PERFORMANCE OF TYPICALLY DEVELOPING CHILDREN BETWEEN 4-5 YEARS ON TWO-TONGUE ARRAY MODULE USING DIGITAL SWALLOWING WORKSTATION

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A Dissertation Submitted in Part Fulfillment of
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ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI, MYSORE-570006
June, 2011

Dedicated to my
Amma , Appa , my
sweet brother and
Dr. Uma Shah
who motivated me in
each and every aspect
of my life

CERTIFICATE

This is to certify that the dissertation entitled ***"Performance of typically developing children between 4 - 5 years on Two-Tongue Array Module using Digital Swallowing Workstation"*** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No.09SLP022). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

Mysore

June, 2011

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CERTIFICATE

This is to certify that the dissertation entitled ***"Performance of typically developing children between 4 - 5 years on Two-Tongue Array Module using Digital Swallowing Workstation"*** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other university for the award of any Diploma or Degree.

Mysore,

June, 2011

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DECLARATION

This dissertation entitled ***"Performance of typically developing children between 4 – 5 years on Two-Tongue Array Module using Digital swallowing workstation"*** is the result of my own study under the guidance of Dr. R. Manjula, professor in speech language pathology, All India Institute of speech and hearing and it has not been submitted earlier at any other University for the award of any Diploma or Degree.

Mysore

June, 2011 **Register No.: 09SLP022**

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I am only one, but still I am one. I cannot do everything, but still I can do something; and because I cannot do everything I will not refuse to do the something that I can do. I thank God for my handicaps, for, through them, I have found myself, my work, and my God.

- Helen Keller

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Friendship isn't about whom you have known the longest... It's about who came, and never left your side...

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List of contents

INTRODUCTION

Breathing and eating are the most basic physiological functions that define life's beginning outside the mother's womb for new born infant. Breathing is reflexive and life sustaining but provides no other intrinsic pleasure. Eating on the other hand is partly a learned response. It requires ingestion of foods, which in newborn must be provided by an outward source. Sucking and swallowing requires a complex series of events and coordination of neurological, respiratory and gastrointestinal systems.

Classically, the process of swallowing has been divided into four consecutive stages (Logemann, 1983). They are, Oral preparatory stage, Oral stage, Pharyngeal stage and Esophageal stage

In the oral preparatory stage, food is taken into the mouth, manipulated into a cohesive bolus, and held there momentarily as it is prepared for transport. In the oral stage, the bolus is propelled posteriorly toward the oropharynx. As the bolus reaches the oropharynx, a pharyngeal swallow response is initiated, setting into motion a series of airway protective and bolus-propulsive events associated with the pharyngeal stage.

The oral preparatory phase of swallowing is a voluntary process. It is a mechanical phase that can be by-passed by dropping liquid or food into the back of the throat. The bolus is kept in the front of the mouth, against the hard palate by the tongue. The front of the tongue is elevated with its tip on the alveolar ridge. The back of the

tongue is elevated and the soft palate is pulled anteriorly against it to keep the food in the oral cavity (the airway is open and nasal breathing continues during this phase). Labial seal is maintained to prevent food from leaking out of the mouth. Buccal muscles are tense. This prevents pocketing of food. Duration of the oral-preparatory stage is variable across individuals (Logemann, 1983, 1997).

The oral stage of the swallow is also voluntary. It starts with the jaws and lips closed, and the tongue tip on the alveolar ridge. A patterned response is initiated at the end of this phase. Inspiration is reflexively inhibited at the beginning of this stage. The food is moved to the back of the mouth by the tongue via an anterior to posterior rolling motion. The anterior portion of the tongue is retracted and depressed while the posterior portion is retracted and elevated against the hard palate. When the bolus passes the anterior faucial pillars/touches the posterior wall of the pharynx, the oral stage ends and the pharyngeal stage begins as the tongue driving force or the tongue's plunger action, forces the bolus into the pharynx. Based on this action**,** Logemann (1997) divides the tongue functionally into (a) 'pharyngeal tongue' which extends from the velum to the hyoid bone and valleculae and functions during pharyngeal stage. (b) 'oral tongue' which extends from the tip to the back, adjacent to the velum and functions during the oral stage of the swallow. Overall, the oral transport stage lasts for approximately one second (Logemann, 1989, 1988; Dobie 1978).

Studies have been conducted to determine the normal variation of non swallowing isometric tongue function as a result of age and gender in healthy individuals. Crow and Ship (1996) examined the tongue strength and endurance of 99 persons with no history of

dysphagia using a handheld tongue force measurement device, the Iowa Oral Performance Instrument (IOPI). The participants, aged from 19 to 96 years, were divided into four age groups based on 20-year age intervals and participated in three trials of strength and endurance tasks. Tongue strength was significantly higher in males than in females and decreased significantly with increasing age in males but not in females. The tongue strength differed significantly between oldest group (ages 80–96) with younger age groups.

In a similar study by Youmans, Stierwalt and Clark in 2002, tongue strength measures were obtained with the IOPI for 77 healthy subjects. The variables of interest were maximum tongue strength, age, and gender. A significant negative correlation was found between tongue strength and age in the absence of any other significant results. That is, as age increased, tongue strength decreased, but there was no difference between genders as was found in some previous investigations. In a video fluoroscopic study by Shawkor, Sonies, Stone and Baum (1983) states the oral phase of swallow was studied and the total time for oral transit in normal individuals was reported to be approximately one second for all consistencies of material (Mandelstam and Lieber, 1970).

Need for the study:

The tongue contributes significantly in the oral and pharyngeal phases of swallowing. Its role includes the formation, placement and manipulation of the bolus during the oral preparatory phase and transferring the bolus posterior to the pharyngeal cavity in the oral phase of swallowing. Till date no studies have attempted to analyze the

performance of typically developing children with respect to tongue pressure generated during swallow to propel the bolus. It is a first kind of study that is done in children using thin liquids of 2 different quantities and the results of the study will be helpful in selecting the appropriate quantity in the management of children with swallowing difficulty in the oral phase.

