impact on swallowing kinematics, hyolaryngeal excursion, and upper esophageal sphincter opening etc., and reduces penetration-aspiration ratings from both clinical and healthy participants. Park et al. (2024) found multifactorial benefits from EMST in those with Parkinson's disease, drawing evidence from differences in swallowing safety, phonation, and respiratory function. Anand et al. (2024) even found the MEP improvements to be comparable when training three days vs five days a week, noting that both training frequencies are viable, and therefore, offers flexibility.

Research on EMST in older populations is sparse in the Indian context, although it is emerging. Kulkarni and Kolase (2020) conducted an interventional pilot study on adults aged over 60 that lived in the community in rural Maharashtra to explore the effect of an EMST protocol on the Peak Expiratory Flow Rate (PEFR) and Maximum Expiratory Pressure (MEP). Thirty older adults took part in a one-week EMST protocol with three sessions per week. The study revealed a significant difference in PEFR before and after the one-week intervention; the MEP showed a positive trend but lacked statistical significance over this short duration. The authors stated that short EMST protocols could provide immediate benefit in expiratory flow capacity for the older person with potential for enhancing airway clearance and pulmonary function. They found that EMST training is feasible, and the short EMST protocol outlined was found beneficial for older populations in India. To build the performance in expiratory muscle strength, longer duration protocols are needed.

There begins to be evidence possible benefits also in post-extubation dysphagia where it is theorized that EMST is simply the application of pressure while swallowing and coughing to possibly improve swallowing and thereby cough strength, strength in breath support and potentially

lower the likelihood of silent aspiration (Skurok et al., 2025). As a summary of these benefits, EMST as an intervention can be reliable, and efficacious, and provides more benefits for the respiratory musculature and airway protection, even if it doesn't completely compensate for the age-related declines. Crucially, the results showed that EMST is beneficial not just for clinical populations, like those with post-stroke dysphagia and Parkinson's disease, but also for healthy older persons, where it enhanced swallowing efficiency.

While there are many other types of training, including inspiratory muscle training and general breathing exercises, that can be used for respiratory therapy, EMST involves training in exhalation. While inspiratory training can increase the volume of the lungs, it will not be as effective as EMST at producing a more powerful cough. As a result, EMST is in a unique position as an intervention that uses a common physiological mechanism to simultaneously affect the respiratory, phonatory, and swallowing subsystems.

2.6.1 Effects of EMST on subsystems

2.6.1.1 Effects on respiratory function

EMST has been widely reported to produce significant improvements in expiratory muscle strength, as evidenced by increases in Maximum Expiratory Pressure (MEP). Higher airflow rates and pressures, which are necessary for efficient breathing and airway clearance, can be produced with improved expiratory strength. Additionally, improvements in cough peak flow and Peak Expiratory Flow Rate (PEFR) have been reported, suggesting improved cough efficacy. This is especially helpful for older individuals, as respiratory impairment is often caused by a decrease in expiratory force (Kim & Sapienza, 2005; Pitts et al., 2008; Kulkarni & Kolase, 2020).

2.6.1.2 Effects on phonatory and articulatory subsystems

Speech production is directly impacted by the changes in respiratory function that occur after EMST. Increased subglottic pressure from increased expiratory power promotes more effective and steady vocal fold vibration. People may exhibit longer Maximum Phonation Time (MPT), better voice quality, and higher vocal energy as a result. Longer breath groups during connected speech are also made possible by improved breath support, which enhances fluency and lessens vocal fatigue (Kim & Sapienza, 2005). Extending this line of evidence, Kim and Sapienza (2006) conducted a study specifically examining the effects of EMST on speech outcomes in healthy elderly adults. The study demonstrated significant improvements in intraoral pressure and vocal intensity following a structured EMST protocol. Notably, these improvements were observed in aerodynamically proximal measures that is, measures directly linked to expiratory airflow generation rather than in acoustic perturbation parameters such as jitter or shimmer. This distinction is important, as it clarifies the mechanism through which EMST influences phonation, by augmenting the aerodynamic platform for speech rather than altering the intrinsic vibratory properties of the vocal folds. These findings indicate that EMST may be particularly effective in improving speech loudness and pressure generation in healthy elderly speakers, even in the absence of neurological compromise.

Furthermore, a more robust aerodynamic foundation for articulatory movements is provided by increased respiratory-phonatory coordination, which may substantially improve speech precision and clarity. Additionally, some research has shown improvements in diadochokinetic (DDK) rates, which may indicate improved motor coordination (Hegland et al., 2019; Sari et al., 2023)

2.6.1.3 Effects on swallowing and airway protection

By strengthening airway protective mechanisms, EMST is essential to increase swallowing safety. Stronger expiratory muscles make coughing more effective and allow aspirated food material to be cleared more quickly. Moreover, better glottal closure during swallowing is facilitated by high improved subglottic pressure, which lowers the risk of airway invasion. Additionally, EMST may help restore the ideal exhale-swallow-exhale pattern, which would enhance respiratory-swallow coordination. Following EMST, studies in neurological populations have shown notable increases in swallowing safety and decreases in aspiration. These results demonstrate its potential use in healthy older people as a preventive measure as well as a rehabilitative intervention.

Age-related alterations in the respiratory, phonatory, articulatory, and swallowing subsystems have been extensively reported in international literature, emphasizing the interdependence of these systems and their combined effects on airway protection and communication. Additionally, a number of clinical populations, including those with

Parkinson's disease, stroke, and multiple sclerosis, have been the subject of extensive research on EMST. The results consistently show improvements in respiratory muscle strength, cough efficacy, speech production, and swallowing safety (Troche et al., 2010; Pitts et al., 2008; Claus et al., 2021; Mancopes et al., 2020).

Within the Indian context, however, research in this domain remains comparatively limited. Although a few studies have explored age-related changes in isolated subsystems such as respiratory or speech parameters, comprehensive and integrated investigations remain scarce. Additionally, there is a lack of population-specific normative data for key measures such as Maximum Expiratory Pressure (MEP), Peak Expiratory Flow Rate (PEFR), Maximum Phonation Time (MPT), and Diadochokinetic (DDK) rates in elderly individuals.

Significantly, there is a lack of published research on the effects of EMST in healthy elderly, especially in the Indian population. Although previous research has demonstrated its effectiveness in clinical population, it is still unknown whether the same advantages apply to healthy older adults, particularly with regard to integrated improvements in speech and swallowing functions. Furthermore, results from Western study populations might not be directly applicable to the Indian setting due to variations in lifestyle patterns, food preferences, anthropometric traits, and linguistic diversity, making it necessary to create population-specific evidence. Therefore, establishing both normative and intervention data in India is essential to inform evidence-based, culturally relevant rehabilitation approaches for speech and swallowing disorders related to aging.

CHAPTER III

METHOD

3.1 Ethical clearance and Informed consent

Following the approval of the *Ethical guideline for Bio-behavioural Research including Human Subjects (Version 2.0)* (All India Institute of Speech and Hearing, 2023), the study was conducted at AIISH, Mysuru. The caregivers of the participants provided consent, following which they were enrolled. The study was approved by the AIISH Bio Behavioural Ethical Committee (reference: SH/IRB/M.5/SLP.29/2025-26 dated 11-03-2026) (Appendix I). All required measures were taken to ensure the safety and confidentiality of participant data, and the caregivers of study participants were provided with comprehensive information about the study.

3.2 Study design

This study used an ABA research design to determine the effect of Expiratory Muscle Strength Training (EMST) on speech and swallowing functions in Indian elderly. According to this design, the first 'A' phase represents the baseline assessment conducted prior to intervention, during which all outcome measures related to respiratory, phonatory, articulatory and swallowing domains were documented. The 'B' phase represents the four-week intervention period, during which the structured EMST program (3 sessions per week) was implemented. The final 'A' phase represents the four-week follow-up assessment after completion of the intervention to determine retention of treatment effects. Intervention was not provided during the interval between post-intervention and follow-up assessment. This design ensured that each participant acted as their own control, enabling comparison of outcome measures across multiple time points. It also facilitated monitoring of both the extent of change and the persistence of treatment effects over time, which was important for determining clinical as well as statistical significance. This design allowed for systematic comparison of pre-intervention, post-intervention and follow-up performance.

3.3 Participants

Five community-dwelling older adults (aged 60–80 years, all female) participated in the study. All participants were native speakers of Kannada (n = 4) or Malayalam (n = 1), passed the Montreal Cognitive Assessment (MoCA) screening, and reported no history of smoking or tobacco use. None had a diagnosed neurological, respiratory, or swallowing disorder, and no contraindications to spirometry or expiratory muscle strength training (EMST) were identified. All participants met the inclusion criteria and except the 3rd participant all others completed three phases of the ABA design: pre-intervention (A1), post-intervention (B), and four-week follow-up (A2). Detailed demographic and clinical characteristics are presented in Table 3.1.

Table 3.1

Detailed demographic and clinical characteristics

Participant	Age	Sex	Height (cm)	Weight (kg)	Language	MoCA Pass	Comorbidities / Contraindications	Completed All Phases
P1	65	Female	163	60	Kannada	Yes	None	Yes
P2	80	Female	160	65	Malayalam	Yes	None	Yes
P3	65	Female	158	65	Kannada	Yes	None	No (follow-up not done)
P4	64	Female	160	73	Kannada	Yes	None	Yes
P5	60	Female	160	78	Kannada	Yes	None	Yes

Note. MoCA = Montreal Cognitive Assessment. P = Participant.

Inclusion criteria:

- Age ≥ 60 years.
- Ability to follow basic instructions. To rule out cognitive impairment, the Montreal Cognitive Assessment (MoCA) [score ≥ 26] (Nasreddine et al., 2005) was administered.
- No history of any respiratory, neurological, or laryngeal conditions.

Exclusion criteria:

- Presence of an upper respiratory infection.
- Smoking
- Neurological or progressive neuromuscular disease
- Vocal fold pathology other than presbyphonia
- Recent speech-language therapy
- Cognitive Impairment
- Any condition deemed by the physician unsuitable for spirometry or EMST (recent surgeries, cardiac conditions, severe COPD/asthma, severe uncontrolled hypertension, severe GERD etc).

3.4 Instrumentation

1. Spirometer – Spiro Q software

Spirometer (Model: Spiro Q software version 1.0.0), along with the handheld SPIRO FLO device (SF100), was used to measure several respiratory parameters and cough strength. Spirometer is a widely used and reliable method for assessing pulmonary function by measuring the volume and flow of air during inhalation and exhalation. The device records respiratory performance and cough strength by analysing airflow through the mouthpiece while the participant performs specific manuevers.

In the present study, the spirometer was used to assess respiratory function and cough strength at three different stages: pre-therapy, post-therapy and follow-up. These measurements helped to determine changes in respiratory performance following intervention.

Participants were asked to inhale and exhale, and to cough through the mouthpiece, according to the standardised procedures recommended for spirometry testing. The various parameters measured using spirometer are mentioned in Table 2.

Table 3.2

The respiratory parameters measured using the spirometer

Parameters	Unit
Forced vital capacity [FVC]	L
Slow vital capacity [SVC]	L
Forced expiratory volume [FEV]	L
FEV1/FVC ratio	%
Tidal volume	L
Peak expiratory flow rate [PEFR]	L/min

2. PRAAT software

Voice recordings were obtained and analysed using PRAAT software (version 6.2.23) (Boersma & Weenink, 2021). PRAAT is a freely available, widely used software package for speech and voice analysis that enables detailed acoustic measurements of speech signals.

In the present study, participants were asked to produce a sustained vowel /a/ at a comfortable pitch and loudness level. The recorded voice samples were then analysed using

PRAAT to extract acoustic parameters including Fundamental Frequency (F0), Jitter (%), and Shimmer (%).

Fundamental frequency (F0) represents the rate of vocal fold vibration and is measured in Hertz (Hz). Jitter (%) and Shimmer (%) refers to the cycle-to-cycle perturbation of the period and amplitude respectively. These acoustic parameters provide objective information regarding vocal fold stability and voice quality.

3. Stopwatch and Voice recorder

A voice recorder (Sony IC recorder) and stopwatch were used to measure Maximum Phonation Time (MPT). MPT is an important aerodynamic measure used to evaluate the efficiency of respiratory and phonatory coordination during sustained phonation tasks.

Participants were instructed to take a deep breath and sustain the vowel /a/ for as long as possible at a comfortable pitch and loudness level. Each participant was asked to perform the task three times, and the duration of each trial was recorded using a stopwatch. Simultaneously, the production was recorded using a voice recorder to ensure accurate documentation of the phonation task. The average duration of three trials was calculated to obtain the final MPT value for each participant.

4. Expiratory Muscle Strength Trainer 150 (EMST-150)

The Expiratory Muscle Strength Trainer 150 (EMST–150) was used as the intervention device in this study. EMST-150 is a handheld respiratory training device designed to strengthen the expiratory muscles involved in breathing, coughing and voice production. The device consists of a plexiglass tube attached to a mouthpiece and contains a spring-loaded, pressure-threshold valve mechanism. The valve opens only when the user generates sufficient expiratory pressure. The resistance level of the device can be adjusted using a variable tension spring, which controls the opening pressure of the valve. The pressure levels are calibrated and measured in centimetres of water pressure (cm H2O).

Figure 3.1

Expiratory Muscle Strength Trainer 150 (EMST-150)

During training, participants were instructed to take a deep breath and then exhale forcefully into the mouthpiece. When the expiratory pressure generated by the participant exceeds the preset threshold level, the valve opens, allowing air to pass through the device. This mechanism provides resistance to exhalation, thereby strengthening the expiratory muscles over repeated practice.

The EMST-150 was used as a training tool in the intervention phase of the study to improve expiratory muscle strength and cough effectiveness. Regular use of the device is expected to improve respiratory support for phonation and improve cough strength by enhancing the force generated by expiratory muscles.

3.5 Procedure

3.5.1 Pre-intervention assessment (Baseline evaluation)

Before the intervention, each participant will undergo a comprehensive baseline assessment to ascertain their cough strength, any swallowing issues, if present, and baseline respiratory and phonatory function characteristics.

1.1 Assessment of swallowing function

Screening for swallowing problems: The investigator screened all participants for dysphagia using the Swallow Abilities Screening Questionnaire for the Indian Elderly (SASQ-IE) (Mohandas, S., & Swapna, N., 2023, in press) (Appendix II). The questionnaire consists of 2 parts: Part A (Demographic data), where the general information regarding each participant will be recorded, and Part B (Questionnaire), which consists of 25 questions under three domains: Activity limitation, difficulties in the oral, pharyngeal, and esophageal phases, and participation restrictions. Scoring was based on whether the symptoms were present: always (score of 1), sometimes (score of 0.5), or never (score of 0). The scores for each question were added up to obtain the total pre-SASQ-IE score.

Cough strength assessment: Cough strength assessment was done objectively and subjectively. An objective measure of cough strength was done using a spirometer (Model: Spiro Q software version 1.0.0), along with the handheld SPIRO FLO device (SF100). The participant was instructed to hold the mouthpiece with lip seal, inhale as much as possible and then to spontaneously cough with maximum effort. Peak expiratory flow (PEF) was noted. This is the most reliable predictor of aspiration risk (Hammond et al., 2008).

Subjective cough strength was assessed using the semiquantitative cough strength score (SCSS) (Khamiees et al., 2001) (Appendix III). The participant was instructed to cough as strongly as possible. The cough strength is scored from 0 to 5 where 0 = no cough on command, 1 = audible movement of air through the endotracheal tube but no audible cough, 2 = weakly (barely) audible cough, 3 = clearly audible cough, 4 = stronger cough and 5 =

multiple sequential strong coughs, to get the pre-SCSS score which indicated the airway protection ability.

Voluntary swallow assessment: The Repetitive Saliva Swallowing Test (RSST) (Oguchi et al., 2000) is a simple, non-invasive clinical screening tool widely used to assess swallowing function, particularly in identifying risk for dysphagia. It was performed by instructing the participants to swallow their own saliva as many times as possible within a fixed time interval, typically 30 seconds. During the task, the investigator placed the index finger on the participant's hyoid and the middle finger on the laryngeal prominence of the thyroid cartilage to palpate the swallowing movements. The laryngeal prominence would move upward and return to its original position when the patient swallows. Each time the laryngeal prominence of the participant touched the examiner's index finger during swallowing, one swallow was counted. Then, the total number of swallows within 30 seconds was measured using a stopwatch and recorded as the pre-RSST count. A cut-off of less than 3 swallows in 30 seconds has been reported as an indicator of potential swallowing difficulty and higher risk for aspiration.

1.2 Assessment of speech functions

1.3 Assessment of respiratory function

A dry digital spirometer (Model: Spiro Q software version 1.0.0), along with the handheld SPIRO FLO device (SF100), was used to evaluate respiratory function. Parameters measured were:

a. Forced Vital Capacity (FVC): Participants was asked to inhale deeply and fully and then to exhale as forcefully and quickly as possible. This measured the maximum volume of air expelled after full inspiration. By performing forced vital capacity (FVC), the following parameters were automatically assessed by the Spiro Q software:

A. Forced Expiratory Volume (FEV) — The volume of air expelled during a predetermined time interval of the FVC maneuver**.**

B. FEV_1/FVC Ratio — This measures the percentage of FVC exhaled in the first second, aids in determining airflow restriction.

C. Peak Expiratory Flow Rate (PEFR) — This measures the maximum flow attained during a forced expiration from full lung inflation.

b. Slow Vital Capacity (SVC): Participants were asked to inhale deeply and then exhale slowly and thoroughly. This measured the maximum amount of air that can be gently expelled following full inspiration. By performing slow vital capacity (SVC), the following parameter was automatically assessed by the Spiro Q software:

A. Tidal Volume (TV) — The volume of air inhaled or exhaled during regular breathing.

Testing procedure:

- Participants were seated comfortably, and to prevent air from escaping, a nose clip was used to cover their noses.
- A technique demonstration was provided, followed by one or two practice runs to guarantee correct technique.
- Three maximal effort trials were performed for each parameter, with at least 30 seconds of rest in between to avoid fatigue.
- The highest value from the three trials was recorded for analysis.

1.4 Assessment of phonatory function

Phonatory function was assessed using two measures: Maximum Phonation Time (MPT) and Acoustic Voice Analysis.

- Maximum Phonation Time (MPT):

  - The participant was asked to sustain the vowel /a/ for as long as possible at a comfortable pitch and loudness following a maximal inspiration.
  - A total of three trials was done, with a minimum of 30 seconds break between each trial.
  - The duration was recorded using a digital stopwatch, and the average of three trials was used for analysis.
- Acoustic voice analysis:
  - A voice recorder (Sony IC recorder) positioned a few centimetres from the lips in a quiet, ambient noise-controlled setting was used to record the longest and most stable /a/ sample.
  - The recording was then assessed using PRAAT software (version 6.2.23) for the following parameters:
    - Fundamental Frequency (F0) — average pitch of the sustained vowel.
    - Jitter (%) and Shimmer (%) — frequency and amplitude perturbation measures, respectively.

1.5 Assessment of articulatory function

The significant parameters measured to assess articulatory function were:

A. Speech intelligibility

Participants were asked to read aloud a standardised passage of their native language i.e, ‘Bangaluru passage’ (Shashidhar, 1984) for native Kannada speakers and ‘Thengu passage’ (Dokhe et al., 2021) for native Malayalam speakers at their comfortable speaking rate and volume and it was audio-recorded for analysis. The recorded sample was evaluated by two speech-language pathologists (SLPs) to reduce subjectivity. Speech intelligibility was assessed using the Ali Yavar Jung National Institute of Speech and Hearing Disabilities intelligibility rating scale (AYJNISHD, 2003) which is a 7-point rating scale (Score 0 - Normal to score 7 – cannot understand at all, even when context is known).

B. Verbal diadochokinesis (DDK)

Two types of tasks were administered: Alternate motion rate (AMR) and Sequential motion rate (SMR). For AMR, participants was asked to repeat a single syllable as rapidly and steadily as they can for 10 seconds (for instance, /pa/, /ta/, and /ka/), a 30 seconds rest was provided after 3 trials of each syllable and for SMR, participants was instructed to repeat a syllable sequence, such as /pataka/, as rapidly and consistently as possible for a duration of 10 seconds and 5 seconds rest was provided after each trial. All productions were audio-recorded and analysed to determine the number of syllables produced per second for each task. The average of three trials were calculated for each syllable sequence. Participants' performance in each task was measured in terms of syllables per second. According to literature, DDK rates for healthy adults are between 5 and 7 syllables per second for AMR and 5 and 8 syllables per second for SMR (Pierce et al., 2013). In Indian populations, diadochokinetic rates vary among languages. AMR levels range from roughly 4.5 to 6.5 syllables per second, while SMR values range from 4.0 to 6.0 syllables per second for young people. However, values differ based on linguistic and phonetic traits, and there is no generally accepted normative range for Indian speakers (Jothi & Amritha, 2019).

C. Speech rate

Speech rate was assessed during connected speech tasks, such as oral reading passages or spontaneous speech samples. The total number of words produced per unit of time was calculated. The total speaking time was calculated by subtracting pauses that lasted more than 2 seconds from the total duration of the recording. Normal conversational speech rate typically ranges between 150-200 words per minute in adults. This measure assesses how well the respiratory, phonatory, and articulatory subsystems are temporally aligned during connected speech. It was expected to diminish due to age-related slowing, thus acting as a sensitive measure of intervention effectiveness.

$$\text{Speech rate} = \frac{\text{Number of words produced}}{\text{Total time taken}}$$

An assessment proforma (Appendix IV) including the participant's demographic details, cognitive status and the measurement values obtained across the three assessment phases (pre-intervention, post-intervention and follow-up) was used to record the data systematically.

Table 3 summarises the outcome measures under each of the domains and used in this study.

Table 3.3

Summary of the outcome measures in each domain

Domain	**Outcome measures**
Respiratory	FVC, FEV, FEV1/FVC, SVC, TV and PEFR
Phonatory	MPD, F0, jitter and shimmer
Articulatory	Speech intelligibility, speech rate and verbal DDK.
Swallowing	SASQ-IE score, PEFR, SCSS, RSST

3.5.2 Intervention – Expiratory Muscle Strength Training (EMST) protocol

An expiratory muscle strength trainer 150 (EMST-150) will be used for intervention, and all participants will undergo a structured 4-week EMST program.

2.1 Duration and frequency of intervention

The total duration of the training program was 4 weeks. Training was provided three days a week, with each session lasting approximately 15-30 minutes. This schedule resulted in a total of 12 therapy sessions over the intervention period. In addition to attending the planned therapy sessions, all participants were instructed to complete the EMST exercises on days when therapy sessions were not scheduled. At the start of the intervention program, a comprehensive daily log checklist (Appendix V) was given to track and record adherence to at-home practices. The checklist was explained to caregivers, who were asked to help participants complete it over the course of four weeks consistently. A session log for examiner (Appendix VI) was also used to record the information regarding each session and also to record weekly baseline resistance.

Session structure

Each 15–30-minute therapy session comprised of a warm-up phase, followed by the Expiratory Muscle Strength Training (EMST) exercises.

Warm-Up phase

Each session began with a quick warm-up exercise to get participants physiologically ready for the EMST exercise. The following guidelines were given to participants: We will start with some light relaxation exercises to prepare your body for the therapy session. These should feel comfortable and never strain you. Please let me know immediately if you experience any discomfort at any point during the session in their native language.

The warm-up included:

1. Comfortable sitting posture: Participants were positioned in an upright posture with feet placed flat on the floor, shoulders relaxed, and the spine maintained in a neutral alignment, ensuring a 90-90-90 posture.
2. Head and neck relaxation: Participants performed slow and gentle movements including circular rotations, lateral flexion, and controlled forward and backward motions of the head and neck.

3. Diaphragm breathing awareness: Participants were instructed to place the dominant hand over the abdomen and the other hand on the chest. They were then asked to inhale slowly for approximately 3 seconds, allowing abdominal expansion with minimal chest movement, followed by a controlled exhalation lasting about 4-5 seconds. This sequence was repeated for three cycles.

