OBJECTIVE MEASURES OF STRENGTH AND ENDURANCE OF LIPS AND TONGUE IN HEALTHY ADULTS IN INDIA

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Certificate

This is to certify that the dissertation entitled "**Objective Measures of Strength and Endurance of Lips and Tongue in Healthy Adults in India"** is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech Language Pathology) of the student Registration Number: 17SLP022. 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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Certificate

This is to certify that the dissertation entitled "**Objective Measures of Strength and Endurance of Lips and Tongue in Healthy Adults in India"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Declaration

This is to certify that the dissertation entitled "**Objective Measures of Strength and Endurance of Lips and Tongue in Healthy Adults in India"** is the result of my own study under the guidance Dr. Swapna. N, Associate Professor of Speech Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree

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Chapter I

INTRODUCTION

Tongue and lips are among the primary articulators and both are muscular structures which have both biological and speech functions. Lips play an important role in changing resonance for different speech sounds especially vowels. Lip closure is important for ingesting food, mastication and swallowing bolus as well as for the production of bilabials. The tongue is involved in oral (preparatory and transport) and pharyngeal (mainly for forming bolus and its transport) stages of swallowing and is involved in the production of different classes of speech sounds like dentals, alveolars, palatals, retroflex, velars, and vowels.

The process of aging brings about changes in anatomy and function of the lips and tongue which occurs as a consequence of sarcopenia. Prominent age-related changes are noticed as reduction of skeletal muscle tissue which affects the strength of tongue (Shiozu, Higashijima, & Koga, 2015). Elderly population (aged 60 years and older) are particularly vulnerable as they show reduction and loss of muscle (Doherty, Vandervoort, & Brown, 1993). Such age- related changes manifest in dysphagia of especially the oral and pharyngeal phases (Ono, Hori, & Nokubi, 2004; Steele & Van Lieshout, 2009). Lip force is of great importance for spoon feeding and to prevent anterior spillage of food or liquid (Chigira, Omoto, Mukai, & Kaneko, 1994). Deficits in lip force can lead to drooling, pocketing of food in the vestibulum (a narrow space between the lips, cheeks and teeth) thereby affecting swallowing. Tongue strength also plays an important role in swallowing especially in the oral and pharyngeal phases. Deficits in tongue movements can lead to poor bolus formation and manipulation, difficulty in bolus propulsion, increased oral transit time, oral

residue in oral cavity, premature spillage into the pharynx, delayed initiation of swallow etc. Lip and tongue force and accurate movement are needed for the act of speaking like for production of vowels and consonants, creating adequate oral resonance and maintaining the adequate rate of speech.

Nonspeech oro-motor assessment often includes measures of strength, range of motion, rhythmicity, target accuracy, and coordination. Tongue depressor is the most common tool used by a speech-language pathologist to assess strength. Standardized quantitative measures has an upper hand in providing more reliable measures. The qualitative method is the most commonly used in clinical assessment, but has a high chance for variation owing to its subjective nature and relation to clinician's experience. Conversely, objective evaluation uses instruments which provide precise and reliable measures.

Iowa Oral Performance Instrument (IOPI) system was developed in early 1990s to objectively measure tongue pressure and resistance (Adams, Mathisen, Baines, Lazarus, & Callister, 2013). It is portable and easy to use, non-invasive, and presents accurate, and reliable measurements (Clark, Henson, Barber, Stierwalt, & Sherrill, 2003). Many studies were carried to measure tongue pressure in the oral cavity (Yoshida, Kikutani, Tsuga, Utanohara, Hayashi, & Akagawa, 2006) during functions such as speech (Solomon & Robin, 2005), and chewing (Hori, Ono, & Nokubi, 2006); at rest (Tsuiki, Handa, & Ohyama, 2007); and the maximum isometric pressures with different portions of the tongue (anterior and posterior) among young adults (Trawitzki, Borges, Giglio, & Silva, 2011). Gender differences were also noted in relation to tongue pressure (Stierwalt & Youmans, 2007; Vitorino, 2010; Clark & Solomon, 2012) and age (Motta, César, Bommarito, & Chiari, 2011), in individuals diagnosed with obstructive sleep apnea (Mortimore, Fiddes, Stephens, & Douglas,

1999), neurological conditions (Hewitt et al., 2008), and disorders in the head and neck area (White, Cotton, Hind, Robbins, & Perry, 2009). The efficiency of this device in assessing tongue and lip strength and endurance has been quoted in several studies conducted in individuals with dysarthria, dysphagia and in measuring effectiveness of their management. Studies have also shown this device's efficiency in measuring the physiological pressure of the tongue during swallowing (Youmans & Stierwalt, 2006; Robbins, Kays, Gangnon, Hind, Hewitt, Gentry, & Taylor, 2007; Solomon, Clark, Makashay, & Newman, 2008; Neel, Palmer, & Gass, 2008).

From several studies conducted in the past, researchers have noted gender-based differences in lip strength, where males had higher measures in lip strength compared to females (Clark & Solomon, 2012; Park, You, Kim, Yeo, & Lee, 2015; Jeong et al., 2017). But Youmans in 2015 reported that lip strength did not vary between males and females significantly. With respect to the age- related changes in lip strength, one study has noted that young adults had significantly higher measures than older adults (Jeong et al., 2017). In contrast, few authors have reported that changes due to aging is not significant in lip strength (Clark & Solomon, 2012; Youmans, 2015). Lip endurance was not taken in to consideration as a measure in most of the studies and it is difficult to reach at a conclusion. One study has reported that significant changes are seen in lip endurance with respect to age but not with gender (Jeong et al., 2017).

Studies from existing literature have shown that age- related changes and gender- based differences are more extensively study with respect tongue strength. These studies have reported that older adults had lower measures in tongue strength and males had higher measures than females (Crow & Ship, 1996; Youmans & Stierwalt, 2008; Youmans, Youmans, & Stierwalt, 2009; Vanderwegen, Guns,

Nuffelen, Elen, & Bodt, 2013; Park, You, Kim, Yeo, & Lee, 2015; Jeong et al., 2017). Even though much research has not been done on tongue endurance measures, one study has reported that this measure showed significant difference between males and females and between young and older adults (Jeong et al., 2017). Vitirino in 2010 reported that no significant differences were reported in tongue strength and endurance measures with respect to age and gender.

Need for the study

Several studies have shown age-related differences in lip and tongue strength in population of different countries like America, Portugal, Korea etc. Some studies have shown decline in strength with aging in measures of lip and tongue strength (Crow & Ship, 1996; Youmans & Stierwalt, 2008; Youmans, Youmans, & Stierwalt, 2009; Vanderwegen, Guns, Nuffelen, Elen, & Bodt, 2013; Jeong et al., 2017) and some other authors have not reported significant changes (Vitirino, 2010; Youmans, 2015). Authors who have studied gender based differences in measures of lip and tongue strength have reported both significant differences (Park, You, Kim, Yeo, & Lee, 2015; Jeong et al., 2017) and non-significant differences (Vitirino, 2010; Youmans, 2015). Measures of lip and tongue endurance have been studied less and was not able to show any demarcated findings to reach a conclusion. Robin, Somodi, Luschei, Moore, Yorkston, and Beukelman (1991) observed significant differences in endurance between adults and children. Results from the existing literature report mixed results with respect to age and gender in measures of lip and tongue strength and endurance, as result of which authors have failed to reach a conclusion.

There is a need to make up for the limited knowledge and inconsistent results with regard to typical and impaired functions. This leads to the necessity in amassing data on typical function which will serve to quantify and understand impaired

functions (Luschei, Moore, Yorkston, & Beukelman, 1991). Basically these findings apply to the population elsewhere, which cannot be drawn parallel to population in India. As a matter of fact, Indian speech-language pathologists (SLP) have no normative basis to compare strength and endurance measures between healthy adults across ages as well as those with pathologies.

Muscles of the tongue and face being fundamental structures for speech, facial expression, eating, and swallowing, diagnostic evaluation of these structures forms an inevitable part of the SLPs' assessment protocol. Strength and endurance testing, are often included, as they help in revealing an underlying neuromuscular impairment, and serve as a diagnostic aid, and provide information to plan intervention. But most of these measures are evaluated based on clinicians' expertise and experience which cannot be reliable or validated. This leads to importance of acquiring data with a valid and accurate objective instrument.

Aim

The present study aims at developing normative data for strength and endurance of lips and tongue in healthy adults across the age range of 50-70 using IOPI. The specific objectives of the study include:

- To investigate the changes in strength and endurance of the lips and tongue, if any, that occurs in relation to aging, especially between middle aged and older adults.

- To determine whether strength and endurance of the tongue and lips vary with gender.

- To assess the clinical validity of the data obtained from the healthy adults by investigating the strength and endurance of the lips and the tongue, in age matched adults with neurological conditions like dysarthria.

Chapter II

REVIEW OF LITERATURE

The term aging is hard to define. A specific age limit (usually 60 or 65 years) is used to classify the population, but it is absolute that physiological age of the body cannot be defined by chronological age. Leonard Hayflick, a cell biologist had explained that aging process and the rate of aging varies among structures like cells, tissues, and organs and also from individual to individual. The process of aging can start from different parts of the body at different times. But according to Paola Timiras, a physiologist aging is defined as the totality of all changes that occur with the passage of time. It has been explained by Riley in 1978 that aging is a lifelong process and it brings about changes on different levels like physical, psychological, and social.

The main concern faced due to advanced age is limitation in functional activity. Aging is often associated with loss of muscle strength, muscle mass, motor units, aerobic capacity, hormonal reserve, and many other physiological changes. These losses result in a reduction in maximum gait speed, ability to perform activities of daily living, and other impairments and disabilities. Initial changes in the anatomy and physiology could have consequences on in functional ability, which in turn could lead to loss of independence, and increased use of medical services, all of which place a significant burden on society in general (Doherty, 2003).