Aim of the study:

To analyze the tongue pressure in the anterior and posterior region during swallowing of typically developing children between the age range of 4 – 5 years using Two-Tongue Array Module using Digital Swallowing Workstation Model 7120 of Kay Pentax for: Dry swallow and Wet swallow (in 2 volume of liquid)

Method:

Sixty typically developing children in the age range of 4-5 years participated in the study. Children were grouped into two depending on their age. Group 1 (4.0 - 4.6) included 15 males and 15females. Group 2 (4.7 – 5.0) included 15 males and 15 females. Informed consent was obtained from the teachers and the parents of the children, before including them in the study. Digital swallow workstation, Model 7120 by Kay Pentax was used. The Two-tongue array bulb module was used to obtain the measure of interest in the study

Implication:

The data obtained on “tongue pressure” (anterior and posterior) in typically developing children aged 4 – 5 yrs will facilitate the comparison of performance of clinical population of the same age group with oro-motor issues.

Limitations:

Two tongue array was used in this study as the size of the oral cavity of 4 – 5 yr old children were small. Verification with three tongue array could have provided an insight into the performance of the mid portion of the tongue during swallow. However three tongue array was not used in the study as the risk of eliciting gag reflex was high with the use of 3 tongue array.

METHOD

The tongue contributes significantly in the oral phase of swallowing. Its role is crucial in the formation, placement and manipulation of the bolus during the oral preparatory phase and transferring of bolus posteriorly to the pharyngeal cavity.

The study aimed to analyze the performance of typically developing children between 4 – 5 years for tongue pressure in the anterior and posterior region during swallowing using the 'Two-Tongue Array Module' of Digital Swallowing Workstation (DSW) Model 7120 by KAY PENTAX.

Aims of the study:

To analyze and compare the tongue pressure generated in the anterior and posterior region of the tongue using the 'two-tongue array module' of DSW elicited in 2 tasks (dry and wet swallow) in typically developing children across:

- Two age groups (4.0 to 4.6 yrs and ≤ 4.6 to 5.0 yrs)
- Gender (males and females)
- Swallowing tasks (dry and wet swallows)

Participants:

Sixty typically developing children in the age range of 4-5 years participated in the study. Children were grouped into two, depending on their chronological age. Group 1 (4.0 to < 4.6) included 15 males and 15 females. Group 2 (≤ 4.7 – 5.0) included 15

males and 15 females. The distribution of males and females across different age groups are depicted in Table 1.

Table1: *Distribution of subjects across different age groups*

Group	Age range (years)	Males	Females
1	4.0 to < 4.6	15	15
2	≤ 4.6 to 5.0	15	15

Inclusion of the participants in the study was based on the criteria that there should be:

- No history of swallowing disorders (based on parental interview)
- No structural and functional abnormalities in the structure of the oral cavity (based on oro motor sensory examination)
- No maxillofacial or congenital anomalies in the face and neck (based on clinical observation)
- No other organic problems or medical problems in the tongue (based on oral mechanism examination)
- No history of epilepsy or recurring epilepsy (based on parental interview)
- No complaint of hearing impairment (based on hearing screening test)
- No speech and language delays [based on the performance on the "Assessment checklist for speech and language domain – Phase 2" by Swapna, Prema and Geetha, (2010)]

Informed consent was obtained from the teachers and the parents of the children, before including them in the study.

Instrumentation:

Digital Swallow Workstation, Model 7120 by Kaypentax was used which a powerful, multi-functional system containing a robust set of features that have been integrated into one platform for the assessment of clients with dysphagia and for research purpose. The Digital Swallowing Workstation has a physiologic data acquisition and visual feedback system which provides real-time displays of critical parameters related to swallowing function. Figure 1 shows the picture of Digital Swallowing Workstation.

Figure 1. Digital Swallowing Workstation

The Two-tongue array bulb module was used in this study to obtain the measure of interest in the study.

Figure 2. Two tongue array bulb

The two bulb tongue array was placed inside the mouth of the participant. Once it was properly placed, it was held firmly in place by its externally extended stainless steel stem by the caregiver/investigator. It was ensured that it remained in the place chosen for the study during the task. The array was placed with the substrate resting against the hard palate and the bulbs oriented downward so that the tongue makes direct contact with them when swallowing or pushing against them. The external stem could be bent at an angle where the array enters the mouth to facilitate positioning in the mouth and holding stem of the array. One bulb of the array rested against the anterior portion of the tongue and the second bulb rested against the posterior portion of the tongue. *Figure 2* shows the picture of 2 tongue array bulb. The materials used to assess the wet swallow included:

- Measuring cup
- Purified water (thin liquid)

Procedure:

Preparation of the participant:

Before performing the test, the tongue array was subjected to calibration as per the prescribed procedure suggested for the operation of this module in DSW. The knob of the module was opened to inflate the bulbs. Once the bulbs were inflated to the pre set value, the knob was closed tightly and then calibrated as per the norms specified for the module

.

The child was made to sit comfortably on a chair. The child was made to relax and the child was instructed not to move the tongue after the placement of the tongue array. They were instructed to swallow on instruction by the investigator. In the instance of wet swallow, the child was instructed to retain the water in the mouth until instructed by the investigator to swallow.

The specific swallowing tasks recorded for each participant were as follows:

Dry swallow: defined as the swallow that involves no ingestion of external food or liquid. Each participant performed one dry swallow. The child was instructed to swallow his/her saliva as normally as possible without any extra effort.