After the breathing exercises, practice trials with EMST device were conducted at very low resistance. During this stage, participants were familiarised with the device and were given instructions on the correct technique for performing the task.

2.2 Intervention procedure

To maximise participant comfort and to familiarise participants with the training device, the investigator conducted first two EMST sessions offline at the participants' homes. Each of the initial sessions included detailed instruction about the intervention and also about the care and precautions to be taken, demonstration of technique, and correction of technique (posture, mouthpiece seal, expiratory effort). Once a participant demonstrated acceptable proficiency and compliance, each subsequent session was conducted online via secure video live streaming. Each online session was live, supervised by the investigator to assess a participant's technique, provide feedback as needed, and ensure adherence to the training protocol.

2.3 Training procedure

During the training, following steps was followed:

a. Participants were seated comfortably and in an upright posture on a chair.
b. The participant was provided a nose clip to prevent nasal air escape.
c. The mouthpiece was inserted into the device.
d. Maximum expiratory pressure (MEP) was identified by turning the blue knob until the screw aligns with the lowest pressure setting, i.e., scale 30 (30cmH2O). The

participant was asked to forcefully blow through the device with a tight lip seal. Participants may use their free hand to secure the lip around the mouthpiece. If the participant was able to blow through at this level, a quarter-turn clockwise increment was made, and he/she was asked to blow through again till they cannot move air through the device.

e. The training began at 75% of the maximum level, i.e., quarter-turn counterclockwise from the maximum level.
f. This was followed by a resting period of 15-20 seconds, followed by performing five repetitions of the same, followed by a break of 30 seconds to prevent fatigue (1 set).
g. Three sets of this training were recommended each day, three days/week for four weeks.

Every week, this resistance was adjusted to consider the improvements in strength. All sessions carried out was under the observation of a qualified professional to guarantee proper posture, mouthpiece sealing, correct technique, and complete involvement of expiratory effort.

3.5.3 Post-intervention assessment (Outcome evaluation)

Following the intervention, to ascertain the improvements in respiratory and phonatory functions, all baseline measures shown in Table 2 were re-administered using the same protocols after completing the 4-week expiratory muscle strength training (EMST) program. The assessments were conducted under the same conditions as the baseline evaluation, and same procedures and instructions were followed for each test to maintain consistency across all the measurements.

Each parameter that was recorded during the baseline assessment was reassessed using the same instruments and standardised procedures. Care was taken to ensure that the testing sequence, participant positioning and administration procedures remain similar to those used during the initial assessment. This approach helped maintain uniformity in the data collection process and ensured that the measurements obtained after the intervention were comparable to the baseline values.

The post-therapy scores obtained for each parameter in the respiratory and phonatory function were then compared with the baseline scores to identify any changes following the 4-week EMST program.

3.5.4 Follow-up assessment (Retention effects)

To determine the retention effects of training provided, the outcome measures mentioned in Table 2 will be taken four weeks post-intervention. This follow-up assessment was carried out to examine whether the improvements observed after the training period were maintained over time in the absence of continued intervention.

During the follow-up phase, all the parameters that were assessed during the baseline and post-therapy evaluations were reassessed. The same instruments, procedures and testing conditions that were used during the earlier assessments were followed to maintain consistency and also to ensure comparability of the results.

Each respiratory and phonatory parameter was measured again using the same standardised protocols. Care was taken to ensure that the testing procedure remained identical to the previous assessments so that any differences observed in the scores could be attributed to the effects of the training rather than variations in the assessment procedure.

The scores obtained during the follow-up assessment were then compared with the baseline and post-therapy assessment scores for each parameter. This comparison helped determine whether the changes observed immediately after the intervention were sustained over the four weeks following the completion of the EMST program and also provided adequate information regarding the retention of the training effects. Figure 1 below summarizes the study phases.

Figure 3.2. Flow chart to depict the study procedure

Pre-Intervention

- Outcome measures measured:
  1. Respiratory measures: FVC, FEV, FEV1/FVC ratio , SVC and TV
  2. Phonatory measures: MPT, F0, jitter and shimmer
  3. Articulatory measures: DDK, Speech intelligibility and Speech rate
  4. Swallowing measures: SASQ-IE score, PEFR , SCSS and Number of swallows in 30 seconds

Intervention

- 3days/week for 4 weeks
  a. Warm-up phase (5 minutes)
- b.EMST program (25 minutes) (5 sets of 5 breaths, i.e., 25 breaths/session)

Post-Intervention

- After 4 weeks or 12 sessions (Same measures as Pre-Intervention)

Follow up

- 4 weeks after intervention (Same measures as Pre-Intervention)

Statistical Analysis

Data analysis using both descriptive and inferential statistical methods was performed using Statistical Package for Social Sciences software (IBM SPSS Statistics version 26). Descriptive statistics including median and interquartile range (IQR) were calculated for all the speech and swallowing variables across the three measurement phases i.e. pre-intervention, post-intervention and follow-up. Due to small sample size and incomplete follow-up data for one participant, non-parametric statistical analysis was done. The Wilcoxon Signed Rank Test was directly applied to compare repeated measures across assessment phases, namely pre-intervention v/s post-intervention, pre-intervention v/s follow-up and post-intervention v/s follow-up. The level of statistical significance was set at $p < 0.05$.

CHAPTER IV

RESULTS & DISCUSSION

The study aimed to examine the effect of Expiratory Muscle Strength Training (EMST) on speech and swallow functions in individuals aged 60 years or older. The objectives of the study included comparing respiratory, phonatory, articulatory and swallow measures across pre-intervention, post-intervention, and four-week follow up phases following EMST intervention in Indian elderly individuals. The study also aimed to understand the association between speech and swallowing measures across the three phases of assessment. Thus, the study was carried out to evaluate the efficacy of EMST on speech and swallowing functions in the elderly population.

4.1 Objective 1: Comparison of respiratory measures pre-, post-, and four weeks after the intervention in Indian elderly

4.1.1 Respiratory measures (litres): FVC, FEV1, SVC and TV

The respiratory volume measures namely Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), Slow Vital Capacity (SVC) and Tidal Volume (TV) are measured in litres and the values of individual participants for these parameters and group descriptive statistics (Median and IQR) across the three assessment phases: pre-intervention, post-intervention and follow-up are presented collectively in Table 4.1and Figures 4.1 – 4.5. For P3, only pre- and post-intervention values were available.

Table 4.1

Individual participant values, Median and Interquartile Range for respiratory volume measures (litres) across assessment phases for all five participants

	Pre-Intervention				**Post-Intervention**				**Follow-up**			
Participant	***FVC***	***FEV1***	***SVC***	***TV***	***FVC***	***FEV1***	***SVC***	***TV***	***FVC***	***FEV1***	***SVC***	***TV***
P1	1.18	1.15	1.29	0.32	1.08	1.08	4.25	0.29	1.18	1.17	4.49	0.65
P2	1.15	1.14	4.58	0.40	1.19	1.11	4.35	0.83	1.16	1.14	4.68	0.80
P3	1.83	1.77	2.17	0.71	1.11	1.11	5.20	0.68	—	—	—	—
P4	1.36	1.34	4.26	0.45	1.22	1.21	4.43	0.49	1.18	1.18	4.44	0.34
P5	1.22	1.21	4.49	1.57	0.97	0.97	4.78	0.55	0.94	0.94	4.82	0.50
Median	**1.22**	**1.21**	**4.26**	**0.45**	**1.11**	**1.11**	**4.43**	**0.55**	**1.17**	**1.16**	**4.59**	**0.58**
IQR	**0.43**	**0.41**	**2.81**	**0.78**	**0.18**	**0.14**	**0.69**	**0.37**	**0.19**	**0.19**	**0.33**	**0.38**

Note. FVC = Forced Vital Capacity (L); FEV_1 = Forced Expiratory Volume in one second (L); SVC = Slow Vital Capacity (L); TV = Tidal Volume (L). IQR = Interquartile Range. — = follow-up data not available.

As seen in Table 4.1, FVC and FEV1 showed a generally declining trend across most participants. P1 showed a modest decrease post-intervention with full recovery at follow-up. P2 showed a slight increase post-intervention with minimal change at follow-up. P3 showed a decrease from 1.83 L to 1.11 L post-intervention; follow-up data were unavailable. P4 exhibited a declining trend across all phases and P5 showed a similar progressive decrease. SVC demonstrated markedly different trends, with most participants showing increases post-intervention, particularly P1 (1.29 L to 4.25 L) and P3 (2.17 L to 5.20 L). Tidal volume showed variable patterns; P5 exhibited a marked decrease from 1.57 L to 0.55 L post-intervention, while P2 showed a notable increase (0.40 to 0.83 L).

The Wilcoxon Signed Rank Test was employed to examine the effect of the intervention across the three time points, with three pairwise comparisons conducted per parameter: post-intervention versus pre-intervention (immediate effect), follow-up versus pre-intervention (overall change from baseline), and follow-up versus post-intervention (maintenance of gains).

FEV1 was the only respiratory parameter to reach statistical significance, with a significant reduction observed from pre-intervention to post-intervention ($Z = -2.023$, $p = .043$). This change was not maintained at follow-up, as the comparison between follow-up and pre-intervention did not reach significance ($Z = -1.069$, $p = .285$), nor did the follow-up versus post-intervention comparison ($Z = -0.378$, $p = .705$). FVC showed a trend toward significance in the post-versus-pre comparison ($Z = -1.753$, $p = .080$), though this did not reach the conventional alpha level. SVC demonstrated approaching significance in both the follow-up versus pre-intervention ($Z = -1.826$, $p = .068$) and the follow-up versus post-intervention comparisons ($Z = -1.826$, $p = .068$), suggesting a possible delayed improvement in slow vital capacity. TV ($Z = -0.135$, $p = .892$) did not show any meaningful changes across time points.

The group median FVC decreased from 1.22 L (IQR = 0.43) pre-intervention to 1.11 L (IQR = 0.18) post-intervention, with partial recovery to 1.17 L (IQR = 0.19) at follow-up. FEV1 followed a similar pattern with a median of 1.21 L (IQR = 0.41) at pre-intervention, decreasing to 1.11 L (IQR = 0.14) post-intervention, and 1.16 L (IQR = 0.19) at follow-up. SVC showed a progressive increase across phases: median SVC was 4.26 L (IQR = 2.81) pre-intervention, rising to 4.43 L (IQR = 0.69) post-intervention and 4.58 L (IQR = 0.33) at follow-up. The narrowing IQR at follow-up for SVC suggests greater consistency across participants.

Tidal Volume showed greater inter-individual variability, with a group median of 0.45 L (IQR = 0.78) pre-intervention, 0.55 L (IQR = 0.37) post-intervention, and 0.57 L (IQR = 0.38) at follow-up.

The significant reduction in FEV1 from pre- to post-intervention is more appropriately interpreted as reflecting a change in expiratory effort strategy rather than a decline in respiratory capacity. EMST enables participants to produce calibrated and strong efforts for their expiratory maneuvers using the pressure threshold valve, and after the training, participants will be able to perform their forced expiratory maneuver in a controlled manner as opposed to performing it abruptly, resulting in low FEV1 readings. According to Sapienza (2008), the EMST technique changes the neuromuscular coordination involved in the expiratory effort. Further evidence on the independence between direct expiratory muscle strength and spirometric indices was found by Kim & Sapienza (2005) after showing that four weeks of EMST training led to improved maximal expiratory pressure but unchanged spirometric indices in healthy elderly subjects. Troche et al. (2010) reported similar results in their randomized trial on EMST in Parkinson’s patients, where the improvement of maximal expiratory pressure occurred without any changes in FVC and FEV1 measurements, indicating that spirometric indices are not sensitive enough to measure changes due to EMST even in individuals with multiple sclerosis.

The deferred pattern of SVC change appearing at follow-up rather than immediately post-intervention is theoretically consistent with the gradual nature of neuromuscular adaptation to resistive training, wherein structural changes in muscle fibre composition and neural drive take time to emerge (Schmidt & Lee, 2011). Since SVC is less dependent on the rate of expiratory pressure development than FVC, it may be more sensitive to training-related changes in muscle endurance and lung compliance. This aligns with Kulkarni and Kolase (2020), who found significant peak expiratory flow improvement but only a positive trend for maximum expiratory pressure over a one-week protocol, concluding that longer training durations are necessary for full spirometric benefit. Tidal Volume and the FEV1/FVC ratio remained stable across all assessment phases, confirming the absence of obstructive airflow changes and indicating that the intervention did not adversely affect pre-intervention respiratory patterns.

Figure 4.1

Respiratory volume measures (FVC, FEV1, SVC, and TV in litres) across pre, post and follow up phases for P1

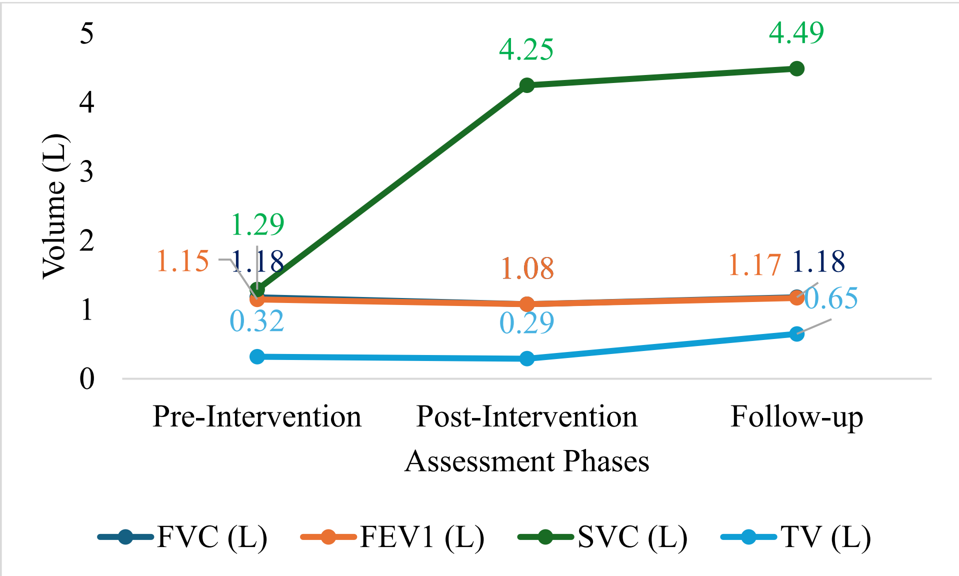


Figure 4.2

Respiratory volume measures (FVC, FEV1, SVC, and TV in litres) across pre, post and follow up phases for P2

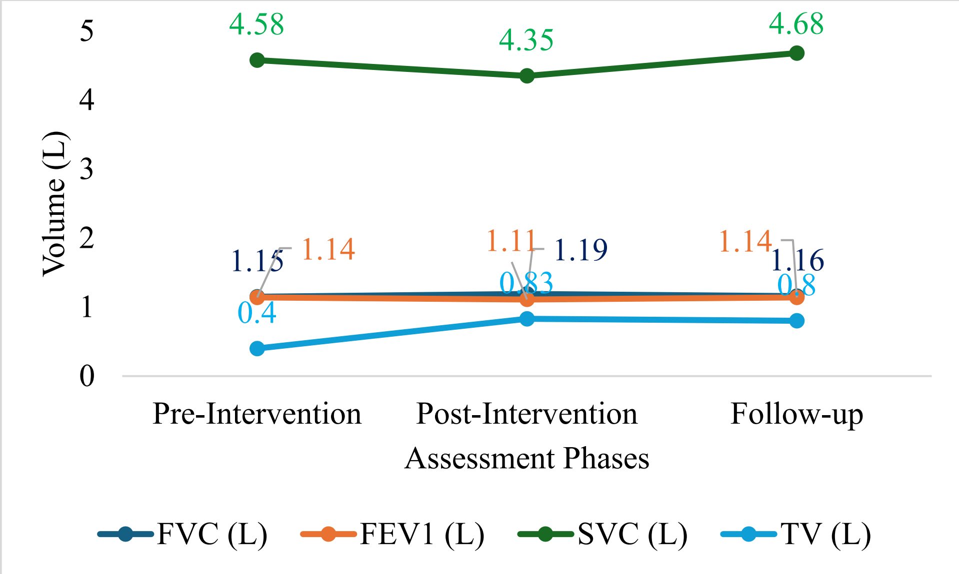


Figure 4.3

Respiratory volume measures (FVC, FEV1, SVC, and TV in litres) across pre, post and follow up phases for P3

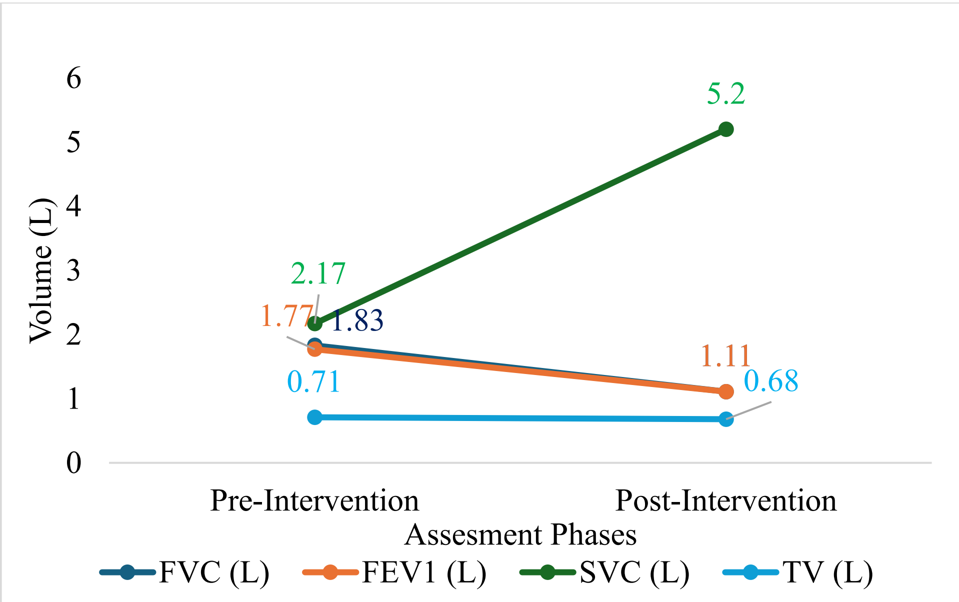


Figure 4.4

Respiratory volume measures (FVC, FEV1, SVC, and TV in litres) across pre, post and follow up phases for P4

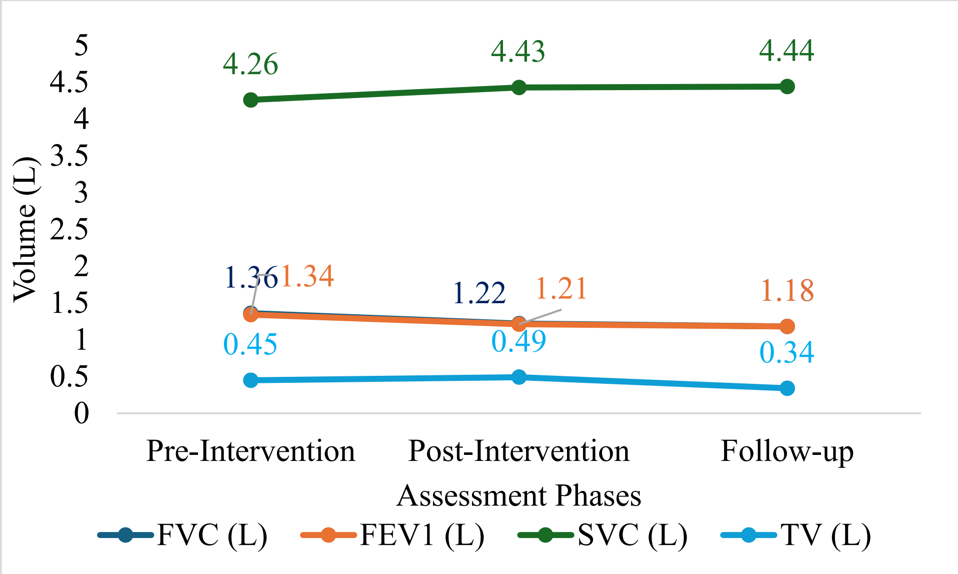
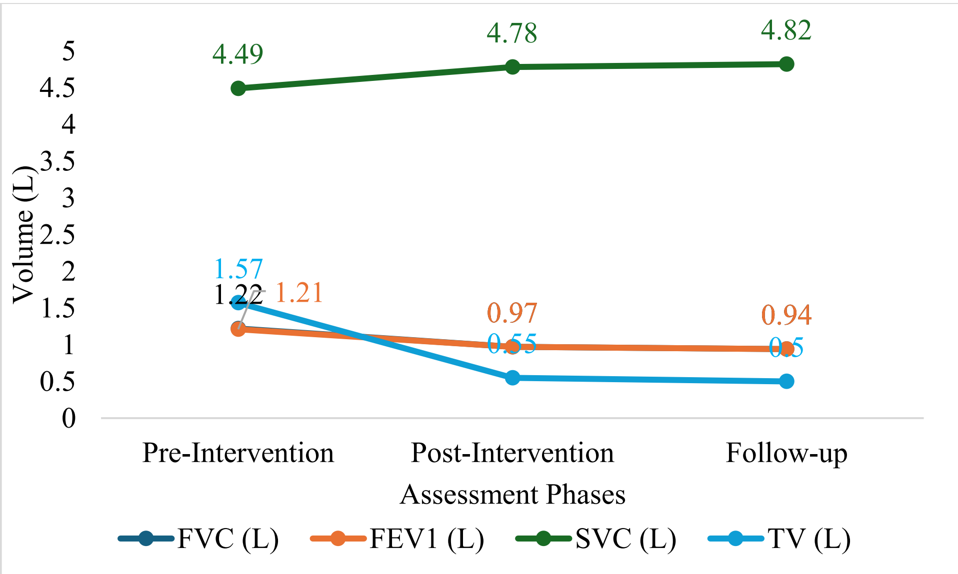


Figure 4.5

Respiratory volume measures (FVC, FEV1, SVC, and TV in litres) across pre, post and follow up phases for P5



4.1.2 Respiratory measure (%): FEV1/FVC ratio

The FEV1/FVC ratio reflects the proportion of forced vital capacity expelled in one second and serves as an indicator of obstructive airway patterns. The values of individual participants for this parameter and group descriptive statistics (Median and IQR) across the three assessment phases – pre-intervention, post-intervention and follow-up are presented collectively in Table 4.2 and Figure 4.6. For P3, only pre- and post-intervention values are available.

Table 4.2

Individual participant values, Median and Interquartile Range for FEV1/FVC ratio (%) across assessment phases for all five participants

Participant	Pre-Intervention	Post-Intervention	Follow-up
P1	99.13	100.00	100.00
P2	99.90	97.69	100.00
P3	100.00	100.00	—
P4	98.33	100.00	100.00
P5	100.00	100.00	100.00
Median	**99.90**	**100.00**	**100.00**
IQR	**1.27**	**1.16**	**0.00**

Note. FEV1/FVC = Forced Expiratory Volume in one second / Forced Vital Capacity ratio (%). IQR = Interquartile Range. — = follow-up data not available.