Effects of aging

Movement is possible due to muscle. Significant changes in muscle mass and quality occur with advancing age. There could be approximately 1% loss of muscle starting from 30 years of age in the process of normal aging, but later there is an

increase in rate of advancement especially after the age of 70 years (Kim, & Choi, 2013). Muscle mass decreases at 1–2% per annum after about 50 years of age (Doherty, 2003; Van Kan, 2009). With respect to decrease in muscle strength, the rate is higher. It is approximately 1.5% per year between ages 50 and 60 and 3% per year thereafter.

Sarcopenia is one of the four main reasons for loss of muscle mass, the others being anorexia, dehydration, and cachexia (Morley, 2007; Von Haehling, & Anker, 2010). Associated to aging, there can be excessive loss of muscle mass which is termed as sarcopenia (Rosenberg, 2011). As a consequence, there is majorly a loss in muscle strength (dynapenia) than loss of muscle mass (Manini, & Clark, 2008). As a result, strength (grip strength) or function (walking speed or distance) has also been included into the definition of sarcopenia.

5 to 10 % of individuals aged over 65 years has higher chances of having sarcopenia. Many factors can lead to sarcopenia (Rolland et al., 2008). Disease coupled with aging is the major underlying cause. Another important age-related cause of sarcopenia is decrease in nitric oxide production in the muscle blood capillaries due to poor blood flow to muscle.

Cells are the basic building blocks of tissues. All cells experience changes with aging. They become larger and are less able to divide and multiply. As aging continues it affects cells' ability to function, or they show abnormal functioning. There is a build-up of waste products (especially fatty substances) in tissue as an effect of aging. As a result connectives tissue becomes stiffer making the organs, blood vessels, and airways more rigid. It also leads to changes in cell membranes affecting its permeability for removal of toxic substances. Tissue will start to lose its

mass, becoming lumpy (nodular) or more rigid. In many instances these changes are not noticeable as most people rarely use their organs to their fullest ability.

Changes are seen in muscle composition, contractile, and material properties of muscle as well as in the function of tendons, a part of loss of muscle mass as a consequence of aging. In aging muscle, there is a loss of motor units via denervation. The motor units that are remaining in the muscle would put in more burden of work into these denervated units. As a result, there would an increase in the number of slow type I fibers compared to fast type II muscle fibers which results loss in muscle power necessary to carry out activities of daily living (Lang, Streeper, Cawthon, Baldwin, Taaffe, & Harris, 2010). Another important aspect is the accumulation of lipids within muscle fibers whih could lead to a significant reduction in muscle strength.

Aging causes various mitochondrial abnormalities such as damage to the mitochondrial membrane permeability pore and apoptosis. Weight loss due to physiological anorexia is associated with aging (Morley, 2007).Weight loss results in a 75% loss of fat and a 25 % loss of muscle and bone. Even if a person regains weight, the change in the amount of muscle would be very marginal. But when there is a weight gain, there would be an increase in fat in the body which could cause sarcopenic obesity.

Effects of aging on the lips and tongue

Aging causes tissue, glandular and muscular changes in the lips and tongue. As a consequence of loss of muscle tone and thinning skin, the face would have a flabby or drooping appearance. This could lead to change in symmetry and appearance of lips. Lips could also be seen to be more chapped leading to roughness

of lips. Lips may look shrunken in case of missing teeth and receding gums. Similar changes, due to loss of bone mass can also be observed in the jaw giving an appearance of reduced size of the lower face. Tongue would normally appear moist and pink. But as a result of above mentioned changes, it would appear to be patchy, fissured and discoloured.

Changes in oral motor function occur with age and are related to the decrease in size and strength of striated musculature that affect the whole body including lingual musculature, known as sarcopenia (Pikus, Levine, Yang, Rubesin, Katzka, Laufer, & Gefter, 2003; Sokoloff, 2004; Stal, Marklund, Thornell, De Paul, & Eriksson, 2003).

Aging of perioral area is affected with a combination of soft tissue lengthening, thinning, and volume loss. As a result of changes in elasticity of muscle, the lip movements like retraction, puckering would be affected. This in turn affects the speech as lips are important for the production of vowels, bilabials and labiodentals and the tongue is important for the production of alveolars, palatals, retroflex and velar sounds. Strength of the movements are affected due to loss of muscle mass. Generally age-related changes to anatomy and physiology would lead to changes in speed or accuracy of motor control. Age-related neuromuscular changes affect the rate and precision of movement of articulators manifested as slower rate of speech.

Aging may decrease the strength and endurance of the lip and tongue, resulting in oro-motor deficits. These can result in problems with chewing, bolus manipulation, difficulty in transiting bolus into the pharynx, leaving oral residue in the oral cavity, leakage from the lips, and aspiration. This leads to greater effort in the process of swallowing due to which they may reduce their food intake leading to

malnourishment and numerous other health repercussions. These speech and swallowing problems can affect their quality of life.

Previous research has revealed that healthy older adults generate lower maximum isometric pressure (MIP) than younger individuals, which is likely due to sarcopenia (Clark, & Soloman, 2012; Park, You, Kim, Yeo, & Lee, 2015). The aged swallow is nonetheless affected by the decrease in MIP due to a decrease in pressure reserve and pattern of pressure generation (Crow, & Ship, 1996).

The existing evidences suggest that anatomical and physiological changes of oral structures especially lip and tongue is seen in the elderly which could have a profound effect on their activities of daily living like feeding, swallowing and communication through speech (Youmans, & Steirwalt, 2006; Youmas, Youmans, & Steirwalt, 2009; Kays, Hind, Gangnon, & Robbins, 2010). Thus it is warranted that we carryout evaluation of oral structures well before the aging process sets in, so as to limit its negative effects and to provide rehabilitation to those with decreased strength and endurance. Routine screening of the elderly through the assessment of lip and tongue strength and endurance also helps in early identification of neurological disorders that can have an impact on feeding, swallowing and speaking.

Evaluation of strength of lips and tongue

Typically, Speech Language Pathologist assess the oro-facial structures by instructing the client to push the tongue or lips against a resistance. For tongue protrusion, the tongue depressor is placed in front of the teeth. For carrying out movement against resistance, clinician holds the tongue depressor in front of the teeth and instruct the client to protrude the tongue against the depressor as hard as possible. Tongue depressor is held horizontally on top the tongue for measuring anterior

(anterior third of the tongue) and posterior (middle of the tongue) tongue elevation. For measuring the lateral tongue movement against resistance, the depressor is placed vertically within the mouth and placed next to the molars. Lip strength is assessed with the tongue depressor placed horizontally between the lips (and without involving the teeth) and asking the client to press the lips tightly against the depressor while the examiner attempts to displace the depressor.

Some clinicians use a 5-point rating scale (1 = normal, 2 = mild, 3 = moderate, 4 = severe, 5 = profound weakness) as well wherein they take best attempt of the task among the repeated trials (Solomon, Clark, Makashay, & Newman, 2008). Usually strength is rated according to a scale, with different categories like normal, mild, moderate, and severe. Such test have no normative data, and ratings are based on the clinician's experience, unlike objective tools which provide quantitative information about strength and can be compared with the normative values. Clinician bias is also eliminated during the objective assessment.

Several devices, including the Tongue Force Measurement System (TOMS), Kay-PENTAX Swallowing Signals Lab (KayPENTAX, Montvale, NJ, USA), JMS tongue pressure manometer (JMS Co. Ltd, Tokyo, Japan) and Iowa Oral Performance Instrument (IOPI Northwest Company, LLC, Carnation, WA) have been developed for assessing the maximum force of the tongue by placing on different locations, which can be used to help diagnose and strengthen weakened tongue muscles.

The tongue force measurement system can be used to assess deficiencies in tongue strength and to monitor a patient’s progress during rehabilitation; TOMS can also be used as an exercise tool for dysphagia rehabilitation (Robinovitch, Herschler, & Romilly, 1991). The core of TOMS is a highly sensitive beam transducer capable of measuring the magnitude of tongue thrusts in upward and side directions. This

transducer is interfaced to a microcomputer which performs high-speed data acquisition and processing. Computer graphics provide instantaneous visual feedback which motivates the individual to maintain a predefined target level.

The swallowing signal lab module of the Digital Swallowing Workstation (DSW, Kay Pentax) also permits the evaluation of tongue pressure against the palate during swallow. The two- and three-channel tongue pressure transducers are used for the same. The three channel transducer is placed on the hard palate and the pressure generated when the anterior, middle and posterior tongue makes contact with the hard palate during a swallow is obtained. The two channel transducer helps in assessing the strength of the left and right side of the tongue.

JMS tongue pressure manometer (JMS Co. Ltd, Tokyo, Japan). It is useful for measuring maximal tongue pressure in children and adults. The bulb and pressure sensor is made of flexible plastic. Subjects are asked to close their lips, bite a hard ring with the upper and lower incisors and then asked to raise their tongue and compress the balloon (made of plastic) onto the palate with maximum effort. The pressure was measured (in kilopascals) using a digital voltmeter attached to the tongue pressure manometer.

Another tool that can be used to assess the strength and endurance of the lips and tongue objectively is the Iowa oral performance instrument (IOPI). The published studies have shown that among all the above mentioned tools for measuring strength and endurance of lips and tongue, the IOPI demonstrate excellent reliability (Adams et al., 2013). It also shows better sensitivity of the measurements for evaluating strength improvements and the effectiveness of interventions in individuals. IOPI has

been utilised as a tool for measurement in this study and its functioning has been explained in the following section.

