DEVELOPMENT AND STANDARDIZATION OF AN ORAL SENSORIMOTOR EVALUATION PROTOCOL FOR CHILDREN (OSEP-C)

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Principal Investigator

Dr. N. Swapna

Reader in Speech Pathology

Department of Speech-Language Pathology

Research officer

Ms. Deepthy Ann Joy

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI, MYSURU – 570 006

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Research officer | **Principal investigator**

Ms.Deepthy Ann Joy | Dr.Swapna. N

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CHAPTER I

Introduction

Speech is the primary mode of human communication. It is the means by which discretely specified linguistic messages are converted to an acoustic signal through a series of motor acts that can be understood by a listener. Speech production is arguably the most complex, skilled motor act executed by human beings. It is complex because it involves more motor fibers than any other human mechanical activity (Fink, 1986) and involves several subsystems such as respiratory, phonatory, resonatory, articulatory and the nervous system which interact and coordinate with each other in time during the production of speech.

The power supply for speech is the expired air from the lungs. This air is segmented into puffs of air by the vibrating vocal folds which are further filtered by the resonant frequencies of the vocal tract. This regulation is brought about by movements of jaw, lips, tongue, soft palate, walls of pharynx and vocal folds which alter the shape of vocal tract. The movements occur due to muscle contractions, which are caused by nerve impulses and the entire process is controlled by the nervous system. The resulting speech is laid over by the prosodic elements of intonation, stress and rhythm which are channelled by the changes in fundamental frequency (F0), duration and intensity. Thus speech process can be viewed as a complex fine motor skill which must be regulated in terms of sequence and duration with great accuracy, speed and rhythmicity.

At the time of birth, only primitive reflexive movements are present in an infant. As the maturation of nervous system takes place, the primitive reflexes are replaced by more coordinated voluntary movements. The gradual development in the speech motor control also takes place, from reflexive crying, prelinguistic vocalizations followed by cooing, babbling to the mastery of adult like speech which demands a lot of complex coordination among the multiple subsystems of speech production. There is an increase in the size of the structures responsible for speech production, remodeling of the shape of individual structures, there are adjustments in the positional relationships between structures, alteration in histology and biochemical properties and adaptations in neural innervations. The acquisition of speech motor control is a slow and gradual process.

Sharkey and Folkins (1982) studied the development of speech motor abilities in normal children (4, 7 and 10 years) and adults by measuring the jaw and lower lip movements. They concluded that basic development in oromotor movements happen upto 4 years and in the late stages, the oromotor system will undergo the process of fine refinement. Ozanne (1992) also reported that there was a progression in the oromotor abilities till the age of 4 years. Cheng, Murdoch, Gooze and Scott (2007) also reported a maturational trend for tongue-jaw coordination as children mature. They concluded that development was nonuniform, with a refinement period from mid-childhood extending into late adolescence. Turan (2013) aimed to develop a normative data for oromotor skills in children in the age range of 3-6 years. It was concluded that the scores of both isolated and sequential oral movements were found to be increasing till the age of 4.5, after which no significant changes were observed. Similar findings were found by Robbins and Klee (1987) where they observed significant changes in the oral motor functioning up to the age of 3.6 years and only a small or insignificant increase in the total oral functional score after the age of four. Kent (1976) reported that adult like use of motor control is achieved by end of first decade of life.

The goal of speech motor control is to produce appropriate acoustic patterns via flexible motor actions that are formed and maintained by “auditory images”. These auditory images become yoked to motor and somato-afferent patterns that are used to generate them (Bernstein, 1967). This integration of the sensory and motor systems critical for speech development occurs due to the rapid maturation in the musculoskeletal growth and neuromotor development (Kent, 1976, 1984; Kent & Vorperian, 1995; Smith, Goffman, & Stark, 1995).

A dysfunction of the motor control centers of the immature brain, however can lead to motor speech impairment and is marked by disturbances to any of the speech subsystems. For instance, about 35% of children with cerebral palsy, which occurs due to a neurological damage, are also diagnosed with dysarthria, a speech disorder involving abnormal strength, speed, and accuracy of movement of the speech system (Hustad, Gorton, & Lee, 2010; Pennington, Roelant, Thompson, Robson, Steen, & Miller, 2013). The deficits associated with dysarthria impede intelligibility, reducing the individual's ability to effectively communicate using spoken language (Pennington, Miller, Robson, & Steen, 2009) which inturn affects their quality of life.

The oral structures, which are a part of the articulatory system, are most frequently affected. The process of speech is realized by the complex and purposive movements of some of these oral structures (speech organs) or articulators. The articulators move in coordination with each other to produce various speech sounds. The active articulators include lips, tongue and soft palate and the passive articulators include teeth, alveolar ridge and hard palate. The articulatory movements for the production of speech are solely under neuromuscular control. These articulators are rich in sensory and motor innervations which enables the smooth production of speech. Generation of movements for speech involves the continuous utilization of sensory information from the muscle receptors and cutaneous mechanoreceptors that are distributed throughout the respiratory, laryngeal and orofacial systems. An impairment in the articulatory system due to a damage in the central nervous system is associated with decrease in speed, strength, steadiness, coordination, precision, tone, and range of motion of the articulators.

Thus oral motor problems are one of the major issues that lead to the difficulties seen during speech production. Rather than a smooth, graded movement, the jaw may move in wide excursions. The lips may close in a weak manner thus resulting in the production of weak bilabial sounds. When the articulators make weak approximations, then there will not be adequate intraoral pressure so as to produce coarticulated speech. Open mouth postures resulting from low muscle tone, paralysis, paresis, mouth breathing will affect the graded jaw movement and tongue position. Independent tongue movement is important for all oral motor processes. Muscle tone and tongue mobility issues can impact tongue shape for speech production and tongue movement during eating and drinking. Difficulties with velopharyngeal closure can significantly affect the individuals' resonation and speech intelligibility.

In addition to the motor problems, sensory issues are also seen in these children in the oral structures due to the brain damage such as decreased or increased sensitivity to temperature or touch. Clinical observations like children indicating for food when there was already food in the mouth, unawareness of presence of saliva in the mouth when asked to swallow, difficulty in telling whether the lips were approximated or separated etc. suggest a defective oral sensory function in children with cerebral palsy. Bobath (1970) noted that the influence of sensory disturbances on the ability to initiate and perform normal movements is profound.

Research has revealed that sensory information is essential for speech motor control and speech acquisition (Borden, 1979; Perkell, 1980; Abbs & Kennedy, 1982; Gracco & Abbs, 1987; Gracco & Abbs, 1989). It has also been found that somatic sensory information is important to the ongoing motor control process. It appears that the central nervous system is constantly receiving information on all phases of speech production and sensory considerations are as important in understanding motor control (Abbs & Kennedy, 1982; Gracco & Abbs, 1989). Adequate sensory perception and integration is required for adequate oral muscle function and motor planning. Thus the speech-language pathologists need to assess the individual's orosensory functions in a systematic manner. Sensory functions inside and outside the oral area need to be assessed.

Hence the assessment of oral sensory motor functions is an essential component of evaluation. The primary objective of an oral mechanism examination is to identify abnormalities in shape, size, colour, texture or other attributes involved in speech, to assess the sensory and motor capabilities of the articulators and to describe any functional and structural features that may be pathogomic (Caruso & Strand, 1999). Specifically, the oral mechanism examination consists of making observations about the client's speech structures at rest (e.g., observing the face in repose for presence of adventitious movements), during the performance of non-speech acts (protruding the tongue), and speech acts (prolonging a vowel). In addition Duffy (2005) stated that the oral mechanism examination helps the clinician obtain information about the integrity of the speech mechanism, e.g., strength, range of motion, speed, and coordination (Duffy, 2005).

In the past a few attempts have been made to develop test materials to assess the oromotor functions in children. Some serve the purpose of screening the orofacial dysfunction such as *Nordic Orofacial Test - Screening* (NOT-S, Bekke, Bergendal, Mcsllister, Sjogreen, &Asten, 2007), while other tests serve the purpose of detailed evaluation such as The Dworkin-Culatta Oral Mechanism Examination (Dworkin & Culatta, 1980), The Frenchay Dysarthria Assessment (FDA; Enderby, 1983), Robbins-Klee protocol (1987) (Robins & Klee, 1987), Oral Motor Evaluation Protocol (Beckman, 1997), The Verbal Motor Production Assessment for Children (VMPAC, Hayden & Square, 1999) measure, The Oral Speech Mechanism Screening Examination-Third Edition (OSMSE-3, St. Louis & Ruscello, 2000), Stockholm Oral motor test battery (STORM, McAllister & Hartsein, 2007), Marshalla Oral Sensorimotor Test (MOST, Marshalla, 2008) etc. Some of the oral motor protocols developed in the Indian context include ComDEALL (Archana & Karanth, 2008), and protocol for oral motor, oral praxis and verbal praxis skills in persons with Down syndrome (Rupela, 2008).

Although the importance oral motor examination has been well established, the sensory assessment of the oral structures has received less focus. According to Caruso and Strand (1999) the registration, orientation, interpretation, and organization of the sensory stimuli on the oral structures should be assessed. The standardized tests of the sensory functions related to speech and other oromotor behaviours is limited (Kent, Martin, & Sufit, 1990). However efforts should be made to include sensory examination in the oral mechanism examination. Sensory information is important to the development of motor skills of speech. The continuous sensory information of various kinds (kinesthetic, tactile, auditory, visual) is critical to the early stages of speech production. Sensory disruption is far more disturbing to children for whom the speech production is affected (Daniloff, Bishop, & Ringel, 1977). Only MOST, STORM, The Dworkin-Culatta Oral Mechanism Examination, and Oral Motor Evaluation Protocol assess the integrity of the intra- and extra-oral musculature and sensation related to speech and swallowing. However these protocols include only certain aspects of sensation, for e.g., MOST assesses only touch and vibration, STORM assesses two-point discrimination, oral stereognosis and oral sensibility, Oral Motor Evaluation Protocol evaluates pressure, and the Dworkin-Culatta Oral Mechanism Examination assesses only touch.

Need for the study

A look into the literature revealed that children develop the orosensory motor skills consequent to the maturation of the neuromuscular system in a gradual manner with refinement in the same with age. Any hindrance to this development can disrupt the fine motor control required for speech production leading to developmental dysarthria. The incidence of children with developmental dysarthria especially consequent to cerebral palsy in Indian population is on the rise owing to the advancements in medical technology in India. Children with dysarthria do exhibit difficulties with the tone, strength, speed, range, accuracy and coordination of the oral structures as well as orosensory problems. Under such circumstances, it becomes essential to evaluate and treat the various subsystems of speech production to improve the overall speech intelligibility. According to Duffy (2013), one of the principles of dysarthria therapy is the accurate and objective quantification of the functioning of the various systems which would prove valuable in monitoring the progress of the clients with dysarthria. One of the subsystems most frequently affected is the articulatory subsystem.

Though attempts have been made in the past to develop tests/protocols to assess the oral motor issues in an objective manner, especially for children with dysarthria, these are limited. Some serve the purpose of screening the orofacial dysfunction while other tests serve the purpose of detailed evaluation as indicated in the previous section. All these tests either incorporate a subsection on oromotor assessment (for e.g., The Dworkin-Culatta Oral Mechanism Examination) or are completely dedicated to assess the oral structure and function (Robins-Klee protocol; Oral motor Evaluation Protocol etc.). Further most of these protocols do not assess the aspects that are affected in children with developmental dysarthria such as tone, strength, speed, and coordination (Protocol for assessing oral motor and verbal praxis skills by Rupela, 2008 etc.). Most of these tests fail to provide a quantitative score based on the assessment. The tests that incorporate the assessment of orosensory aspects are also limited. Only MOST and STORM places a numerical and qualitative value on oral motor movement and assesses both oromotor and orosensory aspects. The other tests protocols such as Oral motor evaluation protocol and the Dworkin –Culatta Examination also includes restricted number of orosensory tasks.

McCauley and Strand (2008) who reviewed the content and psychometric characteristics of a few available standardized currently available tests which aid in the study, diagnosis and treatment of motor speech disorders in children reported that there were problems with the tests developed which were related to overly broad plans of test development and inadequate attention to the relevant psychometric principles during the development process.

Moreover majority of the existing tools have been developed in the West. In the Indian context there are limited tools for the assessment of children especially between 4 to 12 years. There are tests such as the Assessment of oromotor skills in toddlers by Archana and Karanth (2008) which assesses the oromotor skills from 1-4 years and a tool developed by Vani (2008) which has a section on oromotor and sensory assessment. However these do not address the issues related to oromotor weakness generally seen in dysarthria.

Further, there is also evidence that there is maturation of muscle physiology in the speech motor system in children. The diameter of human muscle fiber increases and the muscles increase in size and strength with age (Parker, Round, Sacco & Jones, 1990; Lin et al, 1994). In addition the neural development of speech motor control is also under development. Norms with regard to the oromotor development has been established with respect to western population as a part of the western tests. The norms available, however cannot be generalized to children from other ethnic/linguistic backgrounds as the developmental patterns could vary (e.g., VMPAC, Hayden & Square, 1999, OSMSE-3, St. Louis & Ruscello, 2000, STORM, McAllister &Hartsein, 2007, MOST, Marshalla, 2008) etc.

Speech-Language Pathologists (SLP) are the people who frequently deal with these problems and are one of the leading team members in planning the client centered rehabilitation strategies. Consequently, they need to equip themselves with the necessary resources and expertise to provide quality rehabilitation services to their clients with dysarthria. In the absence of standardized tests, clinicians use the various tasks of the oral mechanism examination discretionarily and modify and/or supplement procedures according to the needs and age of the client (Yorkston, Miller, & Strand, 1995). Most hospitals and clinics have developed forms for the oral mechanism examination that suit the needs of their particular working situations. Hence there is a need to develop a standardized test to assess the oral motor and sensory aspects. Such a tool would go a long way in helping the SLP's in quantitatively assessing the oromotor sensory deficits in much greater depth, which would in turn help them set up specific goals for intervention. Considering this, a need was felt to develop and standardize a protocol for the assessment of oral sensorimotor aspects especially for children in the age group of 4-8 years. Keeping this in view, this study was planned.

Aim of the study

To develop and standardize a protocol for the assessment of oral sensori-motor aspects for children in the age group of 4-8 years. The specific objectives of the study include

1. To develop a protocol for the assessment of oral sensorimotor aspects.
2. To assess the content validity of the developed protocol.
3. To standardize the developed protocol by administering it on typically developing children in the age range of 4-8 years.
4. To assess the clinical validity of the tool by administering the same on children with developmental dysarthria.

CHAPTER II

Review of Literature

Speech is a unique, complex, dynamic motor activity through which we express our thoughts and emotions and respond to and control our environment (Duffy, 1995). It is the means by which discretely specified linguistic messages are converted to an acoustic signal through a series of motor acts that can be understood by a listener. The motor acts include the movements of the peripheral process of respiration, phonation, articulation and resonance in coordination. The movement of these structures in swift, precise gestures helps the production of speech. However the central nervous system is essential to trigger the movement of these structures.

Changes in speech production occur throughout the lifespan as a result of changes in the speech and language processing system, including modifications in the anatomy, physiology, sensory feedback, and motor control (Kahane, 1981; Liss, Weismer, & Rosenbek, 1990; Lowit, Brendel, Dobinson, & Howell, 2006; Torre & Barlow, 2009). The development of the nervous system and the rapid maturation in the musculoskeletal growth is the foundation for the development of speech production (Kent, 1976, 1984; Kent & Vorperian, 1995; Smith, Goffman, & Stark, 1995). This is essential for the integration of the sensory, motor and auditory systems essential for speech development. This development follows a sequence of morphological events which is in proportion with the child's neurologic integrity as well as specific sensory and motor functions. However, the motor progression of speech is influenced by multiple intrinsic (e,g., sensorimotor and cognitive/ linguistic maturation) and extrinsic (e.g., visual and auditory stimulation) factors.

Neural development and speech motor control

According to the findings of Kent (1999, p. 46), by the fifth month of gestation, the brain will have a "full complement of neurons" and the "neuron cell formation is complete by birth". The brain of a newborn child is only one-quarter to one-third of its adult volume, and it continues to grow and specialize according to a precise genetic program, with modifications driven by environmental influences, both positive and negative. Studies using Magnetic Resonance Imaging (MRI) show that the myelination continues well into the third decade of life (Benes, Turtle, Khan & Farol, 1994). By the third month, the dendritic branching in the infant's brain becomes more developed in the oral area of the cortical motor strip than in Broca's area and in the right hemisphere than in the left hemisphere of the brain. There is a peak in the development of the inner language approximately by six months of age. The auditory-motor neural circuitry for vocalization is established largely during the second half of the first year of life (Kent, Netsell, Osberger, & Hustedde, 1987; Oller & Eilers, 1988; Boysson- Bardies & Vihman, 1991; Rvachew, Slawinski, Williams & Green, 1996, as cited by Kent, 1999, p. 47). "Adult-like metabolic activity is observed across the brain regions" by 8-9 months of age (Kent, 1999, p. 46). By around the fifteenth month, "a rapid acceleration in the number of cortical synapses" occurs and the maturation of the hippocampus provides the child with the "neural system for memory" (Kent, 1999, p. 46). Maturation of the dendritic branching occurs in the Broca's area and all over the left hemisphere by two years of age. Developments are in their peak during the fourth year of age, wherein the overall brain metabolism and outer language areas of the cortex matures. By this age, the child will be able to perform complex oromotor and speech tasks. From the age of 6-10 years of life, there is gradual refinement of various temporal variables of speech production (Kent, 1976).

The motor development involves several distinct sequences of stages which involves differentiation (modification of a pre-existing behavior into more specialized one) and integration (consolidation of previously stabilized behaviors with a new one). In between these two stages is a period in which mature forms undergo continual refinement. It is probable that the organization of coordination for speech involves refinement, integration and differentiation of vocal tract components, with each sequence having a distinct effect on the child's sound-producing capabilities (Lenneberg, 1967; Fentress, 1984; Kent, 1992).

During the early motor development differentiation involves increased control of the components required for a motor task. Evidences for the study that the sensorimotor pathways of the child's oral region become more specialized with development are from the studies done on the orofacial reflexes. These reflexes gradually disappear between 3-6 months of age (Humphrey, 1964, 1971; Barlow, Finan, Bradford, & Andreatta, 1993). It is stated that the motor control generally occurs cephalocaudally and proximodistally (Stallings, 1973). For example, during the development for posture, the control is initially achieved in the head and neck area and later in the trunk and the lower limbs. Speech motor control is achieved in a similar manner, where the maturation of the articulatory control is sequential. Prenatally, the control, of the oral structures occurs sequentially (Herring, 1985). As an example, while the lip musculature is in the pre-myoblast stage at 8 weeks gestation (Gasser, 1967), the human foetus can already open the jaw (Humphrey, 1964).

Studies on the development of speech motor control (Eguchi and Hirsch, 1969; Kent, 1976; Smith & Goffman, 1998) indicate that maturational changes take place during the developmental period. According to Herring (1985), the early oral motor developments happen as a function of neuromuscular development. However the coordinative movements required for sucking, chewing and speech requires task- specific maturation in the orofacial control (Moore & Ruark, 1996; Moore, Smith, & Ringel, 1988; Ruark & Moore, 1997).

Thus motor development involves the progression of complex stages and the course of motor development progresses from gross motor skills (includes skills like standing, sitting, walking) to fine motor skills like grasp and manipulation of objects and oral motor skills like swallowing, feeding and speech. Thus when motor development is viewed in a broader interdependent developmental process, it may include neuromotor (postural reflexes, tone and qualitative aspects of movement), developmental motor (fine motor, gross motor and oral motor) and sensorimotor (perceptual/ cognitive) functions.

Oromotor development

Oral motor development refers to the anatomical and physiological changes that occur in the lips, tongue, jaw, teeth, and the hard and soft palates during childhood. Oral motor skills refer to the movement of muscles of the face (e.g. lips and jaw) and oral area (e.g. tongue and soft palate). It includes muscle tone, muscle strength, range of motion (distance), speed, coordination, and dissociation (Kumin, 2015). The movement and coordination of these structures are very important in speech production, consuming various food textures and safe swallowing.

Oral motor skills develop within a system that changes rapidly both in structural growth and neurological control during the first three years of life (Bosma, 1986; Arvedson & Lefton-Greif, 1996). Normal oral motor development begins prior to birth and continues beyond age three. Infants are born with a biologically driven suckle reflex which disappears around the age of four months (Ingram, 1962). When the infant uses the reflex for bottle or breast feedings, they master the suckling and the coordination with breathing (Herbst, 1982). With neuronal growth and maturation the infant acquires volitional control over suckle response (Bosma, 1986; Arvedson & Lefton-Greif, 1996). As the child grows, the suckling and swallowing action is followed by sucking, biting, chewing which are more mature feeding behaviors. These developments occur as the higher cortical centers gain more control

(Arvedson & Brodsky, 1993). By age four, most children safely consume solids and liquids without choking. Thus the development of oral motor skills follows a stepwise progression from the suckle reflex to more complex oral-motor milestones like suck, munch, and chew (Ogg, 1975; Bosma, 1986). These oral motor functions are important for basic survival, such as sucking and swallowing, speech development and growth and development of dental structures. The emergence of each of these oral-motor milestones is also dependent on successful practice (Illingworth & Lister, 1964; Pinnington & Hegarty, 2000).

In addition to the neural maturation, certain anatomical and physiological changes are seen in the vocal tract during the developmental period. The child's vocal tract approaches an adult like configuration during the first three years of life (Kent, 1999). This is a period of incredible growth and change in the child's vocal tract, allowing the child to develop increasingly sophisticated oral movements seen in the processes of eating, drinking and speaking. Some of the structural changes seen in children during the first three years of life include:

- Enlargement of the oral space
- Growth of the jaw and other bony structures of the face
- Disappearance of the sucking pads
- Increased muscle tone and skilled movements of the tongue
- Lowering of the larynx
- Separation of the epiglottis and soft palate
- Development of more sophisticated movements of the larynx during swallowing

During the first three years of life, the child's oral space becomes larger secondary to the growth of the bony structures and the overall maturation of the oral mechanism. Kent

(1999) explains the development of the oral mechanism from 3 years to adulthood. During the period of maturation from 3 to 7 years the overall oral system continues its gradual growth. By the age of 4 years the child's vocal tract has nearly achieved its adult form, and by 5 years it is almost the same shape of an adult. From 7-10 years it would undergo a growth spurt. By age 8, the child's jaw moves with adult like precision. Rapid growth is seen in the individuals tongue and lips between 9 and 13 years. Growth of mandible, tongue and lips continues until 18 years of age.

The mandible follows the general somatic pattern of growth and reaches adult size by the age of about 15-16 years in females and 18 years in males. The overall pattern can be described as an increase in size with relatively little change in shape (Kent & Vorperian, 1995). The mandible is a postural and movement substrate for the tongue and lips. In children, mandible achieves regulatory stability in advance of other oral articulators (Smith, Weber, Newton, & Denny, 1991).

Lips change both in size and shape. The neonate's lips are circular and an increase in width is a major developmental feature. The lips have an early growth spurt between birth and 2 years and a later spurt within the range of 10 to 17 years (Walker & Kowalski, 1972).

The newborn tongue is about 4cm long, 2-3cm wide and 1cm thick (Crelin, 1973; Siebert, 1985). Siebert reported that by the age of 4 years, the tongue grows to about 6cm in length, 4cm in width and 2cm in thickness. The tongue also changes its orientation with growth. In the neonates, the tongue fills the oral cavity which facilitates sucking. As the larynx descends the root of the tongue lengthens. Descent of the posterior third of the tongue has been noted to occur during the first year of life (Crelin, 1973; Laitman & Crelin, 1976). Scammon (1930) believed that the tongue reaches nearly adult size by the age of about 8 to 10 years. Tongue weight increases 10-fold from birth to adulthood and tongue may continue to grow in the adulthood (Siebert, 1985). Kerr, Kelly, and Geddes (1991) stated that lingual maturity is reached at the age of about 15 or 16 years.

Oral-motor development is linked with progressively complex tongue movements (Gisel, Birnbaum & Schwartz, (1998); Morris & Klein, 2000). In the typical developmental pattern, the tongue first moves liquids through a nipple in an anterior/posterior (in/out) pattern (i.e., suckling); and then liquids and pureed foods with a superior/inferior (up/down) pattern (i.e., sucking; Tamura, Matsushita, Shinoda, & Yoshida, 1998; Ayano, Tamuro, Ohtsuka, & Mukai, 2000). As the child's oral motor function advances, s/he learns to stabilize the jaw, working the tongue off this stable base first centrally with sucking and then laterally with munching (Meyer, 2000; Morris & Klein, 2000). Range of movement improves in order to allow sweeping anteriorly, posteriorly, laterally, and with tongue tip elevation.

Pharyngeal growth is in the vertical dimension, whereas pharyngeal depth changes relatively little (Kent & Vorperian, 1995). The length of the pharynx triples from birth to adulthood. By 4 months of age, the disengagement of the nasopharynx and the laryngopharynx is seen. The soft palate has a relatively rapid growth in the first two years of life, which is followed by a more gradual growth that continues until late adolescence (Kent & Vorperian, 1995).

Certain studies carried out provide evidence for the structural development that occur in children. King (1952) took lateral x-rays of the heads of 24 males and 26 females to study the changes in dimensions of pharynx from the age of three months to 16 yrs. His data indicated a gradual lengthening of the pharynx throughout the entire age period and additional slight peri-pubertal growth spurts in both males and females.

According to an MRI study done by Fitch and Geid (1999), length of the vocal tract increased across childhood and puberty in all portions of the vocal tract; only the velum and pharynx enlarged disproportionately during early adulthood. There was a disproportionate increase in pharyngeal length in both transitions. When each segments' change in length was scaled by its average length, the lip, blade, dorsum, and velum segments enlarged by an average of 12% (range 6%-14%) between childhood and puberty, while pharynx length increased by 22%. Similarly, between puberty and adulthood, the upper portions of the vocal tract grew by an average of only 5% (range 3%-9%) while the pharynx increased its length by 25%. This disproportionate change in pharynx length is most pronounced in males. Vocal tract length varied in males and females only after puberty.

In an investigation of the development of articulatory kinematics, Green, Moore, Higashikawa, and Steeve (2000) quantified the relative kinematic contributions of the mandible and the upper and lower lips in achieving oral closure. They found that the closure of the mouth for the bilabial consonant production was accomplished primarily using the jaw with little active assistance of the upper and lower lip. They demonstrated clearly that the role of the jaw was particularly prominent in early speech production, diminishing slightly with development, but still maintaining its relative importance in this closing gesture. They also found that young children learning to articulate their first words rely more on the jaw than on the lips.