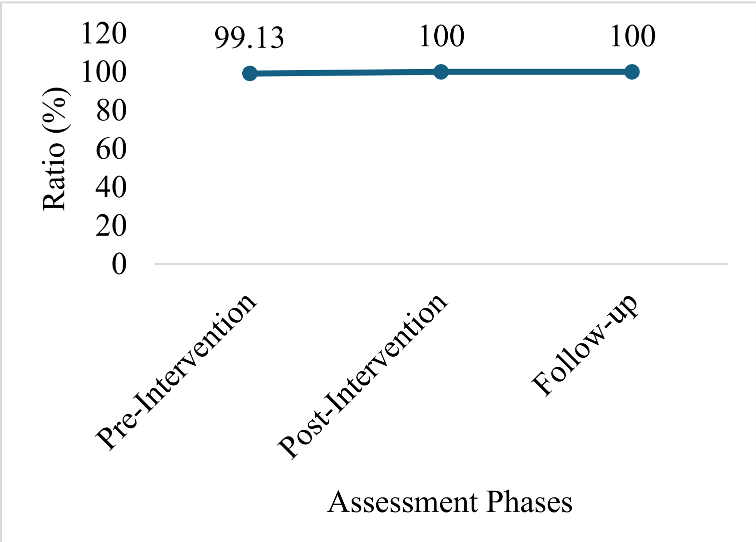
As shown in Table 4.2, FEV1/FVC ratios were at or near 100% across all participants throughout the study. P1 showed an increase from 99.13% to 100.00% post-intervention, maintained at follow-up. P2 showed a slight decrease post-intervention (99.90% to 97.69%) with recovery to 100.00% at follow-up. P3 and P5 maintained 100.00% across all phases. P4 improved from 98.33% pre-intervention to 100.00% post-intervention, retained at follow-up.

FEV1/FVC ratios were at or near 100% across most participants at all assessment phases, indicating normal spirometric airway patency throughout the study period. The Wilcoxon Signed Rank Test revealed no statistically significant differences across any of the three pairwise comparisons (post vs. pre: $Z = 0.000$, $p = 1.000$; follow-up vs. pre: $Z = -1.604$, $p = .109$; follow-up vs. post: $Z = -1.000$, $p = .317$). The group median FEV1/FVC ratio was 99.90% IQR = 1.27) at pre-intervention, increasing to 100.00% (IQR = 1.16) post-intervention, and remaining at 100.00% (IQR = 0.00) at follow-up. The complete absence of IQR variability at follow-up indicates that all four participants with available data achieved a perfect ratio, suggesting normal spirometric airway opening was maintained throughout the study period.

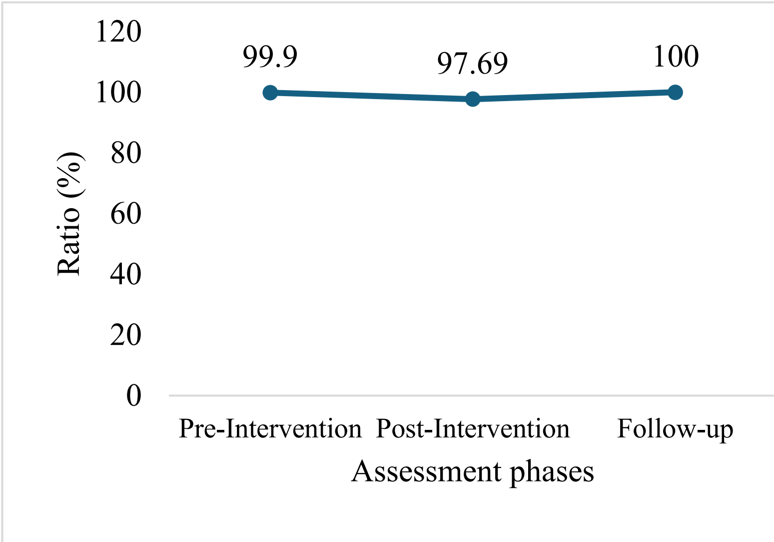
Clinically, the stability and consistency of the FEV1/FVC ratio confirms that the EMST intervention did not introduce or worsen any obstructive airflow pattern across participants. This finding is consistent with prior studies in both healthy and clinical populations where EMST had not been associated with adverse spirometric changes. Chiara et al. (2007) similarly reported that EMST did not negatively affect FEV1/FVC ratio in individuals with multiple sclerosis. The stable FEV1/FVC ratio across the present study sample suggests that the intervention-related reduction in FEV1 observed for some participants was not indicative of airway obstruction but rather reflects the modification of expiratory effort following resistive training.

Figure 4.6

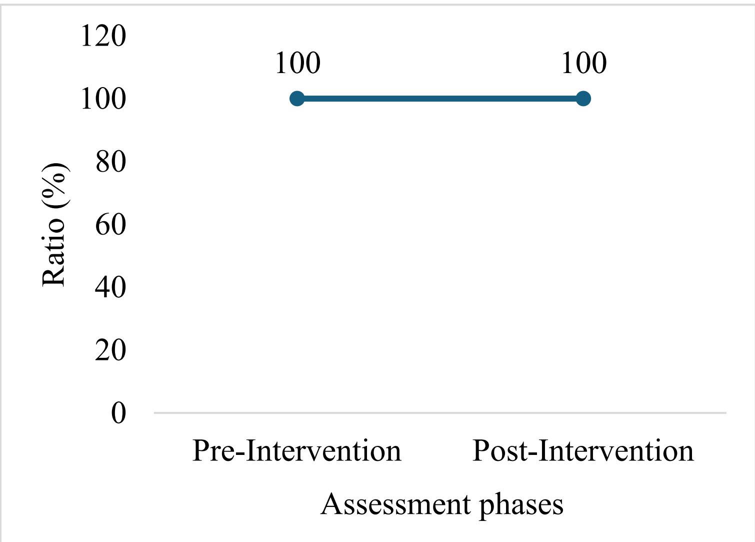
FEV1/FVC ratio (%) across pre, post and follow up phases for (a) P1, (b) P2, (c) P3, (d) P4, (e) P5



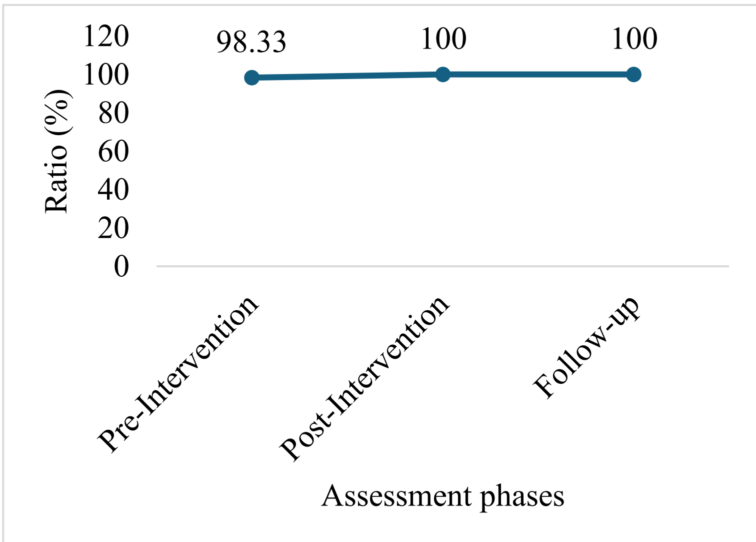
(a)



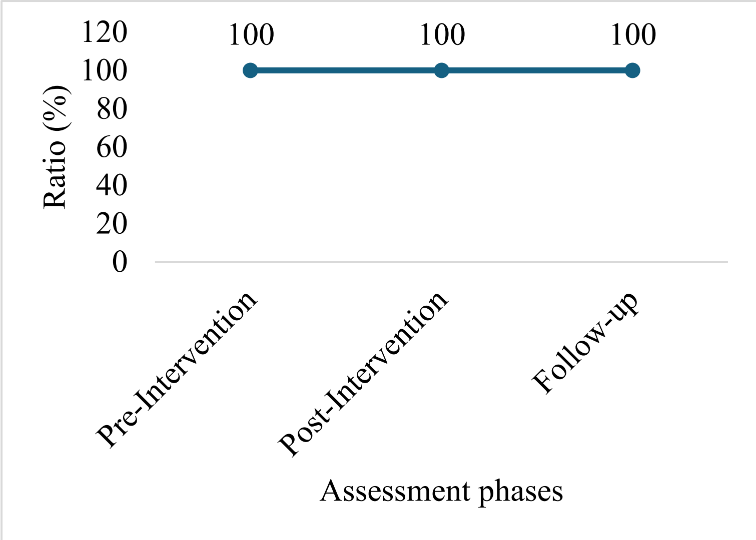
(b)



(c)



(d)



(e)

Table 4.3

Wilcoxon Signed Rank Test Results for Respiratory Measures Across Three Time Points

	Post vs. Pre		Follow-up vs. Pre		Follow-up vs. Post	
Parameter	***Z***	***p***	***Z***	***p***	***Z***	***p***
FEV1	−2.023	.043	−1.069	.285	−0.378	.705
FVC	−1.753	.080	−1.069	.285	−0.368	.713
SVC	−1.483	.138	−1.826	.068	−1.826	.068
TV	−0.135	.892	0.000	1.000	−0.365	.715
FEV1/FVC	0.000	1.000	−1.604	.109	−1.000	.317

Note. * $p < .05$. FEV1 = Forced Expiratory Volume in one second; FVC = Forced Vital Capacity; SVC = Slow Vital Capacity; TV = Tidal Volume.

4.2 Objective 2: Comparison of phonatory measures pre-, post-, and four weeks after the intervention in Indian elderly

4.2.1 Phonatory measure (seconds): Maximum Phonation Time

MPT values for all participants across pre-, post-, and four weeks after the intervention phases, with median and IQR are given in Table 4.4 and represented in Figure 4.7

Table 4.4

Individual participant values, Median and Interquartile Range for Maximum Phonation Time (seconds) across assessment phases for all five participants

Participant	Pre-Intervention	Post-Intervention	Follow-up
P1	15.00	11.00	11.30
P2	13.00	11.00	11.00
P3	20.00	17.00	—
P4	13.00	8.00	12.00
P5	12.00	13.00	12.00
Median	**13.00**	**11.00**	**11.65**
IQR	**5.00**	**5.50**	**0.93**

Note. MPT = Maximum Phonation Time (seconds). IQR = Interquartile Range. — = follow-up data not available.

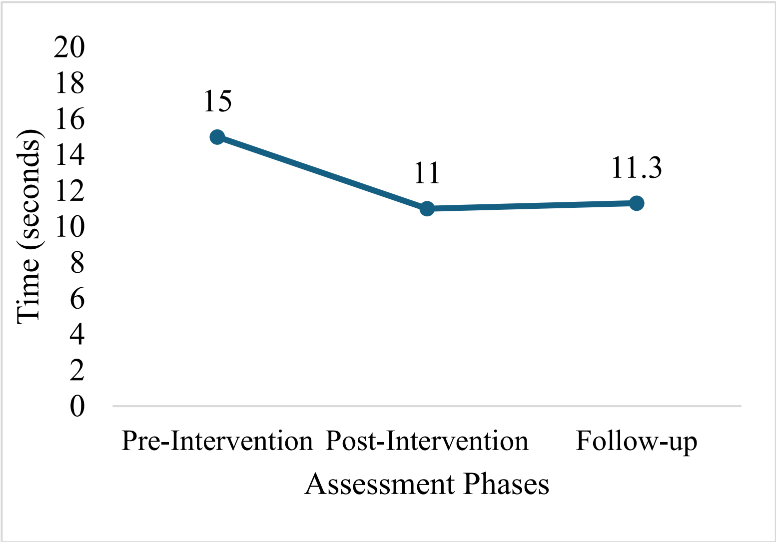
As shown in Table 4.4, MPT showed a generally falling trend post-intervention across most participants. P1 decreased from 15 to 11 seconds post-intervention with modest recovery to 11.3 seconds at follow-up. P2 declined from 13 to 11 seconds and remained stable at follow-up. P3 showed a reduction from 20 to 17 seconds; follow-up data were unavailable. P4 showed more substantial decline (13 to 8 seconds post-intervention) with recovery to 12 seconds at follow-up. P5 showed minimal variation across all three phases.

The Wilcoxon Signed Rank Test did not reveal statistically significant differences for MPT across any of the three pairwise comparisons. However, a trend of approaching significance was observed in the post-intervention versus pre-intervention comparison ($Z = -1.753$, $p = .080$) and the follow-up versus pre-intervention comparison ($Z = -1.604$, $p = .109$). The group median MPT reduced from 13.00 seconds (IQR = 5.00) at pre-intervention to 11.00 seconds (IQR = 5.50) post-intervention, with a slight recovery to 11.65 seconds (IQR = 0.93) at follow-up. The substantially reduced IQR at follow-up (0.93 compared to 5.00 at pre-intervention) indicates that participants progressed towards a similar MPT value at the retention phase, suggesting greater consistency despite the overall reduction from pre-intervention.

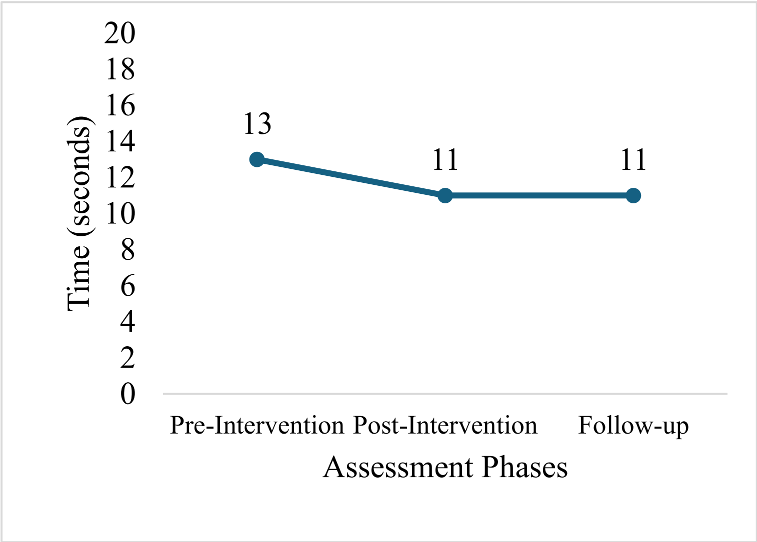
The modest decrease in group median MPT immediately post-intervention, followed by partial recovery at follow-up, may reflect temporary disruption of habitual phonatory strategy during respiratory relearning, consistent with the transitional disruption phase in motor learning, wherein a new movement pattern temporarily impairs established coordination before stabilising at a higher performance level (Schmidt & Lee, 2011). EMST's influence on phonation operates through aerodynamic rather than structural pathways; as such, it cannot reverse the histological changes of presbylarynx, and its aerodynamic effect may be insufficient to produce measurable acoustic change in healthy elderly individuals within four weeks. Several prior studies reported phonatory improvements following EMST; however, these findings were largely observed in populations with greater baseline functional compromise, such as those with neurological disorders, where respiratory-phonatory coordination deficits are more responsive to EMST-driven improvement. Kim and Sapienza (2006) reported significant improvement in vocal intensity and intraoral pressure, measures that are more aerodynamically proximal than MPT or perturbation parameters following EMST, and these findings are not inconsistent with the present results. Future studies combining EMST with direct laryngeal exercises, such as semi-occluded vocal tract exercises or vocal function exercises, may be more capable to demonstrate measurable phonatory improvements in healthy elderly populations.

Figure 4.7

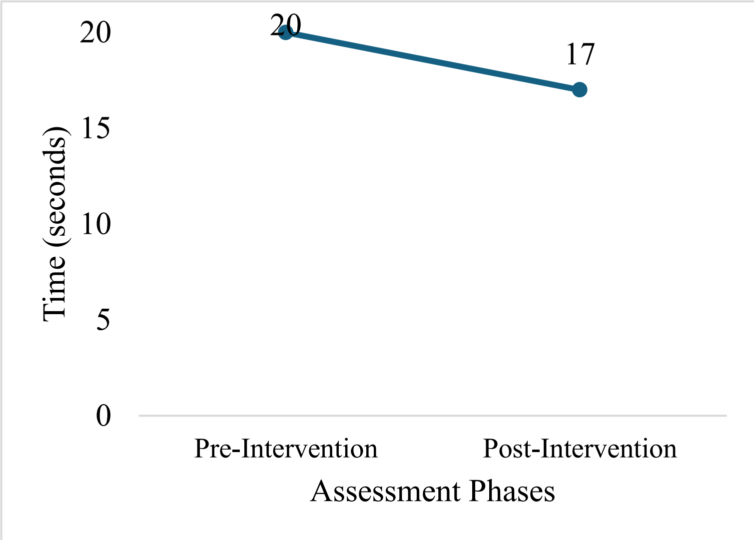
Maximum Phonation Time (seconds) across pre, post and follow up phases for (a) P1, (b) P2, (c) P3, (d) P4, (e) P5



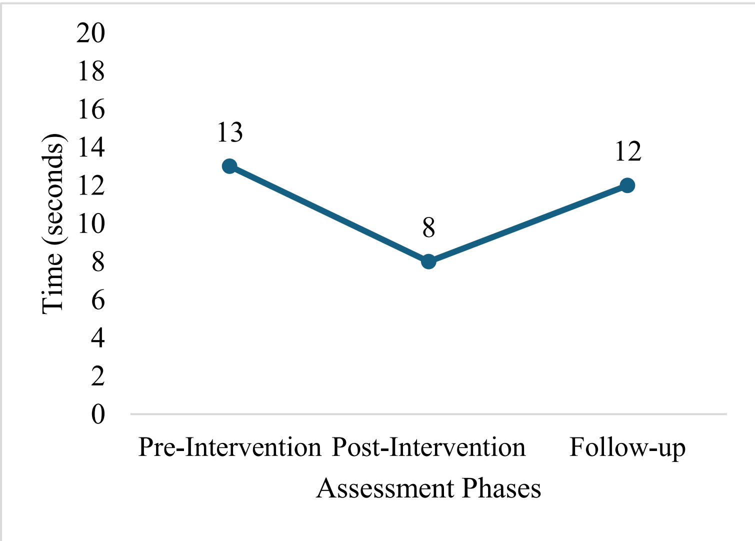
(a)

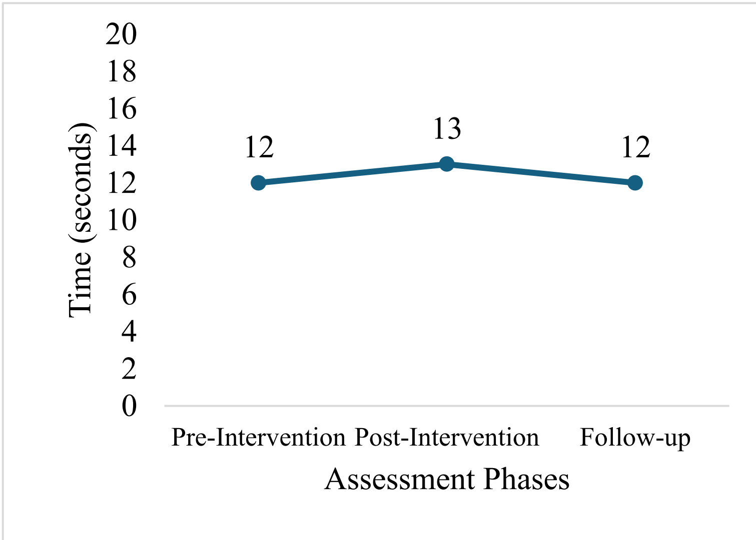


(b)



(c)





(d)

(e)

4.2.2 Phonatory measure (Hz): Fundamental Frequency

F0 values and group descriptive statistics (Median and Interquartile Range) of all participants across assessment phases are given in Table 4.5 and Figure 4.8.

Table 4.5

Individual participant values, Median and Interquartile Range for Fundamental Frequency – F0 (Hz) across assessment phases for all five participants

Participant	Pre-Intervention	Post-Intervention	Follow-up
P1	175.89	160.39	162.00
P2	101.96	158.25	197.63
P3	142.08	175.20	—
P4	90.14	178.64	146.92
P5	194.42	204.48	205.47
Median	**142.08**	**175.20**	**179.82**
IQR	**89.10**	**32.24**	**52.82**

Note. F0 = Fundamental Frequency (Hz). IQR = Interquartile Range. — = follow-up data not available.

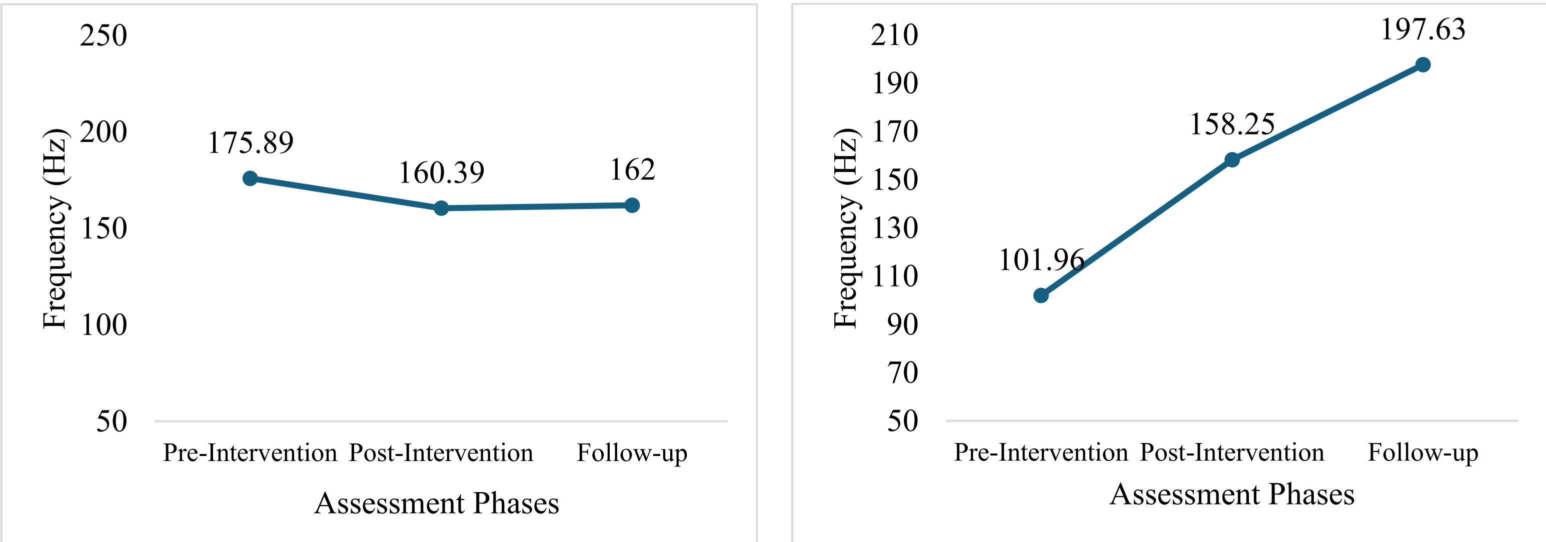
As shown in Table 4.5, F0 showed variable patterns across participants. P1 showed a modest decrease from 175.89 Hz to 160.39 Hz post-intervention with slight recovery to 162.00 Hz at follow-up. P2 demonstrated increase across all phases and P3 showed an increase from 142.08 to 175.20 Hz post-intervention. P4 showed a marked increase post-intervention (90.14 to 178.64 Hz) with partial retention at 146.92 Hz at follow-up. P5 showed a progressive increase across all three phases.

The Wilcoxon Signed Rank Test did not reveal any statistically significant differences for F0 across any of the three pairwise comparisons (post vs. pre Z = -1.483, $p = .138$; follow-up vs. pre $Z = -1.095$, $p = .273$; follow-up vs. post $Z = -0.730$, $p = .465$). The group median F0 increased from 142.08 Hz (IQR = 89.10) at pre-intervention to 175.20 Hz (IQR = 32.24) post-intervention, and further to 179.82 Hz (IQR = 52.82) at follow-up. The broad IQR at pre-intervention (89.10 Hz) reflects considerable baseline variability across participants, while the narrower post-intervention IQR (32.24 Hz) suggests greater consistency in response to the intervention, a trend that was partially retained at follow-up.