Iowa oral performance instrument (IOPI)

The Iowa Oral Performance Instrument (IOPI) is used to measure lip strength, tongue elevation strength and tongue endurance. The IOPI consists of a battery-operated pressure transducer and amplifier. It is a small hand-held portable-top component that contains pressure-sensing circuitry, a peak-hold function, and a timer. It has options for displaying pressure digitally (in kPa) or by a light array (in10% increments). Thin flexible tubing connects the IOPI bulb with the main component. The bulb is pliable and air filled, with an approximate internal volume of 2.8 ml. To ensure accurate measurement, calibration is checked and adjusted if necessary prior to obtaining measures from each individual.

To measure tongue strength, the bulb is positioned behind the individual's incisors so that the middle portion of the bulb is in contact with the alveolar ridge. Instruction is provided beforehand to "push as hard as possible" with his/her tongue on the bulb against the roof of the mouth. Tongue strength obtained using the IOPI has traditionally been defined as the highest pressure generated across three motivated trials (Robin, Somodi, Luschei, Moore, Yorkston, & Beukelman, 1991; Robbins, Levine, Wood, Roecker, & Luschei, 1995). This method is designed to be sensitive to the maximum pressure the subject can produce; however, the average rating across three trials (Robinovitch, Herschler, & Romilly, 1991) may better reflect typical performance. For the tongue endurance task (50% Pmax), the individuals are instructed to exert sufficient pressure with the tongue on the bulb to maintain the light-emitting diodes (LED) at 50% Pmax.

Lip strength (kPa) is assessed with the IOPI bulb placed inside the individual's cheek just lateral to the corner of the mouth. The individuals are instructed to "press the bulb against your teeth by pursing lips as hard as you can". The lip strength was measured on the basis of three test trials with a brief resting period between each trial.

A systematic review was done Adams, Mathisen, Baines, Lazarus and Callister in 2013 to check for the efficacy of the IOPI to measure tongue and hand strength and endurance in adults and those with medical conditions like dysphagia, Parkinson's disease or head or neck cancer. A review of the scientific literature revealed that IOPI was mostly used for tongue strength (38 studies) and endurance (15 studies) measurement. They has also identified the use of IOPI majorly as an evaluation tool and in some instances as an intervention tool as well.

Studies using IOPI in typical population

A number of studies has been carried out using IOPI in typical adult population to measure strength and endurance of oral structures like lips and tongue.

Crow and Ship in 1996 conducted a study in 99 healthy individuals ranging from 21 to 96 years to measure hand and tongue strength using IOPI. They could find that males had greater hand and tongue strength. They also found out that there was statistically significant decrease in tongue strength in individuals over the age of 79 years, whereas changes in the hand strength was seen after the age of 59 years.

Youmans and Stierwalt (2006) studied using IOPI to develop database of tongue function variables in 90 subjects divided into three age groups; 20–39 years, 40–59 years, and 60–79 years. The study has shown that significantly higher maximum isometric pressures were seen in males compared females, and with respect to age higher maximum pressures were seen in youngest group compared to oldest

group. It was also observed that age and gender did not have a significant effect on mean swallowing pressures and percentage of maximum isometric pressures used during swallowing.

Utanohara, Hayashi, Yoshikawa, Yoshida, Tsuga, and Akagawa (2008) measured maximum tongue pressure in 853 healthy Japanese adults in the age range 20-79 years using a disposable balloon type oral probe. They found that maximum tongue pressure were lower in seventies age group than twenty to fifties age group. Gender differences were not obvious in older participants even though men in the age 20-49 years showed higher maximum tongue pressure than women. Authors noted that primary aging was the factor for reduced maximum tongue pressure in older age group.

Youmans, Youmans, and Stierwalt (2009) investigated maximal tongue strength and compared it to mean swallowing pressure in 96 participants with normal swallowing, divided into three age groups with 20 year gap. They could yield significant differences between the youngest and oldest and middle and oldest age groups with respect to maximum tongue strength. Females had higher mean swallowing pressure than males and they used a significantly higher percentage of tongue strength to swallow than males. They specifically noted that females had a reduced tongue strength reserve compared to males.

Kays, Hind, Gangnon, and Robbins (2010) conducted a study to find out if there was a decrease in tongue post meal. They enrolled 22 healthy old (65-82 years) and young (20-35 years) adults. Authors could find that all participants had a decrease in tongue strength and endurance post meal. The decrease in anterior tongue endurance was more significant in young adults when compared with older adults.

Vitorino (2010) examined tongue strength and endurance of 75 healthy Portuguese speakers ranging in age from 20 to 77 years of age using IOPI. They had not observed significant differences in tongue strength and endurance. But the authors found that endurance values for healthy speakers of Portuguese were less compared to those documented in English speakers.

Clark and Solomon (2012) studied age- and gender-related differences in measures such as anterior and posterior tongue elevation, tongue protrusion and lateralization, cheek compression, and lip compression of 71 healthy adult males and females in the age range of 18-89 years using IOPI. They found that males had greater lip and cheek strength measures than females, but tongue strength did not differ between males and females. They could also find that oldest participants had lower tongue protrusion and lateralization strength and lower anterior and posterior tongue elevation strength. But no such differences with respect to age was seen for cheek and lip compression strength.

Vanderwegen, Guns, Nuffelen, Elen, and Bodt (2013) conducted a study in 420 healthy Belgians ranging in age from 20 to 96 years olds using the IOPI to obtain data on the maximum anterior and posterior tongue strength and endurance. Significantly lower strength was noted in older participants compared to younger participants at the anterior and the posterior tongue. They could not observe any changes in endurance with age. It was also reported that males showed higher pressures and longer endurance.

Junior, Virgílio, Tavares, Magalhãe, Galvão, and Ferreira (2014) conducted a study involving 45 healthy individuals aged between 61 and 96 years to measure tongue pressure using IOPI. The mean pressure peak was found to be 44.6 kPa (±16).

The lowest average pressure peak was seen in the oldest subject. They could observe that use of dentures, tongue pressure, and tongue mobility during clicking had an effect on mean pressure peak.

Hiramatsu, Kataoka, Osaki, and Hagino (2015) investigated relation between meal consumption and reduced tongue strength and endurance in 23 young adults (YAs) and 23 older adults (OAs) volunteers. OAs had lower peak tongue pressure than YAs both before and after meal consumption. As shown by repetitive saliva swallowing test result, it is observed that OAs had prolonged first time interval (the time from test initiation to the beginning of the first swallow) after meal consumption. Post meal, OAs had significantly lower number of repetitions of the monosyllable/pa/ than YAs.

Mendes, Nascimento, Mansur and Callegaro (2015) conducted a study on tongue force (using IOPI) and grip strength measures (using Hand Grip) and to verify the association of these measures on water swallowing (time and number of swallows required to swallow 200 ml of water) in three different age groups: young (18-39 years old), adult (40-59 years old) and elderly (above 60 years old) individuals. They found that with increasing age, there was a decrease in tongue force and grip strength, as well as an increase in the time required to drink water. Young and elderly individuals had also shown correlation between reductions in tongue force and grip strength.

Oh (2015) conducted a study to check for the effect of tongue strengthening training and long-term detraining on tongue tip pressure, tongue base pressure, and tongue pressure during effortful swallowing using IOPI in ten young healthy volunteers (21–35 years). Results have shown an improvement in tongue tip pressure,

tongue base pressure, and tongue pressure during effortful swallowing after the training.

Park, You, Kim, Yeo and Lee (2015) carried out study to identify differences in orofacial muscle strength using IOPI in 382 healthy East Asian adult male and females; divided into young (20-39 years), middle-aged (40-59 years), old (60-79 years), and very old (>80 years) groups. They found that males had higher values than female subjects. The male subjects showed significantly lower tongue strength in the old and very old groups and the female subjects showed a similar result in the very old group as compared to other younger groups.

Youmans (2015) examined lip strength (L), cheek strength (C) (bilaterally), anterior (TS), protruding (TP), and lateral tongue strength (TL) (bilaterally) in one-hundred-and-thirty-two participants divided into three age groups: younger (20 - 39), middle (40 - 59),and older (60+) using IOPI. Significant differences was observed with respect to age for the TS and TP variables and TS, TL, and C variables with respect to gender. The TS and TP variable for age demonstrated a statistically significant difference between the youngest and oldest groups. The TS, TL, and C variables for gender exhibited statistically significant differences between the males and females.

Oh, Park, Jo, and Chang (2016) conducted a study in 60 healthy adults aimed at measuring and comparing the maximal tongue strength and endurance of young (20-39 years) and older adults (65-75 years) using IOPI. Young adults had higher maximal tongue strength than the older adults. But in the case of maximal tongue endurance significant differences were not noted between young adults and older adults.

Park, Oh, and Chang (2016) measured and compared maximal tongue strength and tongue strength while swallowing in 80 healthy young (20-39 years) and older adults (> 65 years). They found that young adults had higher tongue strength than older adults. But older adults had higher tongue strength while swallowing.

Jeong, Shin, Lee, Lim, Choung, Pang, Kim, Kim, and Lee (2017) established normative of maximal strength and endurance scores of the tongue, lip, and cheek using the IOPI in 120 healthy adults of Korea divided into 3 groups comprising of young (20- 39 years), middle-aged (40-59 years) and older adults (over 60 years). The results showed that mean maximal tongue strengths and tongue endurance scores were better for men than women. The mean maximal lip strengths were better in older men than women. The mean lip endurance scores were considerably better in young and older men than women. The mean maximal cheek strengths and mean cheek endurance scores were found to be higher in younger men than older men.

Sakai, Nakayama, Tohara, Kodama, Takehisa, Takehisa, and Ueda (2017) studied a total of 201 older patients hospitalised of age greater than 65 years to study relationship between tongue strength, lip strength and nutrition-related sarcopenia (NRS). It included two groups: nutrition-related sarcopenia (NRS) group (78 patients) and non-NRS (123 patients) group. They observed that NRS group had lower median tongue strength and lip strength. Authors reported that chances for NRS to occur decreased when tongue and lip strength was higher.

