# TONGUE PRESSURE MEASURE IN CHILDREN WITH SPASTIC CEREBRAL PALSY (4-5 YEARS) DURING SWALLOWING

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**ALL INDIA INSTITUTE OF SPEECH AND HEARING**

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**May, 2013**

# Certificate

This is to certify that this dissertation entitled **"Tongue Pressure Measure in Children with Spastic Cerebral Palsy (4-5 Years) During Swallowing"** is a bonafide work in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No. 11SLP020). This has been carried out under the guidance of a Faculty of this institute and has not been submitted earlier for the award of any other Diploma or Degree to any other University.

Mysore

May, 2013

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May, 2013

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# Declaration

This dissertation entitled **"Tongue Pressure Measure in Children with Spastic Cerebral Palsy (4-5 Years) During Swallowing"** is the result of my own study under the guidance of **Dr. R Manjula**, Professor of Speech Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier for the award of any Diploma or Degree to any other University.

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# INTRODUCTION

*"There is nothing in the world that we do as much as we do eating* (Will Rogers)".

Swallowing is the process that usually involves movement of food from the mouth to the stomach via the esophagus. The purpose of swallowing is to safely transport food from the mouth to the stomach. Swallowing is the result of successful integration and execution of neural and muscular events (Arvedson & Brodsky, 2002).

Healthy individuals simultaneously perform the sequential sensory and motor patterns of mastication (chewing) and swallowing with little effort and conscious awareness. The act of swallowing includes four stages. The first stage is the oral preparatory phase in which food is masticated in preparation for transfer. This is followed by the oral phase, which entails the transfer of material from the mouth to oropharynx. The third is the pharyngeal phase, in which material is transported away from the oropharynx, around an occluded laryngeal vestibule, and through a relaxed cricopharyngeus muscle into the upper esophagus and the final phase is the esophageal phase, in which material is transported through the esophagus into the gastric cardia. (Groher & Crary, 2010).

The oral preparatory phase involves the oral structures like lips, jaw, tongue, soft palate, muscles of mastication and buccal muscles. Although these structures play an important role in mastication and transfer of bolus, the tongue acts as the major propulsive force for the bolus. The anterior tongue has a greater concentration of connective and adipose tissue, whereas the posterior tongue contains greater concentration of muscle (Miller, Watkin, & Chen, 2002). This structural organization allows for the intrinsic movement and positioning which is needed for speech and swallow. In a collaborative

manner, both the intrinsic and extrinsic lingual muscles propel the bolus from the oral cavity into the pharynx. The unique composition of the muscle fibers and the intricate relation between the lingual muscles facilitates the tongue to rapidly generate the force which is necessary for swallowing. (Lenius, 2008).

Studies have been conducted to determine the normal variation of non swallowing isometric tongue function across different age range and gender in healthy individuals. In a study conducted by Crow and Ship (1996), the tongue strength was examined using a handheld tongue force measurement device, the Iowa Oral Performance Instrument (IOPI). They found that the tongue strength was significantly higher in males than in females and decreased significantly with increasing age in males but not in females. In another study by Youmans, Stierwalt and Clark (2002), tongue strength measures obtained using IOPI showed that as age increased, tongue strength decreased, but there was no difference between genders.

Clark, Henson, Barber, Stierwalt & Sherrill (2003) assessed the relationship between subjective and objective measures of tongue strength and the swallowing impairments in the oral phase and suggested that both subjective and objective measures of tongue strength are predictive of the presence of oral phase dysphagia.

Various researchers have considered tongue pressure as a measure for assessing certain aspects of swallowing, especially in the oral phase. Tongue pressure is the pressure or the stress produced by pressing the tongue against the hard palate (Chen & Engelen, 2012). Tongue pressure measurement has shown to reflect clinical signs of dysphagic tongue movements and is a useful technique for evaluating swallowing (Yoshida, et.al

2006). Utanohara, et.al. (2008) assessed the maximum tongue pressure of 853 individuals in the age range of 20 to 79 using a tongue pressure measurement device which consisted of a disposable oral probe and a recording device (Prototype device PS- 03, ALNIC). The subjects were divided into six groups with an age interval of ten years starting from 20 years. The result showed that the males in the twenties, thirties, and forties showed higher tongue pressure than the females and the tongue pressure decreased from sixties in males and from seventies in females.

Padmatharani (2011) assessed the performance of 60 typically developing children between 4-5 years using the 'Two tongue array module' in the Digital Swallowing Workstation. Different parameters of tongue pressure were analyzed and it was found that anterior tongue pressure was more compared to posterior tongue pressure across dry and wet swallow conditions. It was also found that for the dry swallow condition, tongue achieved the maximum pressure against the palate in a shorter time compared to the wet conditions.

Swallowing and feeding disorders affect typically developing children as well as those with difficulties related to medical or neuro developmental factors. The prevalence of swallowing disorders is variable. It is estimated to be 25-30% in typically developing children (Linscheid, 1992). Individuals with various neuropathologies like CP, TBI, mental retardation, developmental delay shows impairment in swallowing (Arvedson & Brodsky, 2002). Children with cerebral palsy are most likely to exhibit swallowing difficulties. 25- 80% of individuals with cerebral palsy (depending on the subgroup) have additional impairments, with about half of them exhibiting gastrointestinal and feeding problems (Odding, Roebroeck, & Stam, 2006). During the first year of life, 57% of

children with cerebral palsy are estimated to have problems sucking, 38% with swallowing, and 33% with under nutrition (Reily, Skuse, & Poblete, 1996). As the severity of cerebral palsy increases, the severity of oral sensorimotor deficits also increases. Out of all types of CPs' the children with spastic quadriparesis are reported to be the most severely affected (Stallings, Charney, Davies & Cronk, 1993).

A study by Senner, Logemann,Zecker and Gaebler (2004), fourteen person with spastic cerebral palsy (CP) (six females, eight males) ranging from 7 years 11 months to 18 years 2 months measured the frequency of swallowing using cervical auscultation and video recording of the head and neck simultaneously. Results indicated that both the groups tended to swallow less frequently than typically developing participants.

***Need for the study***:

Majority of the children with cerebral palsy are known to exhibit difficulty in swallowing (Odding et. al, 2006; Reily et.al,1996; Stallings et.al, 2006). Most of these studies have reported the prevalence of swallowing and its related disorders based on population surveys and subjective measures. Various studies have shown that the role of tongue in oral phase of swallowing is very important (Hedges, Mc Lean, & Thompson, 1965). The pressure exerted by the tongue is considered as an important measure to assess deviation in swallowing. Most of the studies however are done on typical population during normal swallowing process. There are only few studies that have addressed tongue pressure measures in various disorders where oral phase of swallowing is implicated. These studies have mainly focused and included participants with stroke, post head and neck cancer (Konaka et al, 2010) etc.

In comparison there are limited studies done on children with swallowing disorders. A study by Senner, Logemann,Zecker and Gaebler (2004), included fourteen person with spastic cerebral palsy (CP) (six females, eight males) ranging from 7 years 11 months to 18 years 2 months to measure the frequency of swallowing using cervical auscultation and video recording of the head and neck simultaneously. Results indicated that both the groups tended to swallow less frequently than typically developing participants.

In this study, it is proposed to analyze and compare the tongue pressure in oral phase of swallowing in children with Spastic cerebral palsy aged 4 to 5 years (in six months interval) and compares the same with the norms established on the same age group by Padmatharini (2011) in typical children.

**Aim of the study**

The study aimed to measure and compare the pressure in the anterior and posterior regions of tongue during wet and dry swallow conditions for thin liquid (water) using Two Tongue Array Module of Digital Swallowing WorkStation Model 7120 of Kay Pentax in children with Spastic Cerebral palsy aged 4 to 5 years.

**Objectives of the study**

1) To measure and compare the anterior and posterior pressure of tongue using Two Tongue Array Module of Digital Swallowing WorkStation Model 7120 of Kay Pentax in children with Spastic Cerebral palsy aged 4 to 5 years across:
   - Gender (Males & Females)
   - Age ($> 4.0$ to $\leq 4.6$ years and $>4.6$ years to $\leq 5.0$ years)

- Swallowing tasks (dry & wet swallow)
- Different volumes in wet swallow task (5ml & 10 ml)

2) To compare the results obtained for children with Spastic Cerebral Palsy in this study with that of typically developing children in the age range of 4 to 5 years established by Padmatharini (2011) using the same experimental design.

**Method**

12 children diagnosed as spastic cerebral palsy in the chronological age range of 4- 5 years will be included in the study. They would be divided into 2 groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years). "Two Tongue Array Module" of the Digital Swallow Workstation model 7120 by KAY PENTAX will be used to obtain the measures of interest for the study. The swallowing data will be obtained for two conditions: (1) Dry swallow (2) Wet swallow. For dry swallow the participant will be instructed to swallow the saliva. For wet swallow, mineral water will be used in two measures of 5 ml and 10 ml. For each condition, three recordings will be obtained and only one which represents the wave morphology adequately without any artifacts will be chosen for the analysis. Comparison will be made across the age, gender, dry and wet swallow conditions and two volumes of wet condition. Mean values will be tabulated and compared with the norms established on typical children of the same age groups, using the same experimental design by Padmatharini (2011).

**Implications:** The study will provide an insight into the action of tongue as measured for its pressure in the anterior/ posterior portion during the act of dry and wet swallow. It will also allow for the comparison of the performance of CP children with that of typically developing children of the same age range reported by Padmatharini (2011)

# REVIEW OF LITERATURE

Swallowing is a very complex activity. It involves coordinating the opening and closing of the mouth and lips and chewing while maintaining the inhaling and exhaling cycles of respiration. Food needs to be mixed with saliva, moved to the back of the tongue, and sent on its way down to the esophagus with the help of swallow reflex. The process of swallowing begins at the mouth and ends at the stomach (Gad, 2007). It includes integrated and interdependent group of complex feeding behaviors which emerges from the interacting cranial nerves of the brainstem and governed by the neural regulatory mechanisms in the medulla and the sensorimotor and limbic cortical systems (Groher & Crary, 2010). Along with the peripheral nervous system, the central nervous system is essential for swallowing, as large neural networks including cortical, subcortical, and cerebellar areas are recruited during the process of swallowing (Zald & Pardo, 1999).

Normal swallowing involves fine neuromotor coordination between the upper respiratory and digestive tracts which are controlled by both cortical and brain stem circuits (Miller, 1982). Normal swallowing is mainly divided into four phases: (a) the oral preparatory phase, (b) the oral phase, (c) the pharyngeal phase and (d) the esophageal phase (Sessle & Hannan, 1976; Miller, 1982).

During the Oral Preparatory phase, the food is manipulated in the mouth, tasted, broken down into a consistency ready for swallowing and brought back into a single ball or bolus by the tongue in preparation for the swallow. This stage of deglutition involves five neuromotor behaviors:

a) Lip closure to keep food in the mouth anteriorly.

b) Tension in the buccal and labial muscles which is sufficient to close the lateral and anterior sulci, or pockets between the facial musculature and facial skeleton, so that food does not fall into these sulci during chewing which results in pocketing of food, but rather falls medially onto the tongue.
c) A circular or rotary, lateral movement of the jaw to breakdown the food.
d) A rolling and lateral motion of the tongue to pick the food up as it comes off the teeth, mix it with saliva, and roll it back onto the teeth and
e) An active pulling forward of the soft palate to seal food in the oral cavity posteriorly, and widen the nasal airway (Miller, 1982; Logemann, 1983).