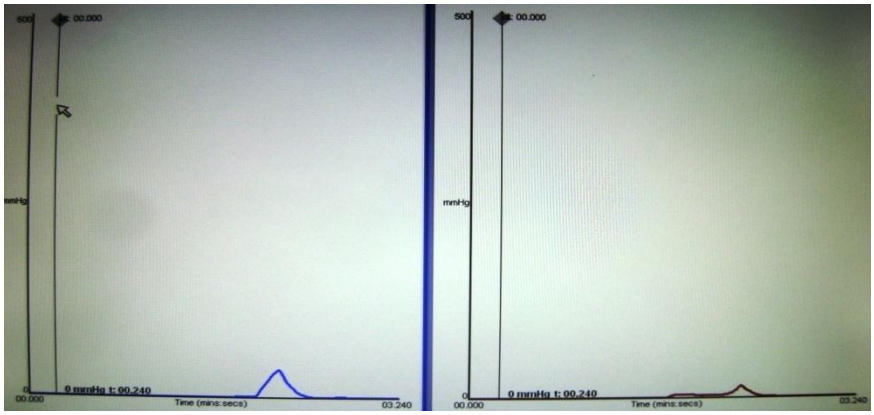
Thin liquid swallow (wet swallow): defined as swallow involving ingestion of water. Swallows were obtained for two volumes of purified water (5ml and 10ml) and for each volume two recordings were obtained.

Water was given through the measuring cup and the child was instructed to swallow as normally as possible. In both the dry and wet swallow phase of the data collection, the participants were requested to swallow in one complete action and only once per recording. Practice trials were given to the participants to familiarize with the task.

Recording:

After preparing the participant by placing the tongue array of the two tongue array bulb module in the mouth, the module was activated for recording the tongue performance on the computer of the Digital Swallowing workstation. The time window frame selected was 8 secs with a display scale of 500 mmHg on the vertical scale. The settings were kept constant across all the participants. Child was given 5ml water in the measuring cup and instructed to swallow only when the investigator indicated to him/her to do so. The tongue pressure was recorded by activating the recording mode of this module and the waveform was saved. For the 10 ml volume and the dry swallow, the same procedure was followed. The order of recording of wet and dry swallows were randomized across participants to counter the order effect. *Figure 3* shows the picture of a waveform obtained from a participant for the wet swallow

Figure 3. Waveform obtained during recording



Anterior bulb Posterior bulb

Analysis

Each of the 'tongue pressure' recorded for each participant in two different conditions (wet and dry condition) at each volume was observed by the investigator by visualizing the tongue pressure waveform.

The following parameters of the 'tongue pressure' were analyzed for each of the selected sample:

- Duration in millisecond from initiation to termination of the tongue action
- Minimum pressure (in mmHg)
- The peak pressure (mmHg) indicating maximum tongue pressure
- Mean pressure (in mmHg)
- The slope of the tongue pressure in terms of mmHg/second.
- The area under the peak - time curve (mmHg/second)

Statistical analysis

The raw data was treated statistically using SPSS version 17.0 and analyzed to compare the ‘tongue pressure’ across selected age groups and conditions of swallow.

RESULTS AND DISCUSSION

The study aimed to analyze the performance of typically developing children between 4 – 5 years for tongue pressure in the anterior and posterior region during swallowing using the 'Two-Tongue Array Module' of Digital Swallowing Workstation (DSW) Model 7120 by KAY PENTAX.

Aims of the study:

To analyze and compare the tongue pressure generated in the anterior and posterior region of the tongue using the 'two-tongue array module' of DSW elicited in 2 tasks (dry and wet swallow) in typically developing children across:

- Two age groups (4.0 to < 4.6 yrs and ≤ 4.6 to 5.0 yrs)
- Gender (males and females)
- Swallowing tasks (dry and wet swallows)

The results have been presented and discussed under the following sections:

1. Comparison between two age groups
2. Comparison between males and females
3. Comparison between anterior and posterior tongue pressure across different conditions of swallow

1. Comparison between age groups:

Mean and standard deviation of all the measured parameters for both the age groups are mentioned in the following Table 2.

Table 2.

Mean and standard deviation in anterior and posterior tongue pressure (in mmHg) across two age groups

		4 to < 4.6 yrs			**≤4.6 to 5.0 yrs**		
Measures	**Position of the bulb**	**Dry Mean (SD)**	**Wet 5ml Mean (SD)**	**Wet 10ml Mean (SD)**	**Dry Mean (SD)**	**Wet 5ml Mean (SD)**	**Wet 10ml Mean (SD)**
Duration of pressure wave	Anterior	0.60 (0.35)	0.71 (0.34)	0.62 (0.26)	0.60 (0.22)	0.52 (0.16)	0.53 (0.17)
	Posterior	0.64 (0.33)	0.76 (0.35)	0.59 (0.19)	0.58 (0.21)	0.68 (0.53)	0.56 (0.17)
Minimum pressure	Anterior	0.83 (1.19)	0.44 (0.52)	0.70 (1.29)	1.11 (0.97)	0.76 (0.85)	1.14 (1.03)
	Posterior	0.64 (0.59)	0.75 (0.73)	0.58 (0.42)	0.83 (0.72)	0.96 (1.13)	1.04 (0.81)
Maximum pressure	Anterior	24.29 (18.26)	21.68 (13.26)	21.48 (13.26)	21.99 (10.75)	17.23 (8.58)	18.45 (10.4)
	Posterior	13.99 (8.25)	13.21 (5.46)	12.79 (7.31)	15.16 (8.04)	11.96 (5.81)	12.62 (7.13)
Mean pressure	Anterior	11.93 (6.80)	9.99 (5.40)	10.48 (5.70)	11.09 (5.36)	8.50 (4.34)	9.88 (5.96)
	Posterior	6.46 (3.02)	6.02 (1.17)	5.82 (2.12)	8.12 (4.64)	5.75 (3.25)	5.96 (2.37)
Area under the pressure wave	Anterior	8.86 (8.02)	7.01 (4.20)	6.12 (4.19)	8.60 (5.75)	5.09 (3.33)	6.11 (4.85)
	Posterior	4.79	4.70	3.67	5.83	3.58	3.66