The fine force control over the jaw may be limited in young children. In the Green et al., (2000) study, the lower lip tended to collide with the upper lip during oral closure. Consequently the lower lip tended to move downwards as it was pushed against the upper lip by the elevating jaw. Collisions of this magnitude between the upper and lower lip during oral closure were typically not observed in the adult participants. Excessive force generation appears to be a characteristic of immature motor control. The limited fine force control over the jaw for speech motor control may partially account for why children have a tendency to master the production of stops prior to fricatives or affricates (Stoel- Gammon & Dunn, 1985) which require relative more fine force control over the mandible than stops.

Analysis of lip movement revealed the clearest evidence of a non monotonic developmental function. Displacement of the upper and lower lips became differentiated with development, such that children progressed initially through a period during which lip displacement is the passive consequence of mandibular movement (e.g., even to the extent that the upper lip is driven superiorly.

The developmental course of coordination among the different structures of the vocal tract varies among the articulators. To produce bilabials, mature talkers simultaneously move the upper lip, lower lip and jaw to achieve oral closure. This coordination patterns among orofacial articulators is in contrast to the patterns exhibited by infants, whose lip and jaw movements are asynchronous and spatially dissimilar (Green et al., 2000). Because of this constraint, infants should be more proficient at producing sounds and sound combinations that do not require precise timing between articulatory gestures.

Performance variability as an indicator of motor development

Across various motor systems, development of motor skill often can be characterized as motor sequences of increased speed of performance (hence faster rate), reduced performance variability across tokens, and increased anticipation across the sequence (Kent, 1976, 1992; Kent & Forner, 1980; Smith, Kenney & Hussain, 1996). These characteristics are common to virtually any skilled motor performance learned by a developing organism.

Performance variability has been hypothesized to play an important role in the development of movement control (Thelen & Smith, 1994). The variability seen in the developing motor system is an indication of a system acquiring new patterns of behavior (Thelen & Smith, 1994). Like the development of most motor skills, the variability of speech motor performance shows an overall decreasing trend with age that is overlaid with some transient periods of elevated variability (Green et al., 2002; Smith & Zelaznik, 2004). The transient periods of elevated variability tend to occur at transitional stages in development when task demands greatly exceed a child's capability (Thelen & Smith, 1994).

Kent (1976) stated that the age of two or three years is assumed as the beginning of a child's extensive usage of speech on a daily basis and concluded that the variability of speech motor control progressively diminishes until the age of 8-12 years, when adult like stability is achieved. Tingley and Allen (1975) and Kent (1976) also suggested that motor patterns for speech are largely preplanned rather than feedback controlled even at the age of five years. Thus exploring formant frequencies, F_0 patterns and temporal patterns, the authors concluded that the declining variabilities reflected an increasing precision of motor control over a five- to eight- year period (Tingley & Allen, 1975; Kent, 1976).

Studies to assess the development of oromotor skills in typically developing children

The mandible has been implicated as the primary articulator supporting earlier speech and nonspeech vocalizations. Sharkey and Folkins (1985) aimed to study the development of speech motor abilities by measuring the jaw and lower lip movements. Participant included 15 normal children (4, 7 and 10 ages) and five adult speakers (3 women and 2 men). They were asked to repeat /ba/ and /ma/ 20 times each. To measure the inferior and superior displacements, strain gauge was placed on the jaw and lower lip and the parameters studied included the duration of jaw opening movements, lip opening movements, jaw-open postures, lip open postures and the timing between the onset of jaw and lip opening. No significant difference was observed in the variability measures across 4, 7 and 10 year group. Also no significant difference in the variability was found between /ba/ and /ma/. It was concluded that basic developments in the oromotor movements happens upto the age of 4 years and in the later stages the oral motor system will undergo the process of fine refinement.

Another study was done by Ozanne (1992) to assess the oromotor developments in 3-5 year old children. Children were instructed to carry out two oromotor tasks (1. Sequential oral movements and 2.movements produced in a meaningful situation with contextual cues). The results of the study indicated that there was a progression in the oromotor abilities up to the age of four years. In an acoustic analysis done by Nittrouer, (1993), it was observed that in articulatory movements which required lingual action, children produced a slower movement compared to adults, whereas an adult like jaw movements was seen in the task which required jaw action.

Comparison of muscle activation patterns (Electromyograms, EMGs) for speech and other early appearing oral-motor behaviors in 15 month old children revealed that emergent speech exhibits greater stability, than behaviors such as chewing, sucking, or other jaw movements (Moore & Ruark, 1996). The EMG signals associated with chewing exhibited relatively high variability across cycles, and lacked consistent activation across muscles. Also, the patterns across the behaviors were distinct: Chewing at 1 year was characterized by highly variable periodicity, poorly defined patterns of muscle activation and weakly established muscle synergies. The temporal overlap of muscle activity in antagonist muscles was significant in the younger children. In contrast, 4 year old generate a very stable (i.e. consistent and predictable within an observation) pattern of muscle activation, exhibiting well defined synergies among muscles (coordinated action of agonist and antagonist muscles).

Green, Moore, Higashikawa, and Steeve, (2000) investigated the jaw and lip coordination of 1-, 2-, and 6-year-olds and young adults using a video-based movement tracking system and found that the synchrony of movements of the articulators increased steadily with age. Similar findings were obtained in a study by Smith and Zelaznik (2004) where they used the Optotrak to investigate the development of jaw-lip coordination from the age of 4–21 years and found that there was a reduction in the variability with respect to the interarticulator coupling in terms of synchrony and consistency of movement with increase in age.

The emergence of an independent lip control for bilabial closure was evidenced in Green et al. (2002)'s measurements on basic [baba] and [papa] productions. The study revealed that compared to the early stability of jaw motion, toddlers from one to two years of age displayed highly variable movements of the upper lip as compared to adults and even six year old children. It means that the fine control of closure, corresponding to the appropriate coordination of the jaw and lips as achieved by adults, is not mastered at two years of age.

Another study was done by Green et al., (2002) to study the jaw and lip movements in 1 year old children and found that jaw movements were established before the other articulators. They have also reported that even during the age of 1 and 2, the movement patterns of jaw were similar to that of adults and was consistent than the upper and lower lip movements. These findings were consistent with the notion that jaw and tongue movements are related during the speech motor development (MacNeilage & Davis, 1990a, 1990b), concluding that the jaw provides the base for the acquisition of specialized motor skills.

Cheng, Murdoch, Goozee, and Scott (2007) studied the of tongue-jaw coordination during speech from childhood to adolescence. Participants included 48 children and adults in the age range of 6 and 38, who were subdivided into 4 different age groups (7-7, 8-11, 12-17 and adults). Electromagnetic articulography (EMA) was used to track the tongue and jaw motion during the productions of /t/ and /k/ which were embedded in sentences. Various aspects of tongue-jaw coordination, including lag, variability index, and maximum speed ratio, during the approach phase of the target consonant productions were analyzed and the effect of age and gender were studied. The results suggest a maturational trend for kinematic tongue–jaw coordination, reflected more specifically by an increase of temporal coupling in the production of /t/, and the spatiotemporal coordination pattern becoming more consistent in /k/ production as children mature. No evidence of gender differences was observed in the development of speech motor coordination. The current findings were consistent with the motor speech developmental trends reported in the literature, stating that development was nonuniform, with a refinement period from mid-childhood extending into late adolescence (Walsh & Smith, 2002; Smith & Zelaznik, 2004).

Turan (2013) aimed to develop a normative data for oromotor skills in children in the age range of 3-6 years. Participants consisted of 188 (82 female and 106 females) typically developing children. They were instructed to execute isolated oral movements like “lick”, “place”, “blow” and sequential oral movements like “kiss and cough”, “yawn and lick”. Scoring was done on a 4 point rating scale, in which a score of 3 indicated better performance. From the study it was concluded that the scores of both isolated and sequential oral movements were found to be increasing till the age of 4.5, after which no significant changes were observed. Similar findings were found by Robbins and Klee (1987) where they observed significant changes in the oral motor functioning up to the age of 3.6 years and only a small or insignificant increase in the total oral functional score after the age of four.

Sensory processing and its significance in the oromotor and speech motor development

"One can only control what one senses" (McCloskey & Prochazka, 1994). Sensory processing in humans involves the reception of a physical stimulus, transduction of the stimulus into a neural impulse, and perception, or, the conscious experience of sensation. Sensory processing is the process whereby an individual receives sensory input (touch, taste, sound, smell, vision, and movement sensation), processes it, and uses it in the organization of behaviors (Dunn, 2002). It is a neurological function through which a person’s brain processes and organizes incoming information from the surrounding environment to produce functional outputs such as; learning, perception, and action (Cheung & Siu, 2009). These processes are foundational to learning, perception, and action (Kandel, Schwartz, & Jessell, 2000; Shepherd, 1994).

The processing of information allows individuals to respond automatically, efficiently, and comfortably in response to the specific sensory inputs received (Yack, Aquilla, & Sutton, 2002; Dunn, 2007). Sensory integration is postulated to be a neurological function that processes and organizes sensation from one's own body and the environment. Sensory integration is the processing of sensory modality inputs from multiple sources for functional outputs that enables an individual to use the body effectively within the environment (Macaluso & Driver, 2005).

The adaptation of existing movement patterns to new activities depends on sensory input (Bobath, 1971). According to Moore (as cited by Burpee, 1999), the central nervous system has five to ten times as many sensory fibres as motor fibres. The sensory fibres do the learning. Sensory systems are estimated to learn 100 times faster than motor fibres. The central nervous system listens to multisensory input, while unisensory input is apt to be ignored. The central nervous system listens to new information or a change in information and "turns off "to sameness.

The function of the sensory system is to provide information to the central nervous system about the external world, the internal environment, and the position of the body in space. Two major types of sensory input are frequently processed by the human brain; the first is the tactile, which refers to the child's ability to perceive touch, pressure or temperature information. The second is the proprioceptive information, which refers to the child's ability to know what position each structure is relative to other structures and in what direction a structure may be moving (Caruso & Strand, 1999). Two primary pathways are responsible for carrying the afferent impulses to the central nervous system. One is the short latency pathway, which carries sensory information from the periphery to either the spinal cord or brainstem. This type of pathway is associated with reflex activity and is fast and automatic. These reflexes play an important role in speech production and swallowing. Another type of sensory pathway is long latency pathways that travel from the periphery to the higher cortical centers, thus mediating more conscious movements. They have longer latencies but permit a more controlled afferent-related corrective output. For e.g., there are reciprocal pathways from the spinal cord to the somatosensory cortex, from the cerebellum to the cortex, and from the basal ganglia to the cortex. Within these larger loops, there are smaller loops. It is this complicated system of interactions among motor systems that allows the highly flexible, rapid, and coordinated movement required for speech (Caruso & Strand, 1999).

The sensory motor systems provide both the structural foundation and the sensory information that enables a child to practice and master oral-motor skills (Morris & Klein, 2000). The sensory and motor systems work together that creates proactive and reactive responses to sensory input that is received from the environment (e.g., kinesthesia, tactile and proprioceptive cues) and internal sensory information from the body (e.g., arousal, hunger etc.). Integrated sensory information is important for developing motor planning skills that incorporate both motor control and motor learning (Roley, Blanche, & Schaaf, 2001). All of these factors must work in a coordinated manner for the child to receive positive feedback from safe oral motor and swallowing skill development. This positive feedback provides information to help the child develop the internal desire that will enable the child to develop self generating progress for the mastery of swallowing and feeding skills.

During speaking, the brain coordinates the movement of respiratory, laryngeal, articulatory and facial muscles in order to produce speech sounds. This task requires the involvement of feedforward mechanisms that mediate speech production and motor control for effective communication (Guenther, Ghosh & Tourville, 2006). However, questions remain as to how the brain monitors speech production to ensure performance accuracy. Evidence provided by several studies shows that sensory feedback information (e.g., auditory and somatosensory) plays a critical role during speech production (Houde, 1998; Lametti, Nasir & Ostry, 2012). The brain continuously monitors feedback information in order to correct for unwanted production errors and update the state of the sensory-motor networks to accomplish current and future speech production goals. Our knowledge of these critically important networks and the underlying neural mechanisms that incorporate sensory feedback to optimize human speech motor behavior are poorly understood.

A well-accepted theory has proposed that the brain manages to produce and monitor speech by comparing the incoming sensory feedback information with an internal representation of the predicted feedback (Rauschecker & Scott, 2009; Hickok, Houde & Rong, 2011). These internal predictions are hypothesized to be generated by an internal forward model (Wolpert, Diedrichsen & Flanagan, 2011) that transmits efference copies of the speech motor commands to sensory modalities in order to characterize and detect disparities (errors) between intended and actual speech feedback. In case of a mismatch between the predicted and actual sensory feedback information, the output of this comparative process will result in generation of an error signal that is projected back from the sensory to motor systems such that speech motor parameters are adjusted to improve production accuracy.

A widely-used experimental strategy to examine the interactions between sensory-motor mechanisms of speech is to apply a perturbation to the auditory feedback while human subjects speak. This technique allows experimenters to externally induce a mismatch between internally-predicted and actual sensory feedback information to understand how the brain detects feedback errors and uses them for speech production and motor control. From a behavioral standpoint, studies have shown that auditory feedback perturbation elicits compensatory vocal reactions that change speech parameters (e.g., pitch, formant, loudness or timing) in the opposite direction of the applied perturbation (Chen et al., 2007; Cai, Ghosh, Guenther & Perkell, 2011). This evidence demonstrates that the brain continuously monitors speech and operates like a feedback-based controller that uses auditory information for speech motor control.

Several factors impact how sensory systems may influence motor control. First, the dynamic of the movement (speed, direction and magnitude) itself will dictate aspects of how that movement is planned and programmed and how much and what type of sensory information will be used. The experience of the individual making that movement will also impact the role of the sensory systems, as will the degree of motor skill of the individual (Caruso & Strand, 1999).

Sensory receptors in the oral cavity

Generation of movements for speech involves the continuous utilization of sensory information from the muscle receptors and cutaneous mechanoreceptors that are distributed throughout the respiratory, laryngeal and orofacial systems. Mouth is one of the most densely innervated parts of the body, in terms of peripheral receptors. These rich innervations play a key role of oral sensorimotor control in eating, drinking, and speaking, as well as many oral sensations. The mouth contains a large range of different tissue types (skin, muscle, teeth) in close proximity and constant interaction. These generate very rich patterns of somatosensory afferent input. Receptors can be classified according to their sensory modality as mechanoreceptors, chemoreceptors, thermoreceptors, and photoreceptors.

Mechanoreceptor is a type of sensory receptor that is present in the oral cavity and responds to mechanical pressure or distortion. These mechanoreceptors are present throughout the vocal tract and can encode ongoing speech movements (Edin & Abbs, 1992; Edin & Johansson, 1995; Gandevia, 1996). Both rapidly adapting (RA) and slowly adapting (SA) cutaneous mechanoreceptor types provide rich sensory innervations throughout the facial skin, oral mucosa, and laryngeal mucosa (Dubner, Sessle, & Storey, 1978). Anterior regions of the oral cavity are more richly populated with receptors than the posterior regions. Hence tongue tip and lips are more sensitive than the hard palate and velum. Midline tactile sensitivity is highest in upper lip followed by lower lip and tongue and the least in incisive papilla. Some of these respond to light touch and adapt quickly (Meissner's corpuscles and free nerve endings), while others respond to deeper pressure or longer stimulation (Ruffini's end organs and Merkel's discs) (Corbin-Lewis & Liss, 2015). Lips and tongue are sensitive to vibratory stimuli. The masseter muscles are also sensitive to vibratory stimuli. Firm and bony structures are more sensitive to vibration than soft and fatty parts. The cutaneous mechanoreceptors are classified by function in the table 2.1 below.

Table 2.1: *Different mechanoreceptors and their detection, adaptation rate, specialization and location*

Mechanoreceptor	Detection	Adaptation rate	Specialization	Location
Pacinian corpuscles	Vibratory pressure and touch (max. sensitivity at about 250 Hz)	Rapid	Yes	Deep skin
Meissner's corpuscles	- Light touch - Changes in texture - Relatively slow vibrations (up to 50 Hz)	Rapid	Yes	Superficial skin
Merkel's discs	- Touch - Pressure - Changes in	Slow	Yes	Superficial skin

	texture Respond from steady state to low frequencies (up to 15 Hz)			
Ruffini endings	- Continuous tension	Slow	Yes	Deep skin
Free nerve Endings	- Touch - Pressure - Stretching - Temperature - Pain	Different types have different rate	No	Wide distribution

A specialized type of mechanoreceptors, known as proprioceptors allows us to know the position of our articulators in space and relative to one another. Proprioception is the more general mechanism that refers to all sensations of position and movement of the limbs, trunk, and oral articulators that are encoded by sensory receptors (Prochazka, 1996). These proprioceptors are located in muscle fibers (neuromuscular spindles) and in tendons (Golgi tendon organs). These receptors are critical in maintaining muscle tone and facilitates controlled movement. The neuromuscular spindles are special receptors embedded in muscle tissue that fire when the length of the parent muscle is increased due to stretch (stretch reflex). Neuromuscular spindles are found to varying degrees in the muscles of the tongue, jaw, and velum. The masseter muscle spindles and tongue muscle spindles could encode the articulatory position and velocity of their respective articulator. Golgi tendon organs are present in the masseter and temporomandibular joint respectively (Capra & Dessem, 1992) and respond to changes in tension associated with muscle contraction. When these receptors fire, they tend to relax the parent muscle on the tendon (Corbin-Lewis & Liss, 2015).

In addition to the mechanoreceptors, there are thermoreceptors which respond to the changes in the temperature and are fairly abundant in the oral mucosa. Some, such as, the end bulbs of Krause, respond specifically to lowered temperature, thereby mediating the sensation of cold. Ruffini-type receptors and free nerve endings, in addition to being mechanoreceptors, are responsible for the sensation of temperature change.

The distribution of these thermoreceptors varies in the oral cavity leading to some regions being more sensitive than the others. The buccal and labial gingiva, transitional and mucosal region of lower lip, buccal mucosa and hard and soft palates are moderately sensitive to cold stimuli were as the transitional and mucosal regions of upper lip are highly sensitive. The lateral areas are more sensitive to cold than medial areas in both upper and lower lips. A narrow strip for perception of heat stimuli is present in the inner surface of lower lip and corner of mouth. Incisive papillae and transverse furrow between the palatine rugae are more sensitive to cold than the rugal ridges. The entire hard palate except a small part of soft palate adjacent to last molar is insensitive to heat. Tip and lateral margins of tongue are highly sensitive to cold stimulus due to the presence of vallate and fungiform papillae. This is also suggested by the increased concentration of nerve terminations in the tongue tip. This sensitivity reduces quickly when it reaches the posteromedial surface of the tongue due to the presence of filiform papillae. The root of the tongue and anterior third of the sublingual mucosa is strongly sensitive to cold were as the floor of the mouth is weakly cold sensitive. Tongue dorsum is oral region that is most sensitive to heat and floor of mouth is weakly sensitive. The sensitivity is found to increase from birth to puberty.

Chemoreceptors respond to the change in taste. They are present in the taste buds located throughout the oral cavity and even in the pharynx. The distribution is most heavy, however, on the tongue. There is no one to one correspondence between taste and receptor type. The primary categories of taste (salty, sweet, sour, and bitter) arise from how the food substance depolarizes given receptor cells.

All this sensory information is relayed via the special sensory fibres, from the mouth to the region of the somatosensory cortex through brainstem and thalamus. Each afferent nerve carries a particular array of information from a particular area. For instance, the chorda tympani, a branch of the facial nerve (VII), carries taste information from the anterior tongue, lingual branch of the V cranial nerve carries pain, pain, tactile and temperature information from the same region. The greater superficial petrosal nerve, another branch of cranial nerve V, carries taste cues from the palate. Multimodal information (i.e. taste, touch, pain, temperature) is carried from the posterior tongue by the cranial nerve IX and from the throat by cranial nerve X.

Sensory development

Touch: Developing nerve trunks are seen in human fetal skin as early as 6 weeks and fine nerve branches extending towards the epidermis are seen by 8-10 weeks (Hogg, 1941; Holbrook, Bothwell, Schatteman, & Underwood, 1988). Adult like nerve patterns, though of reduced density were established in the dermis and epidermis of the limbs at 12 week, throughout the body surface by 35 week (Humphrey, 1964; Valman & Pearson, 1980). Cauna

(1965) reported that pacinian corpuscles make their appearance during the 4th month of gestation and that merkel's discs and meissner's corpuscles are numerous in the skin of late term foetuses. However Cauna also note that pacinian and meissner's corpuscles changed in size, shape and attachment to the epidermis throughout life. The density of these specialized endings also appeared to decrease with age. Thus while skin is innervated very early in development, accessory structures and nerve fibre density continue to mature into the third trimester and beyond.

The development of the central somatosensory nervous system has been less studied in humans, but predictions can be made on the basis of studies done on mammals (Catalano, Robertson, & Killackey, 1996; Schlagger & O'Leary, 1994). Central circuitry is probably established by about 11-12 weeks. Over the next 4-5 weeks, the somatotopic representation of the entire body is completed and primary somatosensory cortex is fully connected to the periphery around 19 weeks. Myelination of the human somatosensory system continues throughout gestation and for about two years after birth (Yakovlov & Lecours, 1967). Both rostral to caudal and peripheral to central developmental gradients are evident in the somatosensory development (Killackey, Jacquin, & Rhodes, 1990).

Several studies have examined the development of tactile limb withdrawal reflexes in humans. These studies indicate that the thresholds increase from 27 weeks to full term infants (Andrews & Fitzgerald, 1994). Schiff and Deytell (1972) found that two point thresholds increased between 7.5 and 19 years of age. Verrillo (1977) also demonstrated that vibrotactile thresholds of 10 year old children were lower than those of young adults. Subsequent studies have confirmed that school-age children have lower vibrotactile thresholds than adults (Frisine & Gescheider, 1977). The results of these studies also suggest that greatest age related changes occur in pacinian channels.

The ability to use tactile information, for e.g., to identify objects or to make judgement of size, improved with age. Infants appear to be able to recognize a familiar object on the basis of touch alone (Gottfried & Rose, 1980). However Schiff and Deytell (1972) showed that the ability to discriminate among patterns and identify objects improved between 7.5 and 19 years of age. Similarly Pick, Klien & Pick 1966) demonstrated that tactile discrimination of arbitrary line figures improved into late childhood. Absolute sensitivity to tactile stimulation also decreases with age. Schiff and Deytell (1972) showed that tactile sensitivity grew poorer with age. The literature with regard to the development of touch in the oral area is limited.

Taste: Taste buds develop and are innervated by taste nerves by the 12th week of gestation (Mennella & Beauchamp, 1991) and the ability to taste develops before birth. The data on taste development in children has been limited. A few studies have been carried out in infants using the four basic tastes, sweet, salty, bitter and sour. Studies were conducted to assess the infants' response to the different tastants. They videotaped the infants' face during the delivery of very small amounts of tastant solution. Distinctive patterns of facial reactions have been described in response to the presentations of different solutions (Peterson & Rainey, 1910). Crook (1978) measured burst pause patterns of nonnutritive sucking and found that this pattern was altered by sucrose and salt, as compared to water. Sucrose lengthened the burst while salt shortened them. Newborns then, appeared to discriminate among common tastes.

Several researchers have shown that distressed preterm and term infants can be soothed merely by giving them a glucose solution o drink, emphasizing the very high reward value that sweet tastes hold for infants (Smith & Blass, 1996; Zoifman, Delaney & Blass, 1996). Furthermore, neonates react with aversion when given bitter (quinine) or sour (citric acid) solution.

Studies have used threshold determination for four basic tastes. Thresholds are reported to be high in children than in young adults, but it is not clear whether this was due to sensory factors or to attentional/motivational differences (Ritcher & Campbell, 1940; reviewed by Cowert, 1981). Age effects were generally weak. More consistent was the evidence of gender differences with girls generally being more sensitive than boys.

A recent study by James, Laing, and Oram (1999) was conducted which provided a careful comparison of the ability of 8-9 year old children and adults to detect taste stimuli. All four tastants were included and gender as well as age differences were assessed. The results showed that 8-9 year old girls did not differ significantly from adult men and women in their detection threshold for any of the four tastes, nor did the men and women differ from each other. In contrast, the 8-9 year old boys had significantly higher thresholds for all the tastants than women. This study supported the immature gustatory sensitivity in boys, but not girls of this age.

It can be summarized that function of the senses start early in the prenatal period and is well established at term birth in humans, but development continues well into childhood or beyond. The somesthesis and gestation reaches structural maturity and functional competence early in ontogenesis. The capacity to process the features of a stimulus develop early, but perceptual processes that involve the synthesis or integration of sensory information continues to improve until adolescence or adulthood.

Studies assessing orosensory aspects in normal individuals

Weber (1961) studied the effect of disrupted sensory feedback in normal adults on speech production under three conditions like high-level air and bone conduction auditory masking, anesthetizing oral structures and combined auditory masking and oral anaesthesia. He found that the two conditions of oral anaesthesia resulted in increased articulatory errors compared to normal reading and auditory masking alone. This indicates the importance of sensory feedback in accurate speech production. Mc Donald and Solomon (1962) in a pilot study in normal children reported that children of 5 years could differentiate texture, weights and forms placed in the oral cavities.

Nordin and Hagbarth (1989) described the response characteristics of 84 low threshold mechanoreceptive afferents innervating facial hairy skin. Innervation density was highest near the corner of the mouth and on the upper lip. Multiunit activity from low threshold mechanoreceptive afferents was recorded during tactile stimulation, vibration changes in tissue conformation and spatial contact areas, and facial movements. The rapidly conducting mechanoreceptive afferents present in perioral tissues were capable of encoding position, velocity, acceleration, load dynamics, as well as directional changes in tissue conformation and spatial contact areas. The slowly adapting units with large receptive fields were spontaneously active stretch receptors and may have corresponded to Ruffini corpuscles, although the possibility of other, intramuscular receptors could not be ruled out. It was concluded that several types of cutaneous mechanoreceptors can operate as sensitive proprioceptors of importance for facial kinesthesia and motor control.