Out of these five activities, the most important is the *tongue mobility*, which facilitates mastication. Without normal tongue range of motion and control, the individual will be unable to chew normally. All of these activities are voluntary and under cortical control. At this point, the oral stage of the swallow is about to be started.

During the oral phase, the tongue elevates and rolls back, sequentially contacting the hard and soft palate, moving the bolus backwards. This phase of deglutition begins when the tongue propels the bolus posteriorly in an upward and backward rolling motion. The tongue squeezes the food along the palate until it reaches the anterior faucial arches. At this point, the swallowing reflex triggers due to the activation of the ninth cranial (or glossopharyngeal) nerve. These nerve impulses are carried to the reticular formation in the brain stem where the swallowing center is located (Miller, 1982). It is clear that it is the tongue activity to initiate the voluntary or oral phase of the swallow that contributes to triggering the swallowing reflex.

When the swallowing reflex is triggered, there is a beginning of the pharyngeal phase or reflexive phase of the swallow, in which the bolus moves through the pharynx and this requires programs at four neuromotor levels:

a) Velopharyngeal closure to close the nasal cavity to prevent food from entering the nose Peristaltic contractions in the pharyngeal constrictors to squeeze the bolus through the pharynx
b) Airway protection, involving two dimensions of movement—laryngeal elevation and laryngeal closure and
c) Cricopharyngeal relaxation to allow the bolus to pass from the pharynx into the esophagus (Miller, 1982).

These neuromotor activities are triggered by the swallowing reflex. It is established that the entire pharyngeal phase of the swallow lasts a maximum of 1 second regardless of food consistency swallowed or age or sex of the patient (Mandelstam & Lieber, 1970).

Once the bolus has passed through the cricopharyngeus muscle at the base of the pharynx, it enters the final phase of the swallow, i.e, the esophageal phase. This is an involuntary process, where the bolus moves through the esophagus and finally enters the stomach by the peristaltic action of the constrictor muscles of the esophagus (Mandelstam & Lieber, 1970).

Swallowing involves the co ordination of various peripheral and central structures during different stages of swallowing. The peripheral structures include the oral, laryngeal and pharyngeal structures, cranial nerves and muscles. During the oral phase of

swallowing, the co ordinated action of the lips, teeth, tongue, jaw, soft palate, muscles of mastication and buccal muscles is very important (Perlman & Schulze-Delrieu, 2003)

Various oral structures play an important role in the act of swallowing. These include the following:

*Lips*:

- Remains closed to prevent food or fluid or saliva falling off from the mouth.
- Maintains intra oral pressure when closed to aid the swallowing process.

*Cheek*:

- Maintains the correct degree of tension to prevent the food falling to the sides of the mouth, or in front of the teeth or gums.

*Jaw:*

- Moves in various directions like from side to side, up and down and in a rotary action when chewing.
- Strength of jaw is important for chewing tougher food consistencies.

*Tongue:*

- Moves food towards the teeth for chewing.
- Mixes food with saliva and collects it into bolus in the middle of the tongue.
- Pushes food backwards towards the throat by pressing against the roof of the mouth.
- Clears away the food residue from gums and cheeks.
- Controls and holds food or fluid for the preparation of swallowing.

Even though all the structures in the oral cavity play an important role in swallowing, the ***tongue*** plays a significant role in the oral and pharyngeal phases of swallowing (Hedges, Mc Lean & Thompson, 1965). It is involved in the formation, placement, and manipulation of the bolus during the oral preparatory phase, posterior transfer of bolus from the oral cavity to the pharyngeal cavity, directing the bolus into the pharyngeal cavity, and retraction against the pharyngeal walls to assist the movement of bolus down the pharynx and into the upper esophageal sphincter during the pharyngeal phase. Any abnormality in the tongue function can lead to various problems in the process of swallowing like impaired mastication, poor bolus formation, abnormal bolus positioning, oral residue, disorganized oral transit, premature spillage of the bolus into the pharynx, and pharyngeal residue. All of these difficulties may lead to oral and/or pharyngeal dysphagia.

Adequate bolus transportation requires the energy for building the pressure in the tongue by pressing it against the hard palate. This is generally regarded as ***tongue pressure*** (Chen & Engelen 2012). Ferguson, Cartwright, Rogers and Schmidt-Nowara (2006) indicated that the pressure which is generated at the midline of tongue when the tip of tongue thrusts against the anterior teeth can be up to 10kPa. Also the magnitude and duration of tongue pressure is found to be significantly higher in anteromedian part and significantly smaller in posteromedian part.

Robinovitch, Herschler, and Romilly (1991) studied tongue function during the oral phase of swallowing with an instrument called the Tongue Force Measurement System (TOMS). They considered two subjects with dysphagia and six subjects without

dysphagia. The subjects were compared across three trials, producing tongue force readings in the superior, left lateral and right lateral directions. Even though the results of the study showed no significant difference which was attributed to small number of subjects, the authors reported trends which indicated differences in forces between the unimpaired and impaired sides with unilateral weakness and dysphagia.

Robbins, Levine, Wood, Roecker and Luschei (1995) examined the maximal isometric pressures and swallowing pressures in two age groups. The first group consisted of 14 males (mean age of 75 years) and the second group consisted of 10 males (mean age of 25 years). They used Iowa Oral Performance Instrument (IOPI) was used to obtain tongue pressures in three different locations on the tongue (tip, blade, and dorsum) during the typical IOPI strength task and a swallowing task. IOPI is a portable device that measures pressure exerted on an air- filled tongue bulb (Lenius, 2008). The swallowing task consisted of a ‘‘dry’’ swallow with the IOPI in place. The results showed that the maximum isometric tongue pressures, or strength measures, were significantly greater for the group of younger subjects than for the older subjects at the tongue blade site. However, the authors found that the peak swallowing pressures were similar between the age groups.

Nicosia et al. (2000) assessed tongue pressure during bolus swallowing and compared it with maximal isometric lingual pressures. Two groups, one elderly (mean age being 81 years) and one young (mean age being 51 years) and each consisting of ten subjects (5 women, 5 men), participated in the study. Three bulb array module of Kay Elemetrics Swallowing Workstation (Model 7100, Kay Elemetrics, Lincoln, NJ) was used and it was attached to each subject’s hard palate. The lingual pressure on the bulbs was

used to determine maximal isometric tongue pressure and lingual pressure during the swallowing of 3-ml semisolid, 3-ml thin liquid, and 10-ml thin liquid boluses. The authors found that there was a significant decrease in maximal isometric pressure in the older group compared to the younger group but there was no significant difference in tongue pressure during swallowing. It was also noted that significantly more time was taken to reach peak pressure during swallowing in the older group than in the younger group with both thin liquid boluses but not with the semisolid bolus. There were no significant gender differences for maximal lingual pressure, swallowing pressures, or time taken to reach peak pressure.

Youmans and Stierwalt (2006), conducted a study to assess the normal tongue physiology during swallowing and maximum isometric tasks to establish a preliminary database of tongue function variables and to determine if differences existed among the variables as a function of age, gender, or varied bolus consistency. The study included Ninety participants (age range between 20–79 years) who were divided into three age groups based on 20 years intervals. Group 1 consisted of subjects aged 20–39 year, Group 2 consisted of subjects aged 40–59 years and Group 3 consisted of subjects aged 60–79 years. Each group consisted of 30 subjects (15 males and 15 females).Various tasks were used to determine maximum isometric tongue pressure, mean tongue pressure during swallowing, and percentage of maximum isometric pressure used during swallowing using Iowa Oral Performance Instrument (IOPI). Results indicated that males had significantly higher maximum isometric pressures than females, and the youngest group had significantly higher maximum pressures than the oldest group. Mean swallowing pressures and percentage of maximum isometric pressures used during swallowing differed as a

function of bolus type but did not differ as a function of age or gender. Also, maximum isometric pressures were correlated with mean swallowing pressures, and mean swallowing pressures and percentage of maximum isometric pressures used during swallowing were correlated between consistencies.

Padmatharani (2011), assessed the performance of 60 typically developing children between 4-5 years using the 'Two tongue array module' in the Digital Swallowing Workstation. The subjects were grouped into two, depending on their chronological age. Group I consisted of 15 males and 15 females in the age range of $> 4.0$ to $\leq 4.6$ years and group II included 15 males and 15 females in the age range of $> 4.6$ to $\leq 5.0$ years. The recordings were done for two swallowing conditions namely dry and wet swallow conditions. In wet swallow condition, two different volumes (5ml and 10 ml) of liquid (water) were assessed. Different parameters of tongue pressure were analyzed and it was found that anterior tongue pressure was more compared to posterior tongue pressure across dry and wet swallow conditions. No significant difference across gender and the selected age group was reported. It was also found that for the dry swallow condition, tongue achieved the maximum pressure against the palate in a shorter time compared to the wet conditions.

**Disorders of Swallowing**

Anatomic or physiologic disorders of swallowing can occur in any phase of the swallow (Logemann, 1983). In the oral preparatory phase, swallowing disorders could range from incomplete lip closure, reduction in tension in cheek musculature or reduction

in motion of lower jaw and reduction in range or coordination of tongue movement, which may be due to neurological, surgical, or traumatic in origin reasons (Logemann, 1983).

Disorders that affect the oral stage of the swallow can also affect the oral preparatory phase. But impairment of tongue function may affect only one particular direction of movement, such as elevation of the tongue, or anterior/ posterior motion of the tongue which is necessary to perform the upward and backward propulsion of the bolus to initiate swallow.

Disorders in the pharyngeal phase of the swallow may include delayed or absent triggering of the swallowing reflex resulting in food falling into the pharynx without any of the four neuromotor aspects of the pharyngeal phase occurring, reduction in velopharyngeal closure resulting in reflux of material into the nasal cavity, damage to pharyngeal peristalsis, damage to the elevation of the larynx, damage to laryngeal adduction, or airway closure, leaving food in the pyriform sinuses after the swallow (Logemann, 1983; Silibiger, Pikielney & Donner, 1967).

A wide variety of patients exhibit swallowing disorders. Many patients with neurologic damage, both congenital (cerebral palsy and myotonic dystrophy) or acquired (CVA, head trauma, Parkinson's disease, or amyotrophic lateral sclerosis) variety exhibit swallowing disorders (Silibiger, Pikielney, & Donner, 1967). Many patients who have undergone surgical or radio therapy treatment for cancer of the head and neck region will exhibit swallowing problems post treatment (Logemann & Bytell, 1979). Some may exhibit swallowing disorder prior to treatment because of their tumor. Many premature

infants exhibit disorders of sucking and swallowing, which may persist into early childhood (Logan & Bosma, 1967).

The epidemiology of oral sensorimotor dysfunction in the general population and in the population of neurologically impaired children is not well defined. Precise incidence and prevalence data are hard to ascertain, but estimates are that 85-90% of children with cerebral palsy (CP) are believed to have swallowing difficulties at some time during their lives.

**Swallowing disorders in Persons with Cerebral Palsy**

Cerebral Palsy (CP) describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to non- progressive disturbances that occur in the developing fetal or infant brain (International Workshop on Definition and Classification of Cerebral Palsy, 2004). CP is caused by events before, during, or after birth. The abnormalities of muscle control that define CP are often accompanied by other neurological and physical abnormalities. CP affects about 1 in every 400 children born or 2 to 2.5 children per live births (Blair & Stanley, 1993a; Odding, Roebroeck, & Stam, 2006) More males are affected than females in a ratio of 1.3:1 (Blair & Stanley, 1997). The prevalence of CP varies according to the birth weight (Pharoah, Platt, & Cooke, 1996).