		(3.95)	(2.55)	(1.78)	(4.16)	(2.59)	(1.72)
Slope of the pressure wave	Anterior	0.62	0.37	0.54	1.27	1.48	1.64
		(3.59)	(2.57)	(2.78)	(2.87)	(4.61)	(3.76)
	Posterior	1.23	0.17	1.00	0.35	0.91	1.58
		(1.99)	(2.10)	(2.78)	(5.78)	(2.94)	(3.20)

From Table 2, it is evident that there is difference in mean scores which is not too large for duration of tongue pressure wave, minimum, maximum and mean pressures and area and slope of the pressure wave across the two age groups compared. However, in all these measures the difference was larger between anterior and posterior tongue pressures in both the age groups. One way repeated measure ANOVA was done to verify the observation made from Table 2. The difference was not found to be statistically significant ($p = 0.182$) across the age groups. This may be attributed to the smaller age interval (6 months) between the age groups considered in the study. It may also be suggestive that a significant difference in tongue pressure measures may not be evident in 6 month intervals and the developmental spurts may involve larger age intervals for such a measure. Study by Youmans, Youmans & Stierwalt (2009) on normal swallowing physiology on 96 participants in the age range of 20-79 years indicated that there were maximum tongue strength differences between the youngest and oldest age groups. However, the study did not comment on the developmental trend if any and hence it is difficult to draw any inference from the same.

2. Comparison between males and females:

In another study by Stierwalt and Youmans (2007) greater tongue strength in males than in females (aged 44 to 99 years) for both younger and older groups were reported. The study by Steile, Bailey and Molfenter (2010) found longer event duration for rise and release phase of swallow in males compared to females. However, there are no studies to date reported in young children. In the absence of any reported literature, it can only be suggested that probably replication of the study on a larger group may throw some light on the gender differences if any in children of different age groups.

Table 3

Mean and standard deviation of the tongue pressure measures (in mmHg) across gender

		Male			**Female**		
Measures	**Position of the bulb**	**Dry Mean (SD)**	**Wet 5ml Mean (SD)**	**Wet 10ml Mean (SD)**	**Dry Mean (SD)**	**Wet 5ml Mean (SD)**	**Wet 10ml Mean (SD)**
Duration of pressure wave	Anterior	0.52 (0.24)	0.62 (0.24)	0.58 (0.30)	0.68 (0.33)	0.62 (0.30)	0.58 (0.19)
	Posterior	0.53 (0.26)	0.77 (0.68)	0.58 (0.17)	0.69 (0.28)	0.60 (0.33)	0.56 (0.19)
Minimum pressure	Anterior	1.07 (0.99)	0.84 (0.79)	0.77 (1.02)	0.87 (1.18)	0.37 (0.58)	1.07 (1.33)
	Posterior	0.81 (0.68)	0.87 (0.61)	0.86 (0.71)	0.67 (0.65)	0.85 (1.20)	0.76 (0.66)
Maximum pressure	Anterior	25.84 (12.31)	20.92 (10.96)	20.27 (12.64)	20.46 (16.9)	17.99 (11.63)	19.67 (13.53)
	Posterior	15.57	12.62	12.00	13.59	12.56	13.40

		(6.43)	(4.94)	(7.34)	(9.49)	(6.33)	(7.03)
Mean pressure	Anterior	13.52	10.16	10.89	9.51	8.34	9.48
		(5.82)	(4.70)	(4.90)	(5.78)	(5.04)	(6.58)
	Posterior	7.18	5.88	5.89	7.40	5.91	5.89
		(2.68)	(1.91)	(2.47)	(4.00)	(3.04)	(2.02)
Area under the pressure wave	Anterior	11.27	7.25	6.40	6.19	4.86	5.84
		(7.00)	(3.95)	(3.66)	(5.93)	(3.47)	(5.26)
	Posterior	5.80	4.27	3.78	4.83	4.01	3.56
		(3.88)	(2.60)	(2.11)	(4.23)	(2.66)	(1.30)
Slope of the pressure wave	Anterior	0.53	1.48	1.07	1.12	0.37	1.10
		(3.69)	(2.67)	(3.46)	(2.86)	(4.51)	(3.23)
	Posterior	0.52	1.27	0.08	1.08	0.53	0.60
		(2.53)	(2.48)	(3.02)	(5.51)	(2.41)	(3.47)

Table 3 depicts the measures of tongue pressure and duration tested across gender. The differences across these measures between genders were not large. This was verified statistically using one way repeated measure ANOVA and the differences were not found to be significant ($p= 0.205$).

As evident from Table 2 and 3, since the mean measures of the tongue pressure (anterior and posterior) were statistically not significant for age and gender, for the rest of the analysis the data was collapsed into one.

3. Comparison between anterior and posterior tongue pressure across different conditions of swallow:

The data was compiled and compared across the anterior and posterior tongue pressure for different swallow conditions for all the six measures.

Duration:

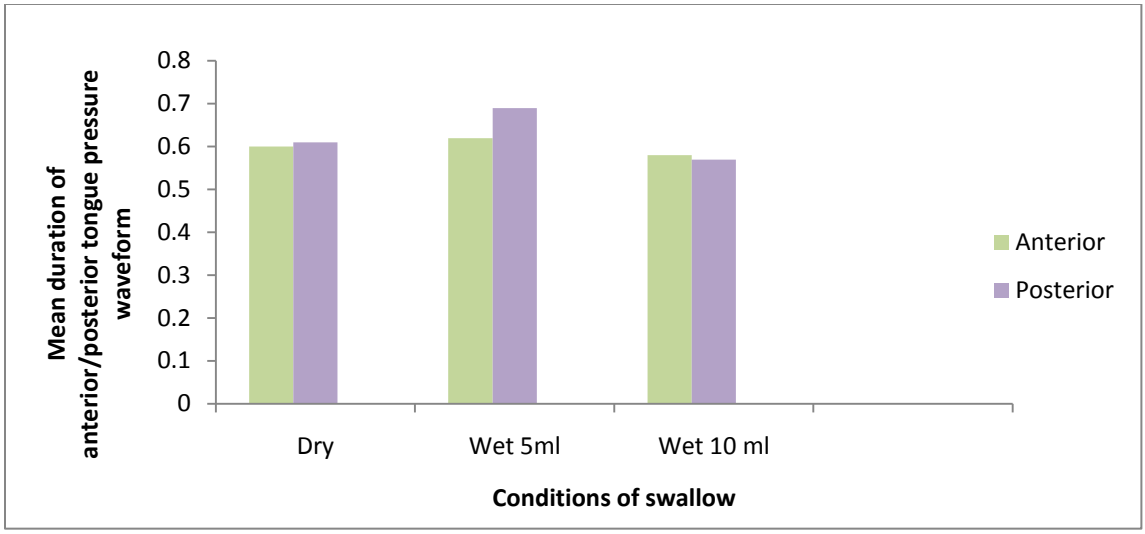


Figure 4. Comparison of mean duration of anterior and posterior tongue pressures across different conditions of swallow

Duration of the tongue pressure wave represents the time between the initiation and termination of the tongue action in anterior and posterior region of the oral cavity respectively during the act of swallowing. *Figure 4* shows that the duration of anterior and posterior tongue pressure was similar across the conditions of swallow i.e., dry, wet (5ml), and wet (10ml).

Studies (Youmans and Stierwalt, 2006, Lee, Sejdiae, Sejdic, Steele and Chau, 2010) have reported influence of bolus type, volume and viscosity on tongue action and swallow. Older healthy adults were found to have a longer duration of tongue contact with the hard palate in the anterior part than in the middle or posterior part during swallow (Ono and Nokubi, 2006). However, direct comparison for the duration of tongue pressure in the anterior and posterior region to propel the bolus in children is not

available. The results of this study revealed that the overall duration for which the tongue acts for a particular type of swallow is more or less the same. That is, the duration of the tongue press or hold in anterior or posterior region does not seem to be a sensitive measure across conditions of swallow when compared to other measures included in the study such as the minimum, maximum and mean tongue pressures.

Minimum tongue pressure:

Minimum tongue pressure refers to the initiation or readiness of the tongue to position itself on the palate and the pressure applied on the palate during the initial process of swallow. Minimum anterior tongue pressure was found to be more for dry swallow and 10ml wet swallow conditions. But the same pattern was not observed in wet 5 ml swallow condition. The inference could vary. Dry swallow, wherein the child is asked to swallow his or her own saliva, is considered to be difficult. The assumption of appropriate tongue posture for this type of swallow may have necessitated the application of more tongue pressure. Likewise, for a higher wet volume (10 ml) compared to a lower wet volume (5 ml), similar dynamics of the tongue may be involved because of the larger bolus volume. In this sense, dry swallow and wet swallow (10 ml) were comparable in nature. If this view is assumed to be correct then it seems like minimum tongue pressure as a measure is sensitive to the bolus type (dry or wet) and volume (larger volume compared to smaller volume).

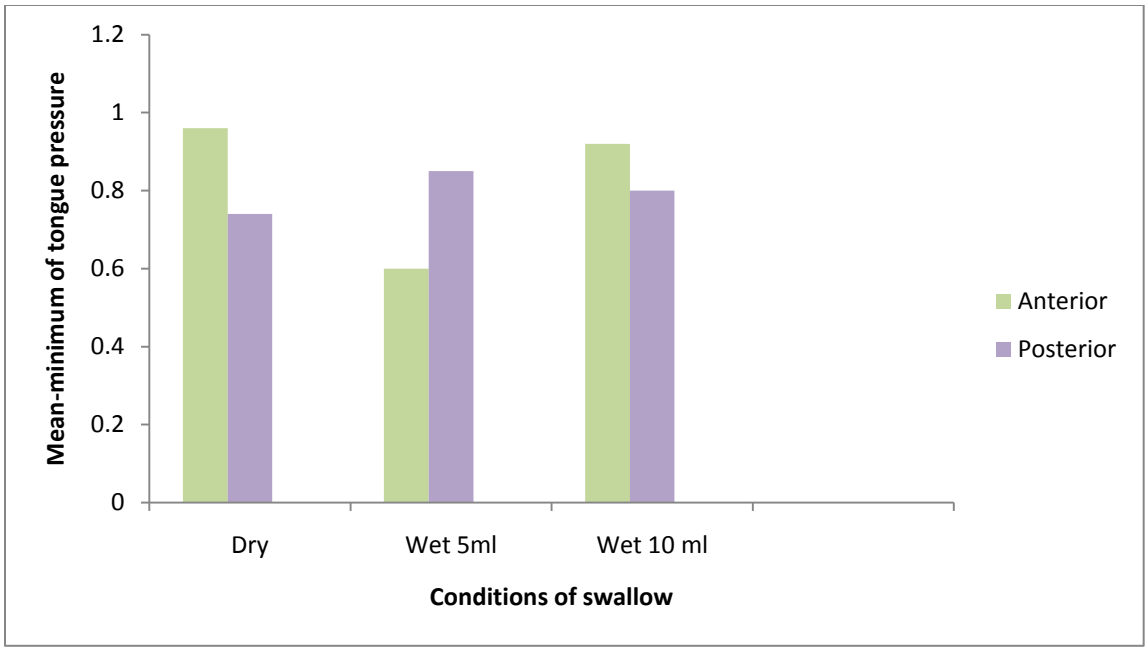


Figure 5. Comparison of mean-minimum of anterior and posterior tongue pressure across different conditions of swallow.

In other words, the initial tongue pressure on the palate for swallow may be proportionate to the type and volume of bolus.