Muller, Ebner, and Homberg (1994) studied the maturation of the fastest afferent and efferent central and peripheral pathways using the recording of somatosensory evoked potentials. Both afferent and efferent central pathways showed a prolonged maturational pattern with adult values being reached by the age of 5 to 7 years for the afferent and by the age of around 10 years for the efferent pathway. In contrast, the maturation for peripheral afferent and efferent pathways showed a similar trend with a fairly constant conduction velocity reached around the age of 3 years. It is concluded that the prolonged maturational central conduction time precludes the usage of a fixed-temporal timing pattern during development in the human sensory motor system.

Motor speech impairment

Normal speech requires the integrity and integration of a number of cognitive, neuromuscular and musculoskeletal activities. Disturbances in any of the above systems results in a speech disorder. Speech impairment can be caused by lesion or dysfunction of the motor control centers of the peripheral or central nervous system or a combination of both systems (Love, 1995). Such speech impairment can be termed as motor speech disorder which are a set of disorders of speech that has occurred as a result of a neurologic impairment affecting the motor programming or neuromuscular execution of speech (Duffy, 1995). It is a collective name for motor speech disorders resulting from neurological damage (Duffy, 2005).

A speech impairment that results from a neurologic impairment affecting the neuromuscular execution of speech is termed dysarthria. Dysarthria designates problems in oral communication due to weakness, paralysis or incoordination of the speech musculature (Duffy, 2005). It is also referred to as the speech disorders characterized by disturbances in strength, tone, speed, accuracy, range and accuracy of movement in the muscles of speech mechanism (Love, 1995). It is marked by disturbances to any of the speech subsystems resulting in unintelligible speech.

Dysarthria can be congenital/developmental (e.g., cerebral palsy) or acquired (e.g., Parkinson's disease, brain injury, stroke). In case of acquired dysarthria, the individual would have developed some speech and language skills prior to the brain damage. Developmental or congenital dysarthria indicates that the neurological insult/damage has taken place at birth or prior to the development of speech and language (Caruso & Strand, 1999). Developmental dysarthria refers to a neurogenic speech impairment that is caused by a dysfunction in the centers of motor control in the immature central and/ or peripheral nervous systems and are marked by disturbances of strength, tone, steadiness, range, coordination, speed and precision of movement in the speech musculatures (Love, 2000).

There could be many causes leading to dysarthria, however, most of the children with developmental dysarthria will never reveal any etiology or cause, even after extensive investigations. The typical causes for dysarthria include complications in the intrauterine development (e.g. infection, exposure to radiation), premature birth, prenatal asphyxia, hypoxia, and any kind of birth trauma during delivery, and problems in the perinatal period or during childhood (Brown, 1976). Premature infants are vulnerable to hypoxic injury as their organs are not completely developed. Recent researches have indicated infections in the mother may triple the risk of the child developing the disorder than intrapartum asphyxia, mainly due to the toxicity to the foetal brain of cytokines that are produced during the inflammatory response (Subramony & Durr, 2011). It can also be caused due to certain syndromes. The syndromes may be “viral, bacterial, genetic, chromosomal, teratogenic or traumatic” (Shipley & Mcafee, 1992). Few of the syndromes include Velocardiofacial syndrome, Cornelia de Lange syndrome, Cri du chat syndrome etc. Toxic and metabolic conditions include Wilson's disease, hypoxic encephalopathy etc.

Cerebral Palsy (CP) is one of the common causes leading to developmental dysarthria. The cause of CP may be either congenital or acquired. CP can be defined as a non-progressive motor disorder that results from an insult to the cerebral level of the central nervous system during the prenatal or perinatal period (Yorkston, Beukelman, & Bell, 1988). The motor disorders of CP are often accompanied by disturbances of sensation, cognition, perception, communication and behavior, epilepsy and secondary musculoskeletal disturbances. The severity of the motor impairment and the associated cognitive communicative and behavioral impairments are different for each child with CP. About 1 in 323 children has been identified with CP according to Centers for Disease Control and Prevention (CDC) and Autism and Developmental Disabilities Monitoring (ADDM, 2008) network.

The risk factors that could cause CP include bleeding in the brain, infections of the central nervous system (meningitis or encephalitis), maternal infections, hypoxia, low birth weight, shock, poisoning from drugs or any other toxic substances, premature birth, physical trauma or injury, seizures. Among the most common risk factors for congenital CP are low birth weight (<1500gms) and premature birth (born at or before 31 weeks of gestation). Odding, Roebroeck, and Stam (2006) reported that multiple gestational pregnancies were a significant risk factor. These can result in the dysfunction of motor or somatosensory cortex of the brain, the cerebellum, corticobulbar pathways, basal nuclei, the neuromuscular junction or the brainstem which are important for nervous system's ability to activate motor units and produce accurate strength and range of movements. Menkes, John, and Flores-Sarnat (2006) reported that upto 10% of cases diagnosed as CP may be due to chromosomal anomalies and continuous gene syndromes.

The effect of CP varies from one child to another. The effects can range from complex physical and cognitive involvement to a barely noticeable limp. The severity and location of brain damage play a major role in the manifestation of CP. Many CP classifications are used today. A few of the popular classifications are based on the part of the nervous system which is implicated, neuromuscular symptoms (spastic, ataxic, dyskinetic, atonic, rigid and mixed) and the topographical distribution (quadriplegia, triplegia, diplegia, monoplegia etc.) (Minear, 1956; Boone, 1972; Shyamala, 1987). Although several types of

CP have been described in the literature, the most commonest are the spastic, ataxic, dyskinetic and the mixed type.

Berker and Yalcin (2010) reported that children with CP could have other associated problems such as intellectual deficits, epilepsy, hearing and visual impairments, feeding and swallowing problems, gastrointestinal problems, sensory problems, dental problems, bowel and/or bladder control problems, skin problems, respiratory issues, behavioral and emotional problems, sleep disturbances, perceptual problems etc.

Limiting oral motor and sensory patterns in children with Cerebral Palsy

Orofacial function is the result of complex integrated activities of the central nervous system and the neuromuscular system. Any damage to these systems can result in an orofacial dysfunction. Neuromotor involvement in the subsystems like lingual, labial, pharyngeal, velar, laryngeal, mandibular, respiratory and body postural control has been implicated in individuals with dysarthria due to CP (Kent & Netsell, 1978). Forty percent of patients with mild to severe CP have oromotor difficulties (Love, Hagerman, & Taimi, 1980). There is significant restriction of oral non speech movements such as voluntary lateralization of the tongue or protrusion and retraction of lips accompanying dysarthria.

Oral weakness can reduce the ability to generate adequate intra-oral breath pressure for consonant production (Hardy, 1961). A child with cerebral palsy may not be able to generate adequate intra-oral breath pressure due to weakness or poor coordination of the palatal, respiratory and articulatory muscles (tongue, lips and jaw) (Hardy, 1961). These weak articulators are less effective in impeding the air stream during consonant production.

According to Morris and Klein (1987), the following are the factors/oral motor patterns that limit the acquisition of adequate oral motor ability.

1. Jaw thrust, exaggerated jaw movements, jaw retraction and jaw clenching

Difficulties with gradual jaw movement are one of the main oral motor problems seen in many of the individuals. The main factor contributing to the difficulties with jaw stability and gradual jaw movement is the low muscle tone in the oral musculature as well as loose ligaments in the temporomandibular joint (TMJ). Individuals with these difficulties may also tense and hold the jaw in a specific position during the completion of an oral motor activity (e.g., biting on a straw while drinking). Another significant factor which affects the stability and graded jaw movement are fluctuating muscle tone and hypertonicity. These problems restrict the individual's smooth and graded movement of the jaw thus leading to fixed postures at certain positions.

Jaw thrust, exaggerated jaw movements, jaw retraction and jaw clenching are some of the few difficulties which are seen in individuals with jaw instability and limited control of the structure. *Jaw thrust* is defined as "a strong downward extension of the lower jaw" (Morris, 1982,p. 142). It is mainly seen in persons with significant neurological deficits. They exhibit jaw thrust while opening the mouth to speak or in anticipation of food." The jaw may appear stuck in the open position" and may have difficulty in closing the mouth to take in food or to speak. (Morris, 1982, p.143). *Exaggerated jaw movements* are seen in individuals who have loose ligaments in the temporo-mandibular joints, low muscle tone in the oral areas, and incoordination in the movements. This is seen in individuals with stroke, traumatic brain injury (TBI), CP, Down syndrome and other neurological disorders. *Jaw retraction* is the "pulling back of the lower jaw so that the molars do not make proper contact" during drinking, eating or speech production (Morris, 1982, p.143). It indicates the individuals attempt to stabilize the jaw, however it moves out of alignment. *Jaw clenching* is the "tight involuntary closure of the jaw which makes the opening of the jaw difficult" (Morris, 1982).

It is commonly seen in individuals with "strong flexor patterns" or a tonic bite reflex (Morris, 1982).

2. *Tonic bite reflex*

   It indicates a "strong closure of the jaw when the teeth or the gums are stimulated" (Morris, 1982, p. 142). When this happens, the individual will be unable to release the bite. This pattern is seen mainly in patients with severe neurological damage like traumatic brain injury and CP.

3. *Exaggerated tongue protrusion and tongue thrust*

   This is seen in individuals who use the front-back pattern of tongue movement to manage liquid, food and their own saliva. The *exaggerated tongue protrusion* maintains the easy flow of movement seen in the normal suckle pattern; however the protrusive movement is exaggerated" (Morris & Klein, 1987, p.87). This pattern is seen in individuals who have mild-moderate low muscle tone of the oral structures. Whereas *tongue thrust* is defined as "a very forceful protrusion of the tongue from the mouth' (Morris & Klein, 1987, p.88). This pattern is mainly seen in individuals who have severe neurological impairments like traumatic brain injury and CP.

4. *Tongue retraction*

   "It is the strong pulling back of the tongue into the pharyngeal space" (Morris, 1982, p. 143). It could be also result of an individual's attempt to control the amount of liquid or food reaching the pharynx. This is seen in those who do not have adequate control of the tongue for feeding.

5. *A bunched, thick, low tone tongue*

   These individuals lack the normal cupped, thin or grooved configuration that helps in efficient sucking and bolus formation" (Morris & Klein, 1987, p. 211). The appearance of the tongue is due to the dysfunction of the intrinsic muscles of the tongue. These muscles are responsible for the thinning and flattening of the tongue to create the “bowl-shaped or cupped configuration” as a passage for efficient movement of the food or liquid to the back of the mouth for swallowing” (Morris, 1982,p.144). The condition is commonly seen in individuals with neurological deficits. These individuals exhibit imprecise articulation of speech sounds associated with intrinsic muscle dysfunction.

6. *Lip retraction*

This is due to the hypertonicity in the cheeks and lips, where these articulators tend “to be pulled into a tight, retracted position” and the lips will have “a form of tight horizontal line over the mouth” (Morris & Klein, 1987, p.216). Sometimes there is an upper lip retraction in which the upper lip is pulled upwards and the face appears as the individual is smiling. This is due to the increased tension in the facial musculatures, and this tension could be a fixing pattern that has been developed by an individual to stabilize the jaw. This can also be seen in individuals with low muscle tone of the oral structures.

7. *Cheek or lip hypotonicity*

“Hypotonia in the cheeks reduces the strength and skill with which the lips can move during drinking, eating and speech production” (Morris & Klein, 1987, p.218). Low muscle tone in the buccinator results in pocketing of food materials in the cheek areas, whereas the same in the musculatures of the lips results in ineffective swallow secondary to reduced intraoral pressure. Low muscle tone in the medial pterygoid, and/or lateral pterygoid muscles, masseter muscles markedly affect stability and control of the jaw.

8. *Lip pursing*

This results when an individual attempts to ‘counteract the effects of lip retraction (Morris & Klein, 1987, p. 216). The person’s lips pucker as though they were pulled together by a drawstring (Morris & Klein, 1987). The condition is seen in individuals with neurological symptoms. “The use of effort to speak or eat in spite of the lip retraction can result in lip pursing” (Morris & Klein, 1987, p.216).

9. *Hypersensitivity, hyposensitivity, sensory overload and sensory defensiveness*

Those individuals who are hypersensitive respond markedly to a small amount or low level of a particular sensory stimuli. In case of hyposensitivity, the person will require a higher amount of stimulation for him to respond. Sensory defensiveness is the result of a previous hypersensitivity to a stimulus that has been perceived as negative. Sensory overload is a “more severe form of sensory defensiveness” (Morris & Klein, 1987,p. 233).

There are reports of impaired discriminative tactile abilities in CP (Clayton, Fleming, & Copley, 2003). Wingert, Burton, Sinclair, Brunstrom, and Damiano (2008) found feature perception to be impaired in CP sample relative to the controls. Impaired stereognosis has been reported (Wingert et al., 2008). They are also impaired in finer grained tactile spatial discrimination (Sanger & Kukke, 2007).

Clinical observations like children indicating for food when there was already food in the mouth, unawareness of presence of saliva in the mouth when asked to swallow, difficulty in telling whether the lips were approximated or separated etc. suggest a defective oral sensory function in children with cerebral palsy.

Speech Characteristics of Cerebral Palsy

Delayed speech and language and articulatory problems resulting from poor motor control as a consequence of the CNS impairment could be seen in children with CP. One of the common characteristic of individuals with CP is dysarthric speech. Some preliminary data suggests that approximately 70% of individuals with CP may have speech disorders (Rutherford, 1944; Wolfe, 1950). Most of these children will have deviations in the voice quality such as breathiness or hoarseness, nasality, disturbances in intensity, pitch and rate. Reduced speech intelligibility is another evident characteristic of these children (Tikofsky & Tikofsky, 1964; Boone, 1972).

Speech problems could vary with the type of CP. The different types of dysarthria found within cerebral palsy have been described by Love and Webb (2001) which have been depicted in table 2.2.

Table 2.2: *Sub-types of dysarthria found within cerebral palsy and the corresponding part nervous system involved*

Sub-types of dysarthria found in CP	Part of nervous system implicated
Spastic	Upper motor neuron
Dyskinetic (hypo or hyperkinetic)	Extrapyramidal tract or basal ganglia
Ataxic	Cerebellum

Studies by Abbs, Hunker, and Barlow (1983) and Brown (1984) suggested that the involvement of limb movements and speech musculature may not correlate and hence the speech disturbance cannot be inferred based on the physiological classification of CP. Considering the speech of CP and few studies carried out by several authors on spastic and athetoid CP, it can be concluded that most of the speech deviations are similar to that of the adults with dysarthria which is acquired due to neural damage (Rutherford,1944; Bery & Eisenson, 1956; Bryne, 1959; Clement & Twitehell, 1959; Hardy, 1961, 1964; Lencione, 1968; Boone, 1972; Darley, Aronson & Brown, 1975; Platt, Andrews, Young, & Quinn, 1980a; Platt, Andrews, & Howie, 1980b). Studies by Byrne (1959) and Lencione (1953) revealed that the speech development of children with spastic and athetoid CP was delayed but it followed a similar course as in the normal children.

Several studies have suggested that the speech characteristics may vary depending on the type of CP. For example children with spastic CP had lesser speech/language and hearing problems than the athetoid group who had more difficulties with speech (Byrne, 1959). The speech of individuals with athetosis (dyskinesia) tends to be characterized by slow rate, dysrhythmia, inappropriate voice stoppages, and reduced stress (Workinger & Kent, 1991). The speech of individuals with spastic CP tends to be characterized by breathy voice, monopitch, monoloudness, hypernasality and voice quality changes throughout an utterance (Workinger & Kent, 1991). According to Blumberg (1955) speech of children with spastic CP was better than athetoids in aspects like loudness, phonation and general control. Research also suggest that individuals with spastic CP may have better speech intelligibility with fewer articulation errors than speakers with athetoid CP. Phonetic analysis indicates that speakers with both types of CP makes similar kinds of errors; those with athetosis simply make a greater quantity of errors (Platt, Andrews, Young, & Quinn, 1980). A study by Lass, Rucello, and Lakawicz (1988) investigated listener perceptions of children with articulation disorders and dysarthria secondary to either CP or other developmental disorders. Results indicated that normal speakers were rated more favourably than dysarthric speakers on nearly all aspects of speaking tasks. Swigert (1997, cited in Palmer, 2005) identified five subsystems of speech production that can be affected in individuals with dysarthria.

Respiration

In children with CP, the muscles which innervate laryngeal, pharyngeal and respiratory functions as well as the brain centers responsible for respiratory regulation may also be affected. Therefore, the task of rapid inhalation and phonation would be affected in these children (Hull, 1940; Mc Donald & Chance, 1964, Lencione, 1968). These problems suggest that the valving of the air stream would prevent them to generate as much intra oral pressure required for speech production (Hardy, 1961). Reduced respiratory capacity and lowered vital capacities in children with spastic quadriplegia were reported by Hardy (1964). This could be because of the spasticity of the abdominal and thoracic wall (Hardy, 1983), thus resulting in production of short utterances. Children with CP tend to have weakness in their respiratory muscles as well as difficulty controlling those muscles for speech production. They also are likely to have difficulty with chest wall movement, including paradoxical movement patterns.

The respiration in children with athetoid CP is often rapid and irregular (Davis, 2000). There is reduced volume of air during inhalation due to reverse breathing and belly breathing in these children (Westlake & Rutherford, 1961; Love, 2000). The reverse breathing may be due to the involvement of thoracic wall muscles more than the abdominal wall muscles.

The analysis of the respiratory support in spastic and athetotic dysarthrics has revealed that both the groups exhibited forced expiration and shallow inspiration, in which the athetotic individuals had uncontrolled breathing patterns. The rhythm of respiration in spastic dysarthrics was found to be broken or spasmodic which interrupts the smooth flow of speech, whereas in athetoid dysarthrics the rhythm was jerky and uncontrolled (Love, 2000).

Phonation

At the phonatory level, children with CP experience adductor or abductor spasms, resulting in inappropriate pitch levels and inadequate subglottal airflow and air pressure (Boone, 1972). Berry and Eisenson (1956) reported that speakers with CP have whispery and hoarse voice. In spastic developmental dysarthria, the pitch is generally high and monotonous. The intensity of the voice is weak and forced. The quality of voice is breathy and forced with a partly nasal resonance (Rutherford, 1944). The duration of the open vowels were found to be short indicating an additional inspiratory support for each sound.

In individuals with athetotic dysarthria, low pitch with sudden uncontrolled rising inflections was seen. In these individuals also the intensity was found to be forced and weak, but there were fluctuations from soft to loud which indicated an inadequate voluntary control. The voice quality was found to be throaty indicating a larger amount of pharyngeal resonance. The duration of production of open vowels suggested a more sustenance compared to spastic dysarthria; the voice was perceived to be wavering (Clement & Twitchell, 1959).

Resonation

Boone (1972) reported resonance problems in children with CP and related it to the malpositioned tongues, palates and mandibles e.g., palatal movements may be sluggish or absent causing problems of nasal emission and hypernasality. Several different types of velopharyngeal dysfunction have been observed in speakers with CP (Netsell, 1969). These are as follows: gradual opening and closing of the soft palate, anticipatory opening, retentive opening, and premature opening of the velopharyngeal port during speech tasks. Individuals with athetoid CP tend to have inconsistent velopharyngeal closure because of unstable velar elevation (Kent & Netsell, 1978), while speakers with spastic CP tend to have consistent hypernasality (Workinger & Kent, 1991).

Articulation

Clement and Twitchell (1959) reported that the tongue was flattened in the rest position and was slightly pulled back from the teeth, with peristaltic movement of the tongue in the athetoid group. The movements of lips in both the groups were found to be different. In the rest position, spastic dysarthrics exhibited a thin lip line with the corners retracted. In the other group, lips at rest were more rounded and there was a frequent alteration between parting and pursing of lips. Other skills like sucking and blowing were found to be more affected in spastic dysarthric than the athetoid group.

The rapid coordinated movement patterns of the articulators are extremely susceptible to neuromuscular breakdowns resulting in misarticulation in CP (Mc Donald & Chance, 1964). Various studies have reported that the speech sounds involving tongue tip and voiceless sounds were most frequently misarticulated by children with CP compared to other sounds (Bryne, 1959). Irwin (1972) carried out a study on the articulatory aspects in children with CP. He found that the dental and glottal sounds were most difficult compared to labial phonemes. For the manner of articulation, the nasals were easier compared to fricatives and glides. He also found that omission errors were more frequent than substitution of phonemes. Another important feature seen in these children is imprecise consonant production and distortion of vowels (Clement & Twitchell, 1959). In addition, errors are common on fricatives and affricates (Platt, Andrews, & Howie, 1980) and voiceless sounds tend to be misarticulated more frequently than voiced cognates (Platt, Andrews, & Howie, 1980; Platt, Andrews, Young, & Quinn, 1980).

All these speech errors are secondary to the persistence of primitive oral reflexes such as jaw extension and tongue protrusion-retraction movements (Peiper, 1963). Jaw extension may inhibit articulatory activity of the tongue and lips and tongue protrusion-retraction movements may inhibit phonation and the voluntary movements of the tongue associated with the production of vowels and consonants. Athetoid and dystonic movements of the limbs and reflexes involving the trunk and limbs such as moro reflex and the tonic labyrinthine reflex may affect the stability of the shoulder girdle, which may affect the control of speech. Overflow movements or dyskinetic movement patterns could affect the oral musculature and result in difficulty in the production of speech.

CP can have an adverse impact on the quality of life of the individual with the disorder and his/her family members. In children a lack of an effective method of communication can lead to emotional and behavioral problems (Royal College of Speech and Language Therapists, 2006), and affects access to education and normal socialization. This all adds to the impact on potential for later employment and participation in and contribution to society (Morgan & Vogel, 2006). The International Classification of Functioning model (Royal College of Speech and Language Therapists RSCLT, 2006) can be used to describe the impact of dysarthria which has been shown in the table 2.3 below:

Table 2.3: *Dimension of dysarthria (ICF dimension) and the corresponding impact on the individual*

Dimension of dysarthria (ICF dimension)	**Impact**
Impairment	• Impaired muscle tone affecting power, precision and range of movement affecting oral, vocal and breathing movements. • Incoordination of the musculature for speech production results in abnormal speech characteristics, e.g., misarticulated phonemes, altered voice quality/ tone/volume, altered resonance, nasal emission, lack of breath support.
Activity	• Reduced intelligibility of speech • Over-quiet voice • Reduced communicative ability •Burden of communication may rest on communicative partner

Participation	• Reduced communication skills can affect self-identity, relationships, and educational and employment. • Social participation and interaction disadvantages and restrictions

Oromotor and orosensory assessment

The primary objective of an oral mechanism examination is to identify abnormalities in shape, size, color, texture or other attributes involved in speech, and to assess the sensory and motor capabilities of the articulators (Caruso & Strand, 1999). Duffy (2005) stated that the oral mechanism examination helps the clinician obtain information about the integrity of the speech mechanism, e.g., strength, tone, speed, range of motion, steadiness and coordination (Duffy, 2005). According to Darley, Aronson and Brown, (1975), these processes are the 'salient features' required for neuromuscular function and form the foundation for all kinds of voluntary movements in the body.

The goal of the oromotor assessment is to understand the pattern and severity of the impairment in the oral structures and includes the examination of structure and function of the oral structures. This assessment is particularly relevant in children with developmental dysarthria who are frequently found to exhibit oromotor problems due to the damage in the central or peripheral nervous system. Generally the examination employs non speech and speech tasks. Non speech tasks focuses on how motor performance varies across nonspeech tasks and the speech tasks focuses on how motor performance varies across speech tasks.

In addition to the oromotor assessment, an assessment of the sensory functions of the oral structures need to be carried out (orosensory assessment), since sensory issues are also seen in these children due to the brain damage such as decreased or increased sensitivity to temperature or touch, which needs to be assessed in a systematic manner.

However, the assessment in children with CP is complex. First, the client, because of the poor mental abilities, resistant behaviors or language involvement, may not be responsive to verbal instructions. Second, the abilities might vary between behaviors and subsystems. In any client, the type and degree of oromotor involvement may vary depending on the magnitude and pattern of limb involvement as well as the extent, nature and loci of lesion (Abbs, Hunker & Barlow, (1983). Further, chronological or the mental age need not predict the developmental patterns of the oro-motor behaviors. Third, the psychological and environmental stresses might degrade the behaviors. Fourth, there could also be deficits seen in oral-motor organization, which leads to dyspraxic type of symptoms and symptoms of developmental delay.

Significance of nonspeech and speech tasks

Speech-language pathologists examine the oral mechanism so as to describe the abnormal movement patterns as well as the structural deformities that could degrade the acquisition of normal speech. It is important to examine the articulators through non-speech tasks and speech tasks. Assessment of speech and nonspeech movements has been found to be helpful in understanding the underlying deficits in dysarthria due to CP.

According to Hixon and Hardy (1964), nonspeech movements would give important information even regarding the loci and extent of paresis, i.e., it provides information regarding the existence of neuromotor involvement of the musculature associated with those movements. However they also concluded that the nonspeech behaviors would give limited clues for the magnitude of speech impairment. However Abbs et al., (1983) stated that nonspeech measures were found to be useful to predict the loci and type of impairments of the subsystems. They concluded that the findings of the nonspeech measures were useful in planning therapy to improve dysarthric speech in cerebral palsy. The non speech tasks have to be used because during speech tasks, the relative severity of the impairment is difficult to differentiate because of the complex interaction of the different subsystems. It is also important to examine each structure in isolation from others in order to estimate the relative contribution of impairment in various components. For example, individuals with severe tongue weakness may attempt to compensate with jaw posturing and movement. The full extent of tongue impairment will not be appreciated unless the jaw is stabilized so that its contribution is diminished. The non speech behaviors are often useful in determining the lesions, locus and general pathophysiologic consequence but the activation of the speech neural mechanisms may be the only valid test of function for the speech motor system. Therefore it is important to examine the several structural and functional features using various speech and non-speech tasks.

Moore and Colleagues (Moore, Smith, & Ringel, 1988; Moore & Ruark, 1996; Green, Moore, Ruark, Rodda, Morve, & VanWitzenburg, 1997; Ruark & Moore, 1997) have studied the relationships and lack of relationship between speech and non-speech tasks. The results of the above mentioned studies indicated that the motor coordination required for speech and non-speech tasks are controlled by different neural mechanisms. This finding was derived from the studies done using Electromyographic (EMG) recording on lip and jaw muscle activity during different speech and nonspeech tasks. Findings of the study carried out by Moore, Smith, and Ringel, (1988) and Ruark and Moore (1997) indicated that the mandibular muscle activity for chewing required the reciprocal activation of the antagonist muscles, whereas the co-activation of the antagonist muscle were required for the mandibular muscle activity for speech. Another study done by Ruark and Moore (1997) in 2-year old children in lip muscle activities indicated that both speech and nonspeech behaviors are mediated by a common neural control mechanism. The conclusions of the studies indicated that although a common neural network may exist for the different speech and nonspeech tasks during the early developments, the control gets differentiated by the age of 2 years, which indicates that the critical learning period for oro-motor abilities occur during the first 2 years of life. By this time, the structures and many of the pathways required for speech and nonspeech processes may be the same, but the areas of neural control and timing of contraction of the muscles appear to be different.