Several studies have shown changes in pattern of strength and endurance of lip and tongue due to primary aging (gradual and inevitable deterioration of body). It is understood that aging could lead to changes in cells and tissues of all major systems of our body like muscular system nervous system, digestive system and so on.

Changes manifested due to age is different with respect to different systems, for example in nervous system, major organs like brain and spinal cord start to lose nerve cells and weight (atrophy). Accumulation of waste products could be seen leading breakdown of nerve cells. As an effect, messages would be transmitted more slowly than in the past to respective centres or organs.

Secondary aging due to disorders or diseases can also lead to changes in the anatomy and function of different body systems apart from effects due to normal aging. Such individuals would exhibit more deteriorating effects in terms of loss of tissue and weakness. One such major reason for oral weakness is impact on the nervous system due to stroke, brain tumour, traumatic brain injury etc. which could be progressive or non-progressive. Neurological symptoms for different aetiologies are different based on site and extent of lesion. Neurologic symptoms may include ipsilateral hemiparesis causing weakness on one side of the body, dysarthria affecting speech, swallowing abnormalities, dysphonia (difficulties in voicing), resting tremor and fasciculations of different extremities or of oral structures like tongue and lips, rigidity and spasticity of muscles, and muscle atrophy.

Studies using IOPI in persons with dysarthria

IOPI is an effective device in evaluating the strength and endurance measures of the oral structures like lips and tongue during routine assessment as well as to note down the effectiveness of a particular rehabilitative procedure by comparing baseline and post- intervention measures. A review through the literature makes us understand that IOPI has been practically used in individuals with Parkinson disease, dysphagia, stroke, head and neck cancer, dysarthria, obstructive sleep apnea etc.

Thesis work of Prendergast (2006) assessed tongue strength using IOPI and speech characteristics in six individuals with Parkinson disease across two sessions of approximately 20 months. After the second session, there was a significant reduction in tongue strength. Perceptions of speech characteristics especially; consonant and vowel imprecision, rate, and overall speech demonstrated a consistent pattern of degradation over time, even though it was not a significant difference.

Solomon, Clark, Makashay, and Newman (2008) studied forty-four adults with dysarthria for orofacial strength. Tongue strength during elevation, lateralization, and protrusion, and lower face muscle strength during bucco-dental and inter-labial compression was tested. Both subjective and objective assessment were done. Maximum resistance against a firmly held tongue depressor was subjectively rated for weakness using a 5-point scale. IOPI was used for the objective measurement. Moderate correlations were found between the objective and subjective evaluations, with the strongest correlations for tongue lateralization.

Neel, Palmer, Sprouls and Morrison (2015) compared speech and voice characteristics in 12 individuals with oculopharyngeal muscular dystrophy (OPMD) with 12 healthy age-matched controls. They had carried out speech subsystem assessment using spirometry, nasometry, phonatory measures (pitch, loudness, and quality), articulatory measures (diadochokinetic rates, segment duration measures, spectral moments, and vowel space), IOPI (tongue-to-palate strength measures during maximal isometric and speech like tasks), quality-of-life questionnaire, and perceptual speech ratings by listeners. They found reduced tongue strength in individuals with OPMD.

Robison (2015) conducted a study to find the influence of an eight week lingual resistance training program on lingual strength and endurance on 2 individuals with ALS across three different time points during the course of intervention. They evaluated for tongue strength, endurance, swallowing, speech and patient-reported outcomes at each time point. They noted that maximum isometric pressure (MIPs) increased by 13% across both participants and tongue endurance increased by 144% following lingual resistance training.

Ray and Klaybor (2016) explored treatment strategies using the IOPI for improving swallowing functions in a 24-year old female with mixed developmental dysarthria. Authors found that rate of swallows increased by 38% due to the exercises and there was decrease in drooling behaviors. Thus they concluded that working with IOPI on tongue strength was helpful in improving swallowing behaviours.

Moon, Hong, Kim, Park, Hahm, Kim, and Cho (2017) studied the impact of lingual strength training (LST) on lingual strength and articulator function in 16 stroke patients with dysarthria. IOPI was used to measure maximum Isometric Tongue Pressures (MIPs). Alternating-Motion Rate (AMR) and Sequential-Motion Rate (SMR) was employed to measure articulator function. Results showed that the individuals showed a significant improvement in lingual strength and AMR (/tə/) after the training.

Byeon (2018) studied the effects of the tongue-pressure exercise protocol and the traditional orofacial exercise on the articulation muscle and percentage of correct consonants of the 21 patients with flaccid dysarthria due to stroke randomly divided into a control group (tongue-pressure protocol using IOPI) and a treatment group (tongue-pressure protocol using IOPI and tongue base exercise). The results showed

that the maximal tongue strength, maximal lip strength, and articulation accuracy were significantly different between the two groups. Authors of the study showed that the combined rehabilitation program consisting of the tongue-pressure protocol and tongue base exercise improved the maximal tongue strength and maximal lip strength significantly more than the single rehabilitation program.

Oral structures especially lips and tongue are most important for the purpose of speaking and for the sustenance of life- feeding or swallowing. The efficiency in carrying out these functions would be affected if there is an impairment in any of these structures. Usually these structures are evaluated for its appearance, symmetry, movement, strength and endurance. But in the current Indian scenario, these evaluations are based on informal assessment protocol biased by clinician's experience. There is widespread acceptance and use of subjective assessment in spite of availability of instrumental evaluation, as there is no norms available for professionals that can be used in their clinical practice.

Protocols are available for the evaluation of strength of the oral structures. Following a specific protocol would be quite helpful for clinicians, as data recorded wouldn't change with respect different clinicians and it would also help in detecting abnormalities leading to better identification of problems. Data obtained thus can be used for future references for clinical and research purposes.

IOPI is one such instrument widely used in the other parts of the world especially west and south-eastern regions to quantify strength and endurance of lips and tongue. Many authors have conducted studies using IOPI in different age groups both in typical and disordered population. But the normative data amassed from these studies cannot be adapted for Indian population. This points to the importance of

carrying out studies in Indian population to develop a normative data, so that clinicians can have access to normative data for lip and tongue strength and endurance across lifespan both in males and females. Thus the aim of the present study was to develop norms among healthy adults of 50-70 years for strength and endurance measures of lip and tongue.

Chapter III

METHOD

This study was carried out with the aim of developing normative data of lip and tongue strength and endurance in healthy adults across the age range of 50-70 years using Iowa Oral Performance Instrument (IOPI).

Participants

A total of 60 healthy adults in the age range 50-70 years were selected for the study. These participants were further divided into two different age groups (50-59.11 years: middle aged adults, and 60-69.11yrs years: older adults). Each group consisted of 30 adults with equal number of males and females. They constituted the typical group. Data was also obtained from 10 adults with dysarthria in the age range of 50-70 years to assess the clinical validity of the data obtained from the healthy adults. These participants constituted the clinical group.

Participant selection criteria

The healthy adults in the required age range were selected from old age homes who volunteered with no deficits in speech and swallowing due to neurologic or structural damage. Demographic details and history concerning their health status was collected through an interview with the participants or their caregivers and informal assessment was done to rule out any oro-motor deficits (dysphagia, dysarthria, facial nerve paralysis). Body mass index of each individual by dividing weight by the square of height was also accounted during inclusion. The assessment of weight and height was accomplished with the participants' barefoot. A weighing scale and a measuring tape was used. Individuals classified as healthy (from 18.5 to 24.9) were included as given by National Institutes of Health, Lung, and Blood Institute in 1998. Apart from

that, the Mini-Mental State Examination (MMSE; Folstein, 1975) was also administered through interview which helps in screening cognitive impairment in older adults. Only those participants without any of these problems were included. Modified Kuppuswamy Socioeconomic scale was administered to include participants from all socio-economic classes in order to have fair representation of population in the study (Saleem, 2018). Details of the study was explained to the participants / their caregivers at the beginning of the study. Written consent was also obtained from the participants.

The ten adults (6 males and 4 females) with dysarthria were also considered for the study. Only those diagnosed by a qualified team of professionals including speech-language pathologist, physiotherapist and a clinical psychologist was included. Among the 10 dysarthria participants chosen, six had mixed dysarthria, two had spastic dysarthria and the other two had flaccid dysarthria. Those adults with associated problems such as sensory impairment, cognitive dysfunction, dementia, seizures, malocclusion (misaligned teeth), loss of upper or lower teeth, dentures, major head or neck cancer or surgery were excluded from the group. An oral motor examination was carried out to identify adults with oro-motor deficits who were included in the validity testing. Participant selection and their participation were done giving due respect to ethical standards. Prior to obtaining data, caregivers/participants were made aware of the details of the study. Written consent was also procured.

Instrumentation

Iowa Oral Performance Instrument (IOPI model 2.2) was used for the study. This was developed by Luschei in the speech department at the University of Iowa in 1992. This instrument gives objective measures of lip and tongue strength as well as lip and tongue endurance. These measures assist clinicians in dealing with individuals

having deficits in speech and swallowing. It provides source of help to document deficits pre and post treatment noting the progress, differentiate between muscle weakness and motor control difficulties, and providing biofeedback during oro-motor exercises thereby motivating the patients.

The IOPI measures the lip compression strength which depends on the strength of the circumferential muscle complex (especially orbicularis oris) that surrounds the mouth because these muscles play a main role in compressing lips against one another. The IOPI also measures the strength of the tongue at its anterior and posterior part. Maximum pressure is measured when an individual press the bulb against the roof of the mouth with the tongue. LCD screen displays the peak pressure in kilopascals (kPa).