Majority of the children with cerebral palsy are known to exhibit difficulty in swallowing (Odding, Roebroeck, & Stam, 2006; Reily, Skuse & Poblete 1996; Stallings, Charney, Davies, & Cronk, 1993). Most of these studies have reported the prevalence of swallowing and its related disorders based on population surveys and subjective measures.

The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception and/or behavior, feeding problems and/or by a seizure disorder (International Workshop on Definition and Classification of Cerebral Palsy, 2004).

Feeding problems are frequently observed in children with cerebral palsy (CP). Researchers have found that 30 to 80% of disabled individuals feed with difficulty. They are especially at risk because of oral, pharyngeal or esophageal dysphagia and due to oral motor dysfunction (OMD). Also due to communication difficulties many of them are unable to request food and drink. Presence of seizures may worsen the feeding intake. Hence these children do not receive adequate nutrition resulting in growth retardation, reported in as many as 48% of children with neurodevelopment handicaps.

Drooling, i.e., 'spilling of saliva from the mouth onto the lips, chin, neck, and clothing' normally occurs in infants and young children, especially when a child is learning a new motor skill or cutting a new tooth. Researchers have determined that children who drool have increased difficulty forming a bolus, reduced lip closure, slightly less intraoral suction, and more oral residue after the swallow. Significant negative correlations have been found between drooling and sucking ability, drooling and chewing ability, and drooling and swallowing. It has been found that in 10 to 38% individuals with cerebral palsy drooling abnormally persists (Johnson & Scott 1993).

Waterman, Koltai, Downey and Cacace (1992), conducted a study to establish the prevalence of dysphagia in a population of children with CP, and to determine if any factors are related to dysphagia. The participants' included 56 CP patients within the age

range of 5–21 years. Fifteen patients had either radiographic or clinical evidence of dysphagia and the 15 patients were compared to the remaining 41 patients without dysphagia. Using data obtained from chart review and interviews with speech pathologists, several factors that contributed to dysphagia were found which included bite reflexes, slowness of oral intake, poor trunk control, inability to feed independently, anticonvulsant medication, coughing with meals, choking, and pneumonia. They also noted trends in the following factors: presence of tongue thrusting, presence of drooling, severity of CP, poor head control, severity of mental retardation, seizures, and speech disorders. Factors that were not related to the presence of dysphagia were the age, cause of CP, and type of CP. They concluded that early, aggressive work-up and identification in CP patients with the risk factors outlined above can reduce the associated pulmonary complications.

Mirrett, Riski and Glascott (1994), tried to find the characteristics and sequelae of dysphagia in children with neurological impairment. They described the histories of the disorder of swallowing and analyzed the videofluorographic swallow studies of 22 patients with the primary diagnosis of severe spastic cerebral palsy within the age range of 7 months to 19 years, who had severe dysphagia and were slow, inefficient eaters. The results showed that 15 patients demonstrated significant silent aspiration. Analysis of specific features of the swallowing patterns indicated that decreased or poorly coordinated pharyngeal motility was predictive of silent aspiration. Moderate to severe impairment in the oral-motor coordination was indicative of severity of the feeding complications. They concluded that early diagnostic workup, including baseline and comparative videofluoroscopic swallow studies, could be helpful in managing the feeding difficulties in

these children and preventing chronic aspiration, malnutrition, and unpleasant lengthy mealtimes.

Gangil, Patwari, Aneja, Ahuja and Anand (2001) conducted a study to determine the magnitude and extent of feeding problems in children with cerebral palsy (CP) and to evaluate the effectiveness of nutritional interventions. Children with cerebral palsy of either sex were enrolled randomly and their parents were interviewed for their perception about feeding problems, nutritional status and for their views about the expected outcome of feeding problems. 100 children (76 boys and 24 girls) with cerebral palsy of mean age 2.5 years (range 1 to 9 years) and mean developmental age of 7.6 months (range 1 to 36 months) were included in the study. Each child was assessed for feeding problems based on Gisel and Patrick feeding skill (Gisel & Patrick, 1988) score; for nutritional status by measurement of weight, skinfold thickness (at biceps, triceps, suprailiac and subscapular), mid arm circumference and caloric intake; neurologically for type and severity of cerebral palsy and for developmental age by Gasell's developmental scale. Equal number of age and sex matched controls were included for comparison of nutritional status and developmental quotient. Various rehabilitation procedures were applied and their response was observed in the follow up ranging from 3-10 months. The result showed that Oral motor dysfunction (OMD) was found in all cases and in each category. Spastic quadriplegic cerebral palsy (SQCP) and hypotonic patients had significantly poor feeding skill score. Spastic quadreparesis, hypotonia and poor feeding skill score had negative effect on nutritional status. After nutritional rehabilitation, good improvement was seen in feeding problems, OMD and nutritional status. Hence they concluded that nutritional status of children with cerebral palsy is poor due to summation of several factors. Hence

they should be thoroughly assessed for feeding problems and nutritional status in order to start timely nutritional rehabilitation which can significantly improve their nutritional status and quality of life.

Senner, Logemann, Zecker and Gaebler-Spira (2004) assessed 14 participants (6 females and 8 males) in the age range 7 years 11 months to 18 years 2 months with a confirmed diagnosis of spastic cerebral palsy (CP). The aim of the study was to define the factors that influence drooling. Participants included those who drooled (CP+, ***n***=14); age and sex matched children with spastic CP who were dry to mild and were infrequent droolers (CP–, ***n***=14) as well as typically developing peers (CTRL, ***n***=14) who served as controls. They used simultaneous cervical ausculation and videotaping of the head and neck for measuring the frequency of swallowing. Saliva production was measured with the Saxon test, a simple gauze-chewing procedure. Also, Pediatric Evaluation of Disability Inventory (PEDI), Test of Nonverbal Intelligence-3 (TONI-3), dysarthria severity scale, and Gross Motor Function Classification System (GMFCS) scores were obtained for each participant. The results showed that both the groups of participants with CP tended to swallow less frequently than typically developing participants and tended to produce less saliva than typically developing controls; even though these differences were not statistically significant. They also found that the children with CP who drool have poorer functional skills scores, lower nonverbal intelligence scores, more severe oral motor involvement, and a tendency to swallow less frequently than children with CP who do not drool. Although the data did not achieve statistical significance, there was also a tendency for participants with CP to swallow less frequently than typically developing participants.

Participants in the CP– group swallowed more frequently than participants in the CP+ group.

Studies show that children with CP have impaired swallowing skills. This can be attributed to the reduced abilities of various structures involved in swallowing mainly the tongue pressure. There are only very few studies which has focused on the tongue pressure in CP. Thus keeping all these in mind, the present study was planned. The method of the study is presented in the next chapter.

# METHOD

## Aim of the study

The study aimed to measure and compare the pressure in the anterior and posterior regions of tongue during wet and dry swallow conditions for thin liquid (water) using Two Tongue Array Module of Digital Swallowing WorkStation Model 7120 of Kay Pentax in children with Spastic Cerebral palsy aged 4 to 5 years.

## Objectives of the study

3) To measure and compare the anterior and posterior pressure of tongue using Two Tongue Array Module of Digital Swallowing WorkStation Model 7120 of Kay Pentax in children with Spastic Cerebral palsy aged 4 to 5 years across:
   - Gender (Males & Females)
   - Age (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years)
   - Swallowing tasks (dry & wet swallow)
   - Different volumes in wet swallow task (5ml & 10 ml)
4) To compare the results obtained for children with Spastic Cerebral Palsy in this study with that of typically developing children in the age range of 4 to 5 years established by Padmatharini (2011) using the same experimental design.

## Participants

Twelve children diagnosed as *Spastic Cerebral Palsy* in the chronological age range of 4 to 5 years were included in the study. They were divided into 2 groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years). The demographic details of the participants are provided in Table 1

Table 1:

*Demographic details of participants*

| Sl No. | Age in years/Gender | Provisional Diagnosis |
|---|---|---|
| 1 | 4.0/M | DSL with Spastic Cerebral Palsy (CP) |
| 2 | 4.1M | DSL with Spastic CP with Behavioral Issues |
| 3 | 4.2/M | DSL with Spastic CP |
| 4 | 4.3/M | ISL with Spastic CP |
| 5 | 4.3/F | DSL with Spastic CP with Right Hemi Paresis |
| 6 | 4.4/F | DSL with Spastic CP |
| 7 | 4.7/M | ELD with Spastic CP |
| 8 | 4.7/M | ISL with Spastic CP with Left Hemi Paresis |
| 9 | 4.8/F | DSL with Spastic CP |
| 10 | 4.9/M | DSL with Spastic CP |
| 11 | 5.0/F | ISL with Spastic CP |
| 12 | 5.0/M | ISL with Spastic CP with Right Hemi Paresis |

*DSL- Delayed speech and language, ISL- Inadequate speech and language, ELD- Expressive language delay*

*Inclusion Criteria for the selection of participants:*

- The diagnosis of Spastic Cerebral Palsy (CP) with mild to moderate involvement was confirmed by evaluation reports of Neurologist, Speech language Pathologist and Physiotherapist/ Occupational therapist.
- The receptive language age of the participants was 3 to 4 years as assessed on a standard assessment battery (Development of an intervention module for preschool children with communication disorders by Swapna, Jayaram, Prema & Geetha, 2010 )
- Only the participants who were able to imitate the oral movements of lip, tongue and jaw after the model (provided by the investigator) were selected for the study.

*Exclusion Criteria followed for the selection of the participants:*

Participants with the following features were not included in the study:

- Gross co morbid disorders such as mental retardation, poor lip seal, excessive drooling, seizures disorders, immobility of tongue (opercular syndrome), praxis errors
- Hyperactive gag reflex
- Nasal regurgitations and fasciculation
- Tremors of lip, jaw or tongue

The same was ascertained by carrying out clinical examination associated with parent interview to collect the history.

**Instrument**

"Two Tongue Array Module" of the Digital Swallow Workstation (DSW) (Model 7120 by KAY PENTAX) was used to obtain the measures of interest for the study. DSW contains a robust set of features that have been integrated into one platform for dysphagia assessment. It comprises of three separate modules:

1. Digital Video Recording System
2. Swallowing Signals Lab
3. Fiberoptic Endoscopic Evaluation of Swallowing (FEES)

The complete workstation offers an unparalleled assortment of capabilities using established techniques. The Swallowing Signals Lab module which was used for this study, is both a physiologic data acquisition and visual feedback system for dysphagic patients that provides real-time displays of critical parameters related to swallowing function. The system includes surface EMG (two channels), tongue pressure transducers (2- and 3-channel configurations), solid state pharyngeal/UES manometry (up to six

channels), cervical auscultation, and respiratory phase (using a nasal cannula with pressure transducer). The two tongue array bulb of the speech signal module of the Digital Swallow Workstation was used in the present study.

*Figure 1.* Picture of Digital Swallow Workstation

**Procedure**

*Calibration:* Prior to the collection of data from each participant, the bulbs of the Two-tongue array were inflated and calibration check was done. The knob of the module was completely opened to inflate the bulb. When the bulbs were inflated to the pre set value, the knob was closed tightly and then it was calibrated as per the specified norms.

*Figure 2.* Two tongue array bulb.

*Preparation of the participant:* The participant was seated comfortably on the chair. The Two-tongue array was placed in the participants's mouth by the clinician to obtain the recording. The array was placed resting against the hard palate and the bulbs oriented towards the tongue with which it makes direct contact during swallowing. The array was placed in such a way that one bulb is rested against the anterior portion of the tongue and the other bulb rested against the posterior portion of tongue. Once the array was placed properly, it was firmly held in place by the externally extended stem by the investigator to avoid slipping or shifting of the array from the position of placement. The external stem was bent at an angle where the array enters the mouth to facilitate positioning in the mouth appropriately and comfortably.