Darley, Aronson and Brown (1975) discussed six salient neuromuscular features that influence speech production. They form a useful framework for integrating observations made during examination. Salient features are those that contribute most directly and influentially to diagnosis. They include strength, speed of movement, range of movement, steadiness, tone and accuracy.

Muscle strength

If a muscle required for speech production, does not have adequate muscle strength, the person will not be able to perform the task adequately. All the subsystems will be affected if there is decreased muscle strength anywhere in the motor speech mechanism. One technique of muscle strength examination is instructing the individual to initiate contraction while the clinician applies resistance. Here the individual will have to resist/ hold against the pressure applied by the clinician. Muscle weakness can affect all three of the major speech systems (laryngeal, velopharyngeal and articulatory) and becomes apparent in all components of speech production (respiration, phonation, resonance, articulation and prosody). Weakness is more evident in lower motor neuron lesions and therefore in flaccid dysarthrias.

Range of movement

Range of movement indicated how far a particular articulator can move during the course of movement. Examples of reduced range of movement are inability to completely open the jaw or protrude the tongue. Decreased range of motion is often associated with hypokinetic dysarthrias. Abnormal variability in range is common in ataxic and hyperkinetic dysarthrias. As cited by Darley (1975) and Duffy (1995), prosody will be significantly affected if there is a reduced range of movement. Examination can be done by asking the patient to completely extend the movement of a particular articulator.

Speed of movement

Rapid speech movements are required for accurate speech production. Even for a short utterance, the tongue as well as the vocal folds makes rapid movements. Excessive speed is uncommon in motor speech disorders, although it may occur in hypokinetic dysarthria. Excessive speech rate in people with dysarthria is mostly associated with decreased range of motion. Reduced speed of movement is one of the salient features of most of the dysarthrias. This can be tested using Diadochokinetic rate (DDK). DDK provides information about a person's ability to make rapid speech movements using different parts of his mouth. For e.g., the sounds /p/, /t/ and /k/ use the front (the lips), middle (the tip of the tongue), and back of the mouth (the soft palate), respectively. DDK rates are measured in terms of iterations per second. The DDK rate is calculated by dividing the total number of iterations by the duration of the trial or by determining the time it took the client to make a set number of iterations. The oral-DDK stimuli that are most frequently used are the monosyllables ‘‘pa’’, ‘‘ta’’ and ‘‘ka’’ (referred also as Alternate Motion Rates) and their combination into trisyllabic sequences, ‘‘pataka’’ (Sequential Motor Rates; Fletcher, 1972).

Any decrease in the AMR or SMR is known as dysdiadochokinesis or adiodochokinesis. Slow movements affect the prosodic features of speech because normal prosody is dependent on quick muscular adjustments that influence the rate of syllable production and pitch and loudness variability.

Accuracy of movement

As reported by Darley (1975), an accurate movement is one in which the strength, range, speed, timing and direction are precisely coordinated. Inaccurate movements can occur in any of the major speech systems and at any level of speech production but are generally perceived most easily in articulation and prosody. Inaccuracy occurs in all dysarthrias. But when it is the result of inadequate timing or coordination it is associated with ataxic dysarthria. When associated with random or unpredictable involuntary variations in movement, it often reflects hyperkinetic dysarthria. If any of the factors are out of synchrony, it will result in inaccurate movement, leading to intermittent hypernasality or distorted consonant production. The AMR and SMR tasks can be carried out for the assessment of the same.

Motor steadiness

It is the ability of a person to keep a particular body part still or without any movement. The two classes of involuntary movements are rhythmic and random or arrhythmic. The most common disorder in which involuntary movements leads to motor unsteadiness is *tremor.* Another major category of involuntary movements consists of random, unpredictable movements that can vary in their speed, duration and amplitude. These abnormal movements include dystonia, dyskinesia, chorea and athetosis. They can be present at rest, during sustained postures and during movement. These kind of movements are majorly seen in hyperkinetic dysarthrias. Motor steadiness is assessed by asking the person to hold on a position or to prolong a vowel.

Muscle tone

Normal muscle tone is the constant amount of muscle contractions that is present always, even when the muscle is in a completely relaxed posture. It maintains a particular muscle in a ‘ready to move’ condition and assists in the quick movements when it is necessary. Decreased or increased muscle tone is seen in individual with brain damage depending on the site of lesion. Decreased muscle tone leads to muscle weakness or paralysis and increased tone to spasticity or rigidity. Muscle tone is primarily examined by applying resistance to a passive movement.

Significance of sensory assessment

The importance of sensory information to speech motor control has been reported frequently (Abbs & Kennedy, 1982; Gracco & Abbs, 1989). Research efforts have been made to assess the potential role of somatic sensory information from skin and muscle receptors located throughout the vocal tract. Results suggested that somatic sensory information, may play a role in speech acquisition (Borden, 1979; Perkell, 1980; Gracco & Abbs, 1987). More recently, it has been found that somatic sensory information is important to the ongoing motor control process. It appears that the central nervous system is constantly receiving information on all phases of speech production and sensory considerations are as important in understanding motor control as perceptual considerations are important for understanding action.

Speaking involves the continuous modulation of the vocal tract producing local and global aerodynamic events structuring the air in characteristic ways. The specific vocal tract configurations are constantly changing during speaking with the same sound exhibiting variable movement patterns dependent on, among other things, phonetic context. From perturbation studies it is known that sensory information from somatic sensory receptors can interact with central motor commands to make short-term (within a few hundred milliseconds) and longer term contextual adjustments in speech motor output.

Thus it becomes important to assess the sensory functions inside and outside the oral area. The types of tactile sensory information clinicians should think about when observing children include touch, temperature, texture, taste, vibration etc.

Individuals with oromotor concerns can also demonstrate difficulties with sensory integration. They often exhibit uneven sensory responses and poor adaptive responses. Difficulties in the organization and integration of the sensory responses can affect both muscle function and motor planning in the oral mechanism. This could be because of specific damage to and/ or poor connections in the central nervous system. Individuals with muscle function concerns exhibit difficulties with oral stability, strength and grading of movement. Individuals with motor planning concerns demonstrate difficulties with the sequencing of oral movements. Adequate sensory perception and integration is needed for adequate oral muscle function and motor planning. Thus the speech-language pathologist also needs to assess the individual's ability to organize and integrate information from the different sensory systems.

Even though we know that afferent information contributes to ongoing speech motor control, sensory testing is not often conducted during the structural-functional examination. One reason for this may be that it is difficult to evaluate, especially in children. Clinicians require the child's cooperation, comprehension, and attention, because they rely on the client's report of sensory information (or lack of sensory information). According to Kent, Martin and Sufit, (1990), standardized examination protocols of sensory functions related to speech and oral motor behaviours are limited.

Assessment protocols available to assess orosensorymotor functions

In the past a few attempts have been made to develop checklists/test materials/questionnaires to assess the oromotor functions. Some of these have been developed for screening purposes while other protocols can be used for diagnostic purposes and provide detailed information of the oral structures. Some of these assess the oral structures and functioning using nonspeech tasks, while some others employ both nonspeech and speech tasks. Among these most are restricted to the assessment of oromotor function, while a few also test the orosensory function in addition to the oromotor asepcts. Some of them are standardized tools, while others are just screening tools and hence not been standardized. The details of these have been outlined below:

1) **The Dworkin-Culatta Oral Mechanism Examination (Dworkin & Culatta, 1980)**

The test is developed for both older children and adults in which the assessment of each subsystem is carried out. A variety of oral-motor behaviors including control of oral secretions, nonverbal, voluntary performance, oral postural control, oral reflexes and speech are assessed. The test also considers the related factors of body posture, oral anatomy as well as touch sensation.

2) Robbins-Klee protocol (Robbins & Klee, 1987)

This is a clinical protocol for assessing the oral and speech motor abilities of children, which contain 86-items. It uses both speech and non speech tasks for assessment. It has two sections: assessment of structural integrity and functional assessment of seven major structures of the vocal tract. It takes 7-10 minutes to administer the protocol. It can be used for children in the age range of 2-6 years. Normative data is available for this age group. The child's performance is summarized on total structural score (TSS 24 points), total functional score (TFS-112 points) and rate and duration measures (monosyllabic repetition rate in number/second, polysyllabic repetition rate in number/second & maximum phonation time in seconds).

3) The oral motor activities for young children (Mackie, 1996)

The questionnaire is divided into part I and part II. Part I assesses the oral motor functions during the nonspeech tasks. The assessment provides information about the stability, strength, mobility and differentiation of the oral structures. The sections are divided based on the characteristics it checks for. In the nonspeech section, tasks are divided into 3 sections which includes positions at rest, strength and stability, mobility and differentiation. The articulators assessed include jaw, cheek, lips and tongue. Instructions to carry out the tasks, the observed / expected responses and the possible indication for each response are provided for each of the task. The section takes approximately 30 minutes to administer. The section for speech tasks (part II) have to be carried out in conjunction with other formal articulation test to evaluate the mobility, control, differentiation and stability of oral structures during the speech production. This section is further divided into 2 parts. The first section is based on the observations during speech production. The second part is based on the observation made from the specific tasks for the different articulators. The assessment is also done using various food textures.

4) Oral motor evaluation protocol (Beckman, 1997)

The protocol can be used to assess minimal competencies for range and strength for the lips, cheeks, jaw, tongue and soft palate with infants. It takes 7 minutes to administer the protocol. It can be used with individuals of all age groups who exhibit oral motor problems. It assesses both oral structure and oral function. Clinician needs to be trained to administer this tool. It examines specific muscle group function. It is a hands-on assessment tool in which the clinician has to physically examine the strength, muscle tone, and responses of the muscle groups which are responsible for each oral function. The strength and range of movement can be scored out of 3 and 5 respectively. The clinician can also observe for the response to pressure in different oral structures.

5) The verbal motor production assessment for children (VMPAC, Hayden & Square, 1999)

The test was developed for children in the age range of 3-12 years. VMPAC is recommended to be part of an assessment battery including hearing, non-verbal cognition, receptive/expressive language, articulation/phonology, behavior, social/pragmatic, and fine- and gross motor control. The VMPAC contains five domains: Global Motor Control, Focal Oromotor Control and Sequencing and two supplementary areas; Connected Speech and Language Control and Speech Characteristics. The test presents some evidence of content validity and well-defined standards.

Global Motor Control consists of 20 items and assesses integrity of the neuromotor system of the child and concludes if abnormal or aberrant conditions exist that would severely complicate the production of speech through 5 underlying categories; muscle tone, breath support functions for phonation, residual of reflexes, vegetative functions and oromotor integrity. A score of 0 indicates no response or severe dysfunction and 1 point indicate no dysfunction. Focal Oromotor Control consists of 46 items and assesses the child's volitional oromotor control for subsystems like: mandibular, labial-facial, and lingual control, both in isolation and in combination with each other through 10 categories. Each item can be assessed through three cueing modalities; Auditory, tactile and visual depending on which modality of feedback the child needs for performing the task. Each modality is scored from 0 to 2 with 0 indicating severe non-verbal/ verbal errors or no response and 2 indicating no errors. If the child can perform the task without errors through auditory modality the score will be 6. Sequencing consists of 23 items, to assess the child's ability to produce non-speech and speech movements in the correct sequential order (sequencing maintenance) through 6 categories. Scoring is from 0 to 2 with 0 indicating no ability or no response and 2 indicating normal production. Connected Speech and Language Control assesses the child's motor control. The area contains 5 items. The precision and coordination of jaw, lip and tongue movements and their interaction, such as co-articulation, are closely observed during the task. The scoring is performed in two parts with the language formulation part scored from 0 to 6 and the oral-verbal precision and coordination part scored from 0 to 7. Speech characteristics include the assessment of the child's pitch, resonance, voice quality, intensity (volume), prosody and rate. A score of 0 indicates no response or severe dysfunction and 1 point indicates no dysfunction. The approximate time taken to administer the test is 30 minutes.

6) Oral Speech Mechanism Screening Examination – Revised (OSMSE-R, Louis & Ruscello 2000)

OSMSE-R is a screening test developed by St. Louis and Ruscello (2000). It is primarily designed for clinical speech/language pathologists but it can also be administered by dentists, orthodontists, physical therapists and myofunctional therapists who have undergone academic training in anatomy and physiology of speech mechanism. It is a quick screening tool that can be administered with minimal training. Total scores are calculated for structure (31), function (24) and overall test (55) and this can be compared with the normative values. The normative values are available from 5 years to >70 years. Scoring criteria has been provided (+ for appropriate structure or movement, - for deviation is structure or function, NT for items that were not evaluated, NR for lack of response, X for incorrect execution of a movement. ✓ inside an oval box is marked for appropriate category description or specific performance to reduce the administration time and facilitate interpretation). The test is standardized for normals and clinical population like articulation disorders, stuttering and persons with head injury. Since it is a screening test formal measures of validity was not derived. Research studies done using OSMSE-R in normal subjects indicated satisfactory inter and intrajudge reliability and criteria validity.

7) **Marshalla Oral Sensorimotor Test (MOST, Marshalla, 2007)**

This is the only known sensorimotor criterion referenced tool developed for children with concomitant feeding difficulties, neurological deficits, developmental disorders, and sensory processing disorders in the age group of 4 -8 years of age. The test consists of 5 subtests which includes motor function subtest (oral movement), sensory function subtest (tactile sensitivity), respiration and phonation, oral and facial tone (resonation). The Motor Function Subtest assesses for range of jaw movements, diadochokinetic rates of lips and tongue, lips and tongue, positioning and oscillating skills of lip, jaw and tongue and nonspeech oral motor exercises. The sensory function subtests examines the responses to the light and deep touch to the oral mechanism, the gag response and responses to vibration to the oral mechanism. The respiration and phonation subtest assess for the ability of the individual to produce and prolong voice on demand, inhale and exhale on demand, alter intonation, rhythm and loudness patterns on demand. The resonance subtest measures for the ability to produce vowels, fricatives and affricates without nasality, nasal sounds with nasality, and sequences of nasal consonants and vowels without nasal bleed. Finally the Oral and Facial Tone subtest provides two simple procedures for specifying muscular tone in the face, lips and tongue. A score of 1 will be provided if the child is able to complete the task and a score of '0' if the child is not able to complete the task. The test requires around 30-40 minutes to administer.

8) **Nordiac Orofacial Test- Screening (NOT-S, Bakke, Bergendal, McAllister, Sjogreen, & Asten, 2007)**

It is a screening instrument which was developed in order to identify the orofacial dysfunction. Assessment is done through both interview and clinical examination. The interview section assesses for sensory function (gag reflex and quantity of food taken in a bite), habits, breathing, drooling, chewing and swallowing and dryness of the mouth. The clinical examination includes assessment of face at rest, and tasks regarding facial expression, masticatory muscle and jaw function, nose breathing, oral motor function and speech. It also includes picture manual for showing the different tasks during the examination. One or more "yes" for impairment in a domain results in one point (maximum NOT-S score 12 points). The test takes 5-13 minutes to administer. This screening tool is a reliable and valid tool for orofacial dysfunction.

9) Stockholm Oral motor test battery (STORM, McAllister & Hartsein, 2007)

It is an assessment battery which includes tasks/tests concerning body and neck posture, oro facial muscular control, oral anatomy, eating related functions, oral sensibility, speech and dental status. It consists of tests for orofacial motor control, two point discrimination, oral stereognosis, tactile assessment, word naming, sentence repetition and non word repetition.

10) Protocol for assessing oral motor, oral praxis and verbal praxis skills in persons with Down syndrome (Rupela, 2008)

It is a questionaire developed for children in the age range of 4- 7 years. There are three sections in the protocol: oral motor, oral praxis and verbal praxis. In the oral motor section the oral structures were tested at rest and movment during speech and, two and three point rating scales are used to assess the items. The oral praxis section assesses for the oral movements in isolation on a five point rating scale (accuracy, rate and number of repetitions required) and sequence on a three point rating scale (accuracy of movements and sequences). The verbal praxis assess for the verbal taks in increasing complexity from isolated verbal movments (4 point rating scale on accuracy and number of repetitions needed), sequential verbal movements (2 point rating scale on accuracy of movements and sequence- motor control score and sequence motor score), diadochokinetic rate (DDK- rate, number of attempts, accuracy and consistency), words(phonological processes including space, timimg and whole word errors and a sequence maintenance score on three point rating scale), sentences (sequence maintenance score using a three point rating scale, percentage of consonants correct and percentage of vowels correct) and spontaneous speech(percentage of consonants correct, percentage of vowels correct number of dysfluencies, groping and phonotactic assessment).

11) ComDEALL (The Communication DEALL (Developmental Eclectic Approach to Language Learning) (Archana & Karanth, 2008)

It is a standardized tool developed by Archana and Karanth in 2008. It was developed for typically developing children in the age range of 1-4 years. The checklist is divided into 4 sections which includes the assessment of jaw movements, tongue movements, lip movements and speech. Each section consists of few tasks which the child has to perform. A score of '0' is given if the child is unable to perform the tasks, score of '1', if the tasks can be performed only spontaneously and a score of '2', if he/she can perform it on demand. Cut off scores for each section is provided separately for age ranges 1-2 years, 2-3 years and 3-4 years. The approximate time taken for the administration is 10-15 minutes.

12) LocuTour's Oral-Peripheral Evaluation Checklist

It is a checklist for oral peripheral evaluation which checks in detail about the oral structures. It involves the evaluation of face which assesses the face at rest, movement and tone, lip protrusion, retraction and strength, drooling and nasal emission; teeth (occlusion, oral hygiene, dentures, saliva and mucosa); and jaw (range, smoothness and symmetry of motion and temperomandibular joint noises). It also assess for structures like hard palate (color, arch, growth, fistula, cleft), soft palate and tongue (size, tone, color, texture & movement of tongue in terms of range & symmetry). The last part checks for the muscular tension in the face, mandible, neck and overall body.

13) Harding University Speech Clinic Oral-facial Examination form

This questionnaire includes the assessment of different oral structures in terms of range of motion, strength, symmetry etc. for each task. The oral structures assessed include face, jaw and teeth, lips, tongue, pharynx, hard and soft palate. In addition, evaluation is done and during the phonation of /a/.

This is only a sample set of assessment protocols. There are many more used by speech-language pathologists to assess the integrity and functioning of the speech mechanism which have been published in texts on motor speech disorders (Caruso & Strand, 1999; Yorkston et al., 1999; Duffy, 2005). Further most hospitals and clinics have developed customized checklists for the oral mechanism examination that suit the needs of their particular working situations.

Studies to Assess the Orosensorimotor Abilities in Children with Cerebral Palsy

Dysarthria in children is described as a sensorimotor problem. In the 1960's, a number of studies concerned with oral sensory and motor deficits concurred in indicating that such deficits play a role in the speech performance of the cerebral palsied. Oral motor, oral tactile (somesthetic) and oral stereognostic abilities both appeared to be implicated.

Hixon and Hardy (1964) studied the underlying neurophysiological mechanisms for speech production. The subjects were 25 children with spastic CP and 25 children with athetoid CP in the age ranging from 4.4 -16.2 years. The task was to repeat certain speech and nonspeech tasks in 10 seconds. Performance was measured based on the number of repetitions in the specified time. The tasks were closing and opening lips, rounding and retracting the lips, raising and lowering the tongue, closing and opening of the jaw, lateralizing the tongue to both sides of the mouth and repetition of the syllables /ma/, /da/, /ga/, and /pa-ta-ka/ . The results indicated that the repetition rate of speech syllables were much higher than the nonspeech tasks. The repetition rate for the syllables /ma/, /da/, /ga/, /pa-ta-ka/ were 24.34, 23.34, 21.48, 5.42 per 10 seconds respectively. The difference in the two tasks could be because of the greater neurological processes involved in speech production. They also justify that central nervous system patterning required for speech production is less difficult than for which required for controlled non-speech activities using the same articulatory structures. Also, a certain series of neuronal patterns are arranged by the CNS for more automatic kind of motor response like speech. One more explanation that the investigators provide for the findings is that the speech movements are facilitated and influenced by the sensory modalities which continuously monitor the automatic speech production. They concluded that evaluation of restricted mobility of the articulators for speech problems seen in individuals with CP cannot be achieved by the use of nonspeech movements of those particular structures. Results of this study do not support those authors (Froeschels & Jellinek, 1941, pp. 58-61; Froeschels, 1943; Westlake, 1951; Perlstein & McDonald, 1953; Westlake & Rutherford, 1961, pp. 1-62) who suggest the use of nonspeech movements of the articulators to evaluate or treat significant restriction of articulatory motility.

Solomon (1965) conducted a study on 6 year old children with athetosis in which they were classified into normal, mildly defective, severely defective and grossly defective categories based on their chewing abilities. Oral sensory function was assessed using tasks like form identification, weight perception, texture discrimination, two- point discrimination and localization of tactile stimulus. The results were compared with the findings of Templin Darley test of articulation. The results suggested that all groups except normals had low score on both tests of texture discrimination and localization of tactile stimuli which also correlated with a poor score in the articulation test.

Hardy (1983) reported that clients with acquired dysarthria secondary to cerebral palsy have intra oral asomesthesia which was determined by a stylus placed on the surface areas of the intraoral structures. He reported that the speech production deficits in such cases can be attributed to the intra oral asomesthesia.

Krick and Van Duyn (1984) described growth retarded infants with CP as having oral-motor impairment characterized by at least two of the following: food loss, poor lip-closure, excessive drooling, coughing, choking, no tongue lateralization, incoordinated swallowing, lip retraction, tonic biting, tongue thrusting and poor motor control.

Reilly, Skuse, and Poblete (1996) attempted to determine the prevalence of oral motor dysfunction among a representative sample of 49 children with cerebral palsy (12 to 72 months of age). A population survey was undertaken by means of a combination of interview and home observational measures.They found that more than 90% had clinically significant oral motor dysfunction. Gangil, Patwari, Aneja, Ahuja, and Anand (2001) conducted a prospective hospital based interventional study. Hundred children (76 boys and 24 girls) in the age range of 1-9 years with CP were recruited for the study. Oral motor dysfunction was found in all the subjects.

Sjakti, Syarif, and Wahyuni (2008) in their study also observed that oro-motor dysfunction was the most frequent cause of feeding problems seen in 56% of their participants who were children with CP in the age range of 13 months to 9 years. Oro-motor dysfunctions reported in the study were poor lip closure, perioral hyposensitiveness/ hypersensitiveness, tongue thrust, limited tongue movement, poor gag reflex, jaw instability and inadequate lip retraction.

Arvedson (2008) reported the different types of oral sensory impairments in children with CP which can affect the feeding abilities such as lack of taste, differentiation of liquids in bottle despite intact sucking, efficiency with liquids better than with solid foods, sorting out food of different textures, e.g., fruit piece in yoghurt. Also there can be food held under tongue or in cheek to avoid swallowing, vomiting - certain textures, gagging when food approaches/ touches lip or tongue or gagging prominent with solids; no mouthing of toys, inability to tolerate others' fingers in mouth, and refusal of tooth brushing.

Parkes, Hill, Platt, and Donnelly (2010) reported the prevalence, clinical associations, and trends over time of oromotor dysfunction and communication impairments in children with CP. Multiple sources of ascertainment were used and children were followed up with a standardized assessment including motor speech problems, swallowing/chewing difficulties, excessive drooling, and communication impairments at 5 years of age. A total of 1357 children born between 1980 and 2001 were studied. Of those with 'early-onset' CP (n=1268), 36% had motor speech problems, 21% had swallowing/chewing difficulties, 22% had excessive drooling, and 42% had communication impairments (excluding articulation defects). All impairments were significantly related to poorer gross motor function and intellectual impairment. In addition, motor speech problems were related to clinical subtype of cerebral palsy; swallowing/chewing problems and communication impairments to early mortality; and communication impairments to the presence of seizures. Of those with CP in GMFCS levels IV to V, a significant proportion showed a decline in the rate of motor speech impairment and excessive drooling over time. It can be concluded that these impairments are common in children with CP and are associated with poorer gross motor function and intellectual impairment.

Clancy and Hustad (2011) also found that children with CP with oro-motor involvement are more likely to have feeding difficulties. They found that children with mild-moderate oro-motor difficulties had issues like asymmetry of oro-facial structures during movement or at rest and drooling and children with severe oro-motor difficulties had issues like extremely limited volitional control of feeding musculature along with severe drooling.

A recent review study Aggarwal, Chadha, and Pathak (2015) also found different types of oromotor dysfunctions in children with CP which had an impact on feeding and swallowing abilities such as difficulty in sucking and swallowing, drooling, poor lip closure and perioral hyposensitiveness/hypersensitiveness. The features of less prevalent oromotor dysfunctions included tongue thrust, limited tongue movement, choking, persistent bite reflex, jaw instability, poor respiratory coordination, poor gag reflex, lip retraction and primitive chewing reflex.

Shabnam and Swapna (2016) investigated the feeding and oro-motor skills on 60 children with CP in the age range of 2-10 years. To assess the feeding and oro-motor skills, the physical domain of Feeding Handicap Index (FHI) (Shabnam, 2014) and the Com-DEALL oro-motor assessment checklist (Archana & Karanth, 2008) was used. The results indicated that feeding and oro-motor problems were present in children with CP and they found strong correlation between physical domain of FHI and the oro-motor scores obtained on the Com-DEALL checklist. The oro-motor difficulties found in children with CP were inadequate lip closure, restricted tongue movement and inadequate jaw movement.

Anne (2017) assessed the oromotorsensory functioning in adolescents with CP using the protocol by Rupela (2008). A high score on the protocol indicated severe impairment in oromotor and orosensory functioning. It was found that all the participants obtained a high score which indicated that they had greater degree of both oromotor and orosensory impairments.