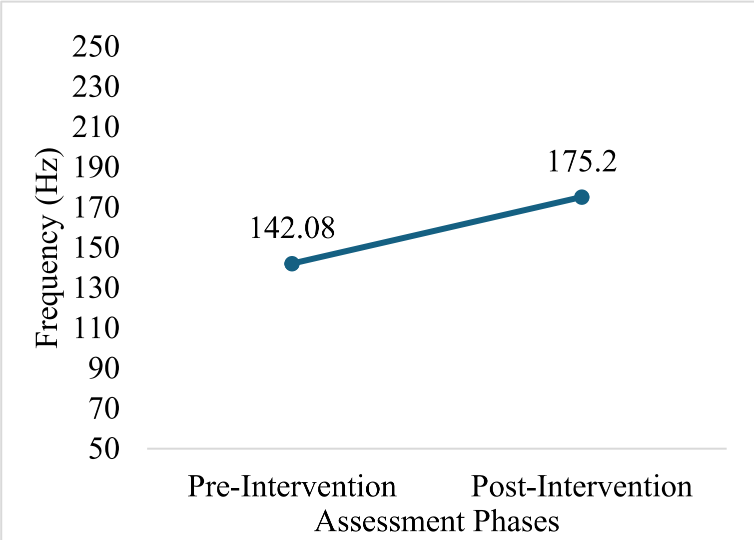
The stability of F0 across statistically significant thresholds is consistent with EMST's underlying mechanism, which targets expiratory muscle strength through aerodynamic loading rather than directly influencing vocal fold tissue properties that determine F0. Age-related changes in F0 have been reported in elderly populations, with previous studies reporting a reduction in F0 among elderly women due to laryngeal structural changes associated with aging (Xue & Deliyski, 2001). In the present study, the stability of F0 across assessment phases suggests that the intervention did not negatively affect pitch characteristics or vocal fold vibration. The modest increase in group median F0 from pre- to post-intervention and follow-up, while not statistically significant, is in agreement with the hypothesis that improved subglottal air pressure following EMST may support vocal fold adduction and frequency regulation; however, the current sample size is insufficient to confirm this trend.

Figure 4.8

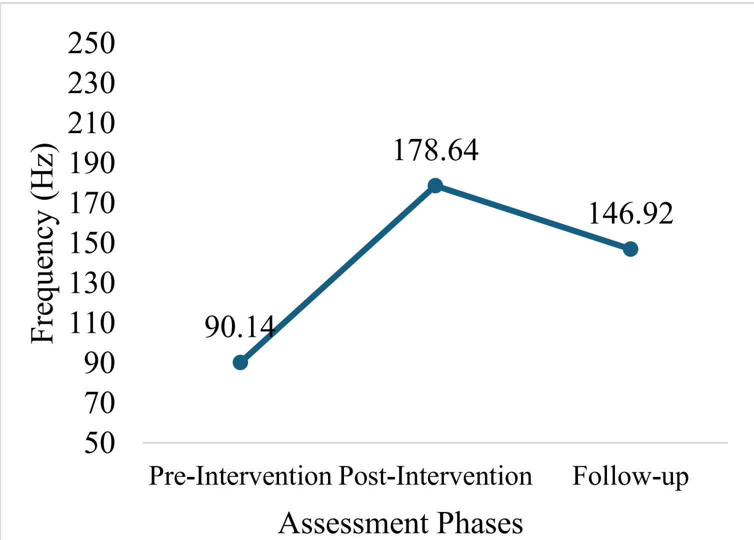
F0 (Hz) across pre, post and follow up phases for (a) P1, (b) P2, (c) P3, (d) P4, (e) P5



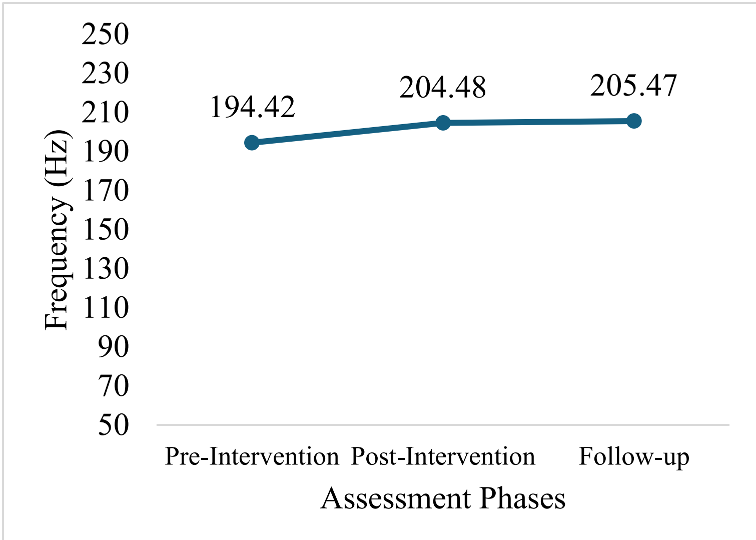
(a) (b)



(c)



(d)



(e)

4.2.3 Phonatory measures (%): Jitter and Shimmer

Jitter and Shimmer values and group descriptive statistics (Median and Interquartile Range) of all participants across assessment phases are given in Table 4.6 and Figures 4.9 – 4.13.

Table 4.6

Individual participant values, Median and Interquartile Range for Jitter and Shimmer (%) across assessment phases for all five participants

Participant	**Pre-Intervention**		**Post-Intervention**		**Follow-up**	
	Jitter	Shimmer	Jitter	Shimmer	Jitter	Shimmer
P1	0.58	9.41	0.18	4.84	0.99	13.58
P2	1.20	13.41	1.35	14.35	0.53	4.17
P3	0.61	5.86	0.56	3.87	—	—
P4	0.29	11.20	0.51	9.41	0.79	17.54
P5	0.60	9.88	0.41	11.99	0.44	8.29
Median	**0.60**	**9.88**	**0.51**	**9.41**	**0.66**	**10.93**
IQR	**0.47**	**4.67**	**0.66**	**8.82**	**0.48**	**11.35**

Note. Jitter and Shimmer expressed as percentages (%). IQR = Interquartile Range. — = follow-up data not available.

As shown in Table 4.6, Jitter and Shimmer showed highly mixed pattern across participants. For jitter, P1 decreased from 0.58% to 0.18% post-intervention but increased to 0.99% at follow-up. P2 showed a modest increase post-intervention with a marked decrease at follow-up. P3 showed a marginal decrease, whereas P4 showed a gradual increase across phases and P5 showed a decrease post-intervention with partial retention at follow-up. For Shimmer, P1 improved post-intervention but increased markedly at follow-up, similarly P2 and P5 showed an initial increase post-intervention with relevant improvement at follow-up and partial reduction at follow-up respectively. P3 showed improvement post-intervention, whereas P4 showed a decrease post-intervention with a marked increase at follow-up.

The Wilcoxon Signed Rank Test did not reveal statistically significant differences for either jitter or shimmer across any of the three pairwise comparisons. For jitter, post vs. pre ($Z = -0.405$, $p = .686$), follow-up vs. pre ($Z = 0.000$, $p = 1.000$), follow-up vs. post ($Z = -0.365$, $p = .715$). For shimmer, post vs. pre ($Z = -0.674$, $p = .500$), follow-up vs. pre ($Z = 0.000$, $p = 1.000$), follow-up vs. post ($Z = 0.000$, $p = 1.000$). The simmer comparisons at follow-up generated a Z of 0.000 ($p = 1.000$), indicating that the sum of positive and negative ranks were exactly equal, reflecting no trend at group level. Group median Jitter was 0.60% (IQR = 0.47) at pre-intervention, 0.51% (IQR = 0.66) post-intervention, and 0.66% (IQR = 0.48) at follow-up. Group median Shimmer decreased slightly from 9.88% (IQR = 4.67) pre-intervention to 9.41% (IQR = 8.82) post-intervention, with a slight increase to 10.93% (IQR = 11.35) at follow-up.

The absence of statistically significant change in Jitter and Shimmer is consistent with the established understanding that EMST's mechanism of action does not directly alter vocal fold tissue properties, which are the primary contributors of acoustic perturbation measures. Previous studies have reported age-related increases in acoustic perturbation measures such as Jitter and Shimmer in elderly (Xue & Deliyski, 2001), associated to age-related changes in laryngeal muscle and mucosal tissue. The stability of perturbation measures across all assessment phases in the present study confirms that EMST did not negatively affect voice quality, which is an important safety finding. Studies reporting phonatory improvements following EMST have mainly involved populations with greater baseline functional compromise, such as those with neurological disorders where respiratory-phonatory coordination deficits are more responsive to intervention, whereas healthy elderly participants may already employ compensatory phonatory strategies that obscure any benefit at group level (Goy et al., 2013; Maslan et al., 2011). The progressive widening of IQR for Shimmer across phases reflects increasing variability in amplitude perturbation patterns among participants over time, highlighting the high inter-individual variability in vocal quality measures.

Figure 4.9

Jitter and Shimmer (%) across assessment phases for P1

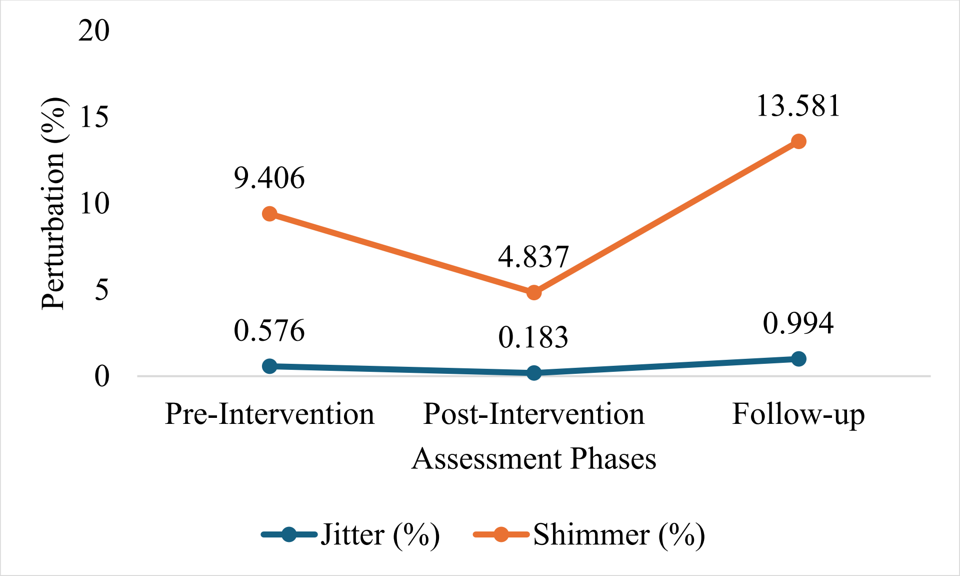


Figure 4.10

Jitter and Shimmer (%) across assessment phases for P2

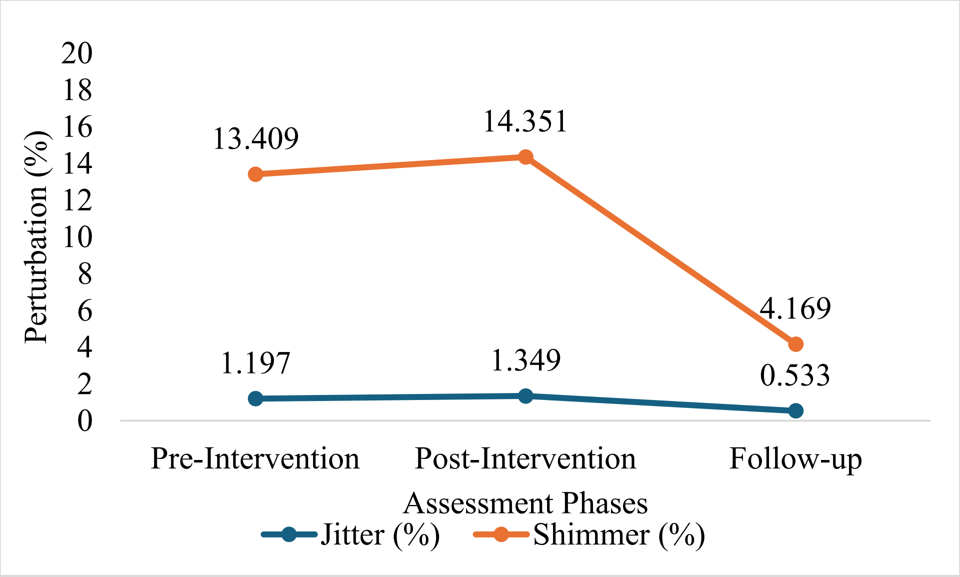


Figure 4.11

Jitter and Shimmer (%) across assessment phases for P3

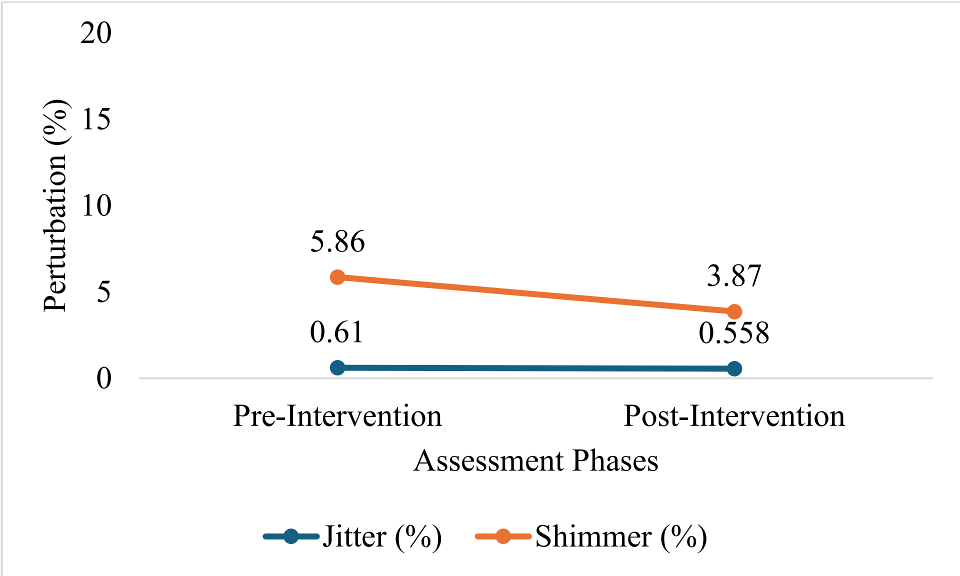


Figure 4.12

Jitter and Shimmer (%) across assessment phases for P4

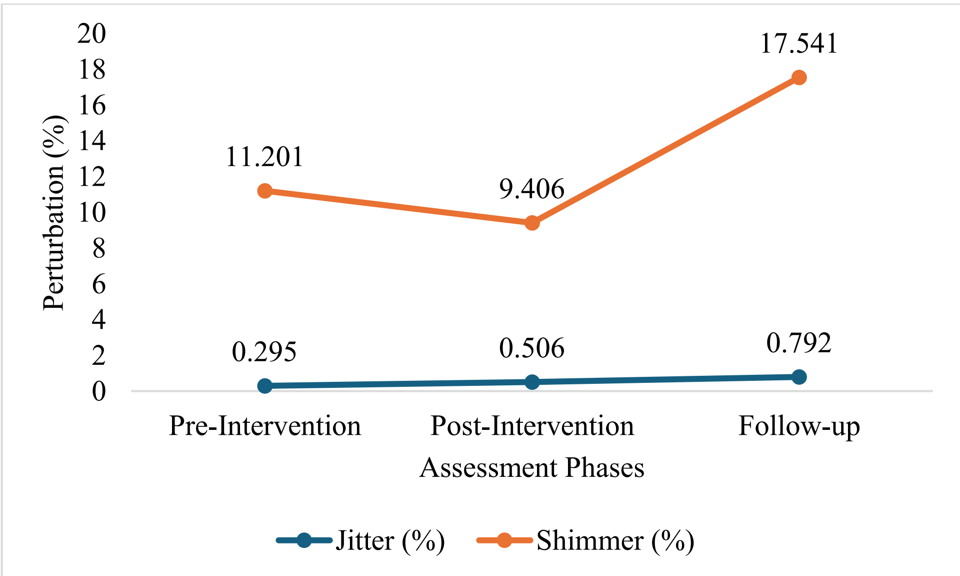


Figure 4.13

Jitter and Shimmer (%) across assessment phases for P5

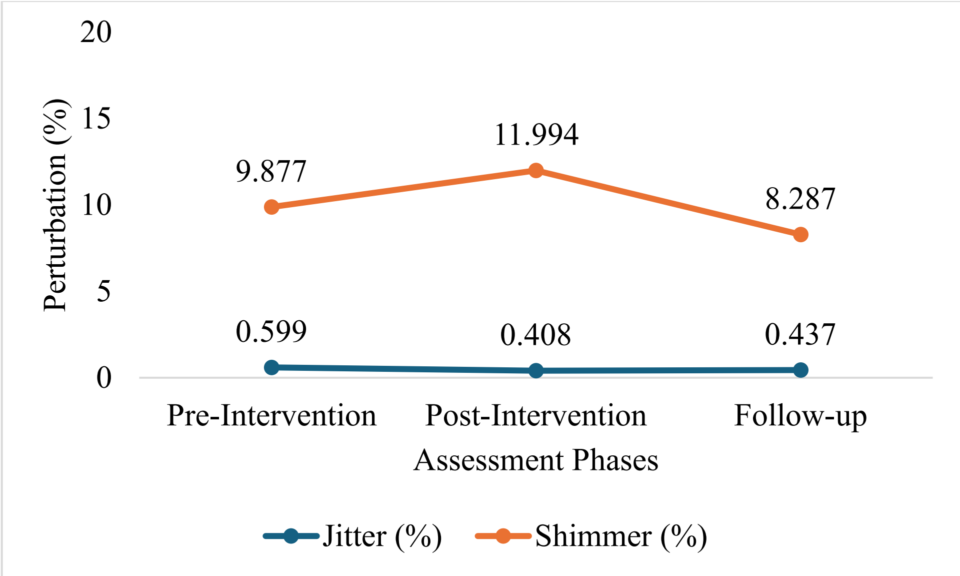


Table 4.7

Wilcoxon Signed Rank Test Results for Phonatory Measures Across Three Time Points

	Post vs. Pre		**Follow-up vs. Pre**		**Follow-up vs. Post**	
Parameter	***Z***	***p***	***Z***	***p***	***Z***	***p***
MPT	−1.753	.080	−1.604	.109	−0.535	.593
F0	−1.483	.138	−1.095	.273	−0.730	.465
Jitter	−0.405	.686	0.000	1.000	−0.365	.715
Shimmer	−0.674	.500	0.000	1.000	0.000	1.000

Note. MPT = Maximum Phonation Time; F0 = Fundamental Frequency.

4.3 Objective 3: Comparison of articulatory measures pre-, post-, and four weeks after the intervention in Indian elderly

4.3.1 Articulatory measures (syllables/sec): AMR and SMR

AMR and SMR values and group descriptive statistics (Median and Interquartile Range) of all participants across assessment phases are given in Table 4.8 and Figures 4.14-4.18 and SMR in Figure 4.19.

Table 4.8

Individual participant values, Median and Interquartile Range for AMR and SMR (syllables/sec) across assessment phases for all five participants

Participant	Pre-Intervention				Post-Intervention				Follow-up			
	AMR /pa/	*AMR /ta/*	*AMR /ka/*	*SMR /pataka/*	*AMR /pa/*	*AMR /ta/*	*AMR /ka/*	*SMR /pataka/*	*AMR /pa/*	*AMR /ta/*	*AMR /ka/*	*SMR /pataka/*
P1	6.40	6.60	6.20	3.90	6.50	6.90	6.30	3.80	6.20	6.20	5.90	3.50
P2	5.10	4.30	4.00	2.40	4.70	4.60	4.70	2.70	5.00	3.90	4.40	2.30
P3	3.60	3.80	3.90	2.00	4.90	4.10	4.30	1.80	—	—	—	—
P4	5.30	5.20	4.90	2.40	5.40	5.00	5.40	3.00	5.10	5.30	5.20	2.70
P5	6.00	5.60	5.80	2.90	5.30	5.20	5.20	3.10	5.50	5.20	5.20	3.00
Median	**5.30**	**5.20**	**4.90**	**2.40**	**5.30**	**5.00**	**5.20**	**3.00**	**5.25**	**5.25**	**5.20**	**2.85**
IQR	**1.85**	**2.05**	**2.05**	**1.20**	**1.15**	**1.70**	**1.35**	**1.20**	**1.00**	**1.75**	**1.13**	**0.98**

Note. AMR = Alternate Motion Rate; SMR = Sequential Motion Rate. Syll/s = syllables per second. IQR = Interquartile Range. — = follow-up data not available.

As shown in Table 4.8, AMR for /pa/ showed minimal variation across most participants, with P3 demonstrating the most notable individual increase (3.60 to 4.90

syllables/sec) post-intervention. AMR for /ta/ showed minor variation across phases, with most participants maintaining relatively stable performance. AMR for /ka/ showed slight increase post-intervention for most participants, with group-level gains stable at follow-up. For SMR /pataka/, P4 and P5 showed notable post-intervention increases, while P3 showed a slight decrease; follow-up data for P3 was unavailable.

The Wilcoxon Signed Rank Test did not reveal statistically significant differences for any AMR or SMR parameter across the three pairwise comparisons (all $p > .05$). However, AMR /pa/ demonstrated a trend approaching significance in the follow-up versus pre-intervention comparison ($Z = -1.841$, $p = .066$), and AMR /ta/ showed a similar non-significant trend at follow-up versus pre-intervention ($Z = -1.512$, $p = .131$). The absence of an immediate post-intervention effect for these parameters, followed by an emerging trend at four-week follow-up, is consistent with a delayed motor learning effect wherein functional gains continue to emerge after termination of training as the nervous system integrates new motor programmes (Schmidt & Lee, 2011). AMR /ka/ did not show any significant trends across comparisons (all $p > .109$). SMR similarly showed no significant differences; however, a trend approaching significance was observed for the follow-up versus post-intervention comparison ($Z = -1.841$, $p = .066$), suggesting a possible delayed strengthening of sequential motor gains.

AMR for /pa/ showed minimal variation across most participants, with the group median remaining stable at 5.30 syllables/sec across pre- and post-intervention phases, with a slight decrease to 5.25 syllables/sec at follow-up, while the IQR progressively narrowed from 1.85 to 1.15 to 1.00 across phases, suggesting greater consistency in performance. AMR for /ta/ demonstrated a group median of 5.20 syllables/sec (IQR = 2.05) pre-intervention, decreasing slightly to 5.00 (IQR = 1.70) post-intervention, and recovering to 5.25 (IQR = 1.75) at follow-up. AMR for /ka/ showed a group median increase from 4.90 syllables/sec (IQR = 2.05) pre-intervention to 5.20 syllables/sec (IQR = 1.35) post-intervention, maintained at 5.20

syllables/sec (IQR = 1.13) at follow-up. SMR for /pataka/ showed a notable group median increase from 2.40 syllables/sec (IQR = 1.20) pre-intervention to 3.00 syllables/sec (IQR = 1.20) post-intervention, with slight reduction to 2.85 syllables/sec (IQR = 0.98) at follow-up.

The effects of EMST on articulation are likely mediated through improvements in aerodynamic support, as the intervention does not directly target articulatory structures. Hegland et al. (2019) proposed that EMST strengthens the aerodynamic support underlying articulatory gestures; if this mechanism operates, improvements in bilabial repetition rate may take several weeks to become measurable as the respiratory and articulatory systems modify. All participants demonstrated normal speech intelligibility throughout, indicating that articulatory systems were functioning within normal limits at pre-intervention, and a ceiling effect may therefore have limited the ability to detect small improvements. The approaching significance trend for AMR /pa/ at follow-up versus pre-intervention is theoretically relevant and, together with the SMR trend, suggests a gradual carryover of articulatory gains beyond the immediate post-intervention period, though interpretation is limited by the small sample size. The IQR narrowing for AMR /pa/ from 1.85 at pre-intervention to 1.00 at follow-up independently indicates a more consistent articulatory performance pattern following the intervention. The absence of similar trends for AMR /ka/ is consistent with the greater motor complexity of velar tasks relative to bilabial and lingual ones (Tafiadis et al., 2022).