*Experimental condition*: The swallowing data were obtained for two conditions: (1) Dry swallow and (2) Wet swallow. For dry swallow the participant was instructed to swallow the saliva. For wet swallow, mineral water was used in two measures of 5 ml and 10 ml

using a measuring cup. During wet swallow, the participant was asked to hold the liquid in the mouth and then the array was introduced. Participants were provided trials for familiarization of task. For each condition, three recordings were obtained and only one which represents the wave morphology adequately without any artifacts was chosen for the analysis.

*Recording the data:* Once the participant was prepared by placing the tongue array in the mouth, the two tongue array bulb module was activated to record the tongue pressure on the DSW. The time window frame selected was 8 seconds. The display scale was 500 mmHg on the vertical scale. The same settings were followed for all the participants. For dry swallow, the participant was asked to swallow saliva when indicated. The recording mode of this module was activated and the waveform was saved to obtain the tongue pressure measures. For 5 ml and 10 ml wet swallow tasks, the participant was given water in the measuring cup and similar procedure as that of the dry swallow was followed.

**Analysis:**

The tongue pressure wave recorded for each participant in the two swallow conditions (wet and dry) at two different volumes was analyzed by the investigator by visualizing the waveform. Different parameters of the tongue pressure wave were analyzed for each of the sample. They are as follows:

- Minimum pressure (in mmHg)
- Maximum pressure (in mmHg)
- Mean pressure (in mmHg)
- Slope of the tongue pressure (in mmHg/second)

- The area under peak (in mmHg/second)

The obtained data was compiled and compared across the measure of anterior and posterior tongue compression for the dry and wet swallow condition with respect peak pressure of tongue compression (measured in mm Hg).

Comparison of the measures was made across the: Age, Gender, Dry and wet swallow conditions and Two volumes of wet condition Mean values were tabulated and compared with the data from another study by Padmatharini (2011) which used the same experimental paradigm, instrument and procedure on typically developing children aged (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years)

**Statistical analysis**

The raw data was analyzed statistically using SPSS version 18.0 to compare the tongue pressure across selected age groups and conditions of swallow.

# RESULTS AND DISCUSSION

The study aimed to measure and compare the anterior and posterior pressure of tongue during dry and wet swallow conditions (thin liquid) using Two Tongue Array Module of Digital Swallowing Work Station Model 7120 of Kay Pentax in children with Spastic Cerebral palsy aged 4 to 5 years, and compare the performance across:

- Gender (Males & Females)
- Age (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years)
- Swallowing tasks (dry & wet swallow)
- Different volumes in wet swallow task (5ml & 10 ml)

One other aim of the study was to compare the results obtained for children with Spastic Cerebral Palsy in this study with the established norms on typically developing children in the age range of 4 to 5 years using the same experimental design and instrument by Padmatharini (2011) (from whom consent is obtained). The results of the present study is presented and discussed under the following sections:

1) Comparison between age groups & genders.
2) Comparison of anterior and posterior tongue pressure across various conditions of swallow for various measures derived.

***Comparison between age groups and genders:***

The measures of tongue pressure considered in the present study are

- Minimum pressure (in mmHg)
- Maximum pressure (in mmHg)

- Mean pressure (in mmHg)
- Slope of the tongue pressure (in mmHg/second)
- The area under peak (in mmHg/second)

In this section, the mean scores obtained for different tongue pressure measures between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the two genders) are discussed.

1) *Minimum, Maximum and Mean Pressure (in* mmHg)

Minimum tongue pressure *(in* mmHg) is the pressure applied during the initial process of swallow and the initiation or readiness of the tongue to position itself on the palate during the act of swallowing. Whereas the maximum tongue pressure *(in* mmHg) indicates the maximum or optimum pressure which is applied by the tongue on palate as a squeezing action before propelling the bolus. The mean tongue pressure *(in* mmHg) is defined as the pressure value at the apex of the waveform during the execution of swallow.

The mean and standard deviation of the tongue pressure measures for two age groups, (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and the genders (Males vs. Females) were computed and presented in Table 2, which shows the mean and standard deviation (SD) of the minimum, maximum and mean pressure for both the age groups.

Table 2

*Mean and SD for the minimum, maximum and mean tongue pressure in children with Spastic CP (in mmHg) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females)*

| | | | Position of Bulb | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Anterior | | | Posterior | | |
| Swallow condition | Age group | TPM | Male | Female | Total Mean | Male | Female | Total Mean |
| DS | *> 4.0 to ≤ 4.6 years* | Min | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| | | Max | 5.62 (2.00) | 8.85 (2.41) | 6.69 (2.52) | 4.49 (1.44) | 6.58 (2.23) | 5.19 (1.85) |
| | | Mean | 0.73 (0.13) | 0.91 (0.28) | 0.79 (0.18) | 0.32 (3.28) | 0.81 (0.07) | 0.48 (0.34) |
| | *>4.6 years to ≤ 5.0 years* | Min | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| | | Max | 15.50 (6.41) | 20.72 (7.76) | 17.24 (6.64) | 7.98 (3.98) | 11.53 (3.57) | 9.16 (3.93) |
| | | Mean | 1.36 (0.34) | 1.68 (0.61) | 1.46 (0.41) | 0.79 (0.16) | 1.42 (0.87) | 1.00 (0.52) |
| W5 | *> 4.0 to ≤ 4.6 years* | Min | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| | | Max | 3.79 (0.89) | 7.79 (3.90) | 5.12 (2.79) | 3.20 (1.23) | 6.09 (2.94) | 4.16 (2.20) |
| | | Mean | 0.66 (0.15) | 0.84 (0.37) | 0.72 (0.22) | 0.31 (0.20) | 0.56 (0.27) | 0.40 (0.23) |
| | *>4.6 years to ≤ 5.0 years* | Min | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| | | Max | 13.42 (2.89) | 25.77 (0.64) | 17.5 (6.76) | 8.04 (3.54) | 11.53 (3.57) | 9.20 (3.65) |
| | | Mean | 1.62 (0.57) | 1.58 (0.75) | 1.61 (0.55) | 0.95 (0.48) | 1.26 (1.11) | 1.05 (0.64) |
| W10 | *> 4.0 to ≤ 4.6 years* | Min | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| | | Max | 4.13 (0.77) | 16.74 (8.74) | 8.33 (7.62) | 3.65 (1.08) | 7.67 (0.70) | 4.99 (2.25) |
| | | Mean | 0.56 (0.28) | 1.14 (0.04) | 0.75 (0.37) | 0.44 (0.23) | 0.82 (0.08) | 0.57 (0.26) |
| | *>4.6 years to ≤ 5.0 years* | Min | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| | | Max | 12.18 (3.92) | 25.77 (0.64) | 16.7 (7.65) | 3.50 (2.16) | 11.49 (3.63) | 6.16 (4.73) |
| | | Mean | 1.77 (1.04) | 2.09 (0.02) | 1.88 (0.82) | 0.73 (0.19) | 1.39 (0.92) | 0.95 (0.55) |

** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow, TPM- Tongue Pressure Measure*

A difference in mean score for maximum and mean pressure across the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) is evident. The younger age group (> 4.0 to ≤ 4.6 years) obtained lesser values of maximum and mean pressure than that of the older age group (>4.6 years to ≤ 5.0 years). The gender wise comparison showed that females obtained slightly better maximum and mean pressure values than males. Robbins, Levine, Wood, Roecker and Luschei (1995) stated that swallowing pressures remain similar across the life span. However Youmans and Stierwalt (2006) indicated that males had significantly higher maximum isometric pressures than females, and the youngest group had significantly higher maximum pressures than the oldest group. Mean swallowing pressures and percentage of maximum isometric pressures used during swallowing differed as a function of bolus type but did not differ as a function of age or gender.

The obtained tongue pressure measures for both conditions (age and gender) were then compared with the established norms on typically developing children in the age range of 4 to 5 years using the same experimental design and instrument by Padmatharini (2011). Table 3 shows the Mean and SD for the minimum, maximum and mean pressure for typically developing children from the study conducted by Padmatharini in 2011 (with informed consent) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females).

Table 3

*Mean and SD for the minimum, maximum and mean pressure in typically developing children (in mmHg) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females)*

| MEASURE | POT | 4.0 to 4.6 | | | ≥4.6 to 5.0 | | | Males | | | Females | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DS | W5 | W10 | DS | W5 | W10 | DS | W5 | W10 | DS | W5 | W10 |
| Min | Ant | 0.83 (1.19) | 0.44 (0.52) | 0.70 (1.29) | 1.11 (0.97) | 0.76 (0.85) | 1.14 (1.03) | 1.07 (0.99) | 0.84 (0.79) | 0.77 (1.02) | 0.87 (1.18) | 0.37 (0.58) | 1.07 (1.33) |
| | Post | 0.64 (0.59) | 0.75 (0.73) | 0.58 (0.42) | 0.83 (0.72) | 0.6 (1.13) | 1.04 (0.81) | 0.81 (0.68) | 0.87 (0.61) | 0.86 (0.71) | 0.67 (0.65) | 0.85 (1.20) | 0.76 (0.66) |
| Max | Ant | 24.29 (18.26) | 21.68 (13.26) | 21.48 (13.26) | 21.99 (10.75) | 17.23 (8.58) | 18.45 (10.4) | 25.84 (12.31) | 20.92 (10.96) | 20.27 (12.64) | 20.46 (16.9) | 17.99 (11.63) | 19.67 (13.53) |
| | Post | 13.99 (8.25) | 13.21 (5.46) | 12.79 (7.31) | 15.16 (8.04) | 11.96 (5.81) | 12.62 (7.13) | 15.57 (6.43) | 12.62 (4.94) | 12.00 (7.34) | 13.59 (9.49) | 12.56 (6.33) | 13.40 (7.03) |
| Mean | Ant | 11.93 (6.80) | 9.99 (5.40) | 10.48 (5.70) | 11.09 (5.36) | 8.50 (4.34) | 9.88 (5.96) | 13.52 (5.82) | 10.16 (4.70) | 10.89 (4.90) | 9.51 (5.78) | 8.34 (5.04) | 9.48 (6.58) |
| | Post | 6.46 (3.02) | 6.02 (1.17) | 5.82 (2.12) | 8.12 (4.64) | 5.75 (3.25) | 5.96 (2.37 | 7.18 (2.68) | 5.88 (1.91) | 5.89 (2.47) | 7.40 (4.00) | 5.91 (3.04) | 5.89 (2.02) |

** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow, POT- Position of Tongue*

**Slope of the Pressure Wave**

Slope measures of the tongue pressure wave are calculated by dividing the changes in pressure (mmHg) over time (seconds). Onset of pressure in the respective sensor marked the beginning of the slope and the peak pressure marked the endpoint of the slope. Mean and SD for the mean slope of tongue pressure wave in children with Spastic CP (in mmHg) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females) were calculated. It can be noted comparison the mean slope of the anterior tongue pressure was more than the posterior in all the swallow conditions.

The obtained slopes of tongue pressure wave for both conditions (age and gender) were then compared with the established norms by Padmatharini (2011). Mean and SD for the Slope of tongue pressure wave in typically developing children (in mmHg) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females) are presented in Table 5 Results showed that pressure slopes were steeper in children with Spastic CP than that of the typically developing children indicating poor onset and offset of swallowing in the children with Spastic CP. The overall wave morphology was poor when compared to the typically developing children indicating impaired swallowing abilities in children with Spastic CP.