The IOPI can be used to measuring endurance. There are high chances of fatigue with reduction in endurance measures. Endurance is inversely proportional to fatigability. Endurance is measured by fixing the target value (50% of his or her maximum pressure) in target mode and quantifying the length of time (seconds) that a patient can maintain top (green) light on.

Procedure

A rapport was built with each participant. The consent was obtained from the participants /concerned caregivers for each participant. A detailed demographic data was obtained. The necessary tools was administered as mentioned in the participant selection criteria. Measures of strength and endurance of lips and the tongue were collected separately for each participant. Instructions and demonstration of task were provided to the participants prior to the actual task performance by the participants. IOPI was set to (0) value by pressing the peak reset button prior to the testing which is seen on LCD display of the instrument. Before collecting data from each participant

the bulb of the IOPI device was washed in running water, dipped in Savlon/Dettol solution for two minutes and then washed again in running water. IOPI was calibrated once in a month as recommended by the manufacturer, to ensure accurate measurement by adhering to the procedure provided in the manual.

Lip strength (inter-labial compression) was measured by placing the bulb in the middle of upper and lower lips (at tubercle of upper lip and groove of lower lip). This placement has been planned, so that the pressure exerted gets distributed evenly across the entire surface of the bulb to provide an accurate pressure reading. The participants was instructed in the following manner, "Press the bulb between your lips as hard as you can for about 2-3 seconds". After the participant has made his or her response, the value displayed was recorded. The instrument was reset again by pressing peak reset button [0]. The participants was asked to rest for 30 – 60 seconds and then the same task was repeated for three trials. Highest of the three recorded values was considered as peak strength values of lips. To measure the endurance of the lip, the LCD display will be set to 50% of the participant's peak pressure using set max arrows of the instrument and timer mode button was pressed. Later bulb was placed in participant's mouth in the same position as described above. The participants was instructed as follows, "Press the bulb as hard as possible until the (green) light illuminates on the device and keep on squeezing the bulb as long as possible". The duration (seconds) that was displayed was recorded. Only one trial was conducted for each participant.

The tongue strength was measured by placing the bulb against the participant's hard palate just behind the alveolar ridge for anterior tongue strength and endurance and for posterior tongue strength and endurance bulb was placed anterior to the end of hard palate. The participants were instructed in the following manner,

“Press the tongue bulb with your front (anterior) part of tongue as hard as you can for about 2-3 seconds”. The same procedure used in recording lip strength was followed for measuring tongue strength at three trials. Measurement of posterior part of the tongue was done following the same procedure. Instructions regarding the placement of bulb was provided and demonstrated. After identifying the peak tongue strength value of the participant, the tongue endurance was measured after 30-60 seconds of rest. Only one trial for each participant was conducted. To measure the endurance of the tongue, the same procedure as described under lip endurance was followed. Later the bulb was placed in the participant’s mouth as placed during strength measurement and the participants were asked to squeeze the bulb until the (green) light illuminates on the device and keep on squeezing the bulb as long as possible. The values was measured in terms of duration (seconds).

Pilot study

A pilot study was carried out in which the data was collected from two healthy adults in the age group. The feasibility of measuring tongue strength and endurance as well as lip strength and endurance was assessed. The time taken for data collection was 20-25 minutes (approximately) including providing instructions, demonstration of the task to the participant by the clinician and actual task performance by the participant.

Assessment of test-retest reliability

To assess the test-retest reliability, the data was obtained using IOPI for strength and endurance of tongue and lips of the 10% of the participants selected randomly from both the age groups, after one week of their initial responses.

Assessment of clinical validity

Strength and endurance of the tongue and lips was measured on 10 adults with dysarthria and these values were compared with the data obtained from healthy adults for evaluating the clinical validity of the normative values obtained.

Data analysis

The strength and endurance measures of tongue and lips obtained from all the participants was averaged and subjected to statistical analysis using SPSS version 20 software. Shapiro- Wilks test was used to compute the normality of the samples. Descriptive statistics was used to obtain mean, median and standard deviation of all parameters. The effect of age and gender on strength and endurance measures of lips and tongue was compared using Multivariate Analysis of Variance (MANOVA) and Mann- Whitney test (for posterior tongue endurance measure). The data from the clinical and control group was compared using Mann- Whitney test. Cronbach's alpha test was carried out to determine the test-retest reliability.

Chapter IV

RESULTS AND DISCUSSION

This study was aimed at investigating lip and tongue strength and endurance in healthy adults across the age of 50-70 years using Iowa Oral Performance Instrument (IOPI) and to develop normative data. The specific objectives of the study were to investigate the age- related changes observed in strength and endurance of lips and tongue across different age groups and gender and also to assess the clinical validity of the data obtained from healthy adults by comparing with data from adults with dysarthria.

A total of 60 healthy adults in the age group of 50-70 years were selected for this study. These participants were further divided into two age groups: 50-59.11 years and 60-69.11 years, each group comprising of 30 participants of which 15 were males and other 15 were females. Clinical group consisted of 10 adults with dysarthria. The strength and endurance measures of lips and tongue were obtained from all the participants using IOPI, which were averaged and subjected to statistical analysis using SPSS version 20 software. Descriptive statistics was done to obtain mean, median, and standard deviation.

Appropriate statistical measures were used as listed below:

- For checking the test- retest reliability, Cronbach's alpha was used.
- Normality of the data was checked using Shapiro-Wilk test. The data for five of the parameters such as lip strength, lip endurance, tongue anterior strength, tongue anterior endurance and tongue posterior strength followed normal distribution, hence two- way MANOVA (parametric) was done to verify the

effect of age and gender and interaction effect of age-gender on these parameters. Data for the tongue posterior endurance did not follow normal distribution and hence was subjected to Mann- Whitney test (non-parametric) to check for significant difference for this parameter across age and gender.

- Mann- Whitney test (non-parametric) was also done to check the significant difference, between the clinical group and the typical group in these six measures mentioned above, as the data did not follow normal distribution.

The results thus obtained are presented and discussed below under different sections:

I. Test-retest reliability

Test- retest reliability was computed for 10% of the total sample of healthy adults. The Cronbach's alpha for the lip strength, lip endurance, tongue anterior strength, tongue posterior strength, tongue anterior endurance and tongue posterior endurance was 0.91, 0.94, 0.92, 0.97, 0.98, and 0.92. The 'α' varied between 0.91 and 0.98, which indicated high test-retest reliability for the obtained data.

II. Comparison of strength and endurance of lip across gender

Descriptive statistics was obtained to find the mean, median, and standard deviation values of lip strength and lip endurance for males and females in both age groups. The mean lip strength (LS) and lip endurance (LE) for males were higher than age-matched females in both the age groups (50-59.11 years and 60-69.11 years). Table 4.1 depicts the mean, standard deviation (SD), median across gender. The two-way Multivariate Analysis of Variance (MANOVA) was carried out to check for any significant differences. There was an overall gender effect $p = 0.00$ ($p < 0.05$), indicating significant difference across gender.

Table 4.1:

Mean, standard deviation (SD), median for strength and endurance of lips across gender

Age	Measure	Females			Males		
		Mean	SD	Median	Mean	SD	Median
50-60	LS	40.18	6.32	40.33	53.64	5.08	51.67
years	LE	47.40	11.48	44.00	59.93	9.25	57.00
60-70	LS	28.11	6.70	27.67	39.27	5.88	41.33
years	LE	28.87	5.76	28.00	32.80	4.87	31.00

**LS: Lip strength; LE: Lip endurance*

Subsequent Analysis of Variance (ANOVA) done separately for lip strength ($p = 0.00$) and lip endurance ($p = 0.00$) showed that significant difference ($p < 0.05$) was seen between males and females, which is depicted in Table 4.2.

Table 4.2:

Results of two-way Multivariate Analysis of Variance (F, p value and effect size) for strength and endurance of lips across gender

Measure	F	*p* value	Effect size
LS	62.57	0.00	0.53
LE	14.826	0.00	0.21

**LS: Lip strength; LE: Lip endurance*

Though there are insufficient studies done in the past with respect to the measures of lip strength and endurance, the results of the present study was found to be in consonance with those in the existing literature. They have reported that gender

based differences were seen for lip strength and lip endurance, where males had higher values than females (Clark & Soloman, 2012; Park, You, Kim, Yeo, & Lee, 2015; Jeong et al., 2017).They have attributed it to the difference in the overall size of the body. Men could generate greater force because of their larger size.

III. Comparison of strength and endurance of lip across age groups

Descriptive statistics was obtained to find the mean, median, and standard deviation values of strength and endurance of lips for both age groups. The mean lip strength and lip endurance for 50-59.11 years were higher than 60-69.11 years for both males and females. Table 4.3 depicts the mean, standard deviation (SD), median. The two-way Multivariate Analysis of Variance (MANOVA) was carried out to check for any significant differences. The overall age effects was revealed to be $p = 0.00$ ($p < 0.05$), indicating significant difference across two age groups.

Table 4.3:

Mean, standard deviation (SD), median for strength and endurance of lips across age groups

Gender	**Measure**	**50-60 years**			**60-70 years**		
		Mean	SD	Median	Mean	SD	Median
Females	LS	40.18	6.32	40.33	28.11	6.70	27.67
	LE	47.40	11.48	44.00	28.87	5.76	28.00
Males	LS	53.64	5.08	51.67	39.26	5.88	41.33
	LE	59.93	9.25	57.00	32.80	4.87	31.00

**LS- Lip strength; LE- Lip endurance*

Subsequent Analysis of Variance (ANOVA) in turn revealed $p = 0.00$ for lip strength and $p = 0.00$ for lip endurance showing a significant difference ($p < 0.05$) between two age groups, which is depicted in Table 4.4.