Figure 4.14

AMR (/pa/, /ta/, /ka/) in syllables per second across assessment phases for P1

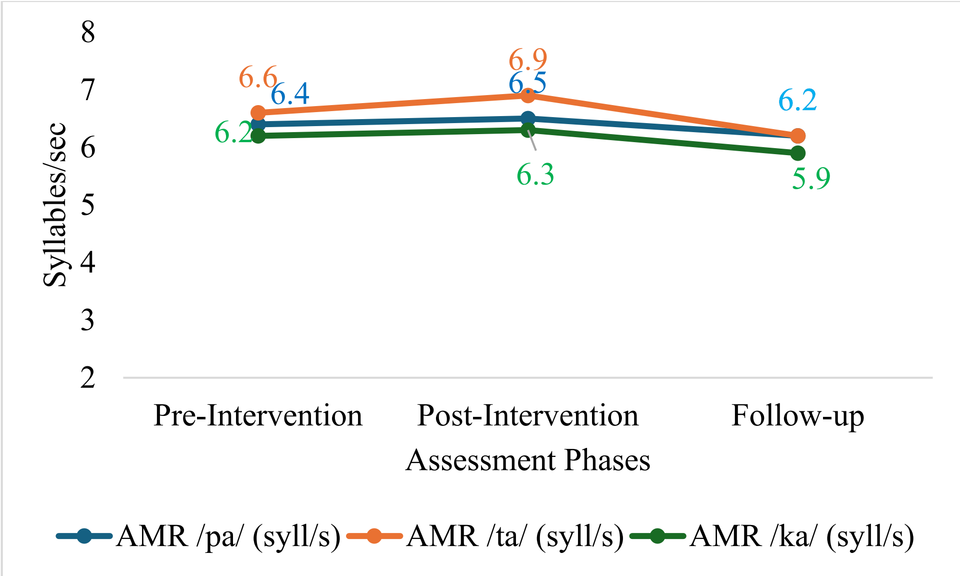


Figure 4.15

AMR (/pa/, /ta/, /ka/) in syllables per second across assessment phases for P2

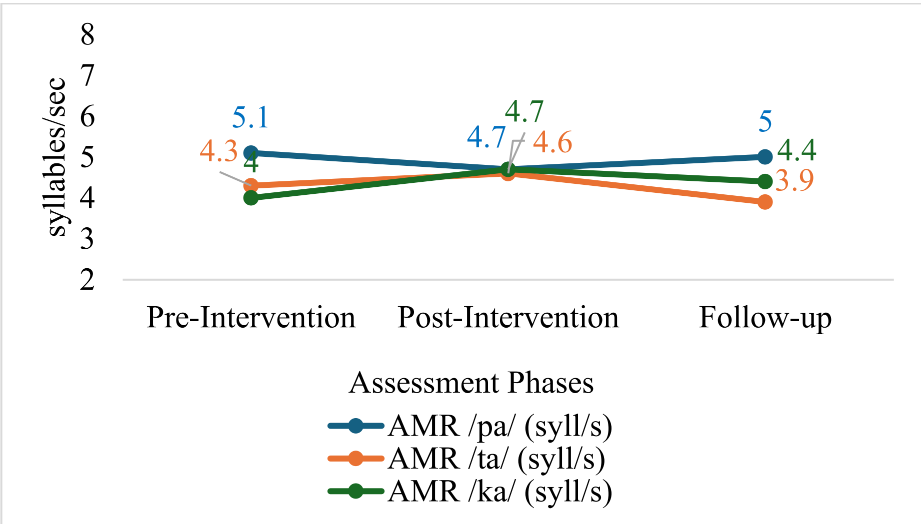


Figure 4.16

AMR (/pa/, /ta/, /ka/) in syllables per second across assessment phases for P3

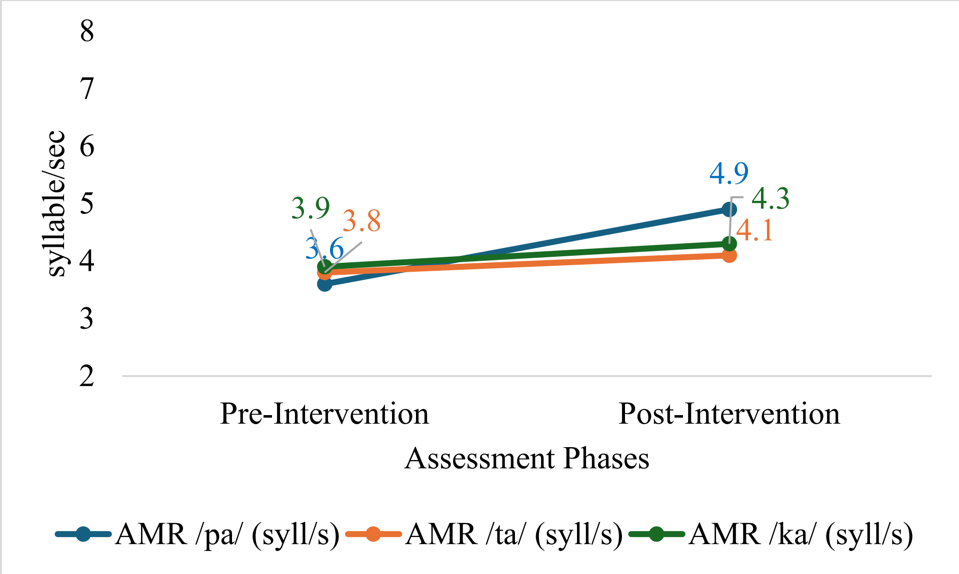


Figure 4.17

AMR (/pa/, /ta/, /ka/) in syllables per second across assessment phases for P4

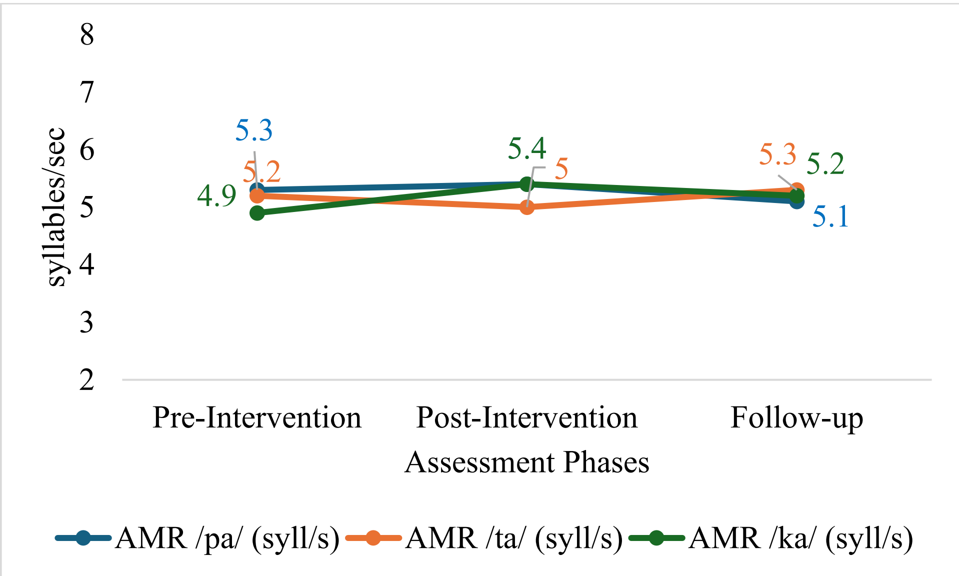


Figure 4.18

AMR (/pa/, /ta/, /ka/) in syllables per second across assessment phases for P5

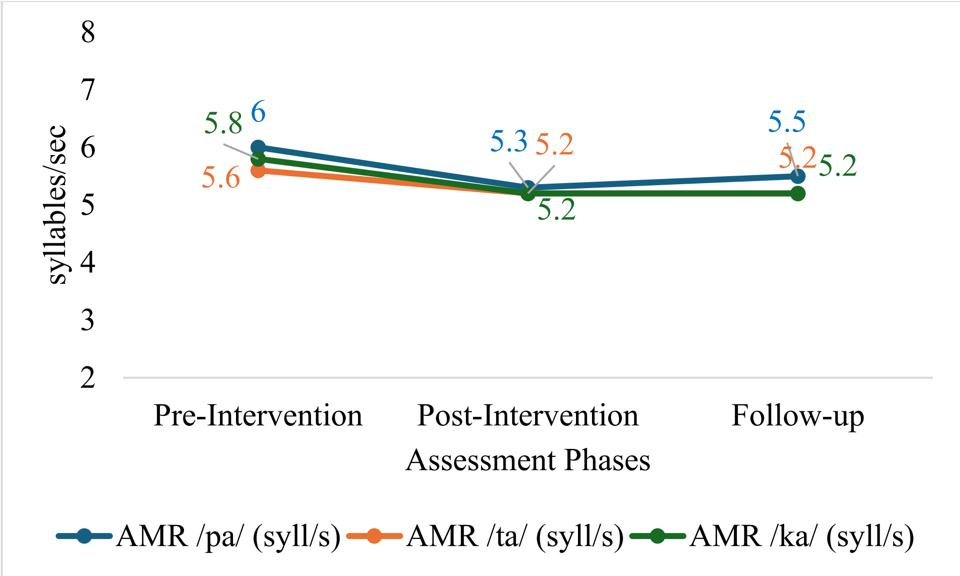
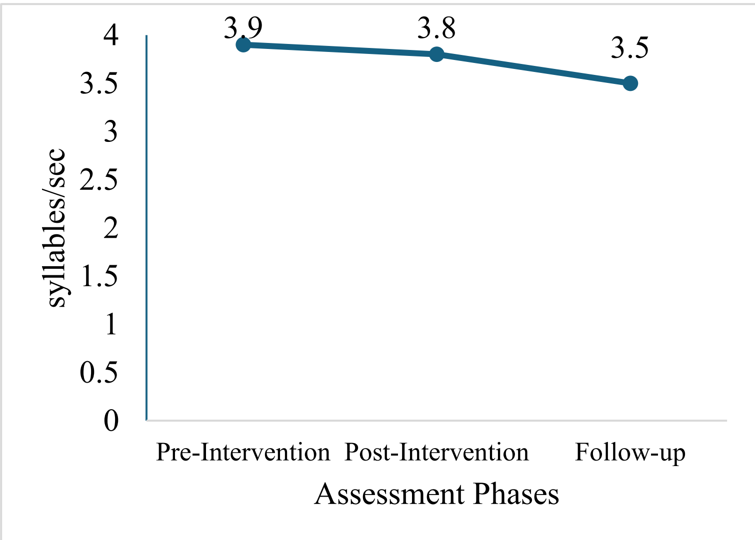
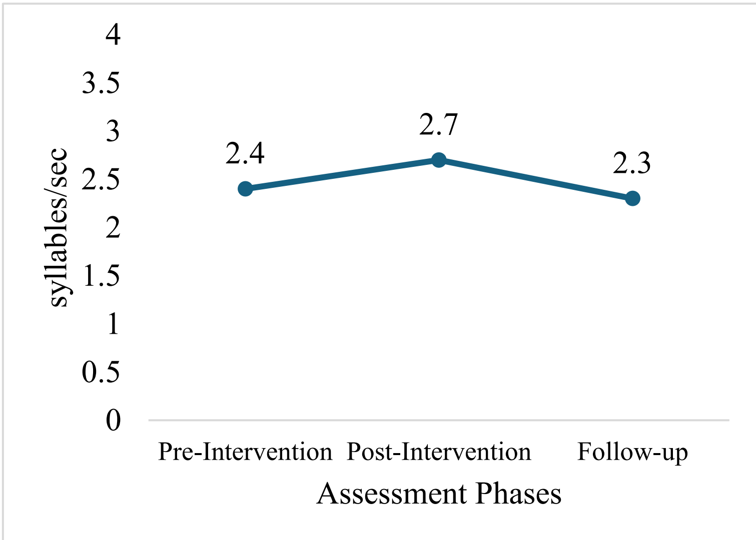


Figure 4.19

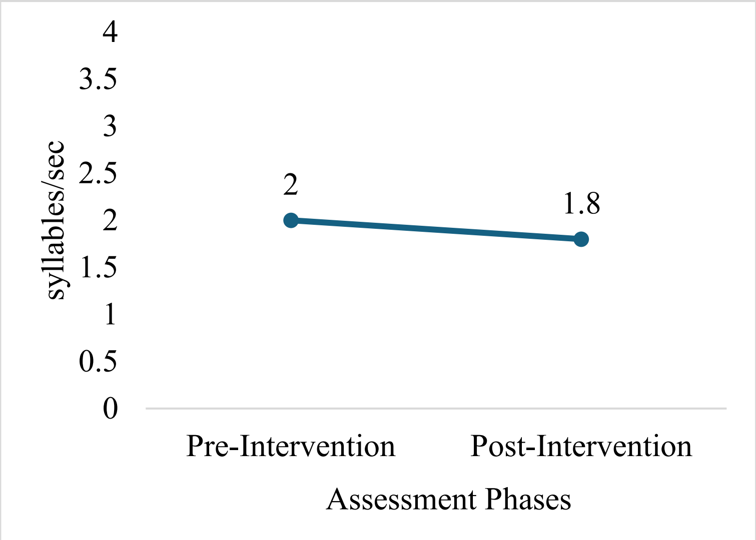
SMR (/pataka/) in syllables per second across pre, post and follow up phases for (a) P1, (b) P2, (c) P3, (d) P4, (e) P5



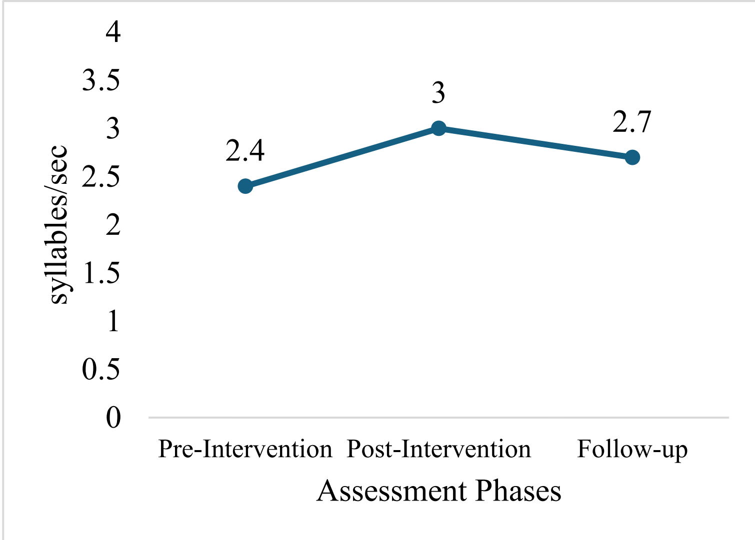
(a)



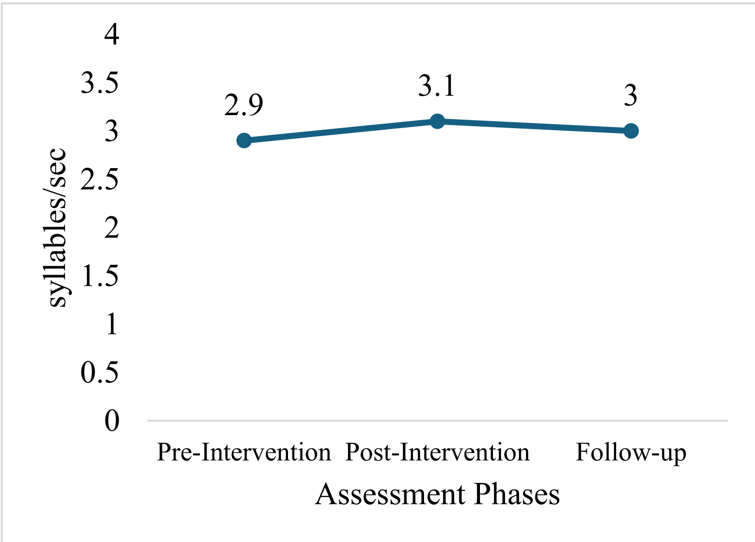
(b)



(c)



(d)



(e)

4.3.2 Articulatory measure (wpm): Speech rate

Speech Rate was measured in words per minute (wpm) using a standardised passage in the participant's native language. Individual values and group descriptive statistics (Median and Interquartile Range) of all participants across assessment phases are given in Table 4.9 and Figure 4.20.

Table 4.9

Individual participant values, Median and Interquartile Range for Speech Rate (words per minute) across assessment phases for all five participants

Participant	Pre-Intervention	Post-Intervention	Follow-up
P1	43.00	86.00	83.00
P2	28.00	30.00	30.00
P3	65.00	67.00	—
P4	120.00	104.00	120.00
P5	71.00	71.00	75.00
Median	**65.00**	**71.00**	**79.00**
IQR	**60.00**	**46.50**	**69.50**

Note. wpm = words per minute. IQR = Interquartile Range. — = follow-up data not available.

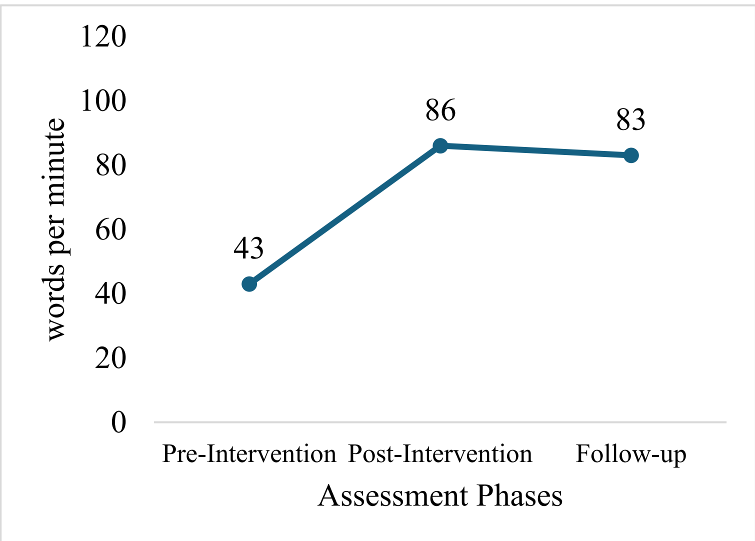
As shown in Table 4.9, speech rate showed notable variability across participants. P1 demonstrated a substantial increase from 43 to 86 wpm post-intervention, with partial retention at 83 wpm at follow-up. P2 showed a modest increase (28 to 30 wpm), retained at follow-up, noting that limited literacy affected reading performance. P3 showed a marginal increase, whereas P4 showed a decrease post-intervention with full recovery at follow-up. P5 remained stable at pre- and post-intervention with a slight increase at follow-up.

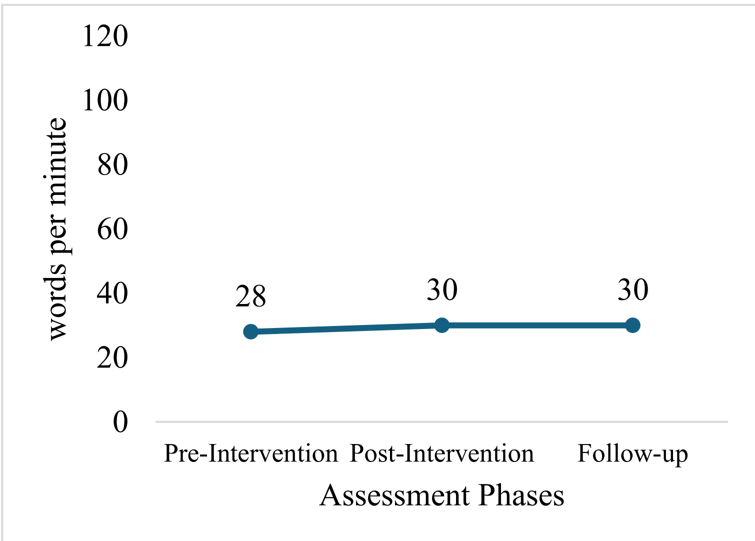
The Wilcoxon Signed Rank Test did not reveal statistically significant differences for speech rate across any of the three pairwise comparisons (post vs. pre Z = -0.736, p = .461; follow-up vs. pre Z = -1.604, p = .109; follow-up vs. post Z = -1.609, p = .285). The group median speech rate increased from 65.00 wpm (IQR = 60.00) at pre-intervention to 71.00 wpm (IQR = 46.50) post-intervention, and further to 79.00 wpm (IQR = 69.50) at follow-up, reflecting a gradual improvement across all assessment phases. The wide IQR across phases reflects considerable inter-participant variability in habitual speech rates, largely attributable to the wide range of pre-intervention performance levels.

The progressive increase in group median speech rate across all phases is perhaps the most practically relevant articulatory finding of the present study. Speech rate in connected oral reading integrates respiratory, phonatory, articulatory and prosodic systems simultaneously; its gradual post-intervention improvement is consistent with Kim and Sapienza's (2005) description of improved breath support for speech as a key mechanism underlying EMST-related gain. The approaching significance trend at follow-up versus pre-intervention (p = .109) further suggests a possible delayed benefit emerging beyond the immediate post-intervention phase. The wide IQR across phases is partly associated to P2's limited literacy affecting reading fluency, which means that this measure captures individual differences in reading skill as much as speech production efficiency.

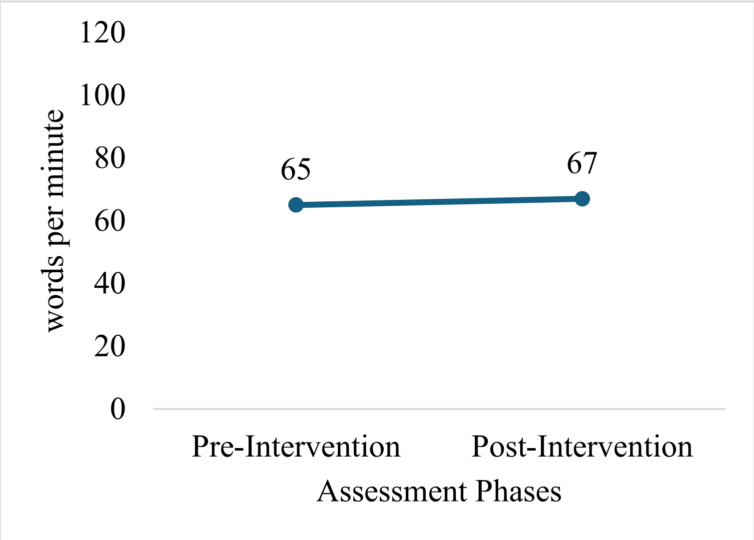
Figure 4.20

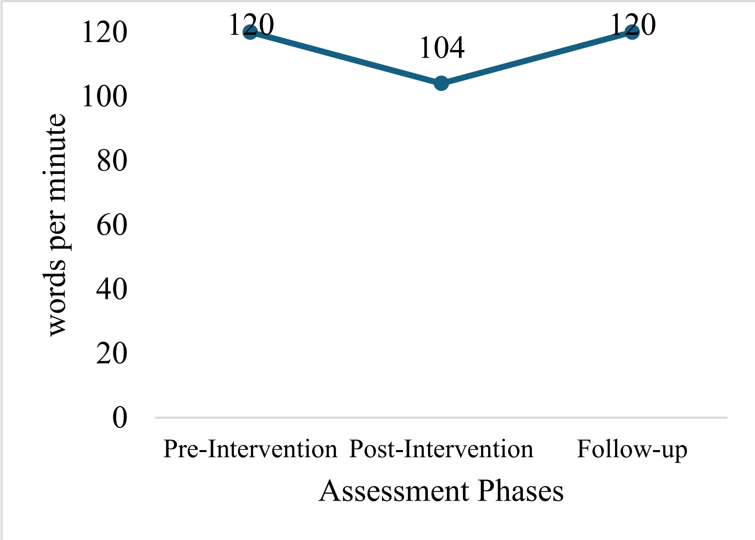
Speech rate (words per minute) across pre, post and follow up phases for (a) P1, (b) P2, (c) P3, (d) P4, (e) P5



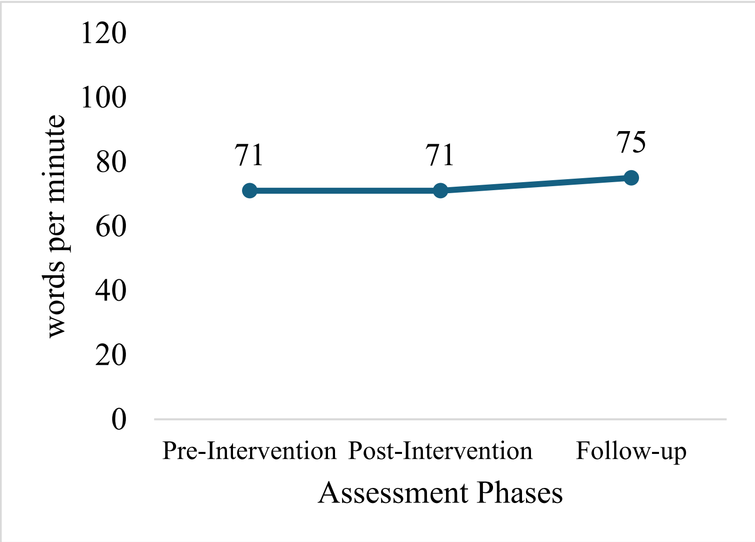


(a) (b)





(c) (d)



(e)

4.3.3 Articulatory measure: Speech intelligibility

Speech intelligibility was assessed using the AYJNISHD intelligibility rating scale (0 = normal intelligibility to 7 = unintelligible). All five participants received a rating of 0 across all three assessment phases indicating normal speech intelligibility was maintained throughout the study period. No change was observed in this measure across any participant or assessment phase.