Table 4

*Mean and SD for the mean slope of tongue pressure wave in children with Spastic CP (in mmHg) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females)*

| Swallow condition | TPM | | Position of Bulb | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Anterior | | | Posterior | | |
| | | Age group | M | F | Total Mean | M | F | Total Mean |
| DS | Slope | *> 4.0 to ≤ 4.6 years* | 0.01 (0.06) | 0.12 (0.10) | 0.04 (0.08) | -0.02 (0.03) | -0.00 (0.00) | -0.02 (0.02) |
| | | >4.6 years- 5 years | 0.05 (0.09) | 0.18 (0.06) | 0.09 (0.10) | -0.00 (0.37) | -0.02 (0.02) | -0.01 (0.29) |
| W5 | Slope | *> 4.0 to ≤ 4.6 years* | -0.02 (0.19) | 0.07 (0.17) | 0.00 (0.17) | -0.04 (0.05) | 0.00 (0.01) | -0.02 (0.04) |
| | | >4.6 years- 5 years | -0.40 (0.64) | 0.069 (0.98) | -0.24 (0.56) | -0.09 (0.33) | -0.00 (0.00) | -0.06 (0.26) |
| W10 | Slope | *> 4.0 to ≤ 4.6 years* | 0.02 (0.52) | 0.20 (0.00) | 0.08 (0.09) | -0.01 (0.03) | 0.28 (0.40) | 0.08 (0.23) |
| | | >4.6 years- 5 years | -0.07 (0.09) | -0.49 (0.89) | -0.21 (0.46) | 0.02 (0.03) | -0.56 (0.79) | -0.17 (0.46) |

** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow, TPM-Tongue Pressure Measure*

Table 5

*Mean and SD for the Slope of tongue pressure wave in typically developing children (in mmHg) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females)*

| SWALLOW CONDITION | | | *Slope* (in mmHg/sec) *Anterior* | *Posterior* |
|---|---|---|---|---|
| DS Mean (SD) | AGE GROUP | > 4.0 to ≤ 4.6 years | 0.62 (3.59) | 1.23 (1.99) |
| | | >4.6 years to ≤ 5.0 years | 1.27 (2.87) | 0.35 (5.78) |
| | GENDER | Males | 0.53 (3.88) | 0.52 (2.53) |
| | | Females | 1.12 (2.86) | 1.08 (5.51) |
| W5 Mean (SD) | AGE GROUP | > 4.0 to ≤ 4.6 years | 0.37 (2.57) | 0.17 (2.01) |
| | | >4.6 years to ≤ 5.0 years | 1.48 (4.61) | 0.91 (2.94) |
| | GENDER | Males | 1.48 (2.67) | 1.27 (2.48) |
| | | Females | 0.37 (4.51) | 0.53 (2.41) |
| W10 Mean (SD) | AGE GROUP | > 4.0 to ≤ 4.6 years | 0.54 (2.78) | 1.00 (2.78) |
| | | >4.6 years to ≤ 5.0 years | 1.64 (3.76) | 1.58 (3.20) |
| | GENDER | Males | 1.07 (3.46) | 0.08 (3.02) |
| | | Females | 1.10 (3.23) | 0.60 (3.47) |

** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow*

**Area under Curve of the pressure wave**

The mean and standard deviation values of the area under pressure curve for children with Spastic CP are shown in the Table 6**.** The obtained data shows that there is a difference in mean score for area of pressure across the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) compared. The younger age group (> 4.0 to ≤ 4.6 years) obtained lesser values than that of the older age group (>4.6 years to ≤ 5.0 years). The gender wise comparison also shows a difference between the two groups. It was observed that the males showed lesser mean values than the females indicating reduced speed of swallowing in males than females.

The mean area of the pressure wave for both conditions considered (age and gender) were then compared with the norms established by Padmatharini (2011) on typically developing children. Table 7 shows the Mean and SD for area under curve for the pressure wave of typically developing children from the study conducted by Padmatharini in 2011. The results showed that the area of pressure wave in children with Spastic CP was more than that of the typically developing children indicating slow and extended period of swallowing in children with Spastic CP. Similar results were obtained by Senner, Logemann, Zecker and Gaebler (2004) who found reduced rate of swallowing in children with CP when compared to typically developing children.

Table 6

*Mean and SD for the Area under curve of tongue pressure wave in children with Spastic CP (in mmHg/sec) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females)*

| Swallow condition & TPM | | AGE GROUP | Position of Bulb: Anterior M | Anterior F | Anterior Total Mean | Posterior M | Posterior F | Posterior Total Mean |
|---|---|---|---|---|---|---|---|---|
| DS | AUC | *> 4.0 to ≤ 4.6 years* | 5.55 (0.86) | 7.23 (2.16) | 6.11 (1.46) | 3.76 (1.68) | 5.84 (0.20) | 4.45 (1.69) |
| | | *>4.6 years to ≤ 5.0 years* | 9.25 (4.18) | 13.09 (4.87) | 10.53 (4.38) | 6.29 (1.32) | 11.17 (6.90) | 7.92 (4.11) |
| W5 | AUC | *> 4.0 to ≤ 4.6 years* | 4.98 (0.76) | 6.71 (2.89) | 5.56 (1.68) | 6.01 (1.40) | 9.49 (4.94) | 7.17 (3.05) |
| | | *>4.6 years to ≤ 5.0 years* | 12.81 (4.46) | 18.71 (3.05) | 14.77 (4.80) | 9.17 (3.53) | 12.73 (4.69) | 10.36 (3.90) |
| W 10 | AUC | *> 4.0 to ≤ 4.6 years* | 5.08 (0.70) | 9.09 (0.46) | 6.42 (2.15) | 2.54 (1.56) | 6.51 (0.73) | 3.86 (2.40) |
| | | *>4.6 years to ≤ 5.0 years* | 17.94 (9.72) | 16.30 (0.34) | 17.3 (7.58) | 4.18 (2.10) | 10.89 (7.30) | 6.42 (5.03) |

** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow*

Table 7

*Mean and SD for the Area under curve of tongue pressure wave in typically developing children (in mmHg/sec) between the two age groups (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years) and between the genders (Males vs. Females)*

| SWALLOW CONDITION | | | *Area Under Curve* (in mmHg/sec) *Anterior* | *Posterior* |
|---|---|---|---|---|
| DS | AGE GROUP | > 4.0 to ≤ 4.6 years | 8.86 | 4.79 |
| | | | (8.02) | (3.95) |
| | | >4.6 years to ≤ 5.0 years | 8.60 | 5.83 |
| | | | (5.75) | 4.16) |
| | GENDER | Males | 11.27 | 5.80 |
| | | | (7.00) | (3.88) |
| | | Females | 6.19 | 4.83 |
| | | | (5.93) | (4.23) |
| W5 | AGE GROUP | > 4.0 to ≤ 4.6 years | 7.01 | 4.70 |
| | | | (4.20) | (2.55) |
| | | >4.6 years to ≤ 5.0 years | 5.09 | 3.58 |
| | | | (3.33) | (2.59) |
| | GENDER | Males | 7.25 | 4.27 |
| | | | (3.95) | (2.60) |
| | | Females | 4.86 | 4.10 |
| | | | (3.47) | (2.66) |
| W10 | AGE GROUP | > 4.0 to ≤ 4.6 years | 6.12 | 3.67 |
| | | | (4.19) | (1.78) |
| | | >4.6 years to ≤ 5.0 years | 6.11 | 3.66 |
| | | | (4.85) | (1.72) |
| | GENDER | Males | 6.40 | 3.78 |
| | | | (3.66) | (2.11) |
| | | Females | 5.84 | 3.56 |
| | | | (5.26) | (1.30) |

** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow*

The anterior and posterior pressure for all the measures shows a greater difference across the swallow conditions. When Freidman test was done to analyze the performance across two age groups (4.0-4.5 years and 4.6- 5.0 years) for all the tongue pressure measure including minimum, maximum and mean tongue pressure, slope of the pressure wave and area under curve of the pressure wave. It was noted that there was a significant difference (p= 0.000) across the age groups. This implies that the anterior and posterior tongue pressures for dry swallow and wet swallow (5ml & 10 ml) is significantly different across two age groups of the individuals with spastic CP. Freidman test was again done to analyze the performance across genders & a significant difference (p= 0.000) was found between males and females.. Hence the anterior and posterior tongue pressures for dry swallow and wet swallow (5ml & 10 ml) is significantly different across genders indicating better performance in females than males.

From the comparison of all the tongue pressure measures across the two age groups ($> 4.0$ to $\leq 4.6$ years and $>4.6$ years to $\leq 5.0$ years) and across the two genders, it can be concluded that there is a difference in mean score for all the measures except minimum pressure and slope of the tongue pressure wave. When the mean scores of the children with Spastic CP were compared to that of the typically developing children, it was evident that the children with Spastic CP obtained poorer scores than the other group in the measures of minimum pressure, maximum pressure, mean pressure, slope of the pressure wave and area under curve of the pressure wave. This can be attributed to the oro motor dysfunctions in children with CP (Gangil, Patwari, Aneja, Ahuja & Anand, 2001 & Senner, Logemann, Zecker & Gaebler-Spira, 2004)

Further statistical analysis using Mann- Whitney U test was done to find out if there is any statistically significant difference across the age groups and across the genders in the measures analyzed in the study. The results indicated that there was significant difference in certain parameters across the two age groups and across the genders which is indicated in table. 8.

Table 8

*Results of Mann- Whitney U test across the two age groups.*

| Measures | Z value | P value |
|---|---|---|
| DS Anterior Maximum | 2.807 | 0.005 |
| DS Anterior Mean | 2.807 | 0.005 |
| DS Posterior Mean | 2.005 | 0.045 |
| DS Posterior AUC | 2.166 | 0.030 |
| W5 Anterior Maximum | 2.887 | 0.004 |
| W5 Anterior Mean | 2.727 | 0.006 |
| W5 Anterior AUC | 2.887 | 0.004 |
| W5 Posterior Maximum | 2.406 | 0.016 |
| W5 Posterior Mean | 2.246 | 0.025 |
| W10 Anterior Maximum | 2.082 | 0.037 |
| W10 Anterior Mean | 2.562 | 0.010 |
| W10 Anterior AUC | 2.562 | 0.010 |

** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow*

Results on typically developing children by Padmatharini (2011) showed that there was no significant difference between the two age groups of typically developing children across the swallow task (p= 0.182). But the results of present study show a significant difference across the age groups in Spastic CP group in the measures of maximum, mean and area under curve of the pressure wave. This may be attributed to improved tongue

strength in the older age group (>4.6 years to ≤ 5.0 years) when compared to that of the younger age group (> 4.0 to ≤ 4.6 years) of children with Spastic CP as a function of drooling, neurological involvement and therapy.

The results of Mann-Whitney U test showed significant difference only for the measures mentioned in Table 9. Padmatharini (2011) found that there is no significant difference across gender (p= 0.205) in typically developing children. Although there was a difference noted in certain pressure measures, overall there was no significant difference across gender. A study conducted by Youmans and Stierwalt (2009) on ninety-six participants (48 males, 48 females; 20–79 years of age) showed that women showed significantly higher pressures than men implying women used a significantly higher percentage of tongue strength to swallow than men.