A systematic review of the literature revealed that the orosensory motor process undergoes several stages of development and maturation throughout the childhood. These skills would be affected in individuals with different motor speech disorders like dysarthria. During the assessment of dysarthria it is very important to carryout orosensorymotor assessment as all these aspects would be affected in these individuals. It was also found that in the available tools, the orosensory assessment was given very less importance even though sensory information plays a major role in speech motor control. Most of these tests fail to provide a quantitative score based on the assessment. In addition, most of these protocols do not assess the aspects that are affected in children with developmental dysarthria such as tone, strength, speed, coordination and lip-jaw-tongue differentiation. Further, there is a dearth of tools available for the assessment of sensorimotor skills in children with dysarthria in the Indian context. Hence there is a need to develop a standardized test to assess the oral motor and sensory aspects. Thus this study was planned with the aim of development and standardization of an oral sensorimotor evaluation protocol for children in the age range of 4-8 years.

CHAPTER III

METHOD

The present study aimed at the development and standardization of a protocol for the assessment of oral sensorimotor aspects for children in the age group of 4-8 years. The study was carried out in the following phases:

Phase I: Construction of the Oral Sensorimotor Evaluation Protocol (OSEP).

Phase II: Administration of OSEP on typically developing children.

Phase III: Assessment of test-retest and interjudge reliability in the control group.

Phase IV: Establishing the validity by administration of OSEP on clinical population.

Phase V: Assessment of test-retest reliability in the clinical group.

Phase I: Construction of the Oral Sensorimotor Evaluation Protocol (OSEP)

As part of this phase, the following steps were carried out:

Step 1: Development of a protocol to assess the orosensorimotor aspects seen in children with developmental dysarthria.

A thorough search of the literature and various tools that are pre existing to assess the orosensorimotor aspects was carried out. The protocol was prepared by collating information from the literature, based on the already existing tools as mentioned in the chapter II under review of literature and based on the complaints concerning oromotor and sensory aspects received from the clients evaluated in the Special clinic for motor speech disorders, Department of Clinical Services, All India Institute of Speech and Hearing, Mysuru. The protocol was divided into three sections: I. Demographic data and general history, II.

Orosensory assessment, III. Oromotor assessment. The details of the sections have been provided below:

I. Demographic data and general history: This section included the personal details of the child, the medical history (prenatal, natal and post natal history), details of the different evaluations (speech and language evaluation, oromotor examination, psychological evaluation, gross and fine motor evaluation, neurological/paediatric assessment) and intervention details.

II. Orosensory assessment: This section was divided into two parts: Part A and Part B.

Part A was divided into ten subsections. The subsections were:

A) Touch: This subsection focused on assessing the awareness of different touch stimuli including Light static touch, Kinetic touch, Deep pressure, Vibration and Double simultaneous touch on the articulators such as cheeks (right & left), lips (upper & lower), jaw, tongue, and palate.

B) Topagnosis: This subsection assessed the ability of the child to localize touch stimuli on the articulators such as upper lip, lower lip, jaw, cheeks and tongue.

C) Two-point discrimination: This subsection assessed the child's ability to discriminate between the stimuli with minimal separation of the points on the above mentioned articulators.

D) Test of oral stereognosis: The subsection focused on the ability to identify different shapes like square, round, triangle and star.

E) Oral form discrimination: This subsection evaluated the child's ability to discriminate between different shapes like square - round, triangle- star etc.

F) Temperature: This subsection included the assessment of the articulators with cold and warm temperature.

G) Taste: This subsection included the assessment of all the four tastes like sweet, salty, sour and bitter using appropriate solutions.

H) Texture: This subsection included the assessment of the articulators for the smooth and rough textures.

I) Assessment of pain: This subsection assessed the ability of the child to perceive the sensation of pain on the articulators.

J) Oro facial sensitivity: This subsection checked for the participant's tolerance to different materials on the facial and oral structures.

Part B: This section consisted of four subsections which included questions related to the assessment of oral and tactile hyper/hyposensitivity. This part was to be completed by gathering information from the parent/caregiver. Under oral hypersensitivity, questions such as 'Does your child avoid certain food textures- especially mixed textures? If yes, specify, 'Does your child resist face wiping?'; under tactile hypersensitivity- 'Does your child avoid touching different objects with palm?', 'Does your child refuse to walk bare foot on rough surface like cement pavement, grass lane etc.; under hyposensitivity, questions such as 'Does your child feel the food in the mouth?', Does your child have difficulty distinguishing between different tastes?'; and under tactile hyposensitivity, questions such as 'Does your child crave for touch, needs to touch everything and everyone? If yes, specify', 'Does your child constantly put things in the mouth?'etc. were included. The responses from the parent/caregiver would be marked under 'yes' (sometimes/ all the time), 'no', 'questionable'.

III. Oromotor assessment: This section was divided into three subsections: Part A, Part B and Part C.

Part A: Oral structural and functional assessment: This subsection included the assessment of articulators such as jaw, lips, tongue, and palate. The assessment of each articulator was to be carried out at rest, during sustained posture and during movement. Each task was assessed in terms of stability, symmetry, range of movement, tone and involuntary movements. For e.g., under evaluation of 'Jaw at rest', questions such as 'Is the jaw size normal in relation to the size of head'?; under evaluation of 'Jaw during sustained posture' questions such as 'Can the child maintain a wide open mouth posture'? and under evaluation of 'Jaw during movement', questions such as 'Can the client open and close the jaw rapidly'? etc. were included

Part B: Lips-jaw-tongue differentiation: This subsection included questions to assess the dissociation of the articulators. Questions such as 'Can the client open and close mouth without moving the head?, 'Can the client say /u/ or /i/ without additional head/jaw movements?' etc. were included.

Part C: Assessment of Diadochokinetic rate (DDK): This subsection included the assessment of Alternate Motion Rate (AMR) and Simultaneous Motion Rate (SMR). The repetition was to be assessed based on the rhythm and articulation accuracy.

The instructions to administer each task under the different sections were prepared which was incorporated into the protocol. A scoring pattern was devised for the section II and III of the protocol. A response choice of "yes" would be assigned a score of 1 and a response choice of "no" would be assigned a score of zero. A severity rating from normal to severe was also included under each section. In addition, a kit containing aids and other materials to assess the orosensory and oromotor aspects was prepared.

Step 2: Content validity check

The content validity of the protocol along with the user manual was assessed by compiling the feedback from 6 experienced speech-language pathologists, 1 physiotherapist and 1 occupational therapist. The judges were asked to rate the appropriateness of each section, subsections and the rating scale used. The feedback was collected on a 3 point rating scale ranging from – contents are not very valid (score 0) to contents are valid (score 2).

As per the rating given by the judges, those questions which were given a score of '2'(valid) were retained. After the content validation, it was found that there was a need to add, delete and modify a few sections of the protocol. In the demographic details and general history, two questions were included and few modifications in the titles were made. In the orosensory section, 5 sections obtained a score of '1' (somewhat valid) and were deleted. The sections were two-point discrimination, oral stereognosis, oral form discrimination, topagnosis and pain. The judges indicated that the task on two point discrimination and topagnosis would be difficult for the children to perform as the children with cerebral palsy have motor and speech-language deficits. The section on pain was deleted since it was felt by the judges that it may be unethical to induce pain in the children and test for it, particularly in children with cerebral palsy. The oral form discrimination and oral stereognosis was almost tapping the same aspect, however it was felt that these do not accurately reflect the somesthetic ability. Hardy (1983) also reported that intraoral stereognosis with the cerebral palsy population may not accurately reflect their intraoral somesthetic ability. Children with cerebral palsy may have difficulty in perceiving a stimulus through one modality and matching that stimulus from among a number of choices that are perceived through another modality. Birch (1964) also reported that stereognostic testing usually entails such type of activity and children with CP tend to have difficulties with these. All subsections under oromotor assessment except dentition and reflex assessment obtained a score of '2' and were retained in the protocol. Initially all the articulators were included for assessment. After the content validation, the articulators which were felt to be inaccessible, especially in the paediatric population were deleted (e.g., soft palate). Modifications were made in the overall severity rating scale. A few modifications in the instructions incorporated in the user manual were also made.

Step 3: Pilot study

A pilot study was carried out on 5 children with developmental dysarthria, and 8 typically developing children in the age range of 4-8 years. The pilot study was carried out in order to

a. Familiarize with the different sections of the protocol and procedures.
b. To check whether the instructions were appropriate.
c. To check whether the materials and aids used for assessment were appropriate.
d. To check for the feasibility of testing the articulators that had been included under each section.
e. To find out the approximate time taken for administration on one participant.

After the pilot study, a few changes were made in the user manual to the instructions in the orosensory section. A few materials for testing were also replaced in the kit.

Step 4: Finalization of the protocol

After incorporating the changes suggested by the judges and from the pilot study, the protocol was finalized. The final version of the protocol has been provided in the Appendix.

Phase II: Standardization of OSEP on typically developing children.

In order to standardize the protocol, the final version of the same was administered on 240 typically developing children in the age range of 4-8 years.

Participants: Children in the age range of 4-8 years were randomly selected from different schools in Mysuru and Kerala. The selected schools were Gangothri Vidyasala, Bogadi, Mysuru, Gangothri government high school, Manasagangothri, Mysuru, Christ Public school, Nanjangud, Little flower primary school, Kottayam, Kerala and St. Joseph’s public school, Kottayam, Kerala who constituted the control group. There were 60 participants each in the age range of 4-4.11, 5-5.11, 6-6.11 and 7-7.11 years. Equal number of males (30) and females (30) were considered in each age group. The participants with no history of neurological, communicative, cognitive, or sensorimotor, and academic impairment were included in the study, which was ensured using the 'WHO Ten-question disability screening checklist' (Singhi, Kumar, Malhi, & Kumar, 2007). Participants belonging to low, middle and high socioeconomic statuses were selected using the NIMH socioeconomic status scale (Venketesan, 2011).

All ethical standards were met for subject selection and their participation. Prior to testing, a written consent was obtained from the school authorities and parents of the participants after explaining the purpose of administration of the test. Ethical approval was also obtained from the AIISH Ethical committee (AEC).

Procedure: The testing was carried out in a relatively noise free environment with minimum distraction. A rapport was established with the children prior to the administration. The purpose of the administration was explained. The demographic data was obtained initially. The WHO Ten-question disability screening checklist was administered on the typically developing children. This was followed by the administration of the developed protocol. The responses obtained were documented in the response sheet based on the rating scale. The approximate time taken to administer the entire protocol was 30 minutes. Positive verbal, social and token reinforcements were provided to maintain the interest of the child during the administration.

Phase III: Assessment of test-retest and interjudge reliability in the control group

Test-retest reliability was carried out on 10% of the participant (10 subjects from each age group) sample selected randomly from both the groups. The protocol was readministered within a period of 8-9 days to assess the test-retest reliability. Another experienced speech-language pathologist administered the same protocol on 10% of the participant sample to assess the interjudge reliability.

Phase IV: Establishing the validity by administration of OSEP-C on clinical population.

Participants: 15 children with developmental dysarthria secondary to cerebral palsy in the age range of 4-8 years (10 males and 5 females) who reported to the Department of clinical services, All India Institute of Speech and Hearing, Mysuru, participated in the study. They were diagnosed as 'Delayed speech and language with Cerebral palsy' by a qualified team of professionals including speech-language pathologist, pediatrician, physiotherapist and a clinical psychologist. The Assessment Checklist for speech-language domain (Swapna, Jayaram, Prema, & Geetha, 2010) was administered to assess their speech and language abilities. Twelve of 15 children had receptive and expressive language delay, 2 of them had age adequate receptive and expressive language abilities and 1 of them only had a expressive language delay. The intelligence quotient of the participants ranged from normal (n=11) to mild degree (n=4) of intellectual disability. Those children who had other associated problems were excluded from the study. Participants belonging to low, middle and high socioeconomic statuses were selected using the NIMH socioeconomic status scale (Venketesan, 2011). All the children belonged to middle (13) and high (2) socioeconomic status. All the children included in the study were enrolled in an intervention program such as speech-language therapy, physiotherapy and pre-school.

Procedure: The testing was carried out in a relatively noise free environment with minimum distractions. Each child was tested individually. A rapport was established with the mother/caregiver. The purpose of administration was explained. The demographic data was obtained initially. The questionnaire was administered in 2-3 sittings. Breaks were given depending upon the cooperation of the child. Social and token reinforcements were given to encourage the child. The parental questionnaire section which included questions regarding oral and tactile hypo/hyper sensitivity in the orosensory part was administered only for the clinical group. The approximate time taken to administer the entire protocol was 90 minutes. All ethical standards were met for subject selection and their participation. Prior to testing, a written consent was obtained from the parents of the participants after explaining the purpose of administration of the test.

Table 3.1: *Details of the clinical group*

Sl. No.	Participant no.	Chronological age	Gender	Type and topographic distribution of CP
1.	S1	6;0	Male	Spastic quadriplegia
2.	S2	7;0	Male	Spastic diplegia
3.	S3	7;0	Male	Spastic diplegia
4.	S4	5;6	Male	Ataxic
5.	S5	6;1	Female	Spastic diplegia
6.	S6	5;7	Female	Spastic diplegia
7.	S7	5;4	Female	Spastic diplegia
8.	S8	4;3	Male	Spastic
9.	S9	5;4	Female	Spastic diplegia
10.	S10	4;6	Female	Spastic diplegia
11.	S11	5;2	Male	Spastic diplegia
12.	S12	6;7	Male	Spastic
13.	S13	6;6	Male	Spastic hemiplegia
14.	S14	7;1	Male	Spastic diplegia
15.	S15	7;3	Male	Spastic quadriplegia

Phase V: Assessment of test-retest reliability in the clinical group

The protocol was re-administered on 6 participants from the clinical group within a period of 2 weeks to assess the test-retest reliability.

Scoring: A score of '1' was assigned for a response choice of "yes" and a score of '0' for the response choice of "no". A severity rating from normal to severe was also included under each section which was assessed by the examiner.

Analysis: Under the orosensory section, the scores for each of the subsections were added up and the total score was calculated. Under the oromotor task, the total score of each articulator at rest, at sustained posture and during movement and the scores of lip-jaw-tongue differentiation and DDK were totalled to obtain the oromotor total score. The severity rating was also noted for each child for the different sections.

Statistical Analysis: The scores obtained from section II (orosensory) and III (oromotor) were totalled, tabulated and further subjected to statistical analysis using SPSS software version 21. Descriptive statistics was carried out to obtain the mean and standard deviation across age and gender. All the data were subjected to the normality test across age and gender. The Shapiro-Wilk test was employed to determine the normality of the data distribution. Non-parametric tests were employed for age and gender comparison since the data did not follow normal distribution principle. Cronbach's alpha was carried out in order to determine the test-retest and inter-judge reliability. The results obtained from all the above statistical measures have been presented and discussed in the next chapter.

CHAPTER IV

RESULTS AND DISCUSSION

The present study aimed at the development and standardization of a protocol (OSEP-C) for the assessment of oral sensorimotor aspects for children in the age group of 4-8 years. The protocol was developed focusing on the assessment of oral sensorimotor issues faced by children with developmental dysarthria. OSEP-C comprises of three sections: I. Demographic data and general history, II. Orosensory assessment and III. Oromotor assessment, for which the content validation was carried out. The protocol was then administered on typically developing children (control group) and children with developmental dysarthria secondary to cerebral palsy (clinical group). The control group consisted of 240 typically developing children with equal distribution of males and females (30 males and 30 females in each age group) and the clinical group included 15 children with developmental dysarthria secondary to cerebral palsy. The scores obtained for both the groups from section II (oral sensory) and III (oral motor) of the developed protocol were totalled, tabulated and further subjected to statistical analysis using SPSS software version 21.

Descriptive statistics was carried out to obtain the mean and standard deviation across the different age groups and gender in both the groups. The Shapiro-Wilk test was employed to determine the normality of the data distribution. The result showed that most of the data was not following the normal distribution principle. Hence non-parametric tests were used for comparison across age and gender. The Kruskal Wallis test was done to see the overall effect of age group. Those parameters which showed a significant difference was further taken up for pair wise comparison using Mann-Whitney U test. Gender effect was also examined using Mann-Whitney U test. Cronbach's alpha was carried out in order to determine the test-retest and inter-judge reliability. The control and clinical groups were compared using Mann-

Whitney U test. The results obtained using the above statistical measures are presented and discussed under following sections:

I. Test- retest reliability and inter-judge reliability
II. Comparison of the orosensorimotor abilities across age groups for the control group
III. Comparison of orosensorimotor abilities across gender in the control group
IV. Comparison of orosensorimotor abilities between clinical and control group
V. Comparison of orosensorimotor abilities across gender in the clinical group
VI. Severity rating across different subsections in the clinical group and control group

I Test-retest reliability and interjudge reliability

The test retest reliability was determined for 40 children (ten from each age group) from the control group. The alpha values obtained on the different subsections were found to be high (0.92-0.99) indicating strong test-retest reliability. The protocol was also re-administered on 6 children with dysarthria and the alpha values obtained ranged between 0.90 - 0.99 indicating strong test retest reliability in the clinical group too.

The interjudge reliability was also determined for 40 children from the control group (ten from each age group). Another speech-language pathologist administered the same protocol on the selected children. The alpha values obtained on the different subsections were found to be high (0.85-0.99) indicating strong inter-judge reliability. The high Cronbach's alpha for both the types of reliability indicated that the tool developed was highly reliable.

II Comparison of the orosensorimotor abilities across age groups for the control group

The mean and standard deviation was obtained using descriptive statistics for the typically developing children in different age groups. Table 4.1 depicts the mean and standard deviation for the control group in the age range of 4 to 8 years.

Table 4.1: *Mean and standard deviation (SD) for all orosensorimotor tasks across different age groups of children included in the control group.*

Section	Tasks	Mean (SD)			
		4-4.11	**5-5.11**	**6-6.11**	**7-7.11**
Oral sensory	Light static touch (Gloved finger)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)
	Light static touch (Tooth pick)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)
	Kinetic touch	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)
	Deep pressure	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)
	Vibration	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)
	Double simultaneous touch	7.37(1.37)	8.07(1.31)	8.35(1.61)	8.68 (1.16)
	Touch total	42.23 (1.48)	43.07 (1.31)	43.35 (1.61)	43.68 (1.16)
	Temperature (Cold)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)
	Temperature (Warm)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)	7.00 (0.00)
	Temperature total	14.00 (0.00)	14.00 (0.00)	14.00 (0.00)	14.00 (0.00)
	Taste total	4.00 (0.00)	4.00 (0.00)	4.00 (0.00)	4.00 (0.00)
	Texture (Smooth)	9.00(0.00)	9.00(0.00)	9.00(0.00)	9.00(0.00)
	Texture (Rough)	9.00(0.00)	9.00(0.00)	9.00(0.00)	9.00(0.00)
	Texture total	18.00 (0.00)	18.00 (0.00)	18.00 (0.00)	18.00 (0.00)
	Orofacial sensitivity	10.00 (0.00)	10.00 (0.00)	10.00 (0.00)	10.00 (0.00)
	Sensory total	88.28 (1.86)	88.98 (1.50)	89.35 (1.16)	89. 67 (1.17)

Oral motor	Jaw at rest	4.98 (0.13)	4.97 (0.18)	5.00 (0.00)	5.00 (0.00)
	Jaw during sustained posture	4.97 (0.26)	5.00 (0.00)	5.00 (0.00)	4.97 (0.18)
	Jaw during movement	4.55 (0.53)	4.67 (0.54)	4.63 (0.55)	4.90 (0.44)
	Jaw total	14.50 (0.57)	14.63 (0.55)	14.65 (0.55)	14.75 (1.31)
	Lips at rest	5.00 (0.00)	5.00 (0.00)	5.00 (0.00)	5.00 (0.00)
	Lip during sustained posture	9.70 (0.53)	9.85 (0.36)	9.80 (0.40)	9.93 (0.36)
	Lips during movement	8.22 (0.72)	8.63 (0.58)	8.58 (0.53)	8.90 (0.54)
	Lip total	22.95 (1.04)	23.48 (0.81)	23.38 (0.85)	23.83 (0.62)
	Tongue at rest	4.98 (0.13)	5.00 (0.00)	5.00 (0.00)	5.00 (0.00)
	Tongue during sustained posture	12.88 (0.45)	12.93 (0.25)	12.92 (0.28)	13.00 (0.00)
	Tongue during movement	8.72 (0.61)	8.85 (0.48)	8.88 (0.32)	8.98 (0.13)
	Tongue total	26.60 (0.94)	26.78 (0.61)	26. 83 (0.46)	26.98 (0.13)
	Palate at rest	8.93 (0.25)	8.85 (0.36)	8.85 (0.36)	8.90 (0.30)
	Palate during sustained posture	2.00 (0.00)	2.00 (0.00)	1.97 (0.18)	2.00 (0.00)
	Palate during movement	2.00 (0.00)	2.00 (0.00)	2.00 (0.00)	2.00 (0.00)
	Palate total	12.93 (0.25)	12.87 (0.34)	12.82 (0.39)	12. 87 (0.34)
	Lips-jaw-tongue-differentiation	9.65 (0.66)	9.75 (0.54)	9.85 (0.36)	9.95 (0.22)

DDK	7.93 (0.25)	7.93 (0.33)	7.97 (0.18)	8.00 (0.00)
Oral motor total	94.57 (2.03)	95. 33 (1.79)	95.50 (1.61)	96.55 (0.95)
Grand total score	182.80 (2.50)	184.13 (2.35)	184.87 (2.05)	186.47 (1.60)

The combined total mean scores for the oromotor and orosensory section increased with increase in age. The total mean scores specifically for the oral sensory and oromotor section were greater for the higher age groups.

Among the five subsections in the orosensory section, the total score obtained in the temperature, taste, texture and orofacial sensitivity sections were similar across age groups. The participants obtained the maximum score for these subsections. A ceiling effect was seen. The participants also obtained maximum scores under touch subsection. However for the double simultaneous touch, there was an increase in mean values across age groups.

Under the oromotor section consisting of six subsections, the jaw total score, lip total score, tongue total score, lip-jaw-tongue differentiation score and DDK score showed an increase with age. However on the palate total score, such a trend was not seen. The figures 4.1, 4.2 and 4.3 depict the mean scores obtained by the participants for oral motor, DDK and oral sensory sections respectively across age groups.

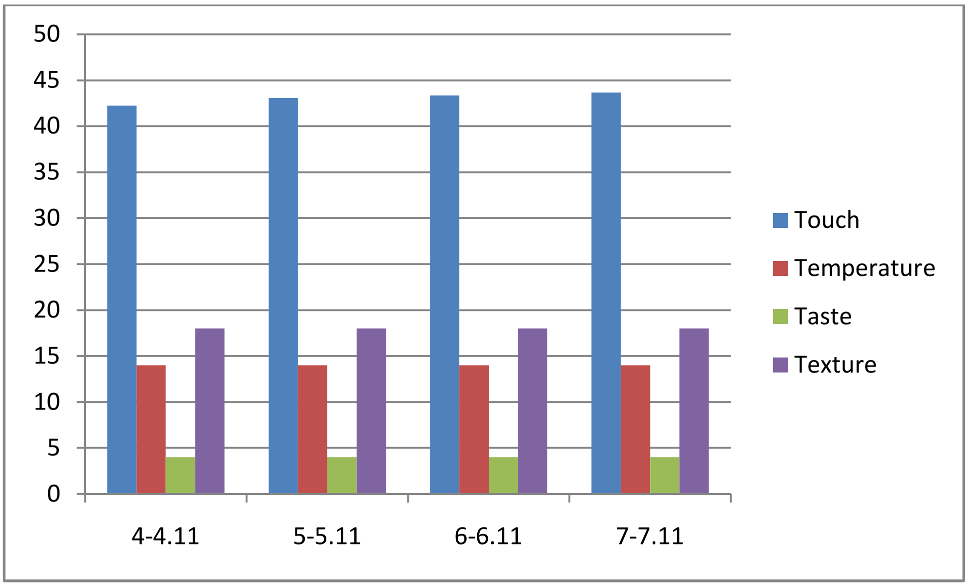

*Figure 4.1: M*ean scores for oral sensory section across age group in the control group.

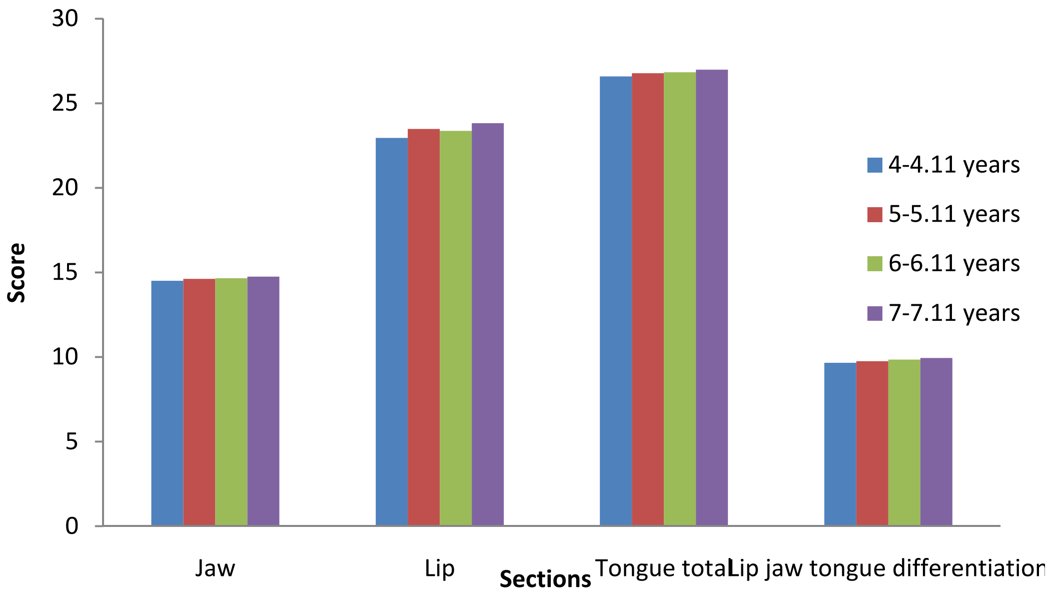

*Figure 4.2: M*ean scores for oral motor section across age group in the control group.