Table 4.4:

Results of two-way Multivariate Analysis of Variance (F, p value and effect size) for strength and endurance of lips across age groups

Measure	F	*p* value	Effect size
LS	72.18	0.00	0.56
LE	114.03	0.00	0.67

**LS- Lip strength; LE- Lip endurance*

The results of the present study indicate that lip strength and endurance measures were lower for older adults compared to the middle-aged adults. Some of the studies in literature have shown a significant change in lip strength and endurance measures across age groups, where young adults had better measures of lip strength and endurance than older adults (Park, You, Kim, Yeo, & Lee, 2015; Jeong et al., 2017).

In contrast to the results of the present study, some of the studies have reported to show no significant difference with age in the measures of lip strength and endurance (Clark & Soloman, 2012; Youmans, 2015). Clark and Soloman (2012) have explained that significant changes in lip strength with age may have not been observed, suggesting that the facial muscles may be less susceptible to the effects of sarcopenia.

IV. Age-gender interaction effect on lip strength and endurance

Subsequent Analysis of Variance was also carried out to reveal age-gender interaction effect for lip strength and lip endurance, as depicted in table 4.5.

Table 4. 5:

Results of tests of significance of lip strength and lip endurance for age-gender interaction effect

Measure	**F**	***p* value**	**Effect size**
LS	0.55	0.46	0.01
LE	4.04	0.49	0.67

**LS- Lip strength; LE- Lip endurance*

For age and gender interaction, $p = 0.46$ ($p = 0.05$) for lip strength and $p = 0.49$ ($p = 0.05$) for lip endurance, thus indicating no significant age and gender interaction effect.

V. Comparison of strength and endurance of tongue across gender

Descriptive statistics was obtained to find the mean, median, and standard deviation values of tongue strength and endurance in the anterior and posterior part for males and females in both age groups. The mean tongue anterior strength (TAS), tongue anterior endurance (TAE), tongue posterior strength (TPS) and tongue posterior endurance (TPE) for males were higher than age-matched females in both the age groups (50-59.11 years and 60-69.11 years). Table 4.6 depicts the mean, standard deviation (SD), median. The two-way Multivariate Analysis of Variance (MANOVA) was carried out to check for significant differences for tongue anterior

strength, tongue anterior endurance and tongue posterior strength. The overall gender effects was revealed to be $p = 0.00$ ($p < 0.05$), indicating significant difference across gender.

Table 4.6:

Mean, standard deviation (SD), median for strength (anterior and posterior) and endurance of tongue across gender

Age	**Measure**	**Females**			**Males**		
		Mean	SD	Median	Mean	SD	Median
	TAS	38.22	6.66	39.00	49.76	3.84	49.00
50-60	TPS	35.69	7.71	34.00	45.07	7.26	42.33
years	TAE	41.13	5.94	41.00	50.13	6.94	50.00
	TPE	30.13	6.19	29.00	47.67	7.44	47.00
	TAS	27.67	6.06	26.67	32.80	3.12	32.33
60-70	TPS	25.82	4.26	26.67	37.27	5.53	38.67
years	TAE	28.27	4.08	28.00	36.67	6.91	36.00
	TPE	24.33	4.47	23.00	31.87	3.46	32.00

** TAS- Tongue anterior strength; TPS- Tongue posterior strength; TAE-Tongue anterior endurance; TPE- Tongue posterior endurance*

Subsequent Analysis of Variance (ANOVA) done separately for tongue anterior strength ($p = 0.00$), tongue anterior endurance ($p = 0.00$) and tongue posterior strength ($p = 0.00$) showed that there was a significant difference ($p < 0.05$) between males and females which is depicted in Table 4.7.

Table 4.7:

Results of two-way Multivariate Analysis of Variance (F, p value and effect size) for strength (anterior and posterior) and endurance of tongue across gender

Measure	F	*p* value	Effect size
TAS	39.50	0.00	0.41
TPS	40.31	0.00	0.41
TAE	30.72	0.00	0.35

**TAS- Tongue anterior strength; TPS- Tongue posterior strength; TAE- Tongue anterior endurance*

To investigate whether any significant differences existed on tongue posterior endurance measure between gender in both age groups, Mann-Whitney test was performed. The results revealed that both at 50-59.11 years (/z/ = 4.45, $p = 0.00$) and 60-69.11 years (/z/ = 3.63, $p = 0.00$), there was a significant difference between males and females for tongue posterior endurance measure.

The results of the present study is in agreement with the studies in the literature which have reported that significant differences is seen with respect to gender, where males have higher tongue strength and endurance values than females (Vanderwegen, Guns, Nuffelen, Elen, & Bodt, 2013; Jeong et al., 2017). Some other studies have reported significant differences between males and females for only tongue strength measures (Crow & Ship, 1996; Youmans & Stierwalt, 2006; Youmans, 2015).

However, Crow and Ship in 1996 reported that they found no significant difference in tongue endurance with respect to gender when they studied 99 healthy individuals ranging from 21 to 96 years. This is not in agreement with the results of the present study, possibly because of the wider age range considered in the Crow and Ship's study and also because of the lesser sample size in different age groups.

Generally the studies have shown that the mean pressure peak values differed according to differences of body measures such as height, weight or overall muscle mass. Another factor pointed out by Macaluso and DeVito in 2004 was that decrease in the levels of hormones like estrogen and progesterone can also have an effect on the muscle force in women, wherein subjects who had undergone hormone replacement therapy could prevent such changes to an extent.

VIII. Comparison of strength and endurance of tongue across age groups

Descriptive statistics was obtained to find the mean, median, and standard deviation values of tongue strength and endurance in the anterior and posterior part for both age groups. The mean tongue anterior strength, tongue anterior endurance, tongue posterior strength and tongue posterior endurance for adults (both males and females) in 50-59.11 years were higher than adults in age group of 60-69.11 years. Table 4.8 depicts the mean, standard deviation (SD), median and overall results of multivariate tests across age groups. The two-way Multivariate Analysis of Variance (MANOVA) was carried out to check for any significant differences for tongue anterior strength, tongue anterior endurance and tongue posterior strength across age groups. The overall age effect was revealed to be $p = 0.00$ ($p < 0.05$), indicating significant difference across two age groups.

Table 4.8:

Mean, standard deviation (SD), median for strength (anterior and posterior) and endurance of tongue across age groups

Gender	**Measure**	**50-60 years**			**60-70 years**		
		Mean	SD	Median	Mean	SD	Median
Females	TAS	38.22	6.66	39.00	27.67	6.06	26.67
	TPS	35.69	7.71	34.00	25.82	4.26	26.67
	TAE	41.13	5.94	41.00	28.27	4.08	28.00
	TPE	30.13	6.19	29.00	24.33	4.47	23.00
Males	TAS	49.76	3.84	49.00	32.80	3.12	32.33
	TPS	45.07	7.26	42.33	37.27	5.53	38.67
	TAE	50.13	6.94	50.00	36.67	6.91	36.00
	TPE	47.67	7.44	47.00	31.87	3.46	32.00

**TAS- Tongue anterior strength; TPS- Tongue posterior strength; TAE- Tongue anterior endurance; TPE- Tongue posterior endurance*

Subsequent Analysis of Variance (ANOVA) done separately for tongue anterior strength ($p = 0.00$), tongue anterior endurance ($p = 0.00$) and tongue posterior strength ($p = 0.00$) showed that there was a significant difference ($p < 0.05$) between both age groups, which is depicted in Table 4.9.

Table 4.9:

Results of two-way Multivariate Analysis of Variance (F, p value and effect size) for strength and endurance of tongue across age groups

Measure	**F**	***p* value**	**Effect size**
TAS	107.64	0.00	0.66
TPS	29.10	0.00	0.34
TAE	70.36	0.00	0.56

**TAS-Tongue anterior strength; TPS- Tongue posterior strength; TAE- Tongue anterior endurance*

To investigate whether any significant difference existed on tongue posterior endurance measure between both age groups within gender, Mann-Whitney test was performed. The results revealed that there was significant difference between both age groups in males (/z/ = 4.62, $p = 0.00$) and females (/z/ = 2.43, $p = 0.01$).

These findings are in consonance with the studies conducted in the past; which have reported that older adults demonstrated significantly lower tongue strength than younger adults (Youmans & Stierwalt, 2006; Youmans, Youmans, & Stierwalt, 2009; Clark & Soloman, 2012; Junior, Virgílio, Tavares, Magalhães, Galvão, & Ferreira, 2014; Hiramatsu, Kataoka, Osaki, & Hagino, 2015; Mendes, Nascimento, Mansur, & Callegaro, 2015; Youmans, 2015; Park, Oh, & Chang, 2016; Oh, Park, Jo, & Chang, 2016). The reason pointed out by the authors is that the age-related reduction in muscle mass and size, as well as reduction in number of motor units, which could have led to the decrease in the tongue strength.

In contrast to the above mentioned studies, Vitorino in 2010 reported that there were no significant differences across age when he examined typical tongue strength and endurance of 75 healthy Portuguese speakers ranging in age from 20 to 77 years of age using IOPI. This could be attributed to the lesser number of subjects in the older age group.

Some studies conducted in the past have also taken tongue endurance measure into consideration, but results obtained in the present study are not in agreement with those in the literature. Studies have reported that tongue endurance had not shown significant changes with age (Vanderwegen, Guns, Nuffelen, Elen, & Bodt, 2013; Oh, Park, Jo, & Chang, 2016).

VI. Age-gender interaction effect on tongue strength and endurance

Subsequent Analysis of Variance was also carried out to find age-gender interaction effect for tongue (anterior and posterior) strength and tongue anterior endurance, as depicted in Table 4.10.