Table 4.10

Wilcoxon Signed Rank Test Results for Articulatory Measures Across Three Time Points

	Post vs. Pre		Follow-up vs. Pre		Follow-up vs. Post	
Parameter	***Z***	***p***	***Z***	***p***	***Z***	***p***
AMR /pa/	−0.135	.892	−1.841	.066	−0.378	.705
AMR /ta/	−0.412	.680	−1.512	.131	−1.089	.276
AMR /ka/	−0.944	.345	−0.184	.854	−1.604	.109
Speech Rate	−0.736	.461	−1.604	.109	−1.069	.285
SMR	−1.084	.279	−0.184	.854	−1.841	.066

Note. AMR = Alternate Motion Rate; SMR = Sequential Motion Rate.

4.4 Objective 4: Comparison of swallowing measures pre-, post-, and four weeks after the intervention in Indian elderly

4.4.1 Swallowing measure (L/sec): Peak Expiratory Flow Rate

Peak Expiratory Flow Rate (PEFR) was used as a clinical index of cough strength, an important indicator of airway protective mechanism relevant to swallowing safety. Individual values and group descriptive statistics (Median and Interquartile Range) of all participants across assessment phases are given in Table 4.11 and Figure 4.21

Table 4.11

Individual participant values, Median and Interquartile Range for Peak Expiratory Flow Rate – PEFR (L/sec) across assessment phases for all five participants

Participant	Pre-Intervention	Post-Intervention	Follow-up
P1	2.28	2.89	3.11
P2	2.54	2.75	3.49
P3	4.34	4.19	—
P4	2.40	2.76	2.87
P5	1.57	3.48	2.93
Median	**2.40**	**2.89**	**3.02**
IQR	**1.52**	**1.08**	**0.51**

Note. PEFR = Peak Expiratory Flow Rate (L/sec). IQR = Interquartile Range. — = follow-up data not available.

As shown in Table 4.11, PEFR showed an overall improving trend across most participants. P1, P2, and P4 showed a progressive increase across all three phases, whereas P3 showed a marginal decrease post-intervention and P5 showed the most marked improvement, from 1.57 L/sec pre-intervention to 3.48 L/sec post-intervention, with partial retention at 2.93 L/sec at follow-up.

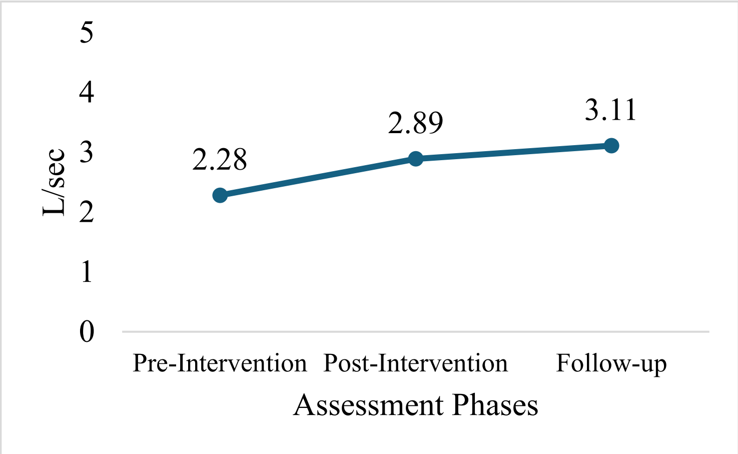
The Wilcoxon Signed Rank Test did not reveal statistically significant differences for PEFR across any of the three pairwise comparisons. However, approaching significance trends were observed in two comparisons post-intervention vs. pre-intervention ($Z = -1.753$, $p = .080$) and follow-up vs. pre-intervention ($Z = -1.826$, $p = .068$). The group median PEFR showed a progressive improvement across all assessment phases, from 2.40 L/sec (IQR = 1.52) pre-intervention to 2.89 L/sec (IQR = 1.08) post-intervention, and further to 3.02 L/sec (IQR =

0.51) at follow-up. The gradual narrowing of IQR from 1.52 to 0.51 indicates both gradual improvement and greater consistency in performance among participants at the follow-up phase.

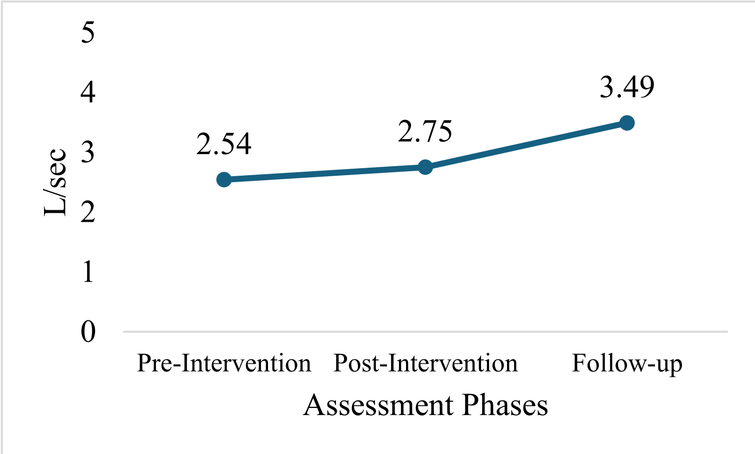
The PEFR findings are the most clinically relevant swallowing-related outcomes of the present study, even in the absence of statistical significance. PEFR was used as an objective measure of cough strength, widely recognised as the most reliable clinical measure for aspiration risk in the elderly (Hammond et al., 2001). The progressive improvement in group median PEFR across all three phases, combined with the remarkably reduced IQR at follow-up, indicates both sustained improvement in cough strength and greater consistency of performance. The approaching significance trends at both post vs. pre and follow-up vs. pre are consistent with the proposed physiological rationale for EMST's effect on cough, as demonstrated by Pitts et al. (2008) in healthy older adults and individuals with Parkinson's disease, and by Moon et al. (2017) in post-stroke patients. An important finding is that most EMST studies reporting significant swallowing improvements have been conducted in populations with pre-existing neurological disorders, where greater baseline deficit provides more potential for statistically observable improvement. The systematic reviews by Mancopes et al. (2021) and Dai et al. (2024), while broadly supportive of EMST, draw evidence predominantly from clinical populations and highlighted the limited evidence available for EMST in healthy elderly.

Figure 4.21

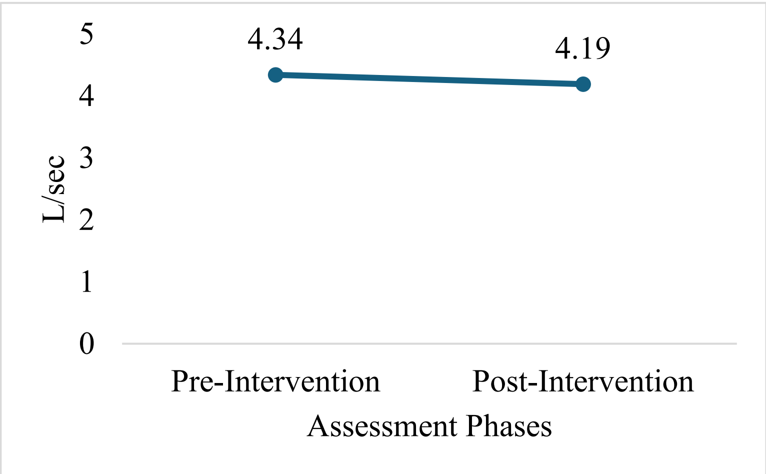
Peak Expiratory Flow Rate – PEFR (L/sec) across pre, post and follow up phases for (a) P1, (b) P2, (c) P3, (d) P4, (e) P5


5
4
3
2
1
0
L/sec
2.28
2.89
3.11
Pre-Intervention
Post-Intervention
Follow-up
Assessment Phases

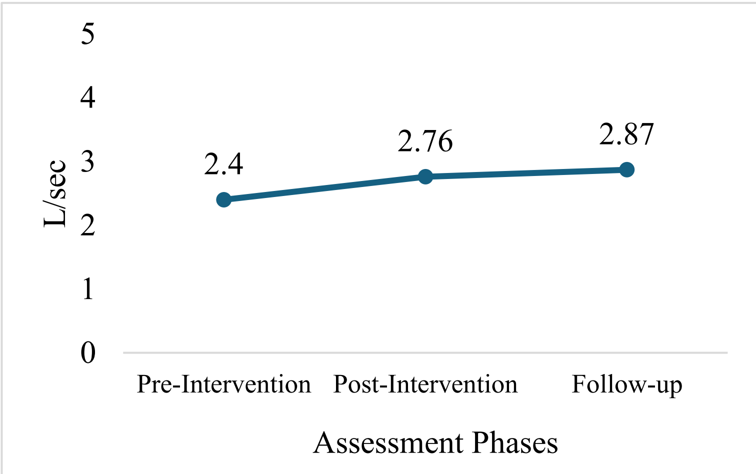
(a)


5
4
3
2
1
0
L/sec
2.54
2.75
3.49
Pre-Intervention
Post-Intervention
Follow-up
Assessment Phases

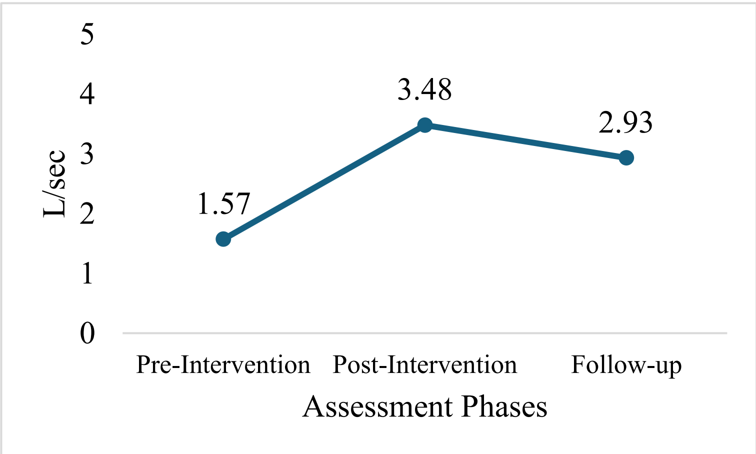
(b)


5
4
3
2
1
0
L/sec
4.34
4.19
Pre-Intervention
Post-Intervention
Assessment Phases

(c)


5
4
3
2
1
0
L/sec
2.4
2.76
2.87
Pre-Intervention
Post-Intervention
Follow-up
Assessment Phases

(d)


5
4
3
2
1
0
L/sec
1.57
3.48
2.93
Pre-Intervention
Post-Intervention
Follow-up
Assessment Phases

(e)

4.4.2 Swallowing measure (count/30 sec): Repetitive Saliva Swallowing Test

The Repetitive Saliva Swallowing Test (RSST) measures the number of voluntary saliva swallows completed within 30 seconds, with a clinical cut-off of 3 swallows indicating normal swallowing frequency. Individual values and group descriptive statistics (Median and Interquartile Range) of all participants across assessment phases are given in Table 4.12 and Figures 4.22.

Table 4.12

Individual participant values, Median and Interquartile Range for Repetitive Saliva Swallowing Test – RSST (count per 30 seconds) across assessment phases for all five participants

Participant	Pre-Intervention	Post-Intervention	Follow-up
P1	13.00	18.00	16.00
P2	15.00	15.00	17.00
P3	25.00	23.00	—
P4	14.00	16.00	18.00
P5	16.00	18.00	17.00
Median	**15.00**	**18.00**	**17.00**
IQR	**7.00**	**5.00**	**1.50**

Note. RSST = Repetitive Saliva Swallowing Test (count per 30 seconds). IQR = Interquartile Range. — = follow-up data not available.

As shown in Table 4.12, all five participants exceeded the clinical cut-off of 3 swallows per 30 seconds across all assessment phases, indicating normal swallowing frequency throughout. P1 increased from 13 to 18 swallows post-intervention, with modest reduction to

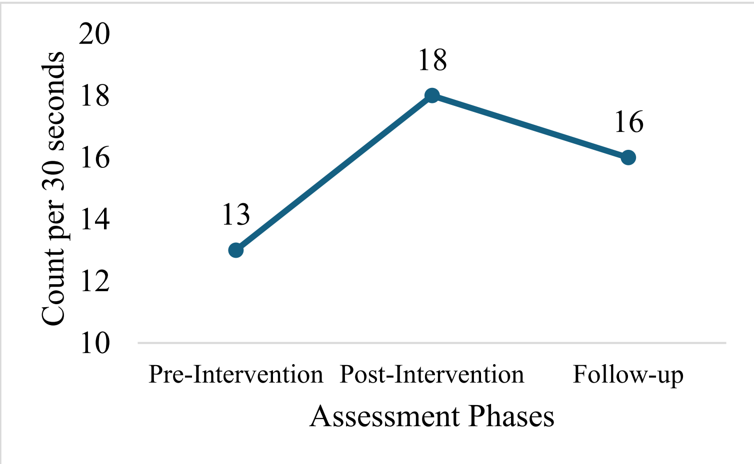
16 at follow-up. P2 maintained 15 swallows pre- and post-intervention, improving to 17 at follow-up. P3 showed a slight decrease from pre-intervention to post-intervention. P4 showed a progressive increase across all phases and P5 increased from 16 to 18 post-intervention with retention at 17 at follow-up.

The Wilcoxon Signed Rank Test did not reveal statistically significant differences for RSST across any of the three pairwise comparisons (post vs, pre $Z = -1.134$, $p = .257$; follow-up vs. pre $Z = -1.826$, $p = .068$; follow-up vs. post $Z = -0.378$, $p = .705$). A trend approaching significance was observed for the follow-up versus pre-intervention comparison, indicating a possible increase in swallowing frequency at follow-up relative to pre-intervention. The group median RSST increased from 15.00 swallows (IQR = 7.00) at pre-intervention to 18.00 swallows (IQR = 5.00) post-intervention, with slight reduction to 17.00 swallows (IQR = 1.50) at follow-up. A considerable reduction in the IQR at follow-up (1.50) indicates consistency of swallowing frequency among participants at the retention phase, suggesting that improvements were consistently maintained.

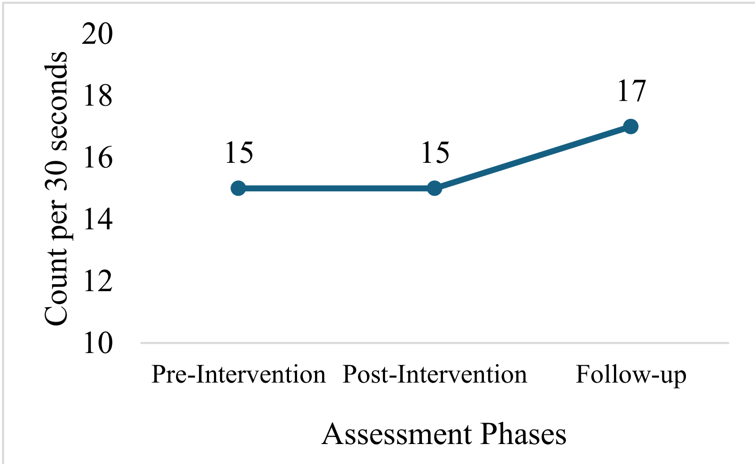
The RSST findings suggest further improvement during the post-intervention period, with a gradual rather than immediate pattern of change. This is consistent with the proposed physiological understanding that hyolaryngeal movement and suprahyoid muscle strengthening, which are the key targets of EMST's effect on swallowing, may require several weeks beyond the active training period before functional improvement becomes measurable. A systematic review by Mancopes et al. (2021) reported that EMST can enhance hyolaryngeal excursion and upper esophageal sphincter opening in both healthy and clinical populations; in healthy elderly individuals, these effects would be expected to emerge gradually. The substantially reduced IQR at follow-up (7.00 at pre-intervention to 1.50 at follow-up) independently constitutes a relevant finding, suggesting that EMST produces not only improvements in swallowing frequency but greater consistency and reliable performance over time among all participants. The fact that all five participants maintained swallowing frequencies far above the clinical dysphagia screening cut-off throughout the study confirms that EMST is safe and does not compromise baseline swallowing function in healthy elderly individuals.

Figure 4.22

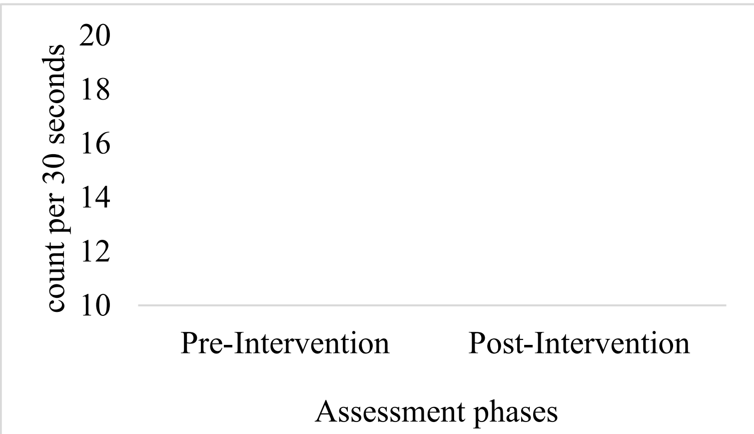
RSST count per 30 seconds across pre, post and follow up phases for (a) P1, (b) P2, (c) P3, (d) P4, (e) P5



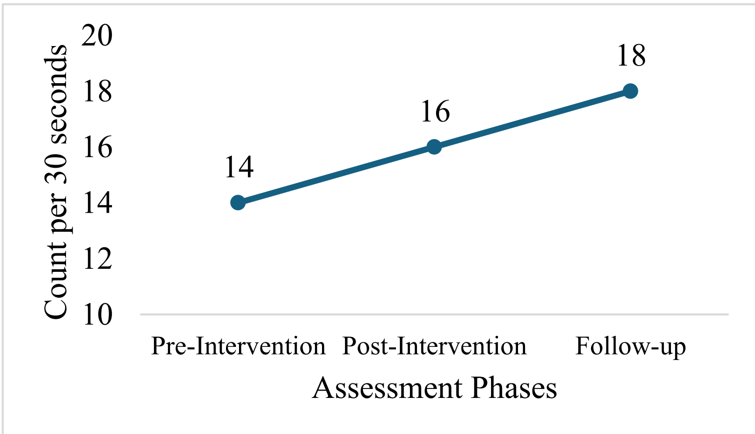
(a)



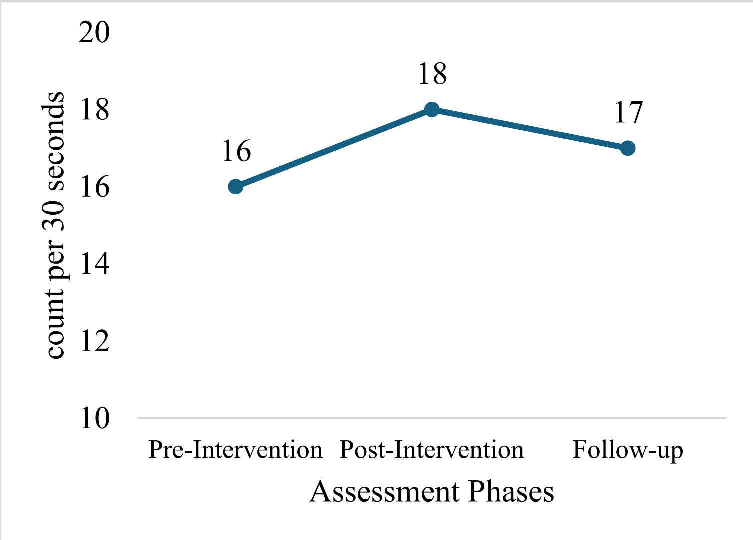
(b)



(c)



(d)



(e)

4.4.3 Swallowing measures: Semi-Quantitative Cough Strength Scale (SCSS) and Swallowing Ability Screening Questionnaire for Indian Elderly (SASQ-IE)

Semi-Quantitative Cough Strength Scale (SCSS) and Swallowing Ability Screening Questionnaire for Indian Elderly (SASQ-IE) are rating scale measures and are reported descriptively. All participants received an SCSS score of 3 across all assessment phases, indicating a moderately strong, audible cough throughout the study. For SASQ-IE, P1 obtained a score of 1 at pre-intervention, indicating the presence of a very mild swallowing-related symptom, which resolved to 0 at post-intervention and was maintained at follow-up. All remaining participants (P2, P3, P4, and P5) received a score of 0 at all available assessment phases, indicating the absence of self-reported swallowing difficulties. No change was observed in SCSS across any participant or phase.

Table 4.13

Wilcoxon Signed Rank Test Results for Swallowing Measures Across Three Time Points

	Post vs. Pre		Follow-up vs. Pre		Follow-up vs. Post	
Parameter	***Z***	***p***	***Z***	***p***	***Z***	***p***
PEFR	−1.753	.080	−1.826	.068	−0.730	.465
RSST	−1.134	.257	−1.826	.068	−0.378	.705

Across the four domains examined – respiratory, phonatory, articulatory and swallowing a total of 48 pairwise comparisons were conducted (16 parameters across 3 comparisons each). Of these, only one parameter reached statistical significance: FEV1 demonstrated a significant reduction from pre-intervention to post-intervention (Z = -2.023, p = .043). The absence of a broader pattern of statistical significance may be attributable to limited statistical power associated with a small sample size, and should not be interpreted as evidence of no treatment effect. Several parameters demonstrated trends approaching significance ($p < .10$), particularly for follow-up versus pre-intervention comparisons, suggesting that treatment gains may continue to emerge beyond the immediate post-intervention period. These observations are clinically relevant and support the need for validation with a larger sample to provide stronger evidence.

4.5 Reliability analysis

To ensure the consistency and accuracy of measurements for perceptual and observational outcome measures, inter-rater and intra-rater reliability analyses were conducted. Reliability was established for measures requiring perceptual judgement or manual observation specifically speech intelligibility, speech rate and diadochokinetic rate (Alternate Motion Rate for /pa/, /ta/ and /ka/ and Sequential Motion Rate for /pataka/). Acoustic and spirometric measures obtained directly from calibrated instrumentation (FVC, FEV1, F0, Jitter, Shimmer, PEFR and so forth) were not subjected to reliability testing as they were derived objectively from equipment outputs without rater-dependent judgements. Reliability was assessed using recordings from two participants, P1 and P2, who served as the reliability sample across all three assessment phases. The scores obtained under both reliability conditions are presented and discussed in the following sections.