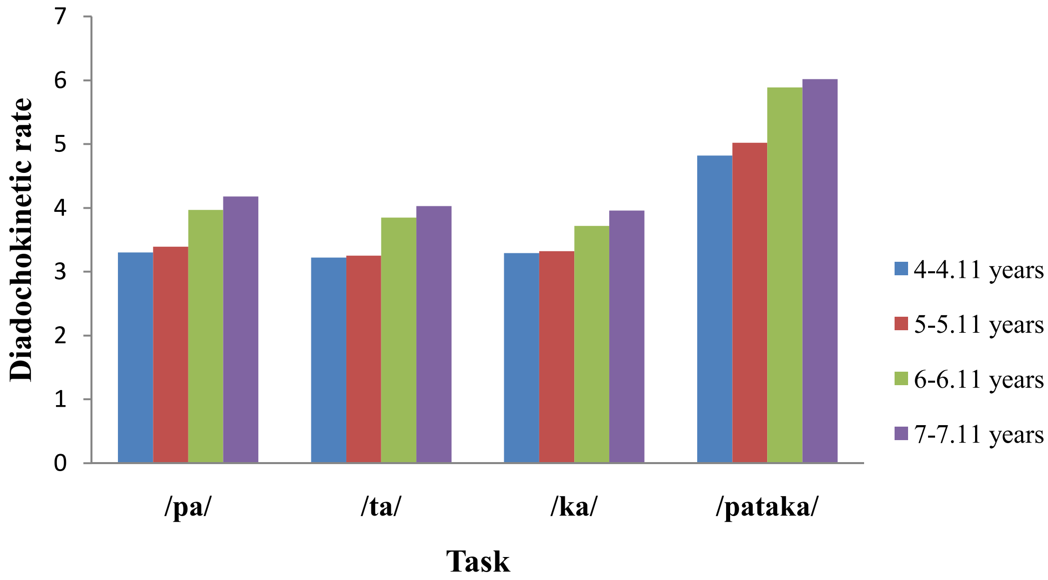

Figure 4.3: Mean DDK scores across age group for /pa/, /ta/, /ka/ and /pataka/ for the control group.

Kruskal Wallis test was done to find if there was any significant difference between the age groups on all the orosensory and oromotor tasks. Table 4.2 indicates the Chi square value and p-value for the different sections. The results of this test revealed that there was a significant difference in the mean scores across age groups for a few of the oral sensorimotor tasks.

Table 4.2: *Chi square values and p-values for orosensorimotor tasks across age group for the control group*

Section	**Parameters**	**Age range**	***Chi square Value*** **(χ 2)**	***P- Value***
Oral sensory	Double simultaneous touch	4-4.11 5-5.11 6-6.11 7-7.11	32.15 (3)	0.00**

Oral Motor	Touch total	4-4.11	81.00 (3)	0.00**
		5-5.11		
		6-6.11		
		7-7.11		
	Sensory total	4-4.11	33.86 (3)	0.00**
		5-5.11		
		6-6.11		
		7-7.11		
	Jaw during movement	4-4.11	20.15 (3)	0.00**
		5-5.11		
		6-6.11		
		7-7.11		
	Jaw total	4-4.11	18.68 (3)	0.00**
		5-5.11		
		6-6.11		
		7-7.11		
	Lips during sustained posture	4-4.11	12.21 (3)	0.00**
		5-5.11		
		6-6.11		
		7-7.11		
	Lips during movement	4-4.11	39.46 (3)	0.00**
		5-5.11		
		6-6.11		
		7-7.11		
	Lips total	4-4.11	34.58 (3)	0.00**

	5-5.11		
	6-6.11		
	7-7.11		
Tongue during movement	4-4.11	11.85 (3)	0.00**
	5-5.11		
	6-6.11		
	7-7.11		
Tongue total	4-4.11	11.38 (3)	0.01*
	5-5.11		
	6-6.11		
	7-7.11		
Lip-jaw-tongue differentiation	4-4.11	10.38 (3)	0.02*
	5-5.11		
	6-6.11		
	7-7.11		
Oral motor total	4-4.11	47.80 (3)	0.00**
	5-5.11		
	6-6.11		
	7-7.11		
Grand total score	4-4.11	72.25 (3)	0.00**
	5-5.11		
	6-6.11		
	7-7.11		

$^{*}P<0.05$, $^{**}p<0.01$

The tasks such as double simultaneous touch, touch total, sensory total, jaw during movement, jaw total, lip in sustained posture, lips during movement, lips total, tongue during movement, tongue total, lip-jaw-tongue differentiation, oral motor total, grand total score showed a significant difference across age. These tasks were further subjected for pairwise comparison using Mann Whitney U test. Table 4.3 and 4.4 represents the /z/ and p values across different age groups for those tasks which showed a significant overall age group effect.

Table 4.3*: Z- values and p-values across age groups for the different tasks in the control group.*

Tasks	**Age group**	***/Z/ value***	***P value***
Double simultaneous touch	4-4.11 vs. 5-5.11	2.84	0.00**
	4-4.11 vs. 6-6.11	4.13	0.00**
	4-4.11 vs. 7-7.11	5.21	0.00**
	5-5.11 vs. 6-6.11	1.25	0.21
	5-5.11vs. 7-7.11	2.72	0.01*
	6-6.11 vs. 7-7.11	1.71	0.09
Touch total	4-4.11 vs. 5-5.11	3.02	0.00**
	4-4.11 vs. 6-6.11	4.26	0.00**
	4-4.11 vs. 7-7.11	6.63	0.00**
	5-5.11 vs. 6-6.11	1.25	0.21
	5-5.11vs. 7-7.11	7.04	0.00**
	6-6.11 vs. 7-7.11	7.18	0.00**
Sensory total	4-4.11 vs. 5-5.11	2.83	0.01*
	4-4.11 vs. 6-6.11	4.36	0.00**

	4-4.11 vs. 7-7.11	5.39	0.00**
	5-5.11 vs. 6-6.11	1.36	0.17
	5-5.11vs. 7-7.11	2.66	0.01*
	6-6.11 vs. 7-7.11	1.62	0.11
Jaw during movement	4-4.11 vs. 5-5.11	1.39	0.17
	4-4.11 vs. 6-6.11	1.02	0.31
	4-4.11 vs. 7-7.11	4.53	0.00**
	5-5.11 vs. 6-6.11	0.38	0.71
	5-5.11vs. 7-7.11	3.20	0.00**
	6-6.11 vs. 7-7.11	3.57	0.00**
Jaw total	4-4.11 vs. 5-5.11	1.42	0.16
	4-4.11 vs. 6-6.11	1.60	0.11
	4-4.11 vs. 7-7.11	4.36	0.00**
	5-5.11 vs. 6-6.11	0.19	0.85
	5-5.11vs. 7-7.11	3.04	0.00**
	6-6.11 vs. 7-7.11	2.87	0.00**
Lips during sustained posture	4-4.11 vs. 5-5.11	1.63	0.10
	4-4.11 vs. 6-6.11	0.94	0.35
	4-4.11 vs. 7-7.11	3.44	0.00**
	5-5.11 vs. 6-6.11	0.72	0.47
	5-5.11vs. 7-7.11	2.11	0.03*
	6-6.11 vs. 7-7.11	2.72	0.00**
Lips during movement	4-4.11 vs. 5-5.11	3.40	0.00**
	4-4.11 vs. 6-6.11	2.87	0.00**
	4-4.11 vs. 7-7.11	6.03	0.00**

	5-5.11 vs. 6-6.11	0.77	0.44
	5-5.11vs. 7-7.11	3.16	0.00**
	6-6.11 vs. 7-7.11	3.96	0.00**
Lips total	4-4.11 vs. 5-5.11	3.05	0.00**
	4-4.11 vs. 6-6.11	2.39	0.02*
	4-4.11 vs. 7-7.11	5.74	0.00**
	5-5.11 vs. 6-6.11	0.68	0.50
	5-5.11vs. 7-7.11	3.24	0.00**
	6-6.11 vs. 7-7.11	3.78	0.00**
Tongue during movement	4-4.11 vs. 5-5.11	1.48	0.14
	4-4.11 vs. 6-6.11	1.55	0.12
	4-4.11 vs. 7-7.11	3.41	0.00**
	5-5.11 vs. 6-6.11	0.03	0.97
	5-5.11vs. 7-7.11	2.19	0.02*
	6-6.11 vs. 7-7.11	2.19	0.03*
Tongue total	4-4.11 vs. 5-5.11	1.20	0.23
	4-4.11 vs. 6-6.11	1.30	0.19
	4-4.11 vs. 7-7.11	-3.42	0.00**
	5-5.11 vs. 6-6.11	0.08	0.94
	5-5.11vs. 7-7.11	2.44	0.02*
	6-6.11 vs. 7-7.11	2.43	0.02*
Lip-jaw-tongue	4-4.11 vs. 5-5.11	0.75	0.46
differentiation	4-4.11 vs. 6-6.11	1.56	0.12
	4-4.11 vs. 7-7.11	3.12	0.00**
	5-5.11 vs. 6-6.11	0.82	0.41

	5-5.11vs. 7-7.11	2.51	0.01*
	6-6.11 vs. 7-7.11	1.81	0.07
Oral motor total	4-4.11 vs. 5-5.11	2.26	0.02*
	4-4.11 vs. 6-6.11	2.78	0.00**
	4-4.11 vs. 7-7.11	6.69	0.00**
	5-5.11 vs. 6-6.11	0.32	0.75
	5-5.11vs. 7-7.11	4.55	0.00**
	6-6.11 vs. 7-7.11	4.70	0.00**
Grand total score	4-4.11 vs. 5-5.11	2.80	0.00**
	4-4.11 vs. 6-6.11	4.68	0.00**
	4-4.11 vs. 7-7.11	7.68	0.00**
	5-5.11 vs. 6-6.11	1.75	0.08
	5-5.11vs. 7-7.11	5.81	0.00**
	6-6.11 vs. 7-7.11	4.49	0.00**

$P<0.05$, $**p<0.01$

Under the orosensory tasks, there was a significant difference seen across most age groups. The significant difference on the double simultaneous touch task was seen between 4-4.11 and 5-5.11, 4-4.11 and 6-6.11, 4-4.11 and 7-7.11, 5-5.11and 7-7.11 age groups. However no significant difference was seen between 5-5.11 vs. 6-6.11 years and between 6-6.11 vs. 7-7.11 years in the double simultaneous task and the sensory total scores and between 5-5.11 vs. 6-6.11 years on the touch total scores.

Under oromotor section, specifically for jaw during movement, there was a significant difference across all age groups except between 4-4.11 vs. 5 to 5.11, 4-4.11 vs. 6 to 6.11 and between 5-5.11 vs. 6 - 6.11 age group. A similar pattern was seen for the jaw total scores, lip during sustained posture, tongue during movement and tongue total scores. In the lip during movement and lip total scores, there was a significant difference across all age groups except between 5-5.11 vs. 6-6.11 age group. There was no significant difference between 4-4.11 vs. 5-5.11, 4-4.11 vs. 6-6.11, 5-5.11 vs. 6-6.11, 6-6.11 vs. 7-7.11 age group on the lip-tongue jaw differentiation task. In the oromotor total scores and the grand total scores, there was no significant difference between the 5-5.11 vs. 6-6.11years age group.

A significant difference on jaw during movement, jaw total, lips during sustained posture, tongue during movement, tongue total, lips- jaw- tongue differentiation were observed between 4-4.11 and 7-7.11, 5-5.11and 7-7.11 and 6-6.11 and 7-7.11 years of age. For lips during movement, lips total, oromotor total and grand total scores, a significant difference was seen between the age groups indicated within parenthesis (4-4.11 and 5-5.11, 4-4.11 and 6-6.11, 4-4.11 and 7-7.11, 5-5.11and 7-7.11, 6-6.11 and 7-7.11).

Thus the results revealed several interesting findings. First, the performance on the orosensory tasks and oromotor tasks increased with age. In the sensory section, only the subtest on double simultaneous touch showed a gradual increase in scores across age groups, while the performance of the participants on all other orosensory tasks reached a ceiling right from the 4-4.11 age group. There was a significant difference on double simultaneous touch across age groups. These results indicated that the double simultaneous touch task was not completely acquired by the age of 4 years and they perform better with age. The increase in the scores of double simultaneous touch was reflected in the touch total scores and the orosensory total scores.

The double simultaneous touch task involved perceiving a stimuli, comparing it with the second stimuli and indicating whether one or two parts of the oral structures were touched. This was cognitively more complex for the children than the other touch related tasks which only involved perceiving the stimuli and indicating its presence or absence. This would have led to the poorer performance on this task compared to the other tasks.

Since the children in the different age groups obtained 100% scores on all the subsections of the orosensory tasks, no significant difference was obtained between age group and a ceiling effect was seen. This indicated that the children acquired the awareness of different sensory stimuli by 4-4.11 years of age. This finding could also be attributed to the simplicity of the response expected from the children for the tasks included under the orosensory skills. All the subsections were awareness based tasks, i.e. the children had to indicate the presence or absence of the stimuli which is generally acquired early in life. Studies that have examined the development of tactile limb withdrawal reflexes in humans indicate that the thresholds increase from 27 weeks to full term infants (Andrews & Fitzgerald, 1994). In addition there are studies which report that infants are able to recognize a familiar object on the basis of touch alone (Gottfried & Rose, 1980).

If the complexity of each of the task would have been increased, such as including more discrimination and identification tasks with more number of stimuli, probably ceiling effect would not have been seen and there could have been differences in performance of the children across age groups, since there are evidences in the literature indicating that the development of somesthesis continues well into childhood and beyond. For example, Mc Donald and Solomon (1962) reported that children of 5 years could differentiate texture, weights and forms placed in the oral cavity. Schiff and Dytell (1972) showed that the ability to discriminate among patterns and identification of object improved between 7.5 and 19 years of age. However, these tasks were not included considering that the protocol was developed for the children with developmental dysarthria consequent to cerebral palsy who could also exhibit other co-morbid disorders.

Under the oral motor section, subsections such as jaw during movement, jaw total, lip sustained posture, lips during movement, lips total, tongue during movement, tongue total, lip-jaw-tongue differentiation, oral motor total, and grand total score showed a significant difference across age groups. The jaw total and the tongue total scores exhibited a developmental trend since there was a gradual increase in the mean scores across age groups and there was also a significant difference between 4-4.11, 5-5.11, 6-6.11 vs. 7-7.11 age groups. The lip total score also showed a similar developmental trend and there a significant difference between all age groups except between the 5-5.11 vs. 6-6.11 years. However, the palate total scores did not show such a developmental trend since there was no significant difference between all age groups.

These results indicated that the oral structures like jaw, lips and tongue undergo a refinement with respect to movement and strength between 4 and 8 years of age. Similar findings were obtained in previous studies too. Kent (2000) reported that during the period of maturation from 3 to 7 years, the overall oral system continues its gradual growth. Sharkey and Folkins (1985) studied sustained postures, movement and coordination of lip and jaw using strain gauge (five adults, and children at ages 4, 7, and 10) and suggested three types of developmental motor processes for speech. One type was regarding the organization of motor system that produced relatively consistent duration parameters by around 4 years of age. The second type of process involved the refinement of the motor organization at 4-7 years of age and the final type of process was related to the reduction in the variability of movement durations studied between children and adult groups. This process may be further involved in precision shaping of the movement patterns. They concluded that the basic developments in the oromotor movements happens upto the age of 4 years and in the later stages the oral motor system will undergo the process of fine refinement. Watkin and Fromm (1984) also found that variability of lip displacement decreased in children from 4-10 years of age.

Though these studies are based on objective measurements, the findings of the present study are consistent with the motor speech developmental trends reported in the literature. Smith and Zelaznik (2004) and Walsh and Smith (2002) stated that oromotor development is non uniform, with a refinement period from mid-childhood (4-6 yrs) extending into late adolescence. Ostry, Feltham, and Munhall (1984) conducted a study using pulsed ultrasound in children from 3-11 years and found that motor development of tongue undergoes a process of refinement rather than significant changes in the motor execution.

A steady increase in the mean scores of jaw, lip and tongue was observed in the current study. Kent (2000) reported that by age 8, the child's jaw moves with greater precision. Fletcher (1989) carried out a palatometric study for the tongue in children of 6-14 years of age and found that the older children reached the initial articulatory positions faster, generated vowels with shorter durations, and articulated more posteriorly than did the younger children indicating a refinement of lingual motor development. Nittrouer (1993) also found that younger children produced slower articulatory movements when compared to adults.

However, an exponential increase in the mean scores was not found across all tasks in the oral motor section. Instead, it could be observed that on a few tasks, the younger age group scored better than the older age group. Similar findings were reported by Green et al., (2002) and Smith et al., (2004), where they concluded that the variability of speech motor performance shows an overall decreasing trend with age that is overlaid with some transient periods of elevated variability and this occurs at the transitional stages in development when task demands greatly exceed a child's capability (Thelen & Smith, 1994). Also the findings of Kent (1976) suggests that the variability of speech motor control progressively diminishes until the age of 8-12 years, when adult like stability is achieved reflecting an increasing precision of motor control over a five- to eight years (Tingley & Allen 1975; Kent 1976). In the present study too, the age group 7-7.11 obtained the highest mean values compared to the other age groups which clearly indicated maturational changes in the oral motor tasks.

Turan (2013) aimed to develop a normative data for oromotor skills in children in the age range of 3-6 years. The results revealed that that the scores of both isolated and sequential oral movements increased till the age of 4.5, after which no significant changes were observed. Similar findings were found by Robbins and Klee (1987) where they observed significant changes in the oral motor functioning up to the age of 3.6 years and only a small or insignificant increase in the total oral functional score after the age of four.

There was a steady increase in the mean scores obtained for lip-jaw-tongue differentiation, which indicated that the ability to move each articulator independently also improved with age. Meyer (2000) reported that the movements of the tongue, lips and mandible are observed to undergo a transformation from synergistic, undifferentiated movements in the infant, to differentiated and refined movements in the toddler and young child. This transformation is crucial for the development of higher levels of articulatory precision and coordination required for verbal communication.

The mean DDK scores for /pa/, /ta/, /ka/ and /pataka/ also reflected a developmental trend. The findings of Canning and Rose (1974) is in agreement with the findings of the present study indicating that there was a positive correlation for DDK rate with age and adult like rates was achieved by 9-10 years of age. Green et al., (2000) investigated the jaw and lip coordination of 1-, 2-, and 6-year-olds and young adults using a video-based movement tracking system and found that the synchrony of movements of the articulators increased steadily with age. Similar findings were obtained in a study by Smith et al., (2004) where they used the Optotrak to investigate the development of jaw-lip coordination from the age of 4–21 years and found that there was a reduction in the variability with respect to the interarticulator coupling in terms of synchrony and consistency of movement with increase in age.

Yarrus and Logan (2002) also found a significant relation between age and overall DDK rate in a study done in boys between 3 and 7 years. The findings of the present study is also in consonance with a previous study done by Wong et al., (2011) in 4-18 year old subjects using Motor speech profile (MSP). Their findings suggested that the average DDK rate increased with age. The findings are consistent with another study done by Williams and Stackhouse (1998) in 3-5 year old children, where they found that the accuracy of productions improved with age. Cheng, Murdoch, Goozee, and Scott (2007) also studied the of tongue-jaw coordination during speech from childhood to adolescence. Their results also suggested a maturational trend for kinematic tongue–jaw coordination, reflected more specifically by an increase of temporal coupling in the production of /t/, and the spatiotemporal coordination pattern becoming more consistent in /k/ production as children mature.

III Comparison of orosensorimotor abilities across gender in the control group

The mean and standard deviation was computed using descriptive statistics separately for the male and female participants. Further the mean scores were subjected to statistical analysis using Mann Whitney U test to check whether there was any significant difference between the male and the female participants on the all tasks included in the protocol. Table 4.4 shows the mean, standard Deviation (SD), /z/ value and *p-value* for both the gender belonging to the control group.

Table 4.4: *Mean, standard deviation (SD), /z/ value and p-value for male and female participants in the control group*

Section	Task	Mean (SD)		/Z/- value	P- value
		Male	Female		
Oral sensory	Double simultaneous touch	8.04 (1.37)	8.19 (1.30)	1.00	0.31
	Touch total	41.38 (3.35)	41.64 (5.49)	0.44	0.66
	Sensory total	88.96 (1.49)	89.17 (1.57)	1.12	0.26
Oral motor	Jaw at rest	4.97 (0.16)	5.00 (0.00)	1.87	0.06
	Jaw during sustained posture	5.00 (0.00)	4.97 (0.21)	1.61	0.11
	Jaw during movement	4.68 (0.56)	4.69 (0.51)	0.10	0.92
	Jaw total	14.59 (1.05)	14.67 (0.54)	0.05	0.96
	Lips during sustained posture	9.85 (0.41)	9.80 (0.44)	1.04	0.30
	Lips during movement	8.64 (0.57)	8.53 (0.64)	1.26	0.21
	Lips total	23.48 (0.87)	23.36 (0.91)	1.17	0.24
	Tongue at rest	5.00 (0.00)	4.99 (0.89)	0.93	0.35
	Tongue during sustained posture	12.96 (0.31)	12.91 (0.28)	1.89	0.06
	Tongue during movement	8.92 (0.33)	8.80 (0.50)	2.35	0.02*
	Tongue total	26.87 (0.60)	26.74 (0.63)	2.65	0.01*
	Palate at rest	8.88 (0.32)	8.88 (0.32)	0.02	0.98
	Palate during sustained	2.00 (0.00)	1.98 (0.12)	1.31	0.19

posture				
Palate total	12.88 (0.32)	12.86 (0.35)	0.56	0.61
Lips-jaw-tongue differentiation	9.79 (0.48)	9.80 (0.49)	0.31	0.75
DDK	7.99(0.16)	7.96 (0.34)	0.71	0.48
Oral motor total	95.71 (1.52)	95.29 (1.97)	1.27	0.20
Grand total score	184.62 (2.25)	184.52 (2.73)	0.06	0.96

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

A comparison across gender in the control group indicated that there was no significant difference in scores between males and females on the orosensory tasks. However the mean scores of the orosensory total section was slightly higher for females than males. Ritcher and Campbell (1940) reported gender differences with respect to the taste sensation with girls generally being more sensitive than boys. The study by James, Laing, and Oram (1991) also supported the fact that an immature gustatory sensitivity was seen in boys, but not girls of the same age.

There was no significant difference in scores between males and females on most of the oromotor tasks except for the task on tongue during movement. Males performed better than the females. It was also seen that the mean scores of the oromotor total section of all the tasks was slightly higher for males than females, unlike the orosensory tasks. The findings are in agreement with findings of Cheng et al., (2007) where they found no evidence of gender differences in the development of speech motor coordination.

IV Comparison of orosensorimotor abilities between clinical and control group

The clinical group (children with dysarthria) was compared to the control group (typically developing children) for the scores obtained for each section and subsections of the orosensorimotor protocol. The mean, median and standard deviation was computed using Descriptive statistics. These mean scores of both the groups were subjected to statistical analysis using Mann Whitney U test. Table 4.5 shows the mean, standard deviation and the results of Mann-Whitney U test. Figure 4.4 depicts the mean scores on the oromotor and orosensory tasks and the grand total score for both the groups.

Table 4.5: *Mean, standard deviation (SD), Z-value and p-value for the clinical and control group*

Section	**Task**	**Mean (SD)**		***/Z/- value***	**P- value**
		Control group	***Clinical group***		
Oral sensory	Light static touch (Gloved finger)	7.00(0.00)	6.93 (0.26)	4.00	0.00**
	Light static touch (Tooth pick)	7.00 (0.00)	7.00 (0.00)	4.00	0.00**
	Kinetic touch	7.00 (0.00)	5.00 (3.14)	9.90	0.00**
	Deep pressure	7.00(0.00)	6.93 (0.26)	4.00	0.00**
	Vibration	7.00(0.00)	6.93 (0.26)	4.00	0.00**
	Double simultaneous touch	8.12 (1.34)	2.27 (1.94)	6.57	0.00**
	Touch total	41.52 (4.62)	35.00 (4.66)	4.81	0.00**

	Temperature (Cold)	7.00(0.00)	7.00(0.00)	-	-
	Temperature (Warm)	7.00(0.00)	7.00(0.00)	-	-
	Temperature total	14.00 (0.00)	14.00 (0.00)	-	-
	Taste total	4.00 (0.00)	4.00 (0.00)	-	-
	Texture (Smooth)	9.00 (0.00)	9.00 (0.00)	-	-
	Texture (Rough)	9.00 (0.00)	9.00 (0.00)	-	-
	Texture total	18.00 (0.00)	18.00 (0.00)	-	-
	Orofacial sensitivity	10.00 (0.00)	10.00 (0.00)	-	-
	Sensory total	89.07 (1.53)	81.00 (4.66)	6.53	0.00**
Oral motor	Jaw at rest	4.99 (0.11)	4.33 (0.49)	11.15	0.00**
	Jaw during sustained posture	4.98 (0.16)	4.27 (1.10)	7.90	0.00**
	Jaw during movement	4.69 (0.53)	3.67 (1.23)	4.26	0.00**

Jaw total	14.63 (0.81)	12.27 (2.37)	5.50	0.00**
Lips at rest	5.00 (0.00)	4.97 (0.20)	10.71	0.00**
Lips during sustained posture	9.82 (0.43)	4.67 (3.33)	8.88	0.00**
Lips during movement	8.58 (0.61)	3.50 (2.52)	7.39	0.00**
Lips total	23.41 (0.89)	12.07 (6.15)	7.35	0.00**
Tongue at rest	5.00 (0.06)	4.87 (0.52)	2.67	0.01*
Tongue during sustained posture	12.93 (0.30)	4.87 (4.10)	11.08	0.00**
Tongue during movement	8.86 (0.43)	3.20 (2.86)	9.22	0.00**
Tongue total	26.80(0.62)	12.93 (6.69)	9.12	0.00**
Palate at rest	8.88 (0.32)	8.67 (0.62)	1.79	0.07
Palate during sustained posture	2.00 (0.00)	2.07 (1.79)	3.13	0.00**
Palate during movement	2.00 (0.00)	1.67 (0.62)	8.05	0.00**

Palate total	12.87 (0.34)	12.00 (1.25)	4.00	0.00**
Lips-jaw-tongue differentiation	9.80 (0.49)	5.40 (2.53)	7.79	0.00**
DDK	7.98 (0.27)	3.53 (2.77)	10.91	0.00**
Oral motor total	95.49 (1.78)	58.20 (18.21)	6.68	0.00**
Grand total score	184.57 (2.52)	139.20 (21.07)	6.55	0.00**

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

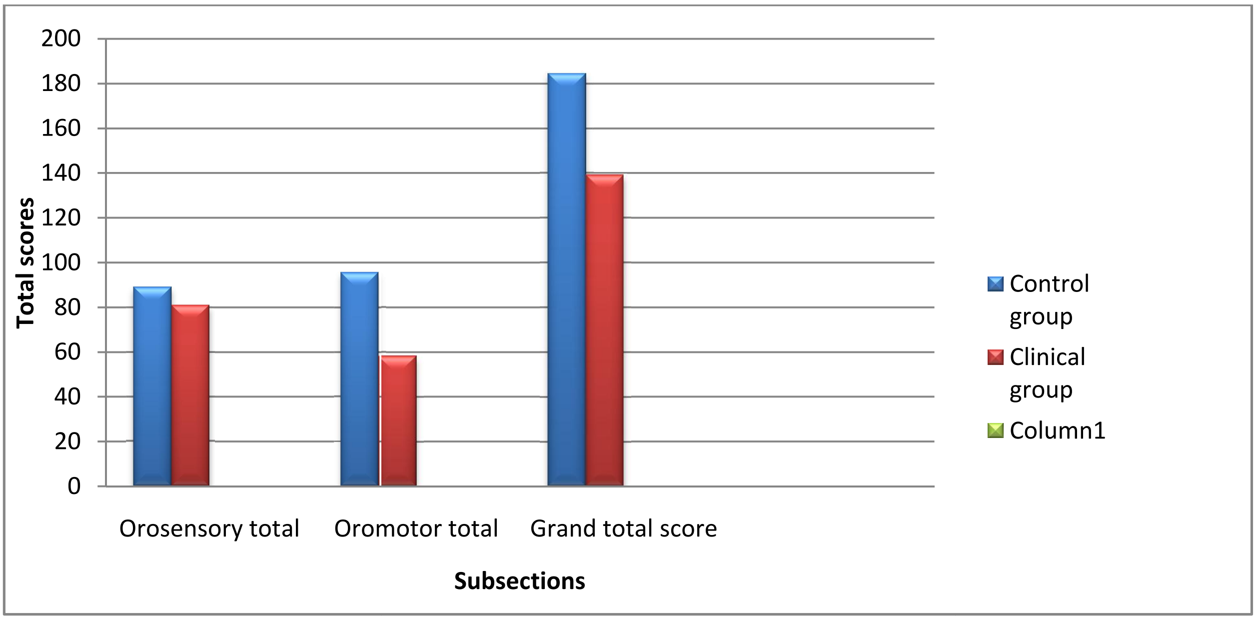

Figure 4.4: Mean total scores for the control and the clinical group for the orosensory and oromotor section and the overall total score on both the sections.