Table 9

*Results of Mann- Whitteny U test across the two age gender.*

| Measures | Z value | P value |
|---|---|---|
| DS Anterior Slope | 2.142 | .032 |
| W10 Anterior Maximum | 2.208 | .027 |
| W10 Posterior Maximum | 2.717 | .007 |
| W10 Posterior AUC | 2.378 | .017 |

** DS- Dry Swallow, W10- 10 ml Wet Swallow*

***Comparison of anterior and posterior tongue pressure across various conditions of swallow***

The obtained measures of tongue pressure in the anterior and posterior pressure was compared across various conditions of swallow for five measures. Two different bolus types (dry and wet) and two different volumes (5ml and 10 ml) were compared for the following measures

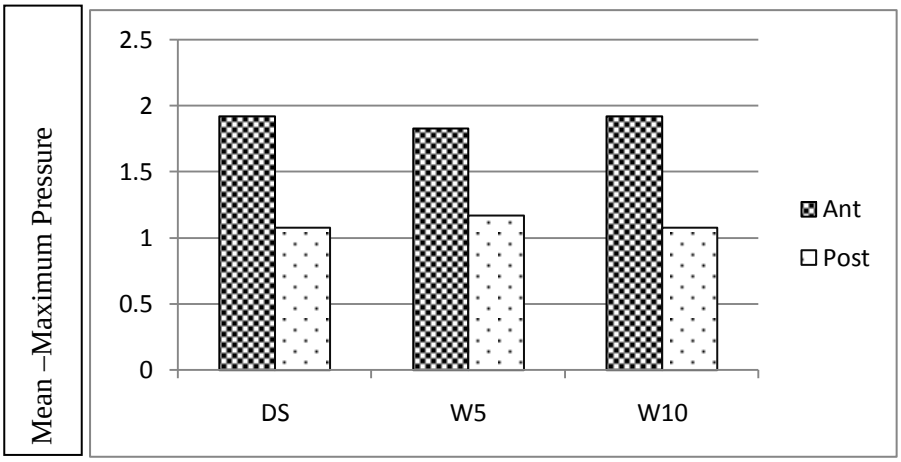
- Minimum tongue pressure
- Maximum tongue pressure
- Mean tongue pressure
- Slope of waveform
- Area under curve of the waveform

**Minimum Tongue Pressure**

The anterior and posterior mean minimum of tongue pressure across all the bolus type (dry and wet) and volume (5ml and 10 ml) was 0.000 mmHg irrespective of the age and gender, indicates that there is no difference in the minimum pressure across the conditions considered in the study. It can be inferred that the pressure applied during the initial process of swallow was very lower than the minimum pressure required for the sensors of the two tongue array bulb to detect. It may also be possible that these children did not produce an initial pressure which is required for squeezing action to produce saliva during dry swallow and to hold the bolus in the mouth for wet swallow till the investigator's instruction to swallow. This may be due to the oro motor dysfunction in children with Spastic CP (Waterman, Koltai, Downey, & Cacace, 1992 & Mirrett, Riski, &

Glascott, 1994). Hence the minimum tongue pressure cannot be considered as a measure which is sensitive to the bolus type and volume in children with Spastic CP.

**Maximum Tongue Pressure:**




** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow, Ant- Anterior, Post-Posterior*

*Figure 3.* Comparison of Mean-Maximum Pressure across three conditions

Figure 3 shows the comparison of anterior and posterior mean maximum tongue pressure across the three different swallow conditions. It can be inferred that anterior pressure was more than the posterior pressure across the swallowing conditions. Padmatharini in 2011 reasoned that probably typically developing children used tipper pattern of swallow. It can be inferred from the results of the present study that the children with Spastic CP also used tipper pattern of swallow as the anterior pressure is more compared to that of posterior pressure.

Further, Friedman test was carried out to test for statistical significance across the swallowing conditions. But there is no statistical significance across the three conditions

($\chi^2$=1.826 *p*=.401).When Wilcoxon Signed Rank test was done to find whether there is any significant difference between the anterior and posterior tongue pressure measures across the three swallowing conditions, it was found that there was a significant difference noted between the anterior and posterior maximum pressure across all the conditions i.e, for Dry Swallow, $|z| = 2.982$ *p*=0.003, for 5 ml Wet Swallow $|z| = 2.668$, *p*=0.008 and for 10 ml Wet Swallow $|z| = 2.981$*p*=0.003. This implies that the anterior pressure is significantly more than the posterior pressure for the mean maximum pressure.

The mean maximum pressure of the dry swallow, 5 ml wet swallow and 10 ml swallow of the present study was compared with normative obtained by Padmatharini (2011) on typically developing children using an independent sample- t test. The results show that there is a significant difference in the anterior and posterior pressure across all the swallow conditions. Table 10 shows the $|t|$ and *p* values of independent sample- t test for anterior and posterior mean maximum pressure of children with Spastic CP and typically developing children.

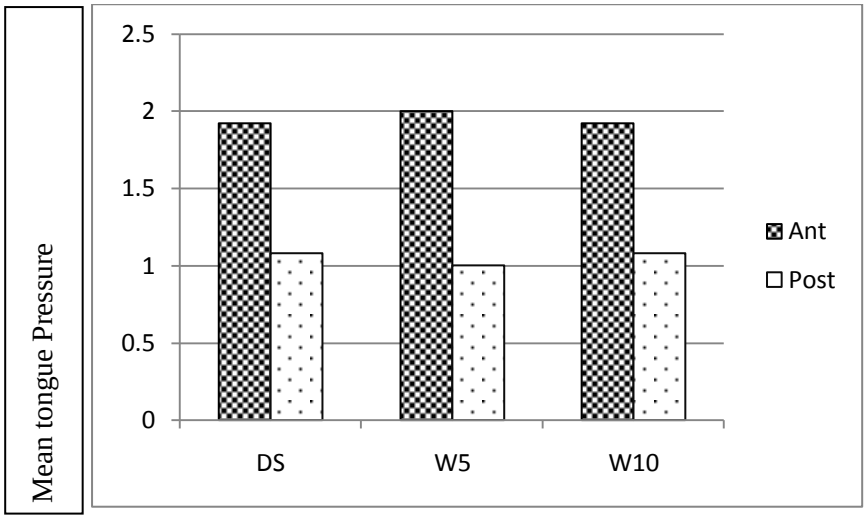
Table 10

*Comparison between the mean maximum pressure of children with spastic CP and typically developing children*

| Swallow conditions | Anterior | | Posterior | |
|---|---|---|---|---|
| | $\|t\|$ | *P* | $\|t\|$ | *P* |
| Dry swallow | 5.272 | 0.000* | 7.129 | 0.000* |
| 5ml wet swallow | 2.835 | .016* | 4.721 | 0.001* |
| 10 ml wet swallow | 2.845 | 0.016* | 6.674 | 0.000* |

*****$p \leq 0.05$ *indicating significant difference*

**Mean Tongue Pressure:**




** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow, Ant- Anterior, Post- Posterior*

*Figure 4.* Comparison of Mean pressure of the wave across three conditions

Figure 4 shows the comparison of anterior and posterior mean tongue pressure across the three different swallow conditions. It can be inferred that anterior pressure was more than the posterior pressure across the swallowing conditions. Further, Friedman test was carried out to test if there was any statistical significance across the swallowing conditions. But there is no statistical significance across the three conditions ($\chi^2$=2.571 *p*=.446). Wilcoxon Signed Rank test was done to find whether there is any significant difference between the anterior and posterior tongue pressure measures across the three swallowing conditions. It was found that there was a significant difference noted between the anterior and posterior mean pressure across all the conditions i.e, for Dry Swallow, $|z| = 2.825$ *p*=0.005, for 5 ml Wet Swallow $|z| = 3.061$, *p*=0.002 and for 10 ml Wet Swallow $|z| = 2.432$, *p*=0.015. This implies that the anterior pressure is significantly more than the posterior pressure for the mean pressure.

The mean pressure of the dry swallow, 5 ml wet swallow and 10 ml swallow of the present study was then compared with normative obtained by Padmatharini (2011) on typically developing children using an independent sample- t test. The results show that there is a significant difference in the anterior and posterior pressure across all the swallow conditions. Table 11 shows the $|t|$ and *p* values for anterior and posterior mean maximum pressure of children with Spastic CP and typically developing children.

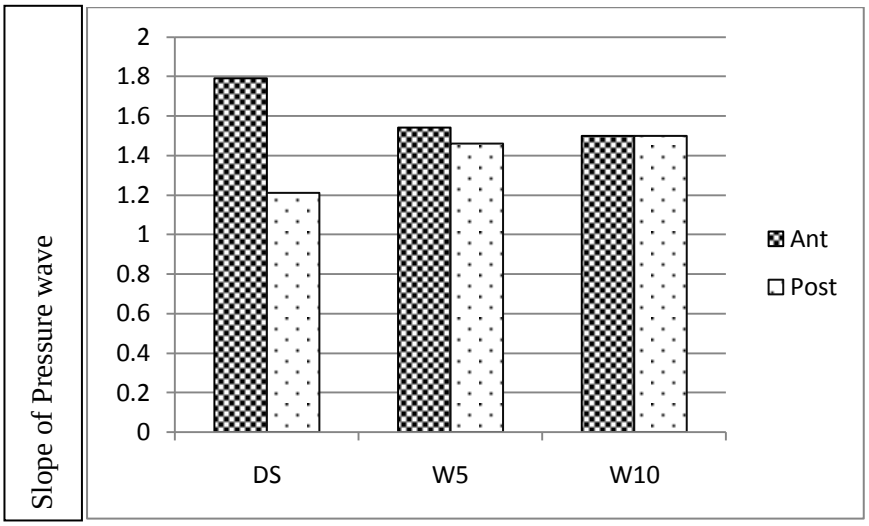
Table 11

*Comparison between the mean pressure of children with spastic CP and typically developing children*

| Swallow conditions | Anterior | | Posterior | |
|---|---|---|---|---|
| | $\|t\|$ | *P* | $\|t\|$ | *P* |
| Dry swallow | 78.554 | 0.000* | 43.168 | 0.000* |
| 5ml wet swallow | 44.219 | 0.000* | 30.243 | 0.001* |
| 10 ml wet swallow | 35.477 | 0.000* | 53.464 | 0.000* |

***p≤0.05 indicating significant difference*

**Slope of pressure wave:**




** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow, Ant- Anterior Post-Posterior*

*Figure 5.* Comparison of Slope of pressure wave across three conditions

Figure 5 shows the comparison of anterior and posterior mean slope of tongue pressure wave across the three different swallow conditions. It shows that anterior mean slope of tongue pressure wave for dry swallow and 5 ml wet swallow conditions were more than that of posterior, whereas it was equal for the 10 ml wet swallow condition. When compared across the three conditions, the anterior slope of dry swallow is more than that of wet swallow condition. It can be inferred that the children with Spastic CP require more strength and duration to initiate dry swallow than wet swallow. The posterior mean slope of tongue pressure wave for dry swallow was lesser than that of the wet swallow conditions which indicates that the maximum pressure is achieved in shorter duration for dry swallow when compared to the other wet conditions.

Further, Friedman test was carried out to test if there was any statistical significance across the swallowing conditions. But there is no statistical significance

across the three conditions ($\chi^2$=2.571, *p*=.276).When Wilcoxon Signed Rank test was done to find if there is any significant difference between the anterior and posterior tongue pressure measures across the three swallowing conditions, it was found that there was a significant difference noted between the anterior and posterior maximum pressure across all the conditions i.e, for Dry Swallow, $|z|$= 1.958 *p*=0. .050. But there was no significant difference for 5 ml Wet Swallow $|z|$=.178, *p*=0.859and for 10 ml Wet Swallow $|z|$= .153 *p*=0. .878. This implies that the anterior pressure is significantly more than the posterior pressure for the mean slope of tongue pressure wave for dry swallow condition.