4.5.1 Inter-rater reliability

Inter-rater reliability was established by having three raters independently score the same set of recordings. The primary (R1) and secondary (R1) rater were two independent, qualified speech-language pathologists with clinical experience and the third rater (J1) was the principal investigator. All three raters scored the audio recordings independently and without any access to each other's ratings. The raw scores obtained by the three raters for all measures and assessment phases are presented in Table 4.14 and illustrated in Figure 4.23 – 4.32.

Table 4.14

Scores obtained by three raters (R1, R2 and J1) across measures and assessment phases for P1 and P2

	P1			**P2**		
Phase	**R1**	**R2**	**J1**	**R1**	**R2**	**J1**
Speech Intelligibility (rating)						
Pre-Intervention	0	0	0	0	0	0
Post-Intervention	0	0	0	0	0	0

Follow-up	0	0	0	0	0	0
Speech Rate (wpm)						
Pre-Intervention	43	43	43	71	71	71
Post-Intervention	86	86	86	71	71	71
Follow-up	83	83	83	75	75	75
AMR – /pa/ (syll/s)						
Pre-Intervention	6.3	6.3	6.4	6.0	6.0	6.0
Post-Intervention	6.4	6.5	6.5	5.3	5.3	5.3
Follow-up	6.1	6.1	6.2	5.5	5.5	5.5
AMR – /ta/ (syll/s)						
Pre-Intervention	6.4	6.4	6.6	5.6	5.6	5.6
Post-Intervention	6.8	6.8	6.9	5.1	5.2	5.2
Follow-up	6.3	6.2	6.2	5.3	5.2	5.2
AMR – /ka/ (syll/s)						
Pre-Intervention	6.2	6.1	6.2	5.8	5.9	5.8
Post-Intervention	6.2	6.3	6.3	5.3	5.4	5.2
Follow-up	6.0	5.9	5.9	5.2	5.2	5.2
SMR – /pataka/ (syll/s)						
Pre-Intervention	3.9	3.8	3.9	2.8	3.0	2.9
Post-Intervention	3.6	3.7	3.8	3.1	3.0	3.1
Follow-up	3.8	3.8	3.5	3.0	3.2	3.0

As presented in Table 4.14, consensus was observed among all three raters for speech intelligibility across all three assessment phases for both P1 and P2, with all raters assigning a score of 0, indicating normal intelligibility throughout. Speech rate scores were also similar across all three raters for both participants at every assessment phase, reflecting perfect agreement for this measure.

For AMR /pa/, minor difference of 0.1 syllables per second were observed between raters for P1 across all three phases, while P2 showed a complete agreement across all phases. For AMR /ta/, R1 and R2 were in complete agreement for P1 at all phases; however, J1 differed by 0.2 syllables per second at the pre-intervention phase and by 0.1 syllables per second at post-intervention and follow-up. For P2, all three raters were in consensus across all phases for AMR /ta/. For AMR /ka/, differences of 0.1 syllables per second were noted between raters for P1 across phases, and a maximum discrepancy of 0.2 syllables per second was observed for P2 at post-intervention between J1 and the other two raters, with complete agreement observed at follow-up for P2.

For SMR /pataka/, the largest inter-rater discrepancies were observed. For P1, a difference of 0.1 syllables per second was noted between R1 and R2 at pre-intervention, while J1 agreed with R1. At post-intervention, rater scores ranged from 3.6 to 3.8 syllables per second, reflecting a maximum difference of 0.2 syllables per second. At follow-up, J1 scored 3.5 syllables per second compared to 3.8 syllables per second by both R1 and R2, a difference of 0.3 syllables per second. For P2, the maximum discrepancy was 0.2 syllables per second. Overall, inter-rater scores were closely consistent across all measures and phases, with the majority of differences limited to 0.1 syllables per second and a maximum discrepancy of 0.3 syllables per second confined to the SMR measure at one phase, indicating satisfactory inter-rater agreement.

4.3.2 Intra-rater reliability

Intra-rater reliability was established to assess the consistency of scores provided by the principal investigator across two independent scoring occasions. The same audio recordings were re-scored by the primary rater on a second occasion (Trial 2), separated from the original scoring session (Trial 1) by a minimum interval of two weeks to minimise the influence of recall. Scores were assigned independently without reference to the original ratings. The raw scores obtained across both trials for all measures and assessment phases are presented in Table 4.15 and illustrated in Figure 4.33 – 4.42.

Table 4.15

Scores obtained across two rating trials (R1, R2 and J1) across measures and assessment phases for P1 and P2

	P1		**P2**	
Phase	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**
Speech Intelligibility (rating)				
Pre-Intervention	0	0	0	0
Post-Intervention	0	0	0	0
Follow-up	0	0	0	0
Speech Rate (wpm)				
Pre-Intervention	43	43	71	71
Post-Intervention	86	86	71	71
Follow-up	83	83	75	75
AMR – /pa/ (syll/s)				

Pre-Intervention	6.4	6.3	6.0	6.1
Post-Intervention	6.5	6.5	5.3	5.4
Follow-up	6.2	6.2	5.5	5.4
AMR – /ta/ (syll/s)				
Pre-Intervention	6.6	6.7	5.6	5.8
Post-Intervention	6.9	6.9	5.2	5.2
Follow-up	6.2	6.2	5.2	5.2
AMR – /ka/ (syll/s)				
Pre-Intervention	6.2	6.0	5.8	5.8
Post-Intervention	6.3	6.0	5.2	5.2
Follow-up	5.9	5.6	5.2	5.2
SMR – /pataka/ (syll/s)				
Pre-Intervention	3.9	3.8	2.9	2.9
Post-Intervention	3.8	3.0	3.1	3.0
Follow-up	3.5	3.6	3.0	3.1

As presented in Table 4.15, speech intelligibility scores were identical across both trials for both participants at all three assessment phases, indicating perfect intra-rater agreement. Speech rate scores were also identical across both trials for all phases and both participants, reflecting complete consistency in the primary rater's scoring of this measure.

For AMR /pa/, a minor difference of 0.1 syllables per second was observed between trials for P1 at pre-intervention, and for P2 at pre-and post-intervention phases. No differences were observed at other phases for this measure. For AMR /ta/, a difference of 0.1 syllables per second was observed for P1 at pre-intervention (Trial 1 = 6.6, Trial 2 = 6.7), and a difference of 0.2 syllables per second was noted for P2 at pre-intervention (Trial 1 = 5.6, Trial 2 = 5.8). Perfect agreement was observed across both trials at post-intervention and follow-up for both participants for AMR /ta/.

For AMR /ka/, P2 showed complete agreement between trials at all three phases, while P1 showed differences of 0.2 syllables per second at pre-intervention (Trial = 6.2, Trial 2 = 6.0), 0.3 syllables per second at post-intervention (Trial 1 = 6.3, Trial 2 = 6.0), and 0.3 syllables per second at follow-up (Trial 1 = 5.9, Trial 2 = 5.6). For SMR /pataka/, scores were in close agreement across most phases, with differences of 0.1 syllables per second or less for the majority of instances. The largest discrepancy was observed for P1 at post-intervention (Trial 1 = 3.8, Trial 2 = 3.0), a difference of 0.8 syllables/second, which is the largest intra-rater discrepancy observed in the present reliability assessment. All other SMR phase comparisons showed differences of 0.1 syllables per second or less. Overall, the intra-rater reliability data indicate acceptable consistency in the primary rater's scoring across the two trials, with the isolated larger discrepancy for SMR at post-intervention for P1 noted as an exception, supporting the overall reliability of the measurements obtained in the present study.

The inter-rater and intra-rater reliability findings indicate that the perceptual and observational measures employed in the present study were scored with a acceptable degree of consistency and accuracy. Score differences were minimal for speech intelligibility and speech rate, where complete agreement was observed across all conditions. For diadochokinetic measures, the majority of discrepancies were limited to 0.1-0.2 syllables per second, which is within the normal range of measurement variability for such measures. Overall, these findings support the reliability and consistency of the obtained data and also strengthen the validity of the outcome measures.

CHAPTER V

SUMMARY & CONCLUSION

The present study was aimed at examining the impact of Expiratory Muscle Strength Training (EMST) on speech and swallowing functions in Indian elderly individuals aged 60 years and above. Aging is associated with well-established physiological changes across the respiratory, phonatory, articulatory, and swallowing subsystems, primarily influenced by sarcopenia, presbylarynx, and presbyphagia. EMST, a task-specific resistive training approach that targets the expiratory muscles, was examined as a potential intervention approach to reduce these age-related declines. This study employed an ABA single-subject design with five community-dwelling elderly females (aged 60-80 years) who were native speakers of Malayalam or Kannada. A structured four-week EMST intervention protocol was implemented using the EMST-150 device, with resistance individualized to 75% of each participant's maximum expiratory pressure, and outcome measures across respiratory, phonatory, articulatory, and swallowing domains were evaluated at pre-intervention, post-intervention, and four-week follow-up.

In the respiratory domain, FEV1 exhibited a reduction post-intervention as a modification of expiratory effort strategy rather than an actual reduction in respiratory capacity, while SVC demonstrated a gradual improvement at follow-up, suggesting delayed neuromuscular adaptation. The FEV1/FVC ratio remained unchanged across assessment phases, indicating the absence of airflow obstruction. In the phonatory domain, improvements were noted in MPT and fundamental frequency across phases, indicating a modest aerodynamic benefit that did not reach measurable acoustic thresholds within four-week study period among healthy elderly.

In the articulatory domain, improvements were noted in AMR rates and speech rate across phases, suggesting delayed translation of respiratory improvements into functional performance during connected speech production, while speech intelligibility remained normal throughout. Among swallowing measures, both PEFR and RSST showed gradual improvement following the intervention and at follow-up, with a markedly reduced variability across participants at follow-up which indicates a greater consistency in airway protection and swallowing frequency, a clinically relevant finding even in the absence of statistically significant changes.

To conclude, the findings suggest that a four-week EMST programme is a feasible, well-tolerated, and potentially beneficial intervention for healthy Indian elderly. Although statistically significant changes were limited, the improvements across multiple domains are clinically relevant and consistent with the proposed physiological rationale for EMST's effects on the interconnected neuromuscular systems involved in speech and swallowing. The limited statistical significance is largely associated to the small sample size and the relatively high baseline functioning of the participants. The hybrid delivery model combining face-to-face and supervised online sessions supported the feasibility of delivering EMST through a telerehabilitation framework, and these findings of the study provide preliminary evidence and establish a foundation for future large-scale, longitudinal investigations to further evaluate the effectiveness of EMST in the elderly population.

5.1 Limitations of the present study

- The study involved only five participants, limiting the generalisability of findings.
- The study sample consisted exclusively of female participants, which limits the applicability of findings to the broader elderly male population. Differences in speech

and swallowing physiology between males and females in the elderly age group could not be explored.

- Follow-up data was unavailable for the third participant, resulting in an incomplete dataset and reducing the ability to evaluate consistency of retention effects across all participants uniformly.
- Home-based EMST practice was monitored through a caregiver-assisted checklist. As objective verification of compliance was not feasible, variations in the actual training dosage among participants cannot be ruled out.
- Retention outcomes were assessed only at four weeks post-intervention. Therefore, long-term sustainability of the observed benefits remains unknown and requires further investigation.
- Limited normative data for speech and swallowing measures specific to the Indian elderly populations constrained the clinical interpretation of individual participant scores and comparisons with population-specific norms.

5.2 Clinical Implications

- EMST is a cost-effective, portable, and easily administered training program, making it appropriate for elderly populations, especially in home-based settings.
- The findings provide preliminary evidence that may assist speech-language pathologists and other rehabilitation professionals in developing and refining evidence-based protocols for integrating EMST into geriatric rehabilitation programs.
- The hybrid model of initial face-to-face training followed by supervised online sessions was clinically feasible across all participants. This supports the potential of EMST

delivery through telerehabilitation framework, improving access for elderly individuals in community settings in India.

- The findings of this study may support interdisciplinary rehabilitation techniques in several domains, such as geriatrics, pulmonology, neurology, and speech-language pathology.
- Development of informational pamphlets on EMST may help increase awareness among elderly, caregivers and healthcare professionals regarding its potential benefits for speech and swallow functions.

5.3 Future Directions

- Further studies should recruit larger and more diverse samples, including both male and female elderly to enhance generalisability of findings and enable subgroup analyses by age and gender category.
- Future studies should include follow-up assessments at 3 months, 6 months and beyond to determine the long-term retention and sustainability of EMST effects.
- Future studies should examine EMST outcomes in elderly individuals with dysarthria, dysphagia or early-stage neurological disorders to evaluate therapeutic efficacy beyond healthy aging population.
- There is a need for language and culture-specific normative databases for speech and swallowing measures in the Indian elderly population, which would strengthen clinical interpretation and applicability in future studies.

REFERENCES

Anand, S., El-Bashiti, N., & Sapienza, C. (2012). Effect of training frequency on maximum expiratory pressure. *American journal of speech-language pathology*, *21*(4), 380–386. https://doi.org/10.1044/1058-0360(2012/11-0048)

Ali Yavar Jung National Institute of Speech and Hearing Disabilities (Divyangjan). (2003). Speech intelligibility rating scale. AYJNISHD.

All India Institute of Speech and Hearing (2023). Ethical guidelines for bio-behavioural research involving human subjects (Version 2.0). All India Institute of Speech and Hearing.

Allen, J., & Miles, A. (2019). Walking the thin white line – managing voice in the older adult. *Speech Language and Hearing*, *22*(1), 25–31. https://doi.org/10.1080/2050571x.2019.1567897

Baumgartner, R. N., Koehler, K. M., Gallagher, D., Romero, L., Heymsfield, S. B., Ross, R. R., Garry, P. J., & Lindeman, R. D. (1998). Epidemiology of Sarcopenia among the Elderly in New Mexico. *American Journal of Epidemiology*, *147*(8), 755–763. https://doi.org/10.1093/oxfordjournals.aje.a009520

Benjamin, B. J. (1982). Phonological performance in gerontological speech. *Journal of Psycholinguistic Research*, *11*(2), 159–167. https://doi.org/10.1007/bf01068218

Bennett, J., Van Lieshout, P., & Steele, C. (2007). Tongue control for speech and swallowing in healthy younger and older subjects. *International Journal of Orofacial Myology*, *33*(1), 5–18. https://doi.org/10.52010/ijom.2007.33.1.1

Boersma, P., & Weenink, D. (2021). *Praat: Doing phonetics by computer (Version 6.2.23) [Computer software]*. University of Amsterdam. https://www.fon.hum.uva.nl/praat/

Brooks, M., McLaughlin, E., & Shields, N. (2017). Expiratory muscle strength training improves swallowing and respiratory outcomes in people with dysphagia: A systematic review.

International Journal of Speech-Language Pathology, *21*(1), 89–100. https://doi.org/10.1080/17549507.2017.1387285

Campbell, E. J. M., & Lefrak, S. S. (1978). How aging affects the structure and function of the respiratory system. *PubMed*, *33*(6), 68–74. https://pubmed.ncbi.nlm.nih.gov/648879

Chiara, T., Martin, A. D., Davenport, P. W., & Bolser, D. C. (2006). Expiratory muscle strength training in persons with multiple sclerosis having mild to moderate disability: effect on maximal expiratory pressure, pulmonary function, and maximal voluntary cough. *Archives of Physical Medicine and Rehabilitation*, *87*(4), 468–473. https://doi.org/10.1016/j.apmr.2005.12.035.

Chiara, T., Martin, D., & Sapienza, C. (2007). Expiratory muscle strength training. *Neurorehabilitation and Neural Repair*, *21*(3), 239–249. https://doi.org/10.1177/1545968306294737

Chilwan, U., Kumar, K. V., Karuppali, S., Aithal, V. U., Dodderi, T., Shameer, S., & Balasubramanium, R. K. (2025). Prevalence of swallow fatigue and its relationship with self reported swallowing difficulties among community dwelling older adults in the Indian population. *Clinical Epidemiology and Global Health*, *33*, 102034. https://doi.org/10.1016/j.cegh.2025.102034

Claus, I., Muhle, P., Czechowski, J., Ahring, S., Labeit, B., Suntrup-Krueger, S., Wiendl, H., Dziewas, R., & Warnecke, T. (2021). Expiratory muscle strength training for therapy of pharyngeal dysphagia in Parkinson's disease. *Movement Disorders*, *36*(8), 1815–1824. https://doi.org/10.1002/mds.28552

Dai, Y., Cai, J., Wang, H., Zhang, Y., Niu, C., & Wang, Y. (2023). Effect of respiratory training on swallowing function in swallowing disorders: a systematic review and meta-analysis. *European Archives of Oto-Rhino-Laryngology*, *281*(3), 1069–1081. https://doi.org/10.1007/s00405-023-08280-7.

Dakin, A. E., Borders, J. C., Curtis, J. A., Hegland, K. W., & Troche, M. S. (2023). Maximal expiratory pressure and its link with cough airflow before and after expiratory muscle strength training in Parkinson's disease. *Perspectives of the ASHA Special Interest Groups*, 1–10. https://doi.org/10.1044/2023_persp-23-00065

Da Costa, J. P., Vitorino, R., Silva, G. M., Vogel, C., Duarte, A. C., & Rocha-Santos, T. (2016). A synopsis on aging—Theories, mechanisms and future prospects. *Ageing Research Reviews*, *29*, 90–112. https://doi.org/10.1016/j.arr.2016.06.005

Devadas, D., More, R. S., Sahni, C., Gupta, M., Nayak, A. K., & Mishra, A. (2022). The aging larynx. *Journal of the Indian Academy of Geriatrics*, *18*(4), 221–226. https://doi.org/10.4103/jiag.jiag_46_22

De Souza Pereira Gama M, M. C., Da Silva, C. D. A., Sanchez, F. F., Marques, J. R. D., Cortez, P. C., Amaral, C. M. S. S. B. D., De Souza, N. M., & Gonçalves, R. L. (2018). Respiratory Muscle Strength Evaluation in Healthy Adult and Elderly Women—Respiratory Muscle Strength Assessment in Adult and Elderly. *Health*, *10*(08), 1031–1036. https://doi.org/10.4236/health.2018.108077

Deliyski, S. a. X. D. (2001). Effects of Aging on Selected Acoustic Voice Parameters: Preliminary Normative Data and Educational Implications. *Educational Gerontology*, *27*(2), 159–168. https://doi.org/10.1080/036012701510755561

Desjardins, M. & Medical University of South Carolina. (2019). Respiratory Muscle Strength Training to Improve Vocal Function of Patients with Presbyphonia. In the Medical University of South Carolina, *MUSC Theses and Dissertations*. https://core.ac.uk/download/480680033.pdf.

Dodderi, T., Sreenath, D., Shetty, M. J., Chilwan, U., Rai, S. P. V., Moolambally, S. R., Balasubramanium, R. K., & Kothari, M. (2024). Prevalence of Self-Reported Swallowing

Difficulties and Swallowing-Related Quality of Life among Community-Dwelling Older Adults in India. *Dysphagia*, *39*(6), 1144–1155. https://doi.org/10.1007/s00455-024-10696-0

Dokhe, Y., Thankappan, K., Sood, R., Jaya, A. C., Balasubramanian, D., Chatni, S., ... & Iyer, S. (2021). Validation of an intelligibility assessment tool in an Indian language for perceptual speech analysis in oral cancer patients. *Indian Journal of Surgical Oncology*, *12*(1), 100-107.

Duffy, J. R. (2013). *Motor speech disorders: Substrates, differential diagnosis, and management* (3rd ed.). Elsevier Mosby.

Eom, M., Chang, M., Oh, D., Kim, H., Han, N., & Park, J. (2017). Effects of resistance expiratory muscle strength training in elderly patients with dysphagic stroke. *Neurorehabilitation*, *41*(4), 747–752. https://doi.org/10.3233/nre-172192

Follmer, A. (2013). The effects of expiratory muscle strength training on swallowing and voice measures in healthy older adults. In *UWM Digital Commons (University of Wisconsin–Milwaukee)*. https://dc.uwm.edu/etd/216

Galluzzi, F., & Garavello, W. (2018). The aging voice: a systematic review of presbyphonia. *European Geriatric Medicine*, *9*(5), 559–570. https://doi.org/10.1007/s41999-018-0095-6

Gascon, L., Belfiglio, M., Nowacki, A. S., Adessa, M., Hashmi, A. Z., & Bryson, P. C. (2024). Prevalence of self-reported voice and swallowing complaints in an outpatient geriatric population. *Laryngoscope Investigative Otolaryngology*, *9*(5), e70012. https://doi.org/10.1002/lio2.70012

Gorham-Rowan, M. M., & Laures-Gore, J. (2005). Acoustic-perceptual correlates of voice quality in elderly men and women. *Journal of Communication Disorders*, *39*(3), 171–184. https://doi.org/10.1016/j.jcomdis.2005.11.005

Goy, H., Fernandes, D. N., Pichora-Fuller, M. K., & Van Lieshout, P. (2013). Normative voice data for younger and older adults. *Journal of Voice*, *27*(5), 545–555. https://doi.org/10.1016/j.jvoice.2013.03.002

Hammond, C. S., Goldstein, L., Zajac, D., Gray, L., Davenport, P., & Bolser, D. (2001). Assessment of aspiration risk in stroke patients with quantification of voluntary cough. *Neurology*, *56*(4), 502–506. https://doi.org/10.1212/wnl.56.4.502

Hammond, C. a. S., Goldstein, L. B., Horner, R. D., Ying, J., Gray, L., Gonzalez-Rothi, L., & Bolser, D. C. (2008). Predicting aspiration in patients with ischemic stroke. *CHEST Journal*, *135*(3), 769–777. https://doi.org/10.1378/chest.08-1122

Hegland, K. W., Troche, M., & Brandimore, A. (2019). Relationship between respiratory sensory perception, speech, and swallow in Parkinson's disease. *Movement disorders clinical practice*, *6*(3), 243-249.

Hiss, S. G., Treole, K., & Stuart, A. (2001). Effects of age, gender, boluS volume, and trial on swallowing apnea duration and Swallow/Respiratory Phase relationships of normal adults. *Dysphagia*, *16*(2), 128–135. https://doi.org/10.1007/s004550011001

Hu, H., Li, J., He, S., Zhao, Y., Liu, P., & Liu, H. (2023). Aging-related decline in the neuromotor control of speech production: current and future. *Frontiers in Aging Neuroscience*, *15*, 1172277. https://doi.org/10.3389/fnagi.2023.1172277

Hutcheson, K. A., Hammer, M. J., Rosen, S. P., Jones, C. A., & McCulloch, T. M. (2017). Expiratory muscle strength training evaluated with simultaneous high-resolution manometry and electromyography. *The Laryngoscope*, *127*(4), 797–804. https://doi.org/10.1002/lary.26397

Iannuzzi-Sucich, M., Prestwood, K. M., & Kenny, A. M. (2002). Prevalence of sarcopenia and predictors of skeletal muscle mass in healthy, older men and women. *The Journals of Gerontology Series A*, *57*(12), M772–M777. https://doi.org/10.1093/gerona/57.12.m772

Ito, N., Watanabe, S., Morita, K., Morita, K., Okuyama, Y., Takizawa, T., Suzuki, K., & Iida, Y. (2017). THE EFFECT OF EXPIRATORY MUSCLE STRENGTH TRAINING ON THE SWALLOWING FUNCTIONS OF THE ELDERLY. *Innovation in Aging*, *1*(suppl_1), 230–231. https://doi.org/10.1093/geroni/igx004.857

Janssens, J., Pache, J., & Nicod, L. (1999). Physiological changes in respiratory function associated with ageing. *European Respiratory Journal*, *13*(1), 197. https://doi.org/10.1034/j.1399-3003.1999.13a36.x

Jeon, Y. K., Shin, M. J., Kim, M. H., Mok, J. H., Kim, S. S., Kim, B. H., Kim, S., Kim, Y. K., Chang, J. H., Shin, Y. B., & Kim, I. J. (2015). Low pulmonary function is related with a high risk of sarcopenia in community-dwelling older adults: the Korea National Health and Nutrition Examination Survey (KNHANES) 2008–2011. *Osteoporosis International*, *26*(10), 2423–2429. https://doi.org/10.1007/s00198-015-3152-8

Kendall, K. (2007). Presbyphonia: a review. *Current Opinion in Otolaryngology & Head & Neck Surgery*, *15*(3), 137–140. https://doi.org/10.1097/moo.0b013e328166794f

Khamiees, M., Raju, P., DeGirolamo, A., Amoateng-Adjepong, Y., & Manthous, C. A. (2001). Predictors of extubation outcome in patients who have successfully completed a spontaneous breathing trial. *CHEST Journal*, *120*(4), 1262–1270. https://doi.org/10.1378/chest.120.4.1262

Kim, J., & Sapienza, C. M. (2005). Implications of expiratory muscle strength training for rehabilitation of the elderly: Tutorial. *The Journal of Rehabilitation Research and Development*, *42*(2), 211. https://doi.org/10.1682/jrrd.2004.07.0077.