Table 4.10:

Results of tests of significance of tongue (anterior and posterior) strength and tongue anterior endurance for age-gender interaction effect

Measure	F	*p* value	Effect size
TAS	5.82	0.02	0.09
TPS	0.39	0.53	0.01
TAE	0.37	0.85	0.00

**TAS- Tongue anterior strength; TPS- Tongue posterior strength; TAE- Tongue anterior endurance*

There was no significant age and gender interaction for tongue posterior strength, {p = 0.53 (p > 0.05} and for tongue anterior endurance {p = 0.85 (p > 0.05)}. For tongue anterior strength, there was a significant age and gender interaction effect, {p = 0.01 (p < 0.05)}.

Thus to summarize, a significant difference in strength and endurance of lip and tongue across age groups was seen due to age-related changes, mainly, sarcopenia. Based on the research evidences, these changes could be hypothesized due to reduction in muscle mass, muscle size, reduced number of motor units, change in proportion of type I and type II muscle fibres in tongue and lip and depletion in the levels of hormones in older adults (Baumgartner, Waters, Gallagher, Morley, & Garry, 1999; Pikus, Levine, Yang, Rubesin, Katzka, Laufer, & Gefter, 2003; Stal, Marklund, Thornell, De Paul, & Eriksson, 2003; Sokoloff, 2004). Some authors have pointed that effects of aging is more prominent in tongue musculature than the lip (Clark & Soloman, 2012; Park, You, Kim, Yeo, & Lee, 2015). Gender differences, like significantly higher values for strength and endurance of lip and tongue were observed mostly because of changes in body characteristics like height, weight and body mass index as suggested by existing literature.

In comparison with the present data, the mean values of strength and endurance measures of lip and tongue in healthy Indian adults were lower than the age-matched American, and Portuguese population where IOPI was used as the measuring instrument. In comparison with age- matched Korean population for older adults, it was observed that Indian population had lower values for tongue strength compared to them in the study conducted by Park, Oh and Chang in 2016 and higher values than those recruited in the study by Oh, Park, Jo and Chang in 2016. Therefore, the present study supports the importance of developing region specific norms to

study differences in functional aspects of lip and tongue across the life span by eliminating difference in measures of strength and endurance due to ethno cultural variations, linguistic backgrounds, races, and life-style changes.

VII. Normative data for lip and tongue strength and endurance across gender and age

To provide comparative data for clinical applications, means have been depicted in the Table 4.11 in addition to median, and standard deviations for both males and females across both the age groups (50-59.11 years and 60-69.11 years). This data could be used for comparing strength and endurance measures of lips and tongue in adults with dysarthria with healthy adults based on gender.

Table 4.11:

Mean, median, and standard deviation of lip and tongue strength and endurance in males and females at 50-60 years and 60-70 years

Age	Gender	Measure	Mean	SD	Median
50-60 years	Females	LS	40.17	6.32	40.33
60-70 years			28.11	6.70	27.66
50-60 years		LE	47.40	1.48	44.00
60-70 years			28.87	5.76	28.00
50-60 years	Males	LS	53.64	5.08	51.67
60-70 years			39.27	5.88	41.33
50-60 years		LE	59.93	9.25	57.00
60-70 years			32.80	4.87	31.00
50-60 years	Females	TAS	38.22	6.66	39.00

60-70 years			27.67	6.06	26.67
50-60 years		TAE	41.13	5.94	41.00
60-70 years			28.27	4.08	28.00
50-60 years	Males	TAS	49.76	3.84	49.00
60-70 years			32.80	3.12	32.33
50-60 years		TAE	50.13	6.94	50.00
60-70 years			36.67	6.91	36.00
50-60 years	Females	TPS	35.69	7.71	34.00
60-70 years			25.82	4.26	26.67
50-60 years		TPE	30.13	6.19	29.00
60-70 years			24.33	4.47	23.00
50-60 years	Males	TPS	45.07	7.26	42.33
60-70 years			37.26	5.53	38.67
50-60 years		TPE	47.67	7.44	47.00
60-70 years			31.87	3.46	32.00

**LS- Lip strength; LE- Lip endurance; TAS- Tongue anterior strength; TAE- Tongue anterior endurance; TPS- Tongue posterior strength; TPE- Tongue posterior endurance*

VIII. Comparison of strength and endurance of lip and tongue between healthy adults and adults with dysarthria

The mean, median, and standard deviation values for all six measures (lip strength, lip endurance, tongue anterior strength, tongue anterior endurance, tongue posterior strength and tongue posterior endurance) were obtained for adults with dysarthria using descriptive statistics. The clinical group exhibited lower mean values

of strength and endurance measures of lip and tongue than healthy adults. Mann-Whitney test was performed to check whether any significant differences were present between healthy adults and adults with dysarthria on all these measures. The results revealed significant differences ($p < 0.05$) on all these measures in comparison to healthy adults. Results also revealed significant gender differences ($p< 0.05$) in the clinical group. The results of Mann-Whitney test (/z/ and *p* values) along with mean, median and standard deviation values have been depicted in the Table 4.12.

Table 4.12:

Mean. Standard deviation, median and results of Mann- Whitney test (/z/ and p values) for the control and clinical group on strength and endurance measures of lips and tongue

Age	**Gender**	**Measure**	**Clinical group**			**Control group**			**/z/**	***p***
			Mean	SD	Median	Mean	SD	Median	**value**	**value**
		LS	23.39	8.27	22.33	46.46	9.09	47.17	3.61	0.00
	Males	LE	7.00	5.21	5.50	46.37	15.60	47.00	3.82	0.00
		LS	17.25	2.78	18.00	34.14	8.87	33.83	3.21	0.00
	Females	LE	8.25	2.50	8.50	38.13	12.98	35.00	3.21	0.00
		TAS	18.55	9.79	15.00	41.28	9.28	41.17	3.23	0.01
50-70	Males	TAE	5.50	2.34	5.50	43.40	9.65	44.00	3.82	0.00
years		TAS	17.17	3.61	18.16	32.94	8.24	32.17	3.16	0.00
	Females	TAE	6.50	3.11	7.50	34.70	8.24	34.50	3.21	0.00
		TPS	12.44	5.71	12.17	41.17	7.48	40.00	3.82	0.00
	Males	TPE	4.00	1.79	4.50	39.77	9.85	38.50	3.83	0.00
		TPS	16.00	1.90	16.17	30.75	7.91	29.33	3.21	0.00
	Females	TPE	4.75	2.50	4.50	27.23	6.07	26.00	3.22	0.00

The results of the present study are in agreement with the studies in the existing literature. Solomon, Robin, Mitchinson, VanDaele, and Luschei (1996) conducted an examination of tongue strength and endurance characteristics using IOPI in individuals with Parkinson disease and found that tongue strength measures of

the participants with Parkinson's were significantly lower when compared to the neurologically healthy controls; however, measures of tongue endurance were not.

Several studies have shown that IOPI being employed for noting the progress of strength and endurance measures of lip and tongue in the intervention or to check for the efficacy of a particular treatment protocol in different population like dysarthria. Thesis work of Prendergast (2006) examined tongue strength utilising IOPI and speech characteristics in six individuals with Parkinson disease across two sessions of approximately 20 months. A significant reduction in tongue strength was observed at the second session. Even though not statistically significant, perceptions of speech characteristics especially; consonant imprecision, vowel imprecision, rate, and overall speech demonstrated a consistent pattern of degradation over time.

Robison (2015) conducted a study to explore the impact of an eight week lingual resistance training program on lingual strength and lingual endurance on 2 individuals with ALS across three different time points during the course of intervention. They noted that maximum isometric pressure (MIPs) increased by 13% across both participants and tongue endurance declined increased by 144% following lingual resistance training.

Ray and Klaybor (2016) explored treatment strategies using the IOPI for improving swallowing functions in a 24-yearold female with mixed developmental dysarthria. Authors found that rate of swallows increased by 38% due to the exercises and there was decrease in drooling behaviors. Thus they concluded that working with IOPI on tongue strength was helpful in improving swallowing behaviours.

Moon, Hong, Kim, Park, Hahm, Kim, and Cho (2017) investigated the effects of lingual strength training (LST) on lingual strength and articulator function in 16

stroke patients with dysarthria. They assessed the lingual strength by measuring maximum Isometric Tongue Pressures (MIPs) using IOPI and articulator function using the Alternating-Motion Rate (AMR) and Sequential-Motion Rate (SMR). Results showed that the individuals showed a significant improvement in lingual strength and AMR (/tə/) after the training. This shows that IOPI can be useful to improve lingual strength in such patient there by contributing to improved articulation.

Byeon (2018) studied the effects of the tongue-pressure exercise protocol and the traditional orofacial exercise on the articulation muscle and percentage of correct consonants of the 21 patients with flaccid dysarthria due to stroke randomly divided into a control group (tongue-pressure protocol using IOPI) and a treatment group (tongue-pressure protocol using IOPI and tongue base exercise). The results showed that the maximal tongue strength, maximal lip strength, and articulation accuracy were significantly different between the two groups. Authors of the study showed that the combined rehabilitation program consisting of the tongue-pressure protocol and tongue base exercise improved the maximal tongue strength and maximal lip strength significantly more than the single rehabilitation program.

The findings indicate that adults with dysarthria had lower strength and endurance of lip and tongue in comparison to age matched healthy adults. Many studies in the literature have indicated that adults with dysarthria frequently have oro-motor involvement exhibiting poor muscle tone and strength. This dysfunction will subsequently lead to compromise in functions of non-speech movements, speech and swallowing like reduced rate and range of lip and tongue movements like retraction, protrusion, elevation etc., improper articulation, reduced clarity of speech, poor resonance of speech, reduced rate of speech, poor lip seal, drooling, poor bolus

formation and manipulation, pocketing of food in oral cavity, slow oral transit time, premature spillage into pharynx, delayed swallow initiation, slow pharyngeal transit time, food residue in pharynx, aspiration/penetration before, during and after swallow etc. Some authors have also suggested the efficacy of using the IOPI as a rehabilitative biofeedback tool for improving strength and endurance of lip and tongue and further resulting in improvement in functions of speech and swallowing.