It may also be possible that children who participated in the study tried to produce saliva with the squeezing action in the anterior palate for the dry swallow after the bulb was placed in position. Whereas, in wet swallow condition as the volume of liquid placed in the oral cavity increased, more initial pressure was required to hold the bolus on the tongue before the instruction to swallow was given by the investigator. This postulation can only be verified using study design and instruments which reflect the ongoing process of tongue activity during swallow.

Maximum tongue pressure, Mean tongue pressure and Area of the tongue pressure waveform:

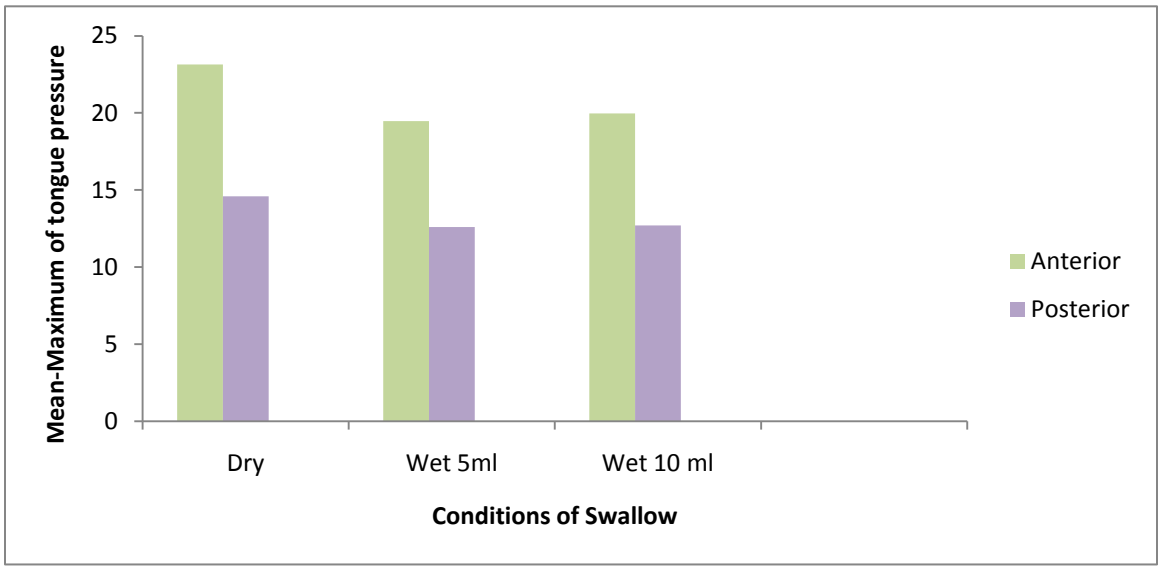


Figure 6. Comparison of mean maximum of anterior and posterior tongue pressure across different conditions of swallow.

In this section, 3 measures, viz., mean maximum tongue pressure, mean tongue pressure and mean area of tongue pressure wave is presented (*figure 6, 7 and 8* respectively). The maximum pressure indicates the maximum or optimum pressure applied by the tongue on the palate as a squeezing action before propelling the bolus. *Figure 6* shows similar trend for all the three conditions wherein the mean maximum anterior tongue pressure is more compared to the posterior tongue pressure across all the conditions (dry, wet 5ml, and wet 10ml) of swallow. As reported by Corey, Daniels, Degeorge and Rosenbek (2007) adults (mean age 69 years) use their anterior tongue or tongue tip against the alveolar ridge to hold the bolus before swallow (tipper pattern of swallow). There are no available reports in literature about the pattern of swallow in children or younger adults. From this study the result of mean maximum, mean and area

of tongue pressure waveform suggest that children between 4-5 years predominantly use a tipper pattern of swallow.

To test if the difference was statistically significant, MANOVA was run on the data and it revealed that difference between maximum tongue pressure and anterior dry ad posterior dry condition was significant. ($p=0.000$). Similar results were obtained for anterior 5ml and posterior 5ml conditions.

Study by Stierwalt and Youmans (2007) in adults in the age range 20 to 79 years of age indicated that the maximum tongue pressure used during swallowing was significantly greater for honey-thickened liquid compared to thin liquids, but the study did not address the tongue pressure differences between anterior and posterior region. It will be interesting if future studies address the changes in the tongue pressure across different consistencies of the bolus in children.