The mean slope of tongue pressure wave of the dry swallow, 5 ml wet swallow and 10 ml swallow of the present study was again compared with normative obtained by Padmatharini (2011) on typically developing children using an independent sample- t test. The results show that there is a significant difference in the anterior and posterior slope of pressure wave across all the swallow conditions indicating a slow onset and offset of the swallow in children with Spastic CP. Table 12 shows the $|t|$ and *p* values for anterior and posterior mean maximum pressure of children with Spastic CP and typically developing children.

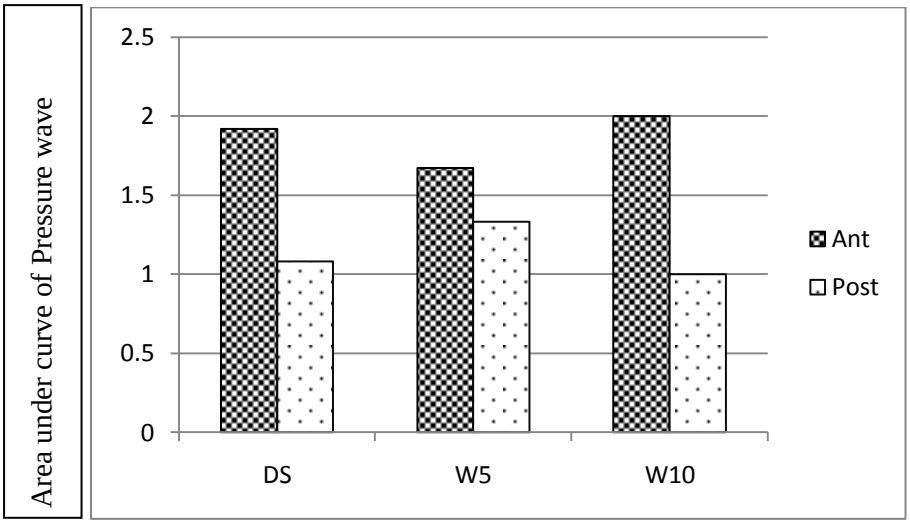
Table 12

*Comparison between the mean slope of pressure wave of children with spastic CP and typically developing children*

| Swallow conditions | Anterior | | Posterior | |
|---|---|---|---|---|
| | \|t\| | *P* | \|t\| | *P* |
| Dry swallow | 31.089 | 0.000* | -.512 | 0.000* |
| 5ml wet swallow | 53.464 | 0.000* | 3.466 | 0.005* |
| 10 ml wet swallow | 3.059 | .011* | 2.689 | 0.021* |

***p≤0.05 indicating significant difference*

**Area under Curve:**




** DS- Dry Swallow, W5- 5ml Wet Swallow, W10- 10 ml Wet Swallow, Ant- Anterior, Post-Posterior*

*Figure 6.* Comparison of Mean-Area under Curve across three conditions

Figure 6 shows the comparison of anterior and posterior mean-area under curve for pressure wave across the three different swallow conditions. Further, Friedman test was carried out to test if there was any statistical significance across the swallowing conditions. But there is no statistical significance across the three conditions ($\chi^2$=1.613 $p$=.446).When Wilcoxon Signed Rank test was done to find whether there is any significant difference between the anterior and posterior tongue pressure measures across the three swallowing conditions, it was found that there was a significant difference noted between the anterior and posterior mean-area under curve for pressure wave across all the conditions i.e, for Dry Swallow, $|z| = 2.805$ $p$=0.005, and for 10 ml Wet Swallow $|z| = 3.059$ $p$=0.002. No significant difference was noted for 5 ml Wet Swallow $|z| = 1.098$, $p$=0.272. This implies that the anterior pressure is significantly more than the posterior pressure for the mean-area under curve of pressure wave for the dry swallow and 10 ml wet swallow condition It can be inferred that anterior mean-area was more than the posterior for dry swallow and 10 ml wet swallow indicating longer duration of contact of tongue with the palate in the anterior portion than the posterior.

The mean-area of the dry swallow, 5 ml wet swallow and 10 ml swallow of the present study was compared with normative obtained by Padmatharini (2011) on typically developing children using an independent sample- t test. The results show that there is a significant difference only in the posterior pressure of 5ml wet swallow. Table 13 shows the $|t|$ and $p$ values for anterior and posterior mean-area of children with Spastic CP and typically developing children.

Table 13

*Comparison between the Mean-Area under Curve children with spastic CP and typically developing children*

| Swallow conditions | Anterior | | Posterior | |
|---|---|---|---|---|
| | \|t\| | *p* | \|t\| | *P* |
| Dry swallow | 0.379 | 0.712 | 0.681 | 0.510 |
| 5ml wet swallow | 2.444 | .033 | 4.420 | 0.001* |
| 10 ml wet swallow | 2.620 | 0.024 | -1.212 | 0.251 |

***p≤0.05 indicating significant difference*

Overall, it was observed that children with Spastic CP showed poor performance in all the measures of tongue pressure across all the tasks when compared to typically developing children indicating swallowing ability in children with Spastic CP. The earlier studies on children with CP also showed that they exhibit impairment in their feeding skills. Senner, Logemann, Zecker and Gaebler-Spira (2004) found that children with CP tended to swallow less frequently than typically developing participants and tended to produce less saliva than typically developing controls; even though these differences were not statistically significant. Moderately to severely impaired oral-motor coordination was indicative of severity of the feeding complications in spastic cerebral palsy within the age range of 7 months to 19 years (Mirrett, Riski, & Glascott, 1994). A study conducted by Gangil, Patwari, Aneja, Ahuja and Anand (2001) showed that Oral motor dysfunction (OMD) was found in Spastic quadriplegic cerebral palsy (SQCP) who had significantly

poor feeding skill score. These impairments can be attributed to reduced tongue pressure measures compared to the typically developing children as it is known that the tongue plays a significant role in the oral and pharyngeal phases of swallowing (Hedges, Mc Lean and Thompson, 1965). Also, the tongue pressure is found to be a sensitive measure to assess the role of tongue in the act of swallowing.

Overall, there was a significant difference in the tongue pressure measures across the age groups for maximum, mean and the mean area. There was no significant difference on the measures of tongue pressure across gender. The minimum tongue pressure was not a measure sensitive to bolus type and volume in children with Spastic CP. The anterior maximum pressure was more than the posterior indicating a tipper pattern of swallow in children with Spastic CP like the typically developing children. Anterior slope was more for dry swallow compared to the wet swallow indicating that the children with Spastic CP required more strength and duration to initiate dry swallow. Whereas the posterior slopes for dry swallow was less which indicated that the maximum pressure was achieved in shorter duration for dry swallow than the wet swallow. The mean area under curve showed that anterior pressure is significantly more than the posterior pressure for the mean-area under curve for pressure wave for the dry swallow and 10 ml wet swallow condition. It can be inferred that anterior mean-area was more than the posterior across for dry swallow and 10 ml wet swallow indicating longer duration of contact of tongue with the palate at the anterior portion than the posterior. There was a significant difference noted in the maximum, mean and slope of the pressure wave between children with Spastic CP and typically developing individuals.

Hence it can be concluded that the tongue pressure measures derived for two tongue array module of Digital Swallow Station (except minimum tongue pressure) are sensitive measures which can be used to evaluate the role of tongue in swallowing in children with Spastic CP. The measures of tongue pressure in children with Spastic CP are significantly lower than that of the typically developing children of the same age (established by Padmatharini, 2011) indicating impaired swallowing skills in children with Spastic CP. Thus children with Spastic CP exhibits poor tongue pressure and slow and extended period of swallowing.

# SUMMARY AND CONCLUSIONS

The present study aimed to measure and compare the anterior and posterior pressure of tongue using Two Tongue Array Module of Digital Swallowing WorkStation Model 7120 of Kay Pentax in children with Spastic Cerebral palsy aged 4 to 5 years across:

- Gender (Males & Females)
- Age (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years)
- Swallowing tasks (dry & wet swallow)
- Different volumes in wet swallow task (5ml & 10 ml)

It also aimed to compare the results obtained for children with Spastic Cerebral Palsy in this study with that of typically developing children in the age range of 4 to 5 years established by Padmatharini (2011) using the same experimental design.

Twelve children diagnosed with *Spastic Cerebral Palsy* in the chronological age range of 4 to 5 years were considered in the present study. They were divided into 2 groups based on their chronological age (> 4.0 to ≤ 4.6 years and >4.6 years to ≤ 5.0 years). Two swallowing conditions were considered for the study which included dry swallow and wet swallow (mineral water). The wet swallow condition included two different volumes i.e. 5 ml and 10 ml.

The two tongue array module of Digital Swallow Workstation was used to obtain the measures of interest. The Two-tongue array bulb was placed in the participants's mouth to obtain the recording. The array was placed such that one bulb was rested against the anterior portion of the tongue and the other bulb, against the posterior portion of

tongue. The array was placed properly and held firmly in place by the externally extended stem by the investigator. The external stem was bent at an angle where the array enters the mouth to facilitate positioning in the mouth appropriately and comfortably, after which the waveform during the process of swallowing was recorded. The following measures were obtained

- Minimum tongue pressure (mmHg)
- Maximum tongue pressure(mmHg)
- Mean tongue pressure (mmHg)
- Slope of the pressure wave(mmHg/sec)
- Area under curve of the pressure. (mmHg/sec)

The measures obtained were subjected to statistical analysis and the following salient features were observed

- There was a significant difference in the tongue pressure measures across the age groups for maximum, mean and the mean area.
- There was no significant difference on the measures of tongue pressure across gender.
- The minimum tongue pressure was not a measure sensitive to bolus type and volume in children with Spastic CP.
- The anterior maximum pressure was more than the posterior indicating a tipper pattern of swallow in children with Spastic CP like typically developing children.
- Anterior slope was more for dry swallow compared to the wet swallow indicating children with Spastic CP required more strength and duration to initiate dry swallow. Whereas the posterior slopes for dry swallow was less which indicated

that the maximum pressure was achieved in shorter duration for dry swallow than the wet swallow.

- The mean area under curve showed that anterior pressure is significantly more than the posterior pressure for the mean-area under curve for pressure wave for the dry swallow and 10 ml wet swallow condition. It can be inferred that anterior mean-area was more than the posterior across for dry swallow and 10 ml wet swallow indicating longer duration of contact of tongue with the palate at the anterior portion than the posterior.
- There was a significant difference noted in the maximum, mean and slope of the pressure wave between children with Spastic CP and typically developing individuals.

Hence to conclude, the tongue pressure measures (except minimum tongue pressure) can be used as a sensitive measure to evaluate the role of tongue in swallowing in children with Spastic CP. It is also evident from the study that the measures of tongue pressure in children with Spastic CP are significantly lower than that of the typically developing children of the same age.

**Limitations:**

Verification with three tongue array which was not done, would have given an insight to the action of mid portion of tongue. The age group considered was 4-5 years. A wide age range with more subjects would have probably helped in commenting about the developmental trend for tongue pressure in the swallowing act in children with Spastic CP.

**Future Recommendations:**

The results of the present study suggests the need for an in depth analysis to study the different tongue functions in the act of swallowing. Further research is needed to gain knowledge on the tongue functions in the act of swallowing including the variables such as more number of subjects, different bolus type, viscosity and volume, different age groups and different types of CP.