Kim, J., Sapienza, C. M., & Dept. of Communication Sciences and Disorders, University of Florida. (2006). Effects of Expiratory Muscle Strength Training with the Healthy Elderly on Speech. *11–2*, 1–16. https://www.e-csd.org/upload/11(2)_1.pdf

Kim, J., Davenport, P., & Sapienza, C. (2008). Effect of expiratory muscle strength training on elderly cough function. *Archives of Gerontology and Geriatrics*, *48*(3), 361–366. https://doi.org/10.1016/j.archger.2008.03.006.

Kirkwood, T. B. (2005). Understanding the odd science of aging. *Cell*, *120*(4), 437–447. https://doi.org/10.1016/j.cell.2005.01.027

Kost, K. M., & Sataloff, R. T. (2018). Voice disorders in the elderly. *Clinics in Geriatric Medicine*, *34*(2), 191–203. https://doi.org/10.1016/j.cger.2018.01.010

Kreul, E. J. (1972). Neuromuscular Control Examination (NMC) for parkinsonism: vowel prolongations and diadochokinetic and reading rates. *Journal of Speech and Hearing Research*, *15*(1), 72–83. https://doi.org/10.1044/jshr.1501.72

Krishnan, G., & Goswami, S. (2018). Dysphagia research in India: A status report. *Journal of Indian Speech Language & Hearing Association*, *32*(2), 39. https://doi.org/10.4103/jisha.jisha_44_17

Kulkarni, N. P., & Kolase, R. R. (2020). EFFECT OF EXPIRATORY MUSCLE STRENGTH TRAINING ON PEFR AMONG COMMUNITY DWELLING ELDERLY RURAL POPULATION: AN INTERVENTIONAL STUDY. In International Journal of Creative Research Thoughts (IJCRT), *International Journal of Creative Research Thoughts (IJCRT)* (Vol. 8, Issue 4, pp. 2392–2394) https://ijcrt.org/papers/IJCRT2004330.pdf

Lee, S. H., Yim, S. J., & Kim, H. C. (2016). Aging of the respiratory system. *Kosin Medical Journal*, *31*(1), 11–18. https://doi.org/10.7180/kmj.2016.31.1.11.

Langmore, S. E., Terpenning, M. S., Schork, A., Chen, Y., Murray, J. T., Lopatin, D., & Loesche, W. J. (1998). Predictors of aspiration Pneumonia: How important is dysphagia? *Dysphagia*, *13*(2), 69–81. https://doi.org/10.1007/pl00009559

Madiwalappagol, S. I. (2025). POPULATION AGEING IN INDIA- a GROWING CONCERN. *International Journal of Advanced Research*, *13*(01), 665–669. https://doi.org/10.21474/ijar01/20241

Mancopes, R., Smaoui, S., & Steele, C. M. (2020). Effects of expiratory muscle strength training on VideoFluoroscopic Measures of swallowing: A Systematic review. *American Journal of Speech-Language Pathology*, *29*(1), 335–356. https://doi.org/10.1044/2019_ajslp-19-00107

Mankar, K., M, S., & Dindugala, R. (2021). Effect of age, gender, and body mass index on peak expiratory flow rate and other pulmonary function tests in healthy individuals in the age group 18-60 years. *National Journal of Physiology Pharmacy and Pharmacology*, *0*, 1. https://doi.org/10.5455/njppp.2022.12.08302202106102021

Maslan, J., Leng, X., Rees, C., Blalock, D., & Butler, S. G. (2011). Maximum phonation time in healthy older adults. *Journal of Voice*, *25*(6), 709–713. https://doi.org/10.1016/j.jvoice.2010.10.002

Martin-Harris, B., Brodsky, M. B., Michel, Y., Ford, C. L., Walters, B., & Heffner, J. (2005). Breathing and swallowing dynamics across the adult lifespan. *Archives of Otolaryngology - Head and Neck Surgery*, *131*(9), 762. https://doi.org/10.1001/archotol.131.9.762

Martin-Harris, B., Brodsky, M. B., Michel, Y., Castell, D. O., Schleicher, M., Sandidge, J., Maxwell, R., & Blair, J. (2008). MBS Measurement Tool for Swallow Impairment—MBSIMP: Establishing a standard. *Dysphagia*, *23*(4), 392–405. https://doi.org/10.1007/s00455-008-9185-9

Melton, L. J., 3rd, Khosla, S., Crowson, C. S., O'Connor, M. K., O'Fallon, W. M., & Riggs, B. L. (2000). Epidemiology of sarcopenia. *Journal of the American Geriatrics Society*, *48*(6), 625–630.

Moon, J. H., Jung, J., Won, Y. S., Cho, H., & Cho, K. (2017). Effects of expiratory muscle strength training on swallowing function in acute stroke patients with dysphagia. *Journal of Physical Therapy Science*, *29*(4), 609–612. https://doi.org/10.1589/jpts.29.609.

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MOCA: a brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Nishikawa, H., Fukunishi, S., Asai, A., Yokohama, K., Nishiguchi, S., & Higuchi, K. (2021). Pathophysiology and mechanisms of primary sarcopenia (Review). *International Journal of Molecular Medicine*, *48*(2). https://doi.org/10.3892/ijmm.2021.4989

Nguyen, A. M., Bacci, E. D., Vernon, M., Birring, S. S., La Rosa, C., Muccino, D., & Schelfhout, J. (2021). Validation of a visual analog scale for assessing cough severity in patients with chronic cough. *Therapeutic Advances in Respiratory Disease*, *15*. https://doi.org/10.1177/17534666211049743

Oguchi, K., Saitoh, E., Mizuno, M., Baba, M., Okui, M., & Suzuki, M. (2000). The Repetitive saliva swallowing Test (RSST) as a screening test of functional dysphagia. (1). Normal values of RSST. *The Japanese Journal of Rehabilitation Medicine*, *37*(6), 375–382. https://doi.org/10.2490/jjrm1963.37.375

Orimo, H., Ito, H., Suzuki, T., Araki, A., Hosoi, T., & Sawabe, M. (2006). Reviewing the definition of “elderly.” *Geriatrics and Gerontology International/Geriatrics & Gerontology International*, *6*(3), 149–158. https://doi.org/10.1111/j.1447-0594.2006.00341.x

Park, J., Oh, D., & Chang, M. (2016). Effect of expiratory muscle strength training on swallowing-related muscle strength in community-dwelling elderly individuals: a randomized controlled trial. *Gerodontology*, *34*(1), 121–128. https://doi.org/10.1111/ger.12234

Pierce, J. E., Cotton, S., & Perry, A. (2013). Alternating and sequential motion rates in older adults. *International Journal of Language & Communication Disorders*, *48*(3), 257–264. https://doi.org/10.1111/1460-6984.12001

Pitts, T., Bolser, D., Rosenbek, J., Troche, M., & Sapienza, C. (2008). Voluntary cough production and swallow dysfunction in Parkinson's disease. *Dysphagia*, *23*(3), 297–301. https://doi.org/10.1007/s00455-007-9144-x

Pitts, T., Bolser, D., Rosenbek, J., Troche, M., Okun, M. S., & Sapienza, C. (2008). Impact of expiratory muscle strength training on voluntary cough and swallow function in Parkinson's Disease. *CHEST Journal*, *135*(5), 1301–1308. https://doi.org/10.1378/chest.08-1389.

Pereira, J. V. B., Rossi, V. C., Chone, C. T., & Constantini, A. C. (2025). Voice symptoms, dysphagia risk, quality of life, and mental health in total laryngectomized patients: a self-perception study. *Brazilian Journal of Otorhinolaryngology*, *91*(5), 101657. https://doi.org/10.1016/j.bjorl.2025.101657

Ptacek, P. H., Sander, E. K., Maloney, W. H., & Jackson, C. C. R. (1966). Phonatory and Related Changes with Advanced Age. *Journal of Speech and Hearing Research*, *9*(3), 353–360. https://doi.org/10.1044/jshr.0903.353

Ramig, L. A., & Ringel, R. L. (1983). Effects of physiological aging on selected acoustic characteristics of voice. *Journal of Speech Language and Hearing Research*, *26*(1), 22–30. https://doi.org/10.1044/jshr.2601.22

Ramig, L. A. (1983). Effects of physiological aging on vowel spectral noise. *Journal of Gerontology*, *38*(2), 223–225. https://doi.org/10.1093/geronj/38.2.223.

Rangarathnam, B., & Desai, R. (2020). A preliminary survey of dysphagia practice patterns among speech-language pathologists in India. *Journal of Indian Speech Language & Hearing Association*, *34*(2), 259. https://doi.org/10.4103/jisha.jisha_20_19

Robbins, J., Hamilton, J. W., Lof, G. L., & Kempster, G. B. (1992). Oropharyngeal swallowing in normal adults of different ages. *Gastroenterology*, *103*(3), 823–829. https://doi.org/10.1016/0016-5085(92)90013-o

Sari, N. I. a. P. D. J., Setiawati, N. E., & Nurhasanah, N. L. (2023). Effectiveness of expiratory muscle strength training on dysphagia risk in Pre-Frail elderly. *Jurnal Profesi Medika Jurnal Kedokteran Dan Kesehatan*, *17*(2), 185–189. https://doi.org/10.33533/jpm.v17i2.6653

Sato, K., & Hirano, M. (1997). Age-Related changes of elastic fibers in the superficial layer of the lamina propria of vocal folds. *Annals of Otology Rhinology & Laryngology*, *106*(1), 44–48. https://doi.org/10.1177/000348949710600109

Sapienza, C. M. (2008). Respiratory muscle strength training applications. *Current Opinion in Otolaryngology & Head & Neck Surgery*, *16*(3), 216–220. https://doi.org/10.1097/moo.0b013e3282fe96bd

Sapienza, C., Troche, M., Pitts, T., & Davenport, P. (2011). Respiratory Strength Training: Concept and Intervention Outcomes. *Seminars in Speech and Language*, *32*(01), 021–030. https://doi.org/10.1055/s-0031-1271972.

Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning: A behavioral emphasis* (5th ed.). Human Kinetics.

Sharma, G., & Goodwin, J. (2006). Effect of aging on respiratory system physiology and immunology. *Clinical Interventions in Aging*, *1*(3), 253–260. https://doi.org/10.2147/ciia.2006.1.3.253

Singh, D. P., & Singh, V. K. (2024). A Narrative Review on Defining Aging: A Multidisciplinary review of Biological, Psychological, Sociological, and Clinical Perspectives with a Focus on Successful Aging. *Student's Journal of Health Research Africa*. https://doi.org/10.51168/sjhrafrica.v5i6.1207

S, K., & Shetty, R. (2023). An acoustic analysis on voice changes in adults and geriatrics. *International Journal of Health Sciences and Research*, *13*(5), 106–118. https://doi.org/10.52403/ijhsr.20230513

Skurok, P., Johnston, B. W., Brown, E., Timothy, C., Morse, C., & Turton, P. (2025). Effects of Expiratory Muscle Strength training on swallowing in Survivors of Critical Illness: A Protocol for a Systematic Review and Meta-Analysis. *Health Science Reports*, *8*(2). https://doi.org/10.1002/hsr2.70337

Smina, M., Salam, A., Khamiees, M., Gada, P., Amoateng-Adjepong, Y., & Manthous, C. A. (2003). Cough peak flows and extubation outcomes. *CHEST Journal*, *124*(1), 262–268. https://doi.org/10.1378/chest.124.1.262

Spazzapan, E. A., Cardoso, V. M., Fabron, E. M. G., Berti, L. C., Brasolotto, A. G., & De Castro Marino, V. C. (2018). Características acústicas de vozes saudáveis de adultos: da idade jovem à meia-idade. *CoDAS*, *30*(5), e20170225. https://doi.org/10.1590/2317-1782/20182017225

Sun, Y., Zhao, W., Kang, X., Wang, X., Kim, H., Wan, Q., ... & Xie, Q. (2024). Speech acoustic parameters for predicting presbyphagia: a preliminary study in the elderly Shanghainese population. *Journal of Voice*.

Su, Y., Liu, B., & Zhang, J. (2025). Efficacy of Respiratory Training in Elderly Patients with Dysphagia: A Systematic Review and Meta-Analysis. *Clinical Otolaryngology*, *50*(6), 1053–1060. https://doi.org/10.1111/coa.70002

Tankó, L. B., Movsesyan, L., Mouritzen, U., Christiansen, C., & Svendsen, O. L. (2002). Appendicular lean tissue mass and the prevalence of sarcopenia among healthy women. *Metabolism: clinical and experimental*, *51*(1), 69–74. https://doi.org/10.1053/meta.2002.28960

Tafiadis, D., Zarokanellou, V., Prentza, A., Voniati, L., & Ziavra, N. (2022). Diadochokinetic rates in healthy young and elderly Greek-speaking adults: The effect of types of stimuli. *International Journal of Language & Communication Disorders*, *57*(5), 1085–1097. https://doi.org/10.1111/1460-6984.12747

Tong, J. Y., & Sataloff, R. T. (2022). Respiratory function and voice: the role for airflow measures. *Journal of Voice*, *36*(4), 542-553.

Tremblay, P., Deschamps, I., Bédard, P., Tessier, M., Carrier, M., & Thibeault, M. (2018). Aging of speech production, from articulatory accuracy to motor timing. *Psychology and Aging*, *33*(7), 1022–1034. https://doi.org/10.1037/pag0000306

Troche, Okun, Rosenbek, J., Musson, N., Fernandez, H., Rodriguez, R., Romrell, J., Pitts, T., Wheeler-Hegland, K., & Sapienza, C. (2010). Aspiration and swallowing in Parkinson's disease and rehabilitation with EMST. *Neurology*, *75*(21), 1912–1919. https://doi.org/10.1212/wnl.0b013e3181fef115.

Troche, M. S., Brandimore, A. E., Godoy, J., & Hegland, K. W. (2014). A framework for understanding shared substrates of airway protection. *Journal of Applied Oral Science*, *22*(4), 251–260. https://doi.org/10.1590/1678-775720140132.

United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World population prospects 2019: Highlights* (ST/ESA/SER.A/423).

Valenzano, T. J., Guida, B. T., Peladeau-Pigeon, M., & Steele, C. M. (2020). Respiratory–Swallow coordination in healthy adults during drinking of thin to extremely thick liquids: a research note. *Journal of Speech Language and Hearing Research*, *63*(3), 702–709. https://doi.org/10.1044/2019_jslhr-19-00163

Walston, J. D. (2012). Sarcopenia in older adults. *Current Opinion in Rheumatology*, *24*(6), 623–627. https://doi.org/10.1097/bor.0b013e328358d59b

Wang, Z., Wang, Z., Fang, Q., Li, H., Zhang, L., & Liu, X. (2019). Effect of expiratory muscle strength training on swallowing and cough functions in patients with neurological diseases. *American Journal of Physical Medicine & Rehabilitation*, *98*(12), 1060–1066. https://doi.org/10.1097/phm.0000000000001242

Wohlert, A. B., & Smith, A. (1998). Spatiotemporal stability of lip movements in older adult speakers. *Journal of Speech Language and Hearing Research*, *41*(1), 41–50. https://doi.org/10.1044/jslhr.4101.41

Zapata-Soria, M., Cabrera-Martos, I., Heredia-Ciuró, A., Prados-Román, E., Martín-Nuñez, J., & Valenza, M. C. (2024). Effects of Home-Based Daily Respiratory Muscle Training on Swallowing Outcomes in Patients with Chronic Stroke: Protocol for a Randomized Controlled Trial. *Journal of Clinical Medicine*, *13*(18), 5547. https://doi.org/10.3390/jcm13185547

Zhuang, J., & Jia, J. (2022). Effects of respiratory muscle strength training on Respiratory-Related Impairments of Parkinson's Disease. *Frontiers in Aging Neuroscience*, *14*. https://doi.org/10.3389/fnagi.2022.929923

APPENDIX I

IRB Approval Letter for the Dissertation

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.29/2025-26 **Date: 11.03.2026**

Title of the Dissertation	: Effect of Expiratory Muscle Strength Training (EMST) on Speech and Swallow Functions in Indian Elderly.
Name of the Student	: Ms. Parvathy V
Guide	: Ms. Sindhusha Chandran
Co-Guide (if any)	: -
Proposed Duration of the Project	: 06 months
Source of funding	: Non-funded Master's dissertation
Estimated budget	: Nil
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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

सदस्य सचिव / Member Secretary
Signature & Name of the Member Secretary-IRB
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APPENDIX II

Swallow Abilities Screening Questionnaire for the Indian Elderly (SASQ-IE)

Questionnaire Questions: To be administered by the professional.

Mark whether the symptoms present as- always, sometimes or never.

Domains	S.no	Questions	Never 0	Sometimes 0.5	Always 1
Activity Limitations	Q1	Do you have any difficulty with swallowing?			
	Q2	Have you made any changes in your diet due to swallowing difficulties? For example- eating mashed food instead of hard solids			
	Q3	Has the quantity of food eaten per meal reduced because of swallowing difficulty?			
	Q4	Have you lost weight over the years unintentionally due to reduced intake of food?			
	Q5	Have you stopped eating spicy food?			
Difficulties in Oral Phase, Pharyngeal Phase and Esophageal Phase	Q6	Do you have dry mouth?			
	Q7	Does your mouth feel dry while chewing or swallowing solid food?			
	Q8	Does food spill out of your mouth while eating or drinking?			
	Q9	Does water spill out of your mouth while eating or drinking?			
	Q10	Do you have trouble chewing solid food like Chakli, peanut barfi, etc?			
	Q11	Do you chew the food more slowly and carefully, taking longer time to complete the meal?			
	Q12	Do you find difficulty in moving food inside your mouth?			

	Q13	Do you find it difficult to initiate a swallow after the food is chewed?			

	Q14	Do you find food particles remaining in your mouth even after many swallows?			
	Q15	Do you cough/ choke/ clear your throat while/ before/ after swallowing? (mention when)			
	Q16	Do you cough/ choke/ clear your throat while watching TV/ mobile/ newspaper while eating?			
	Q17	Do you cough/choke/ clear your throat more often while you're talking to other people when eating?			
	Q18	Do you feel like that the food you ate is stuck in your throat? (specify consistency)			
	Q19	Do you think you need to swallow hard for it to go? (specify consistency)			
	Q20	Do you need to take water more often during meal time for the food to go into your stomach?			
	Q21	Do you feel the need to swallow many times to push the food into your stomach?			
	Q22	Do you frequently get burps with sour liquid or food coming back into your throat?			
Participation Restrictions	**Q23**	Do you avoid eating in public places due to difficulties in eating/drinking or swallowing?			
	Q24	Do you feel embarrassed/ uncomfortable to eat in social gatherings?			
	Q25	Do you feel upset that you are unable to eat like others?			

'Never' contains a score of 0, 'Sometimes' contains a score of 0.5 and 'Always' contains 1.

The scores for each question must be added up to obtain the Total SASQ-IE Score.

APPENDIX III

SCSS Semi-quantitative cough strength scale

Score	Description of cough strength
0	No cough on command
1	Audible movement of air through the endotracheal tube but no audible cough
2	Weakly (barely) audible cough
3	Clearly audible cough
4	Stronger cough
5	Multiple sequential strong coughs

APPENDIX IV

Assessment Proforma used for recording the speech and swallowing outcome measures obtained from the participants across pre-intervention, post-intervention and follow-up phases.

ASSESSMENT PROFORMA

Study Title: Effect of Expiratory Muscle Strength Training (EMST) on Speech and Swallow Functions in Indian Elderly.

Investigator:

PART A – Demographic Details

Name of participant:

Age/Gender:

Education:

Primary language:

Height(cm): Weight(kg):

Smoking status: Never/Former/Current

MOCA: Passed/Failed

Contraindications for spirometry: YES/NO

Contraindicators	**Yes/No**
Recent surgeries	
Cardiac conditions	
COPD/asthma	
Severe uncontrolled hypertension	
Severe GERD	

PART B – Assessment Scores

I. Respiratory Measures (spirometry)

Parameter	**Pre Therapy (Date:)**			**Post Therapy (Date:)**			**Follow Up (Date:)**		
FVC (L)									

FEV1 (L)									
FEV1/FVC ratio (%)									
SVC (L)									
TV (L)									

II. Phonatory Measures

Parameter	Pre Therapy				Post Therapy				Follow Up			
MPT (s)												
F0 (Hz)												
Jitter (%)												
Shimmer (%)												

III. Articulatory Measures

Parameter	Pre-Intervention				Post-Intervention				Follow up			
AMR (syllables/s)												
SMR (syllables/s)												
Speech intelligibility												
Speech rate (words/min)												

IV. Swallowing Measures

Parameter	Pre Therapy				Post Therapy				Follow Up			
PEFR (L/min)												
SASQ-IE Total score												
SCSS												
No. of swallows in 30 seconds												

APPENDIX V

Participant daily log maintained to document the completion of EMST sessions, participant compliance, and observations recorded throughout the intervention period.

PARTICIPANT DAILY LOG

Name: Age/Gender: Start Date:

Instructions: Before beginning the exercise, perform a 5-minute warm-up. This includes head and neck relaxation exercises and slow, deep breathing, inhale deeply through the nose, hold for 2–3 seconds, and exhale slowly through the mouth. Repeat this 5–6 times.

For the EMST sessions, ensure you are seated upright with your back straight and feet flat on the floor. Place the EMST 150 device in your mouth, ensuring a firm seal with your lips around the mouthpiece. Take a deep breath in, then exhale forcefully through the device, using your expiratory muscles to push the air out against the resistance. Each forceful expiration counts as one repetition. Complete 5 repetitions per set, with a brief rest of 1–2 minutes between sets. Perform a total of 5 sets per session. Ensure the device is cleaned after every use.

If you experience any dizziness, discomfort, or difficulty breathing at any point during the session, stop immediately.

Day	Date	Warm-up Completed (5 minutes)	EMST session completed	No. of sets done	How did you feel before/during/after exercise? (Fatigue / Discomfort / Other)
1					
2					
3					
4					
5					
6					
7					
8					

9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					

APPENDIX VI

SESSION LOG FOR EXAMINER

Examiner session log used to document the participant attendance, completion of EMST sessions, number of sets completed, weekly baseline regarding resistance adjustment and observations recorded by the examiner throughout the intervention period.

Name: Age/Gender: Start Date:

Day	Date	Warm-up Completed (5 minutes)	EMST session completed (25 minutes)	No. of sets done	Notes
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

WEEKLY BASELINE OF EMST

Week	Date	Resistance adjusted (cm H20)
1		
2		

3		
4		