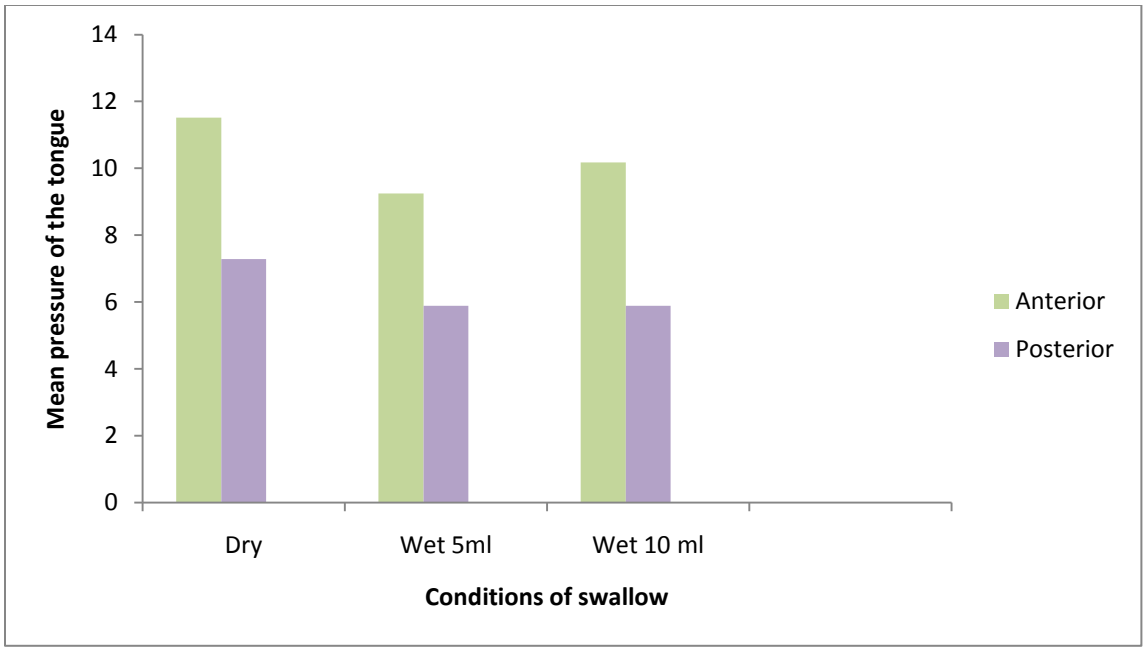


Figure 7. Comparison of overall mean pressure in anterior and posterior tongue pressure across conditions of swallow

Just like in mean maximum pressure, the overall mean tongue pressure for anterior portion is found to be more compared to the posterior portion (*figure 7).* The mean tongue pressure measured in the dry and wet swallow conditions followed a similar pattern as the mean maximum tongue pressure across these conditions of swallow. MANOVA was run on the data which revealed significant difference in the mean tongue pressure in anterior and posterior tongue pressures in different conditions of swallow (p= 0.001).

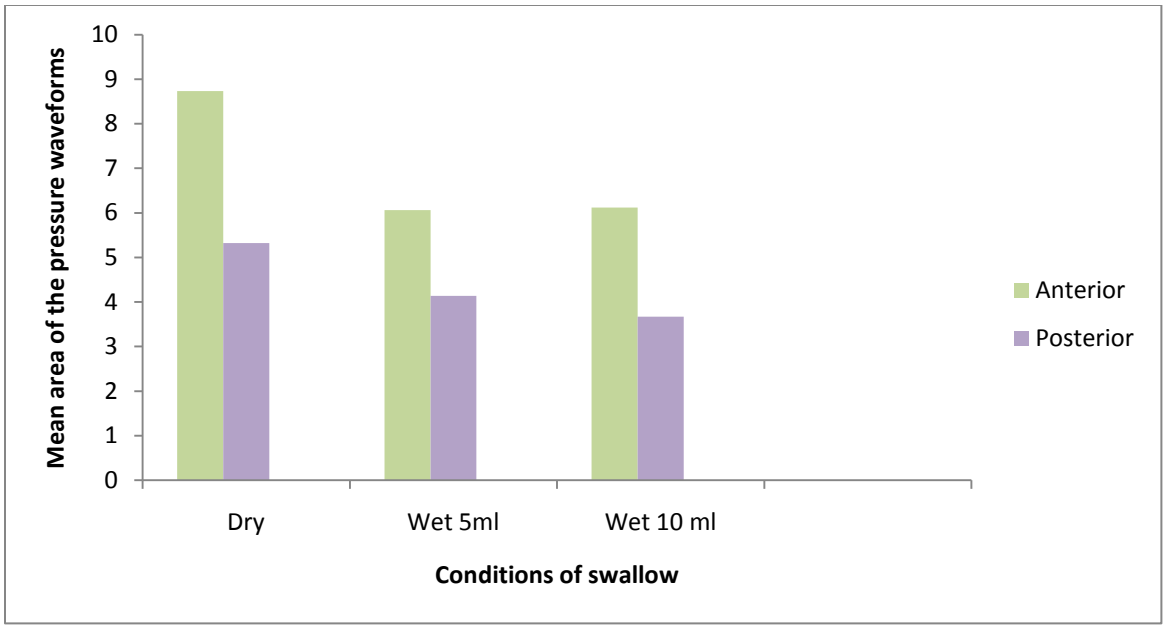


Figure 8. Comparison of mean area of tongue pressure wave across different conditions of swallow.

Figure 8 shows the mean area of tongue pressure. Here also a similar pattern was observed as in mean maximum tongue pressure and the mean tongue pressure. In summary, as the mean maximum tongue pressure, the mean tongue pressure and the area under the waveform was increased for anterior compared to posterior tongue pressure in all three conditions viz dry, wet (5ml) and wet (10ml).

Mean slope of the tongue pressure:

Figure 8 reveals that the mean slope of the tongue pressure wave form for the anterior portion of the tongue is negative in all the conditions of swallow, whereas, the posterior portion of the tongue has a negative slope only in the dry swallow condition. This suggests that the tongue achieves the maximum pressure against the palate in a shorter time for dry swallow compared to the other conditions of swallow. The absence of any bolus in dry swallow condition may facilitate the tongue to achieve its readiness state even before swallow in both anterior and posterior portions of tongue.