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# APPENDIX A

## ASSESSMENT CHECKLIST FOR SPEECH & LANGUAGE DOMAIN

**Case name:** **Case No.:** **Age/sex:** **Date:**

**Language:** **Examiner:** **School/Class:**

**Class teacher/Clinician**:

**Instructions:** Rate speech and language abilities of the child for each of the items based on the scoring pattern given.

**Scoring**: **0**-Not applicable/absent; **0.5**-Totally dependent/physical/verbal prompt, **1**-Consistent & independent

**Note:** C- Comprehension; E- Expression

| Level & age group in years | Item Code | Item | Item Code | Item |
|---|---|---|---|---|
| XV 4.1-4.6 | C-18 | Understands reflexive pronouns such as myself, themselves, yourself, himself, herself, itself, e.g., he brushed his teeth himself, She took bath herself. * | E-18 | Describes short stories in simple and compound sentences |
| | C-19 | Understands quotatives, e.g., he said "She took her home", mother said "take the pencil" etc. | E-19 | Expresses demonstrative nouns such as these and those e.g., These are my books; Those are my brother's books etc. |
| | C-20 | Knows common antonyms (opposites), e.g., big x small, hard x soft, heavy x light etc. * | E-20 | Uses PNG (person, number and gender) markers, e.g., The cat is/cats are sleeping, He is/ they are sleeping, mother is sleeping , This is my glass, these are my glasses etc.* |
| | C-21 | Understands conditional clauses (if, unless), e.g., If there is picture of fan in this page, clap your hands, Unless | E-21 | Speaks of imaginary conditions such as such as "I hope, I feel……."e.g., I hope it rains, I feel that she |

| | | | | |
|---|---|---|---|---|
| | | I call your name you should not touch the picture * | | will come to play with me, etc. |
| | C-22 | Comprehends long stories when told or read and retells it and can answer content related questions based on the story | E-22 | Asks for clarification/asks for explanation, repetition etc. E.g., In a conversation with the mother or when a specific request is made if the child doesn't understand, s/he ask for repetition or explanation. |
| | C-23 | Processes longer and more complex language structures, e.g., "Can you find something that lives in a tree, has feathers and a yellow crest" etc. | E-23 | Adds new information such as elaborating in a conversation with 2-3 people, (e.g. If the mother gives a brief account of an event to another known person, which is also familiar to the child, s/he try to add new information or elaborate, which the mother has not provided) |
| **XVI 4.7-5.0** | C-24 | Understands synonyms (meanings), e.g., shut–close, sad-grief etc. | E-24 | Expresses antonyms (opposites), e.g., cry x laugh; half x full, brother is a boy, sister is a -----, etc. and synonyms, (words which are similar in meaning), e.g., shut–close, sad-grief etc.* |
| | C-25 | Understands small paragraphs | E-25 | Expresses reflexive pronouns such as myself, themselves, yourself, himself, herself, itself, e.g., He is taking the basket himself, The machine started itself etc. * |
| | C-26 | Understands jokes | E-26 | Expresses conditional clauses such as if, unless, e.g., He can't get in to the train unless it stops, If the train moves, the goat will die etc.* |
| | C-27 | Understands spatial and | E-27 | Speaks in |

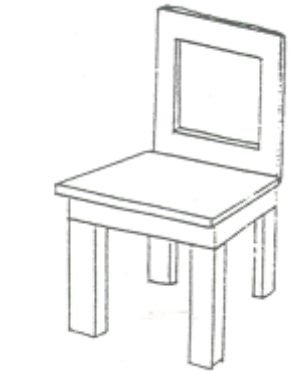
| | | | | |
|---|---|---|---|---|
| **XVII**<br>**5.1-5.6** | | temporal concepts, e.g., before/after, whole/half etc., e.g., She had half an apple, The rabbit went before the tortoise etc.* | | sentences/clauses of 8 or more words in length using since, in order that, as soon as, until, even though, although, before, after etc. e.g., Come and see me as soon as the work is finished, Don't come until you finish eating, the baby ate the cookie before I could put it on the table, let's go to the store after we eat etc. |
| | C-28 | Understands passive sentences, e.g., The rat was killed by the cat etc. | E-28 | Utters a few blends such as ks.a, skr, st, str, s., t etc. Speech is 100% intelligible. |
| **XVIII**<br>**5.7-6.0** | C-29 | Understands the concepts of left and right | E-29 | Uses quotatives, e.g., He said "she took her home", He asked "will you go in an auto or a bus", Mother is asking "You seem to have fever", "Will you take the medicine? etc. |
| | C-30 | Understands time concepts such as today/ tomorrow/yesterday, for a long time, for years, a whole week, in the meantime, sooner-later, two things at once etc.), e.g., What is the day tomorrow? Yesterday did you go to school? etc. | E-30 | Expresses hints that do not mention the intention in the request, e.g., those smell good" etc. |

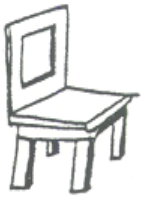
**C-18**

Understands reflexive pronouns like myself, themselves, yourself, himself, herself, itself, e.g., She brushed her teeth <u>herself</u>, She took bath <u>himself</u>.

**C-20**

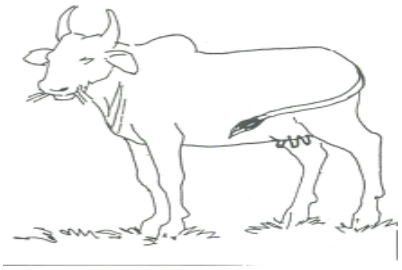
Knows common antonyms (opposites), e.g., big x small, hard x soft, heavy x light etc.





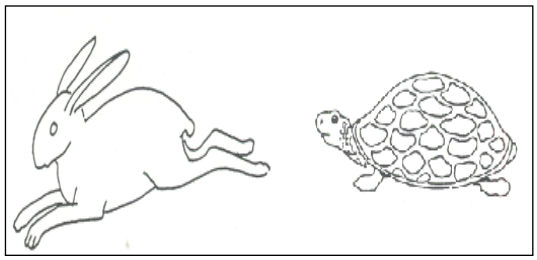
**C-21**

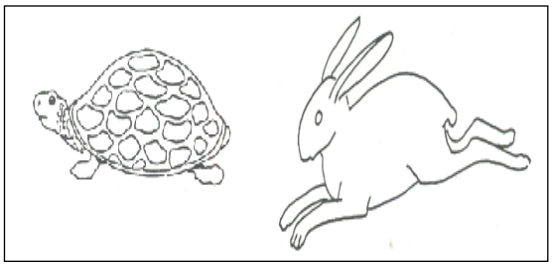
Understands conditional clauses (if, unless), e.g., If there is picture of fan in this page, clap your hands, Unless I call your name you should not touch the picture

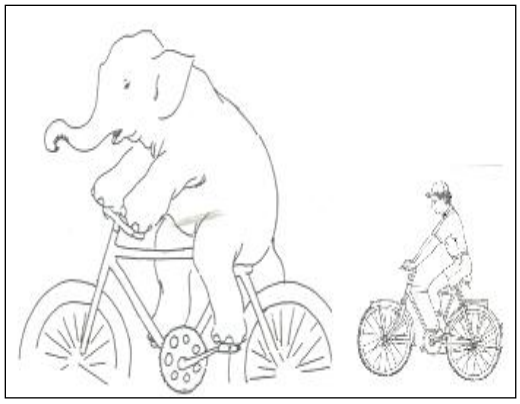


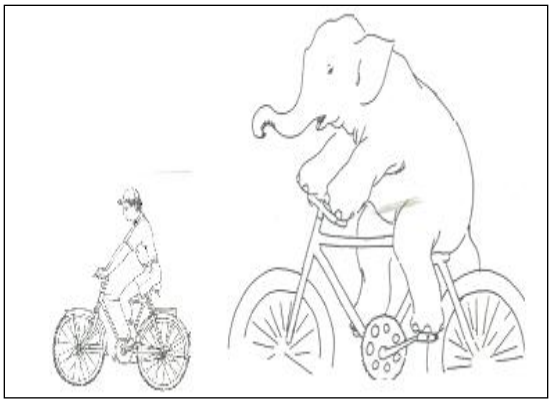
**C-27**

Understands spatial and temporal concepts, e.g., before/after, whole/half etc., e.g., The rabbit went before the tortoise etc.





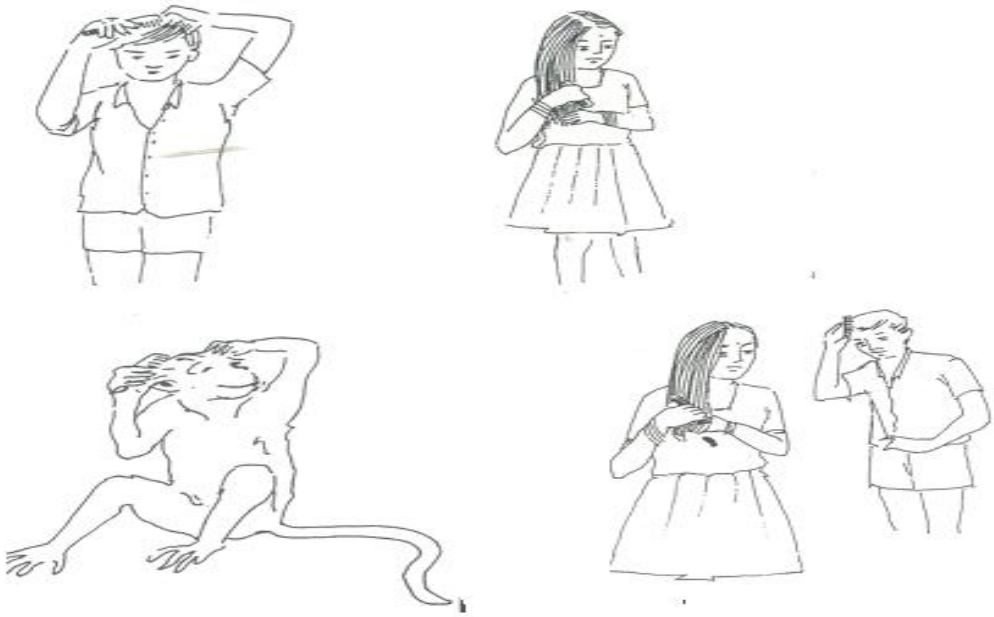




## Expression

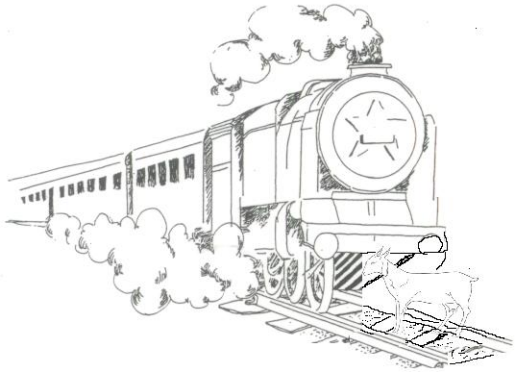
**E-25**

Expresses reflexive pronouns like myself, themselves, yourself, himself, herself, itself, e.g., he is taking his basket himself, The machine started itself, he is combing his hair himself etc .



**E-26**

Expresses conditional clauses like if, unless, e.g., he can't get in to the train unless it stops, If the train moves the goat will die.



**E-20**

Uses PNG (person, number and gender) markers, e.g., The cat is/cats are sleeping, He is/ they are sleeping, mother is sleeping, This is my glass, these are my glasses etc.

**E-24**

Knows common antonyms (opposites), e.g., big x small, hard x soft, heavy x light etc.