In sum, the results of comparison of strength and endurance measures of lip and tongue (anterior and posterior) across gender revealed that there was a significant difference between males and females in both the age groups. The overall mean values of strength and endurance of measures of lip and tongue, were higher in males than females in both age groups due to differences in the overall physique like height, weight, body-mass index which consequently makes males to generate more force than females. Further, the results of age-group comparison revealed highly significant differences for lip strength and endurance, tongue strength and endurance at anterior and posterior parts within each gender. Therefore, it can be opined that age-related changes in tissue which leads to sarcopenia has an effect on the oro-muscular strength and endurance measures. Results also revealed age and gender interaction which was not significant for lip strength, lip endurance, tongue posterior strength and tongue anterior endurance. But effect was significant in the case of tongue anterior strength. Further, comparison of strength and endurance measures of lip and tongue between healthy adults and clinical group (dysarthria) revealed significant differences, where clinical group exhibited lower mean values of strength and endurance measures of lip and tongue than healthy adults. Results could revealed significant gender differences between males and females. Thus the normative data developed for strength and endurance of lip and tongue, can be used as a reference during assessment and

rehabilitation of adults with oro-motor deficits associated with various speech and swallowing disorders.

Chapter V

SUMMARY AND CONCLUSIONS

Tongue and lips are among the primary articulators and both are muscular structures which have both biological and speech functions. The aging process leads to changes in anatomy and function of the lips and tongue which occurs as a consequence of sarcopenia. Prominent age-related change is noticed as reduction of skeletal muscle tissue which affects the strength of tongue and lip force. Such age-related changes manifests in dysphagia of especially the oral and pharyngeal phases. Apart normal aging process, many diseases could be a causative factor for oro-motor deficits has been discussed in literature. These reasons make it important to implement assessment and treatment protocol to keep close watch on impairment of functions like speech, and swallowing due to oro-motor deficits. Nonspeech oro-motor assessment often includes measures of strength, range of motion, rhythmicity, target accuracy, and coordination. Such qualitative method is the most commonly employed in clinical practice, but has a high chance for variation owing to its subjective nature and relation to clinician's experience. To avoid such situations, objective evaluation using instruments is emphasized which provides precise and sensitive measures.

Iowa Oral Performance Instrument (IOPI) system was developed in early 1990s to objectively measure tongue pressure and resistance. It is a portable device being widely used to assess strength and endurance of lip and tongue both for assessment and intervention. Research has been done using IOPI both in typical population and clinical population and has shown its reliability for use. Some studies conducted by authors could show age-related and gender based differences in lip-

tongue strength and endurance. Most of the studies could account lower values of strength and endurance of lip and tongue in clinical compared to typical population.

A review of existing literature revealed that studies to measure the lip- tongue strength and endurance in the Indian population was sparse. Most of the research was done to measure tongue strength, turning a blind eye to strength and endurance measures of lip. Some works were also done to check for efficacy of IOPI in rehabilitation. Such limited number of studies does not provide a reliable and valid data to reach a conclusion. Researchers have shown interest in developing norms, some using IOPI but these findings apply to the population elsewhere, which cannot be drawn parallel to population in India owing to various ethnic/ linguistic backgrounds as the developmental and aging pattern and physiology could vary.

Strength and endurance testing using objective measure often help in revealing an underlying neuromuscular impairment, and serve as a diagnostic aid, and provide information to plan intervention. This along with the fact that Indian speech-language pathologists (SLP) have no normative basis to compare strength and endurance measures between healthy adults across ages as well as those with pathologies makes it lot more essential to carry out a study. Keeping this in mind, the present study was framed with the aim of developing normative data for strength and endurance of lips and tongue in healthy adults across the age range of 50-70 using IOPI. The specific objectives of the study were to investigate the changes in strength and endurance of the lips and tongue, that occurs in relation to aging, to determine whether strength and endurance of the tongue and lips varies with gender and to assess the clinical validity of the data obtained from the healthy adults by investigating the strength and endurance of the lips and the tongue, in age matched adults with dysarthria.

The present study included two groups; typical group and the clinical group. Typical group consisted of a total of 60 healthy adults in the age range 50-70 years further divided into two different age groups (50-59.11 years: middle aged adults, and 60-69.11yrs years: older adults). Each group consisted of 30 adults with equal number of males and females. Whereas the clinical group consisted of10 adults (6 males and 4 females) with dysarthria (diagnosed by qualified team of professionals) in the age range of 50-70years to assess the clinical validity of the data obtained from the healthy adults. All ethical standards were met for participant selection and their participation. Participants were selected into each group based on detailed case history and informal (Oral motor examination) and formal screening (Mini-mental state examination, socioeconomic scale).

The participants were measured for their strength and endurance of lip and tongue using IOPI with appropriate instructions and demonstrations provided by the clinician for each participant. Lip strength (inter-labial compression) was measured by placing the bulb between upper and lower lip and the participants were asked to press as hard as possible. Three trials was performed with a rest period in between the trials and the values displayed on the device was noted down. Similar placement was used to measure the endurance of lip and the LCD display was set to 50% of the participant's peak pressure and was instructed to press hard until the green light illuminates on the device. The duration (seconds) that was displayed was recorded for one trial for each participant. Following this, anterior (placing the bulb against the participant's hard palate just behind the alveolar ridge) and posterior (bulb was placed anterior to the end of hard palate) tongue strength and endurance were measured by asking participants to press the bulb as hard as possible. Instruction, number of trials and values noted to be noted were similar to lip strength and endurance measurement.

Later test-retest reliability was done for all six tasks i.e., lip and tongue (anterior and posterior) strength and endurance on 10% of total participants who were randomly selected after one week of initial data collection.

The data thus collected from both groups were subjected to statistical analysis using SPSS version 20 software. Descriptive statistics was used to obtain mean, median and standard deviation of all parameters. The effect of age and gender on strength and endurance measures of lips and tongue was compared using Multivariate Analysis of Variance (MANOVA) and Mann- Whitney U test (for posterior tongue endurance measure). The data from the clinical and control group was compared using Mann- Whitney U test. Cronbach's alpha test was carried out to determine the test-retest reliability.

The results of the study indicated that, the test-retest reliability was high for strength and endurance measures of lip and tongue. The results of comparison of strength and endurance measures of lip across gender revealed that for lip strength and endurance significant difference was seen between males and females in both the age groups. Further, the results of comparison of tongue (anterior and posterior) strength and endurance across gender revealed significant difference in both the age groups. The overall mean values of strength and endurance of measures of lip and tongue, were higher in males than females in both age groups. Further, the results of age-group comparison revealed significant differences for lip strength and endurance, tongue strength and endurance at anterior and posterior parts within each gender.

Results also revealed age and gender interaction which was not significant for lip strength, lip endurance, tongue posterior strength and tongue anterior endurance, but the effect was significant in the case of tongue anterior strength.

Further, comparison of strength and endurance measures of lip and tongue between healthy adults and clinical group (dysarthria) revealed significant differences on all these measures in comparison to healthy aged adults. Results also revealed significant gender differences in the clinical group. The clinical group exhibited lower mean values of strength and endurance measures of lip and tongue than healthy adults.

Clinical implications

The results from the current study can be used as a normative with respect to age and gender related differences for strength and endurance of lip and tongue. This data will expand the data set on normal strength and endurance of lips and tongue, especially in adults progressing through biological aging, which allows us to get more refined interpretations of oro-motor weakness in pathological conditions. The norms developed will facilitate the use of IOPI for diagnostic purposes todocument the strength and endurance of the lips and tongue of adults with speech and or swallowing disorders. The use of this will enhance the objectivity, precision of measurement and face validity of the assessment process in the clinical practice. It will reduce the clinician bias of subjective rating of lips and tongue weakness during evaluation. Therapeutic goals can be made more precise interms of whether strengthening exercises are required for the client or not rather than clinician's self-assumption bias. These norms will help in choosing target values for the strength and endurance of lips and tongue during therapy and to monitor the efficacy of treatment with respect to non-speech tasks. This data will also provide the groundwork for active rehabilitation where in IOPI can be used as a feedback tool where by patients can be made empowered and satisfied with treatment.

Limitations of study

Drawbacks were also noted in the present study which has to be taken into consideration. Factors of lips and tongue such as lip-jaw relations, dentition, diameter-thickness of lips and tongue and muscle length could not be outlined during the study. Additional factors like order of testing, nutrition status, respiratory, lifestyle diseases and level of activity were not managed, which could have influenced the measures in both the groups. The data cannot represent the whole Indian population as the subjects who volunteered for this study were recruited only from South India. Although most Indians seem to have similar physical characteristics, there may be differences related to the orofacial muscle strength due to different speech sounds produced in diverse languages in India which has to be looked into.

Future directions for research

Future studies could focus on developing normative data in younger adults for strength and endurance of their lips and tongue in the Indian context, which would help in understanding the effect of aging in adults. This could also serve as data to be compared with clinical group. Research has to be carried out considering factors like body- mass index, physical activity, food habits etc. to investigate what factors are correlated with the strength and endurance of the tongue and lip according to ethnicity or area. Studies can also be done to evaluate the characteristics of the tongue and lip during the course of oro-motor strengthening treatment by obtaining pre-treatment, one-, three-, six-, and 12-month measures of strength and endurance for individuals with oro-motor deficits. Conducting studies to determine the correlation between lip-tongue measures and speech intelligibility, feeding, mastication and swallowing abilities would also be beneficial for clinical applications. Future work has also be done to know about impact of this tool on the prevention of swallowing or speech

disorders through oro-motor exercise. Such data will help in incorporating tongue exercises into routine of adults to maintain their oro-motor health.

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