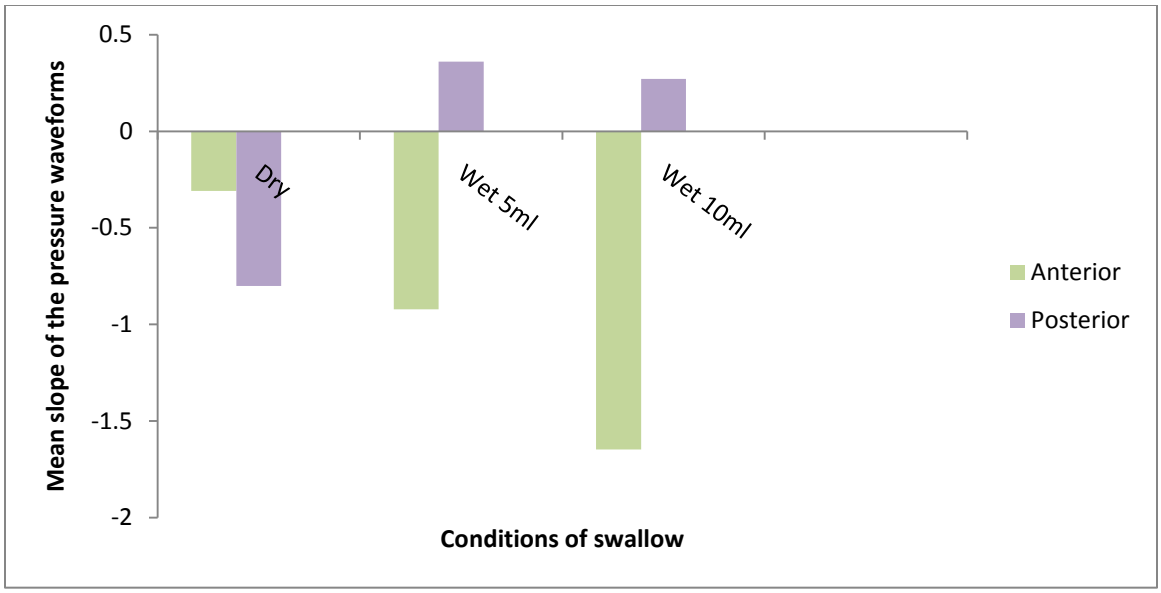


Figure 9. Comparison of mean slope of anterior and posterior tongue pressure for different conditions of swallow

Thus, the maximum pressure across the palate can be achieved faster compared to swallowing of liquid. But, as seen from the *figure 8*, the negative slope of wet 10ml condition is higher than the dry and wet 5ml condition. This may be indicative of the fact that there is increased demand for tongue strength and speed of action to hold the bolus before swallow.

Overall, the measures of duration and the measure of slope of tongue pressure waveform indicate that though the overall time for which the tongue remains in contact with the palate in the anterior and the posterior position does not vary significantly, the time in which tongue achieves maximum pressure on the palate vary across the characteristics of bolus and type of swallow. It can be inferred that any intrinsic physiological changes of the tongue during swallow of the bolus happens within a specific time interval.

SUMMARY AND CONCLUSION

The study aimed to analyze the performance of typically developing children between 4 – 5 years for tongue pressure in the anterior and posterior region during swallowing using the 'Two-Tongue Array Module' of Digital Swallowing Workstation (DSW) Model 7120 by KAY PENTAX, in two swallowing tasks (dry and wet swallow) and was compared across age groups (4.0 to < 4.6 yrs and ≤ 4.6 to 5.0 yrs), gender (males and females) and swallowing tasks (dry and wet swallows).

There were a total of sixty participants who participated in the study. Participants were sub grouped into two age groups depending on their chronological age. There was a six months age interval between both groups (4.0 to < 4.6 and ≥4.6 to 5.0). In each age group there were a total of 30 participants with an equal number of males and females (15 males and 15 females).

The tongue pressure was recorded by activating the recording mode of the module and recording was done for the dry, wet (5ml) and wet (10 ml) conditions and the waveform was saved. In both the dry and wet swallow phase of the data collection, the participants were requested to swallow in one complete action and only once per recording. Practice trials were given to the participants to familiarize with the task. The recorded waveforms were analyzed for obtaining the tongue pressure and duration measures. The following parameters of the 'tongue pressure' were analyzed for each of the selected sample:

- Duration in seconds from initiation to termination of the tongue action
- Minimum pressure (in mmHg) applied by the anterior and posterior tongue on the palate
- The maximum pressure (mmHg) applied by the anterior and posterior tongue on the palate
- Mean pressure (in mmHg) applied by the anterior and posterior tongue on the palate
- The area under the tongue pressure waveform (in mmHg second)
- The slope of the tongue pressure waveform (in mmHg/second).

The data obtained were treated with suitable statistical procedure (One way repeated measure ANOVA).

Salient findings of the study were:

- There was no significant difference seen in the measures of tongue pressure across gender and across the selected age groups (4.0 – 4.6 years and ≤ 4.6 to 5.0 years).
- Duration of the tongue pressure in the anterior or posterior region is not a sensitive measure across conditions of swallow when compared to other measures included in the study such as the minimum, maximum and mean tongue pressures.
- Minimum tongue pressure was sensitive to the bolus type (dry or wet) and volume (larger volume compared to smaller volume)

- Maximum anterior tongue pressure was more compared to the posterior tongue pressure across all the conditions (dry, wet 5ml, and wet 10ml) of swallow.
- Children between 4-5 years predominantly used a tipper pattern of swallow as observed from the results of mean maximum, mean and area of the tongue pressure waveform for the anterior and posterior part of the tongue across various conditions of swallow.
- For dry swallow condition, tongue achieved the maximum pressure against the palate in a shorter time compared to the other conditions of swallow as seen by the negative slope in the dry swallow condition.
- The higher mean slope for wet 10ml swallow condition suggested a probable demand for tongue strength and speed inorder to hold the 10ml liquid bolus as seen in.

Future directions of the study:

The results of this study have suggested the need for in depth analysis of various tongue action in the swallow act. Many areas of research interest can be taken up to substantiate the scanty and sketchy database available on action of tongue during swallowing. A few of them could be:

1. Studying the developmental trend of tongue pressure patterns across age groups in children to facilitate comprehensive understanding of patterns of tongue movement during oral phase of swallow.
2. Studying the effect of bolus type, viscosity and volume on the tongue pressure and duration measures.

3. Addressing the gender differences if any in children by including a larger population since such differences are commonly reported in adults.
4. Studying the bilateral symmetry of the tongue pressure for various bolus characteristics using the same two tongue array module.
5. Verifying for the pattern of swallow i.e., the tipper and the dipper pattern can be studied on different age groups across different bolus type and volume of bolus.
6. Verifying the sensitivity of the tongue array module for quantification of isometric strength and weakness of the tongue in various clinical population who have difficulty in oral phase of swallow.
7. Studying the effectiveness of this module as a bio feedback aid in therapeutic interventions for persons with swallowing difficulties in the oral phase.

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