The results of the Mann Whitney U test revealed that the mean scores of the clinical group were significantly poorer than the control group in both the sensory and the motor sections. The present findings are in consonance with a recent study by Anne (2017) who assessed the oromotorsensory functioning in adolescents with CP using the protocol by Rupela (2008). The results revealed that all the participants obtained a high score which indicated that they had greater degree of both oromotor and orosensory impairments.

On the orosensory tasks such as light static touch, kinetic touch, deep pressure, vibration and double simultaneous touch, the clinical group obtained significantly lower mean scores than the control group. Hardy (1983) reported that clients with acquired dysarthria secondary to cerebral palsy have intra oral asomesthesia which was determined by a stylus placed on the surface areas of the intraoral structures. He reported that the speech production deficits in such cases can be attributed to the intra oral asomesthesia. Clayton, Fleming, and Copley (2003) also reported impaired discriminative tactile abilities in CP. Wingert, Burton, Sinclair, Brunstrom, and Damiano (2009) reported that they are also impaired in finer grained tactile spatial discrimination.

Other investigators like Auld, Boyd, Moseley, Ware, and Johnston (2012); Clayton et al., (2003); Cooper, Majnemer, Rosenblatt, and Birnbaum (1995); Sanger and Kukke (2007) have also suggested that children with CP have sensory deficits areas like proprioception, tactile discrimination and stereognosis. The findings of the present study is in agreement with the findings of Kułak, Sobaniec, Kuzia, and Bockowski (2006); Kurz, Arpin, and Corr (2012); Kurz and Wilson (2011); Riquelme and Montoya (2010); Teflioudi, Zafeiriou, Vargiami, Kontopoulos, and Tsikoulas (2011), who concluded that the motor impairments seen in children with CP would be partially related to the inefficient processing by the sensorimotor cortices. Altogether these experimental results indicated that the somatosensory cortices of children with CP may not adequately process sensory stimulation. They also opined that abnormally suppressed somatosensory processes should affect the motor performance in children with CP; however, this link has not been established. Thickbroom, Byrnes, Archer, Nagarajan, and Mastaglia (2001) concluded that there can be differences in the organization of sensory and motor pathways in CP and some of the motor deficits seen in these children could be because of the impairments in the sensorimotor integration at the cortical level.

Kurz, Heinrichs-Graham, Arpin, Becker and Wilson (2014) used magnetoencephalography to measure the responses to tactile stimulation to the bottom of the foot in the somatosensory cortices in children with cerebral palsy. The results indicated that the neurons in the somatosensory cortices of children with cerebral palsy were desynchronized suggesting that they were unable to fully integrate the external stimulus into ongoing sensorimotor computations. They also concluded that the motor performance errors of children with cerebral palsy are linked with the neural synchronizations within the somatosensory cortices. Hence oral sensory functions can also be affected in these children as observed in the current study.

However on a few subsections like temperature, taste, texture and orofacial sensitivity, there was no significant difference between the clinical and the control group. However, Arvedson (2008) reported different types of oral sensory impairments in children with CP such as lack of taste, differentiation of liquids in bottle despite intact sucking, sorting out food of different textures, e.g., fruit piece in yoghurt. This could be attributed to the age groups considered in both studies and the methodological differences.

On the oromotor tasks, children in the clinical group obtained significantly lower mean scores in all the subsections. This indicated that the movement and strength of lip, tongue, jaw and palate of children with dysarthria were limited compared to typically developing children. Neuromotor involvement in the subsystems like lingual, labial, pharyngeal, velar, laryngeal, mandibular, respiratory and body postural control has been implicated in individuals with dysarthria due to CP (Kent & Netsell, 1978). There is significant restriction of oral non speech movements such as voluntary lateralization of the tongue or protrusion and retraction of lips accompanying dysarthria. Krick and Van Duyn (1984) reported oral-motor impairment in infants with CP such as no tongue lateralization, lip retraction, tonic biting, tongue thrusting and poor motor control. Morris and Klein (1987) also reported that children with CP could have oromotor problems such as jaw thrust, exaggerated jaw movements, jaw retraction and jaw clenching, exaggerated tongue protrusion and tongue thrust, tongue retraction, bunched, thick, low tone tongue, lip retraction and pursing, cheek or lip hypotonicity etc. Nip (2013) reported that children with CP have reduced rate in a DDK task when compared to typically developing peers. Nip (2017) found a reduced spatial coupling between the upper and lower lips and reduced temporal coupling between all articulators as compared to their typically-developing peers in diadochokinetic and syllable repetition tasks.

Several studies report that children with CP have associated feeding problems due to oral sensorimotor issues. Krick et al., (1984) found that infants with CP have any of the following oral motor impairment: excessive drooling, choking, coughing, reduced tongue lateralization, tonic biting, lip retraction, tongue thrust, poor lip closure, incoordinated swallowing, and food loss. Similarly Vivone, Tavares, Bartolomeu, Nemr, and Chiappetta (2007) have reported that 58-86% of the children with CP in their study had signs of dysphagia. A survey was done by Calis, Veugelers, Sheppard, Tibboel, Evenhuis, and Penning (2008) on 166 children with CP in the age range of 2 to 19 years. They found that the prevalence of dysphagia in 99% of the children with CP. They concluded that dysphagia is directly related to the severity of motor impairment. Similar findings were obtained in a prevalence study done on children with CP in the age range of 12 to 72 months by Reilly, Skuse and Poblete (1996) and they have concluded that majority of children in their study had a clinically significant oral motor dysfunction.

Gangil, Patwari, Aneja, Ahuja, and Anand (2001) and Sjakti, Syarif, and Wahyuni (2008) also found that most of the children with CP had clinically significant oral motor dysfunction which lead to feeding problems. Oro-motor dysfunctions reported were poor lip closure, tongue thrust, limited tongue movement, poor gag reflex, jaw instability and inadequate lip retraction.

Aggarwal, Chadha, and Pathak (2015) also found different types of oromotor dysfunctions in children with CP such as poor lip closure, tongue thrust, limited tongue movement, choking, persistent bite reflex, jaw instability, poor respiratory coordination, poor gag reflex, lip retraction and primitive chewing reflex. Shabnam and Swapna (2016) reported oro-motor difficulties in children with CP such as inadequate lip closure, restricted tongue movement and inadequate jaw movement. Anne (2017) assessed the orosensori motor functioning in adolescents with CP using the protocol by Rupela (2008). A high score on the protocol indicated severe impairment in oromotor and orosensory functioning. It was found that all the participants obtained a high score which indicated that they had greater degree of both oromotor and orosensory impairments.

A subsection under orosensory section was dedicated to checking the oral and tactile hyper/hypo sensitivity through a series of questions (Part B). This subsection was administered only for the clinical group. The scores were obtained by adding up the total score under each response (yes/ no/questionable) of all the 15 children with CP. Then the percentage of each response was calculated and shown in table 4.6. The results revealed that 76% of the children did not have sensory issues. However 11.5% of the parents did report that their children had these issues sometimes and 12.5% of them reported that their children had these issues all the time. The details of the parent response on sensory problems has been depicted in the table 4.6.

Table 4.6: *Percentage of parent response on sensory problems*

Sensory problems	**Sometimes (%)**	**All the Time (%)**	**No (%)**
Oral hypersensitivity	19	13	68
Oral hyposensitivity	10	20	70
Tactile hypersensitivity	7	10	83
Tactile hyposensitivity	10	7	83
Total percentage	11.5	12.5	76

Hypersensitivity, hyposensitivity, sensory overload and sensory defensiveness have been reported in children with CP (Morris & Klein, 1987).Clinical observations like children indicating for food when there was already food in the mouth, unawareness of presence of saliva in the mouth when asked to swallow, difficulty in telling whether the lips were approximated or separated etc. suggest a defective oral sensory function in children with cerebral palsy.

Arvedson (2008) also reported food held under tongue or in cheek to avoid swallowing, vomiting - certain textures, gagging when food approaches/ touches lip or tongue or gagging prominent with solids; no mouthing of toys, inability to tolerate others' fingers in mouth, and refusal of tooth brushing. Sjakti, Syarif, and Wahyuni (2008) and Aggarwal et al., (2015) also reported of perioral hyposensitiveness/ hypersensitiveness.

V. Comparison across gender in the clinical group

The mean and standard deviation was computed using descriptive statistics separately for the 10 male and 5 female participants. Further the mean scores were subjected to statistical analysis using Mann Whitney U Test to check whether there was any significant difference between the male and the female participants on the all tasks included in the protocol. Table 4.7 shows the mean, standard Deviation (SD), /z/ value and *p-value* for both the gender belonging to the control group.

The comparison across gender in the clinical group indicated that there was no significant difference in scores between males and females on all orosensory tasks, however on the oromotor tasks, there was a significant difference on the task on lip during movement. The males had significantly poorer lip movement compared to the females.

Table 4.7: *Mean, SD, /z/ value and p-value for the male and female participants in the clinical group*

Section	**Tasks**	**Mean (SD)**		***/Z/- value***	***P-value***
		Males	**Females**		
Oral sensory	Light static touch (Gloved finger)	6.90 (0.32)	7.00 (0.00)	0.71	0.48
	Light static touch (Tooth pick)	6.90 (0.32)	7.00 (0.00)	0.71	0.48
	Kinetic touch	5.50 (2.92)	4.40 (3.67)	1.05	0.29
	Deep pressure	6.90 (0.32)	7.00 (0.00)	0.70	0.48
	Vibration	6.90 (0.32)	7.00 (0.00)	0.70	0.48
	Double simultaneous	2.80 (1.93)	1.20 (1.64)	1.52	0.13

	touch				
	Touch total	35.90 (4.46)	33.20 (5.02)	1.00	0.32
	Sensory total	81.90 (4.46)	79.20 (5.02)	1.00	0.32
Oral motor	Jaw at rest	4.40 (0.52)	4.20 (0.45)	0.75	0.45
	Jaw during sustained posture	4.30 (1.06)	4.20 (1.30)	0.07	0.95
	Jaw during movement	3.70 (1.42)	3.60 (0.89)	0.45	0.65
	Jaw total	12.40 (2.67)	12.00 (1.87)	0.50	0.61
	Lips at rest	4.30 (0.67)	4.80 (0.45)	1.45	0.15
	Lips during sustained posture	3.90 (3.25)	6.20 (3.27)	1.42	0.16
	Lips during movement	1.90 (2.18)	5.00 (2.55)	2.06	0.04*
	Lips total	10.10 (5.38)	16.00 (6.16)	1.67	0.10
	Tongue at rest	4.80 (0.63)	5.00 (0.00)	0.71	0.48
	Tongue during sustained posture	4.90 (4.12)	4.80 (4.55)	0.25	0.81
	Tongue during movement	3.30 (3.20)	3.00 (2.35)	0.12	0.90
	Tongue total	13.00 (7.16)	12.80 (6.42)	0.06	0.95
	Palate rest	8.60 (0.70)	8.80 (0.45)	0.47	0.64
	Palate during sustained posture	1.70 (0.68)	2.80 (3.03)	0.55	0.58
	Palate during movement	1.60 (0.70)	1.80 (0.45)	0.47	0.64
	Palate total	11.90 (1.29)	12.20 (1.30)	0.40	0.69
	Lips-jaw-tongue	5.50 (2.92)	5.20 (1.79)	0.06	0.95

differentiation				
DDK	3.40 (2.76)	3.80 (3.11)	0.19	0.85
Oral motor total	56.30 (19.64)	62.00 (16.32)	0.49	0.62
Grand total score	138.20 (22.70)	141.20 (19.67)	0.31	0.76

**P<0.05*

VI. Severity rating across different subsections in the clinical group and control group

The perceptual rating of severity for different subsections was carried out by the examiner at the end of each task. The severity ratings obtained for the participants were totaled under different degrees of severity (normal, mild, moderate and severe) to obtain the distribution of severity across different tasks. Table 4.8 shows the distribution of severity of the problem across the tasks in the clinical group. Figure 4.5 depicts the severity rating across different subsections of the protocol in both the groups.

Table 4.8 Severity rating across different subsections for the clinical group and control group.

Severity	Normal		Mild		Moderate		Severe	
	Clinical	**Control**	**Clinical**	**Control**	**Clinical**	**Control**	**Clinical**	**Control**
Orosensory	0	240	15	0	0	0	0	0
Jaw	3	240	9	0	2	0	1	0
Lip	0	240	3	0	5	0	7	0
Tongue	1	240	2	0	5	0	7	0
Palate	7	240	8	0	0	0	0	0
Lip-jaw-tongue differentiation	2	240	3	0	6	0	4	0
DDK	0	240	4	0	3	0	8	0
Oromotor total	0	240	6	0	3	0	6	0

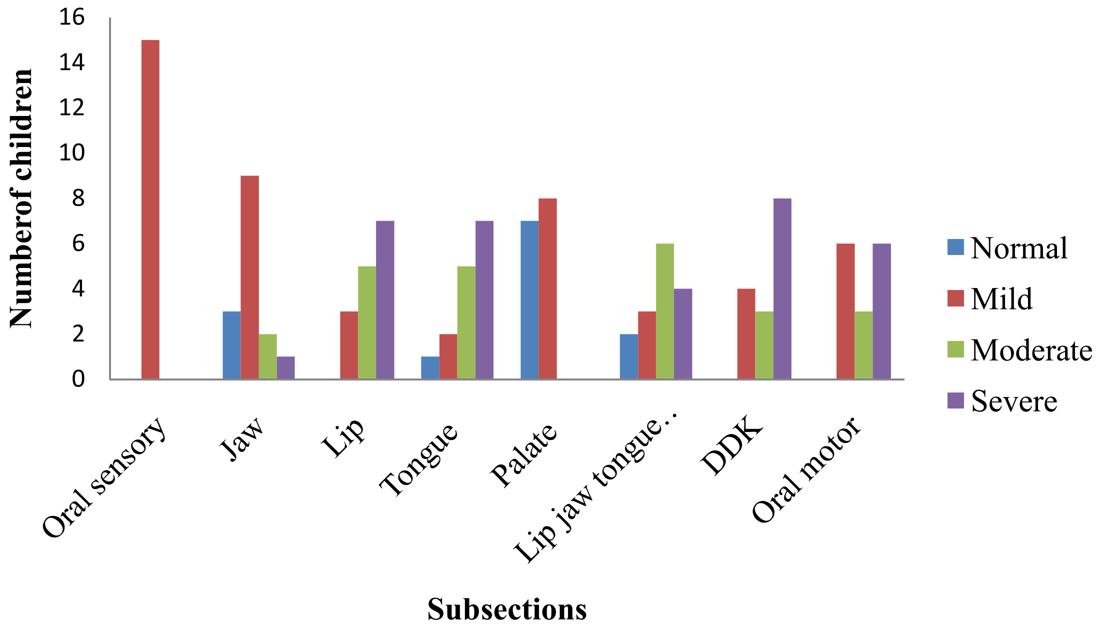

Figure 4.5: *Comparison of severity across different sub sections in the clinical group.*

From the table it can be observed that for clinical group, all the children had mild degree of severity in the orosensory tasks. Under the oromotor section, majority of the children had severe degree of problems for lip, tongue and DDK, whereas, moderate degree of problems were noticed in lip-jaw-tongue differentiation. Jaw and palate were the oral structures that were mildly affected. Approximately 50% of the children also had a structurally and functionally normal palate.

Lip and tongue are the active articulators involved in the production of speech which have greater degrees of freedom of movement compared to other articulators. Hence the effect of weakness and stiffness will be more evident in these articulators resulting in severe degree of problems. DDK tasks involve the combined and coordinated action of lip and tongue and any weakness in these structures will result in poor performance in DDK.

To sum up the results obtained, the Cronbach's values for the test retest and inter-judge reliability in the control group were found to be high indicating a strong test-retest and inter-judge reliability in the control group. The alpha values for test retest reliability in the clinical group were again high. This indicated that the tool was reliable for measuring the oromotor and sensory aspects.

Overall, it can be observed that there was a process of refinement that was happening in the age range 4-8 years for the orosensorimotor abilities. Both sensory and motor aspects were affected significantly in the clinical population compared to control group. There was a significant difference between the control and the clinical group. This indicated that the tool has good clinical validity and can be used in identifying the oromotor and orosensory problems. It was observed that all the children had mild degree of problems for orosensory subsection. Parental report also suggested mild degree of orosensory problems in the participants. Under the oromotor section, majority of the children had severe degree of problems for lip, tongue and DDK, whereas, a moderate degree of problems were noticed in lip-jaw-tongue differentiation. Jaw and palate were only mildly affected. There was also no significant difference in the performance across males and females in both the groups.

Chapter V

Summary and Conclusions

A dysfunction of the motor control centers of the immature brain can lead to motor speech impairment and is marked by disturbances to any of the speech subsystems. Cerebral Palsy (CP) is one of the common causes leading to developmental dysarthria in children. Neuromotor involvement in the subsystems like lingual, labial, pharyngeal, velar, laryngeal, mandibular, respiratory and body postural control has been implicated in individuals with dysarthria due to CP. Articulatory system is frequently implicated in these children and approximately forty percent of children with mild to severe CP have oromotor difficulties. The oral structures, which are a part of the articulatory system, are most frequently affected. An impairment in the articulatory system due to a damage in the central nervous system is associated with decrease in speed, strength, steadiness, coordination, precision, tone, and range of motion of the articulators. There is significant restriction of oral non speech movements such as voluntary lateralization of the tongue or protrusion and retraction of lips accompanying dysarthria. Thus oral motor problems are one of the major issues that lead to the difficulties seen during speech production.

In addition to the oro motor problems, sensory issues are also seen in these children in the oral structures due to the brain damage such as decreased or increased sensitivity to temperature or touch. Clinical observations like children indicating for food when there was already food in the mouth, unawareness of presence of saliva in the mouth when asked to swallow, difficulty in telling whether the lips were approximated or separated etc. suggest a defective oral sensory function in children with cerebral palsy.

Research has revealed that sensory and motor information is essential for speech motor control and speech acquisition. It has also been found that somatic sensory information is important to the ongoing motor control process. Adequate sensory perception and integration is required for adequate oral muscle function and motor planning. Hence the assessment of oral sensory motor functions is an essential component of evaluation. The primary objective of an oral mechanism examination is to identify abnormalities in shape, size, colour, texture or other attributes involved in speech, to assess the sensory and motor capabilities of the articulators and to describe any functional and structural features that may be abnormal. Specifically, the oral mechanism examination consists of making observations about the client's speech structures at rest (e.g., observing the face in repose for presence of adventitious movements), during the performance of non-speech acts (protruding the tongue), and speech acts (prolonging a vowel). In addition the oral mechanism examination helps the clinician obtain information about the integrity of the speech mechanism, e.g., strength, range of motion, speed, and coordination.

In the past a few attempts have been made to develop test materials to assess the orosensorimotor functions in children. Though such attempts have been made in the past, these are limited. Some serve the purpose of screening the orofacial dysfunction while other tests serve the purpose of detailed evaluation as indicated in the previous section. All these tests either incorporate a subsection on oromotor assessment (for e.g., The Dworkin-Culatta Oral Mechanism Examination) or are completely dedicated to assess the oral structure and function (Robins-Klee protocol; Oral motor Evaluation Protocol etc.). Further most of these protocols do not assess the aspects that are affected in children with developmental dysarthria such as tone, strength, speed, and coordination (Protocol for assessing oral motor and verbal praxis skills by Rupela, 2008 etc.). Most of these tests fail to provide a quantitative score based on the assessment. The tests that incorporate the assessment of orosensory aspects are also limited. Only MOST and STORM places a numerical and qualitative value on oral motor movement and assesses both oromotor and orosensory aspects. The other tests protocols such as Oral motor evaluation protocol and the Dworkin-Culatta Examination also includes restricted number of orosensory tasks.

McCauley and Strand (2008) who reviewed the content and psychometric characteristics of a few available standardized currently available tests which aid in the study, diagnosis and treatment of motor speech disorders in children reported that there were problems with the tests developed which were related to overly broad plans of test development and inadequate attention to the relevant psychometric principles during the development process.

Moreover majority of the existing tools have been developed in the West. In the Indian context there are limited tools for the assessment of children especially between 4 to 12 years. There are tests such as the Assessment of oromotor skills in toddlers by Archana and Karanth (2008) which assesses the oromotor skills from 1-4 years and a tool developed by Vani (2008) which has a section on oromotor and sensory assessment. However these do not address the issues related to oromotor weakness generally seen in dysarthria.

Speech-Language Pathologists (SLP) are the people who frequently deal with these problems and are one of the leading team members in planning the client centered rehabilitation strategies. Consequently, they need to equip themselves with the necessary resources and expertise to provide quality rehabilitation services to their clients with dysarthria. Hence there is a need to develop a standardized test to assess the oral motor and sensory aspects. Such a tool would go a long way in helping the SLP's in quantitatively assessing the oromotor sensory deficits in much greater depth, which would in turn help them set up specific goals for intervention. Considering this a need was felt to develop and standardize a protocol for the assessment of oral sensorimotor aspects especially for children in the age group of 4-8 years. Keeping this in view, this study was planned. The aim of the study was to develop and standardize a protocol for the assessment of oral sensorimotor aspects especially for children in the age group of 4-8 years. The specific objectives of the study include a) to develop a protocol for the assessment of oral sensorimotor aspects, b) to assess the content validity of the developed test, c) to standardise the tool by administering on typically developing children and d) to assess the clinical validity by administering the tool on children with developmental dysarthria.

The protocol was prepared by collating information obtained from the literature as well as based on the already developed tools. The protocol was divided into three sections: I. Demographic data and general history, II. Orosensory assessment, III. Oromotor assessment. The section I included the personal details of the child, the medical history (prenatal, natal and post natal history), details of the different evaluations (speech and language evaluation, oromotor examination, psychological evaluation, gross and fine motor evaluation, neurological/paediatric assessment) and intervention details. The section II on orosensory aspects was divided into Part A and B. Part A comprised of subsections on touch, temperature, taste, texture, and orofacial sensitivity. Part B comprised of questionnaire to assess oral and tactile hyper and hyposensitivity. The oromotor section (section III) comprised of three parts A, B and C. These included oral structural and functional assessment, lips-jaw-tongue differentiation and assessment of Diadochokinetic rate respectively.

The content validity of the protocol along with the user manual was assessed by compiling the feedback from 6 experienced speech-language pathologists, 1 physiotherapist and 1 occupational therapist. The judges were asked to rate the appropriateness of each section, subsections and the rating scale used. The feedback was collected on a 3 point rating scale ranging from – contents are not very valid (score 0) to contents are valid (score 2). A pilot study was carried out on 5 children with developmental dysarthria, and 8 typically developing children in the age range of 4-8 years. After the content validation and pilot study, the protocol was finalized.

In order to standardize the protocol, the final version of the same was administered on 240 typically developing children in the age range of 4-8 years. There were 60 participants each in the age range of 4-4.11, 5-5.11, 6-6.11 and 7-7.11 years. Equal number of males (30) and females (30) were considered in each age group. The participants with no history of neurological, communicative, cognitive, or sensorimotor, and academic impairment were included in the study, which was ensured using the 'WHO Ten-question disability screening checklist' (Singhi, Kumar, Malhi, & Kumar, 2007). Participants belonging to low, middle and high socioeconomic statuses were selected using the NIMH socioeconomic status scale (Venketesan, 2011). All ethical standards were met for subject selection and their participation. The testing was carried out in a relatively noise free environment with minimum distraction. The demographic data was obtained initially, which was followed by the administration of the oral sensorimotor protocol. The responses obtained were documented in the response sheet based on the rating scale. A score of '1' was assigned for a response choice of "yes" and a score of '0' for the response choice of "no". A severity rating from normal to severe was also included under each subsections. The approximate time taken to administer the entire protocol was 30 minutes. Positive reinforcements were provided to maintain the interest of the child during the administration.

Test-retest reliability and inter-judge reliability was carried out on 10% of the participant (10 subjects from each age group) sample selected randomly from both the groups within a period of 8-9 days to assess the test-retest reliability. The inter-judge reliability was also determined for 40 children from the control group. The clinical validity of the tool developed was also established by administering the protocol on 15 children with developmental dysarthria secondary to cerebral palsy in the age range of 4-8 years (10 males and 5 females). The protocol was re-administered on 6 participants in the clinical group within a period of 2 weeks to assess the test-retest reliability.

The scores for each of the subsections were added up and the total score was calculated. The scores obtained from section II (oral sensory) and III (oral motor) were totalled, tabulated and further subjected to statistical analysis using SPSS software version 21. Descriptive statistics was carried out to obtain the mean and standard deviation across age and gender. All the data were subjected to the normality test across age and gender. The Shapiro-Wilk test was employed to determine the normality of the data distribution. Non-parametric tests were employed for age and gender comparison since the data did not follow normal distribution principle. Cronbach's alpha was carried out in order to determine the test-retest and inter-judge reliability.

The results indicated that there was refinement of orosensorimotor abilities in the age range of 4-8 years. The combined total mean scores for the oromotor and orosensory section increased with increase in age. The total mean scores specifically for the oral sensory and oromotor section were greater for the higher age groups. Among the five subsections in the orosensory section, the total score obtained in the temperature, taste, texture and orofacial sensitivity sections were similar across age groups. The participants obtained the maximum score for these subsections. A ceiling effect was seen. All the other sections under touch also had maximum scores for subtasks. However for the double simultaneous touch, there was an increase in mean values across age groups. Under the oromotor section consisting of six subsections, the jaw total score, lip total score, tongue total score, lip-jaw-tongue differentiation score and DDK score showed an increase with age. However on the palate total score, such a trend was not seen.

Kruskal Wallis revealed that there was a significant difference in the mean scores across age groups for a few of the oral sensorimotor tasks. The tasks such as double simultaneous touch, touch total, sensory total, jaw during movement, jaw total, lip in sustained posture, lips during movement, lips total, tongue during movement, tongue total, lip-jaw-tongue differentiation, oral motor total, grand total score showed a significant difference across age. There was no significant difference in the performance across gender in both the groups on all the tasks.

There was also a significant difference between the control and the clinical group. This indicated that the tool has good clinical validity and can be used in identifying the oromotor and orosensory problems. Both sensory and motor aspects were affected significantly in the clinical population compared to control group. It was observed that all the children had mild degree of problems for orosensory subsection. Parental report also suggested mild degree of orosensory problems in the participants. Under the oromotor section, majority of the children had severe degree of problems for lip, tongue and DDK, whereas, a moderate degree of problems were noticed in lip-jaw-tongue differentiation. Jaw and palate were only mildly affected.

The test retest reliability was determined for 40 children from the control group. The alpha values obtained on the different subsections were found to be high indicating a strong test-retest reliability (0.92-0.99). The alpha values obtained ranged between 0.90-0.99, indicating strong test retest reliability in the clinical group too. The interjudge reliability was also determined for 40 children from the control group. The alpha values obtained on the different subsections were found to be high (0.85-0.99) indicating strong inter-judge reliability. This indicated that the tool was reliable for measuring the oromotor and sensory aspects.

Implications of the study

This study provides a standardized tool to assess the oromotor and orosensory problems in children with dysarthria in the age of 4-8 years. This test will be the first of its kind developed in India. This will help speech-language pathologists in the objective assessment of oromotor and orosensory skills. It would help in quantifying these problems by providing a quantitative score. These quantitative scores will strengthen the clinical findings made by speech-language pathologists. This would help the speech-language pathologists in prioritizing the goals taken up during speech therapy. The protocol could also be used to monitor the progress achieved during therapy. Future research could focus on the standardizing the protocol on other age groups. The tools can also be validated on conditions other than cerebral palsy leading to dysarthria.

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APPENDIX

ORAL SENSORIMOTOR ASSESSMENT PROTOCOL FOR CHILDREN (OSEP-C)

SECTION I: DEMOGRAPHIC DATA & GENERAL HISTORY

Name of the child: Reg. No:

Age/ Gender: Date of birth:

Provisional diagnosis: Date of evaluation:

Name of the parent/guardian: Language (mother tongue):

Present address: Permanent address:

Mobile no: Landline no (if any) :

Email id:

Socio-economic status: (NIMH Socio-economic status Scale, Venketesan. S, 2011)

Highest occupation	
Highest education	
Annual family income	
Property	
Per Capita Income	

Presenting complaints:

Age of onset:

Medical history:

Prenatal history:

Natal history:

Postnatal history:

Details of past investigations (CT/MRI reports):

Details of evaluations at AIISH

1. Results of OME:

2. Speech and language evaluation:

Speech assessment:

Tests Done	Findings
1.	
2.	

Language assessment:

Tests done	Findings
1.	
2.	

3. Psychological evaluation:
   a) Mental Age / Developmental Age:
   b) Social Age:
   c) Intelligence Quotient**:**
   Impression:

4. PT/OT evaluation

5. Neurological/Paediatric assessment:

Associated problems:

Findings of relevant investigations carried out:

Overall diagnostic impression and recommendation:

Intervention details:

Type of therapy/Treatment taken	Yes/No	Duration & Frequency
Speech and language therapy		
Physical therapy		
Occupational therapy		
Behavioural therapy		
Surgical treatment		
Pharmacological treatment		
Special Education		

Educational background of the child: Regular/special

Name of the school :
Standard :

SECTION II: OROSENSORY ASSESSMENT

Instructions: This section is divided into five parts: Part A (Touch), Part B (Temperature), Part C (Taste), Part D (Texture) and Part E (Orofacial sensitivity). Read through the instructions provided under the parts below. The assessment in this section has to be carried out by blindfolding the client. Instruct the client to sit straight, relax and follow your instructions carefully. Familiarize the client with the type of task, the stimuli and the expected response. Carry out the task with the eyes open initially. Provide 2-3 practice trials. Make sure that the client has understood the instructions. Provide each stimuli three times with an interval of three seconds on each articulator to ensure the consistency of the response. In case the responses are inconsistent, increase the number of stimuli presentations to five. Place a tick mark (√) under the respective articulator if the client can perceive the stimuli and place a cross mark **(×)** if it is difficult for the client to perceive the stimuli.

Scoring: Assign a score of '1' if the client is able to perceive the stimuli and a score of '0' if the client is unable to perceive the stimuli. At the end of each part, total the score and enter it in the table provided. Further, carry out the overall severity rating at the end of this section.

PART A: Touch

This part is further subdivided into light static touch, kinetic touch, deep pressure, and vibration, double simultaneous touch.

Materials required: Gloves, vibrating toothbrush, tooth pick

a. Light static touch: Touch lightly with gloved finger in the center of different articulators mentioned in the table below. Ensure that the skin is only touched lightly and not brushed/ stroked. Instruct the client to indicate the presence of touch either verbally (by saying 'yes', when touched) or through a gesture/ head nod. Later repeat the same task with the blunt end of a tooth pick.

b. Kinetic touch: Gently move the gloved finger horizontally on different articulators mentioned in the table below. Instruct the client to indicate the direction of a moving stimulus either verbally or gesturally.

c. Deep pressure: Touch with deep pressure using a gloved finger (moderate force, where pain is not elicited) on the specific articulators mentioned in the table below. Instruct the client to indicate the presence of deep pressure either verbally (by saying 'yes') or through a gesture/ head nod.

d. Vibration: Touch corresponding sites on one or both sides of the articulators mentioned in the table below using a vibrating brush. Instruct the client to indicate the presence of the vibration either verbally (by saying 'yes', when vibrated) or through a gesture/ head nod.

Sl. No.	**Stimuli**		**Light static touch**		**Kinetic touch**	**Deep pressure**	**Vibration**
	Articulators		**Gloved finger**	**Tooth pick**			
1.	Cheeks	Right					
		Left					
2.	Lips	Upper					
		Lower					
3.	Jaw						
4.	Tongue						
5.	Palate						
	Score						
	Total score						

e. Double simultaneous touch: Touch corresponding sites on one or both sides of the articulators mentioned in the table below using a gloved finger. Instruct the client to indicate if both or one parts were touched by either saying 'one' when single point is touched or 'two' when two points are touched or by pointing to appropriate pictures.

Sl.No.	**Articulators**	**Yes**	**No**
1.	Lip-cheek		
2.	Lip-jaw		
3.	Lip-tongue		
4.	Jaw-cheek		
5.	Jaw-tongue		
6.	Cheek-tongue		
7.	Right cheek-left cheek		
8.	Upper lip-lower lip		
9.	Tongue (right-left)		
10.	Tongue (front-back)		
Total score			

Part B: Temperature

Materials required: Tongue depressor, warm water

Instruction: Place the tongue depressor on different articulators to check cold sensation. Dip the tongue depressor in normal running water to maintain cold temperature. To check perception of hot temperature, dip the tongue depressor in warm water (20-40^{o}C) and touch different parts of articulators mentioned. Alternate between hot and cold temperatures with firm pressure for short, equal periods of time.

Sl.No.	**Articulators**		**Temperature**	
			Cold	**Warm**
1.	Cheeks	Right		
		Left		
2.	Lips	Upper		
		Lower		
3.	Jaw			
4.	Tongue			
5.	Palate			
	Total score			

Part C: Taste

Materials required: Sugar solution**,** Salt solution, Lemon juice, methi seed solution (methi soaked overnight in water) which will be prepared by mixing 1/4th tea spoon of each in 100ML of water, dropper

Instruction: A drop of each of the solution (Sweet-sugar solution, Sour- lemon juice, Salty- salt solution, Bitter- methi seed solution) will be placed on the anterior two thirds of the tongue. Instruct the client to indicate the perception of the taste either verbally or through a gesture/ head nod. Before presenting the stimuli, ensure that the mouth is rinsed with water.

Sl.No.	**Taste**	**Yes**	**No**
1.	Sweet		
2.	Sour		
3.	Salty		
4.	Bitter		
	Total score		

Part D: Texture

Materials required: Smooth- flat end of a plastic spoon, Rough- point brush.

Instruction: Familiarize the client with the smooth and the rough stimuli. Stroke lightly with the items mentioned on different parts of face/articulators mentioned in the table below. Instruct the client to indicate the perception of the texture either verbally (by saying ‘yes’, when vibrated) or through a gesture/ head nod.

Sl.No.	Articulators		Smooth	Rough
1.	Cheeks	Right		
		Left		
2.	Lips	Upper		
		Lower		
3.	Jaw			
4.	Inner cheeks	right		
		left		
5.	Tongue			
6.	Palate			
	Total score			

Part E: Oro facial sensitivity

Materials required: Handkerchief, tongue depressor

Instruction: Stroke the face and neck with a handkerchief and oral areas with a tongue depressor for a duration of three seconds. Assess if the client can tolerate the stimuli on the different structures.

Sl. No.	Can the client tolerate the stimuli on			Yes	No
1.	Face				
2.	Neck				
3.	Lips	Upper			
		Lower			
4.	Inner cheeks	Right			
		left			
5.	Gums	Upper			
		Lower			
6.	Tongue				
7.	Palate				
Total score					

Part B: This portion checks the oral and tactile hyper/hypo sensitivity though a series of questions. Ask these questions to the parents/caregivers to elicit appropriate information. Place a tick mark (√) under 'Yes' if the client exhibits the behaviour and under 'No' if the client does not. Also check if a particular behaviour is exhibited some time or all the time and place the tick mark under the respective column. If the informant is unsure, place a tick mark (√) under 'Questionable'.
P.S: This section only supports the previous subsection on oro facial sensitivity and hence scoring of this section should not be carried out.

Sl.No.	Question	Yes		No	Questionable
		Some times	All the time		
I	**Oral Hypersensitivity** ***(over responsive to oral stimuli)***				
1.	Does your child have a limited food repertoire? If yes, specify				
2.	Does your child show an extreme preference to a particular type of food (a picky eater)? If yes, specify				
3.	Does your child avoid certain food textures - especially mixed textures? If yes, specify				
4.	Does your child show food aversions based on taste? If yes, specify				
5.	Does he avoid spicy food?				
6.	Does your child gag on food of different textures/ temperatures /tastes/touch? If yes specify				
7.	Is it difficult for the client to discriminate the differences in taste? If yes specify(sweet/sour/salty/bitter)				
8.	Does your child continued to prefer soft or pureed food beyond 2 years of age?				
9.	Does your child have difficulty in sucking, chewing or biting his food?				
10.	Does he prefer eating either hot or cold food only?				
11.	Does your child have difficulty tolerating the caregivers' fingers in the mouth?				
12.	Does the client show resist face wiping?				
13.	Is the hyper/hypo sensitivity same on both the sides of the face/articulators?				
14.	Does the client cry constantly while brushing his/her teeth every day?				
15.	Is your child oversensitive to toothpaste and mouthwash?				
II	**Tactile hypersensitivity** ***(over responsive to tactile stimuli)***				
1.	Does your child avoid touching different objects with palm?				
2.	Does your child gets agitated, anxious or aggressive when touched or does he dislike being touched?				
3.	Does your child avoid touching certain textures of material (blankets, rugs, stuffed animals)? If yes specify				
4.	Does your child refuse to wear new or stiff clothes, clothes with rough textures,				

	turtlenecks, jeans, hats, or belts, etc.? if yes specify				
5.	Does your child dislike feeling of showers or being splashed with water?				
6.	Does your child avoid using hands for play?				
7.	Does your child avoid messy play with glue, play dough/clay, mud, sand, finger paints etc.? if yes specify				
8.	Does your child feel excessively ticklish?				
9.	Does your child refuse to walk bare foot on rough surface like cement pavement, grass lane etc.if yes specify				
10.	Does your child show signs of distress while brushing his teeth, combing his hair, washing his face, cutting his nails, etc. if yes specify				
11.	Does your child walk on his toes all the time?				
12.	Does your child avoid light touch (e.g., a kiss) but seek out deep touch (e.g., a bear hug)? If yes specify				
III	***Oral Hyposensitivity (under responsive to oral stimuli)***				
1.	Does your child feel the food in the mouth?				
2.	Does your child chew, lick or taste inedible objects?				
3.	Does your child show a liking towards intense flavours, i.e., salty, hot and spicy, sweet, sour food? If yes specify				
4.	Does your child have excessive drooling? (beyond the teething stage)				
5.	Does your child love vibrating toothbrush?				
6.	Does your child get food all over the face (in and around the mouth) by the end of the meal?				
7.	Does your child take large bites and stuff the mouths, or even "pocket" food in the cheeks				
8.	Does your child have difficulty distinguishing between different tasting foods				
IV	**Tactile hyposensitivity** ***(under responsive to tactile stimuli)***				
1.	Does your child crave for touch, needs to touch everything and everyone? If yes specify				
2.	Does your child make light of his injuries like cuts bruises etc.?				
3.	Does your child ignore his/her dirty hands, running nose etc.?				
4.	Is your child self abusive like biting himself, banging his head, hitting himself, etc.? If yes specify				
5.	Does the child constantly put things in the				

	mouth?				
6.	Does the child exhibit teeth grinding? (Bruxism)				
7.	Does your child show too much of liking towards vibrating toys?				
8.	Does your child seeks surfaces that provides strong tactile feed back (i.e., walking on pebbles, rough door mat/carpet)? If yes specify				
9.	Does your child always seem to have something in their mouths; toys, pens, pencil tips, gum, candy, or inedible objects (i.e., paper clips, rubber bands, shirt sleeves and collars, strings etc.)? If yes specify				

Severity rating for oro sensory aspects	**Normal**	**Mild**	**Moderate**	**Severe**

Summary of findings of oral sensory section

Sl. No.	**Part**	**Tasks**	**Score**
1.	Part A	Light static touch	
		Kinetic touch	
		Deep pressure	
		Vibration	
		Double simultaneous touch	
2.	Part B	Temperature	
3.	Part C	Taste	
4.	Part D	Texture	
5.	Part E	Oro-facial sensitivity	
Total score			

SECTION III: OROMOTOR ASSESSMENT

Instructions: This section is divided into three parts: Part A (Oral structural and functional assessment), Part B (Lips-jaw-tongue differentiation) and Part C (Diadochokinetic rate). Read the questions stated under part A & B and assess for the structural and functional integrity of the oral structures. Place a tick mark (√) under the column 'yes', if the oral structural and functional aspects are normal and under the column 'no', if abnormal.

Scoring: Assign a score of '1' for 'yes' and '0' for 'no'. At the end of each part, total the score and enter it in the table provided. Further, carry out the overall severity rating for each articulator.

Part A: ORAL STRUCTURAL AND FUNCTIONAL ASSESSMENT

Note: In the subsection 'a' under each articulator (at rest position), look for tone, structural abnormalities or involuntary movements, if any.

In the subsection 'b' under each articulator (at sustained posture), instruct the child to maintain the posture for a count of 5 (5 sec). Look for stability, symmetry, range of movements and the strength. Also check for involuntary movements.

In the subsection 'c' under each articulator (during movement), instruct the child to move the respective articulator five times as rapidly as possible. Look for speed, accuracy, symmetry, regularity and range of movement. Also check for involuntary movements.

I. EVALUATION OF JAW			
Sl. No.	**a. Jaw at rest**	**Yes**	**No**
1.	**Is the jaw size normal in relation to the size of head?** If abnormal specify: (too small/ too large)		
2.	**Is symmetry of the jaw normal?** If abnormal specify: deviated to (right/left)		
3.	**Is the mouth closed with lips together?** If no specify (mouth partly open/ mouth wide open with the jaw lowered/mouth tightly closed with the jaw clenched) Tone: Increased/decreased/variable		
4.	**Is jaw orientation normal?** If no, specify:		
	* Prognathia (jaw projecting forward to a marked degree with respect to frontal plane of the face)		
	* Retrognathia (jaw receding backwards to a marked degree with respect to frontal plane of the face)		
5.	**Is the jaw steady and stable at rest?** If no, specify (quick/slow involuntary movements such as chorea/dystonia/tremor/tics/myoclonus/ fasciculations/spasms/writhing)		
Total			
Sl. No.	**b. Jaw during sustained posture**	**Yes**	**No**
1.	**Can the client maintain a wide open mouth posture?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected		

	Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
2.	**Can the client maintain a closed mouth posture?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
3.	**Can the client resist the force applied to open the jaw by the examiner when told to clench teeth?** If no, specify: Strength Slightly reduced/ markedly reduced		
4.	**Can the client resist the force applied to close the jaw by the examiner when told to hold it open?** If no, specify: Strength: Slightly reduced/ markedly reduced		
5.	**Is the jaw opening adequate and maintained during the production of /a/?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
Total:			
Sl. No.	**c. Jaw during movement**	**Yes**	**No**
1.	**Can the client open and close the jaw rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
2.	**Can the client repeat jaw movements to left and right direction rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
3.	**Can the client perform rotatory movements (circular) of the jaw rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		

4.	**Can the client repeat the sound /a/?** E.g. /a-a-a/? If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
5.	**Can the child move the jaw without any associated temporo mandibular joint noises?** If no specify if the noises are grinding/popping		
Total			

Sl. No.	Sub section	Score
1.	Jaw at rest	
2.	Jaw during sustained posture	
3.	Jaw during movement	
	Total score	

Severity rating for jaw	**Normal**	**Mild**	**Moderate**	**Severe**

II. EVALUATION OF LIP			
Sl. No.	**a. Lips at rest**	**Yes**	**No**
1.	**Is the appearance of lip normal?** If no specify: scar/cleft (unilateral / bilateral) Others:_____________		
2.	**Is symmetry of the lip normal?** If no specify: deviated to (right/left)		
3.	**Can the child swallow saliva adequately?** If no, specify: Drooling: Activity related/posture specific Constant/intermittent		
4.	**Is the upper and lower lip aligned normally?** If no, specify (lips retracted in a smile position/lips partly open/lips fully open?) Tone: Increased/decreased/variable		
5.	**Are the lips steady and stable at rest?** If no, specify (quick/slow involuntary movements such as chorea /dystonia / tremor/ tics/ myoclonus/ fasciculations/ spasms/writhing)		
Total			
Sl. No.	**b. Lips during sustained posture**	**Yes**	**No**
1.	**Can the client maintain closed lip posture?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		

2.	**Can the client maintain a retracted lip posture?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
3.	**Can the client maintain a protruded lip posture?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
4.	**Can the client puff cheeks (on right / left / both sides) and sustain it for a duration of 10 sec?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Lip seal: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
5.	**Is the lip movement adequate and maintained during the production of /i/?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
6.	**Is the lip movement adequate and maintained during the production of /u/?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
7.	**Can the client resist the examiner's attempt to retract lips when told to pucker?** If no, specify: Strength: Slightly reduced/ markedly reduced		
8.	**Can the client resist the examiner's attempt to pucker lips when told to retract?** If no, specify: Strength: Slightly reduced/ markedly reduced		
9.	**Can the client resist the examiner's attempt to pull out the tongue depressor held horizontally between the lips when told to hold on to it tightly?** If no, specify: Strength: Slightly reduced/ markedly reduced		
10.	**Can the client resist the examiner's attempt to press the cheeks with moderate force when told to hold the cheeks in the puffed up position?** If no, specify: Strength: Slightly reduced/ markedly reduced		
Total			

Sl. No.	c. Lips during movements	Yes	No
1.	**Can the client retract the lips rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
2.	**Can the client round the lips rapidly as in /o/?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
3.	**Can the client protrude the lips rapidly as in /u/?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
4.	**Can the client alternatively protrude and retract the lips rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
5.	**Can the client repeat cheek puffing rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
6.	**Can the client rapidly repeat cheek puffing alternately on the left and right side?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
7.	**Can the client repeat /p/?** E.g.. /p-p-p/. If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected		

	Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
8.	**Can the client repeat /i-u/?** If no, specify if: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
9.	**Can the client repeat /a-u/?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/ Considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
Total			

Sl. No	**Subsection**	**Score**
1.	Lips at rest	
2.	Lips during sustained posture	
3.	Lips during movement	
	Total Score	

Severity rating for lips	**Normal**	**Mild**	**Moderate**	**Severe**

III. EVALUATION OF TONGUE			
Sl. No.	**a. Tongue at rest**	**Yes**	**No**
1.	**Is the tongue size normal?** If no specify: (large/small)		
2.	**Is symmetry of the tongue normal?** If no specify: deviated to (right/left)		
3.	**Is the tongue orientation normal?** If no specify (forward and downward placement /backward placement/tongue thrust Tone: Increased/decreased/variable		
4.	**Is the tongue appearance normal?** If no, specify: fissured/atrophied unilateral / bilateral		
5.	**Is the tongue steady and stable at rest?** If no, specify: (quick/slow involuntary movements such as chorea/ dystonia/ tremor/ tics/ myoclonus/ fasciculations/ spasms/writhing)		
Total			
Sl. No.	**b. Tongue during sustained posture**	**Yes**	**No**

1.	**Can the client maintain tongue in the protruded posture?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
2.	**Can the client maintain tongue in the retracted posture?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
3.	**Can the client sustain the tongue in the lateral position (towards the left/ right) outside the mouth?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
4.	**Can the client sustain the tongue in the lateral position (towards the left/ right) inside the mouth?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
5.	**Can the client sustain the tongue in the medial position between the teeth?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
6.	**Can the client elevate the tongue to touch the upper lip and sustain it?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
7.	**Can the client touch the lower lip with the tongue and sustain it?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
8.	**Can the client touch the palate with the tongue and sustain it?** If no, specify: Stability: Normal/slightly reduced/markedly reduced		

	Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
9.	**Is the tongue movement adequate and maintained during the production of /t/?** If no, specify: Stability: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Tone: Normal/increased/decreased/variable Involuntary movements: Present/absent. If present specify		
10.	**Can the client resist the pressure applied by the examiner on tongue tip by pushing inward when told to protrude medially?** If no, specify: Strength: Slightly reduced/ markedly reduced		
11.	**Can the client resist the pressure applied by the examiner downward on the tongue tip with a tongue depressor when instructed to elevate?** If no, specify: Strength: Slightly reduced/ markedly reduced		
12.	**Can the client resist the pressure applied by the examiner on the tongue when instructed to lateralize outside the mouth?** If no, specify the side which was not able to resist____________. Also specify Strength: Slightly reduced/ markedly reduced		
13.	**Can the client resist the pressure applied by the examiner on the tongue when instructed to lateralize inside the mouth?** If no specify the side which was not able to resist____________ Also specify Strength: Slightly reduced/ markedly reduced		
Total			
Sl. No.	**c. Tongue during movement**	**Yes**	**No**
1.	**Can the client move the tongue back and forth rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
2.	**Can the client move the tongue laterally outside the mouth rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
3.	**Can the client move the tongue laterally inside the mouth rapidly?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced		

	Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
4.	**Can the client sweep the tongue on the upper teeth and lip?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
5.	**Can the client sweep the tongue on the lower teeth and lip?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
6.	**Can the client sweep the tongue on the palate?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
7.	**Can the client repeat /t/?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
8.	**Can the client repeat /k/?**If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
9.	**Can the client alternately repeat /t/-/k/?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
Total			

Sl. No.	Sub section	Score
1.	Tongue at rest	
2.	Tongue during sustained posture	
3.	Tongue during movement	
	Total Score	

Severity rating for tongue	**Normal**	**Mild**	**Moderate**	**Severe**

IV.	**EVALUATION OF PALATE**		
Sl. No.	**a. Palate at rest**	**Yes**	**No**
1.	**Is the size of the soft palate normal?**		
2.	**Is the arching of the hard palate normal?** If no, specify: (low/ high)		
3.	**Is the orientation of the soft palate normal?** If no, specify: (low/ high)		
4.	**Is symmetry of the soft palate normal?** If no, specify: deviated to (right/left)		
5.	**Is the surface colour of the palate normal?** If no, specify ___________		
6.	**Is the appearance of the palate normal?** If no specify: scar/cleft/fistula (unilateral / bilateral) Others:_____________		
7.	**Is the appearance of uvula normal?** If no, specify:		
8.	**Is the uvula symmetrical?** If no specify: deviated to (right/ left)		
9.	**Is the soft palate steady and stable at rest?** If no, specify (quick/slow involuntary movements such as chorea/dystonia/tremor/tics/ myoclonus/fasciculations/writhing)		
Total			
Sl. No.	**b. Palate during sustained posture**		
1.	**Is the movement of the soft palate normal during the sustained phonation of /a/?** If no, specify: Symmetry: Partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
2.	**Is the resonance normal during the phonation of /a/?** If no, specify: Hypernasality/hyponasality		
Total			
Sl. No.	**c. Palate during movement**		
1.	**Is the movement of the soft palate normal during repeated phonation of /a/?** If no, specify: Speed: Normal/slightly reduced/markedly reduced Accuracy: Normal/slightly reduced/markedly reduced Symmetry: Normal/partially affected/markedly affected Range of movement: Normal/partially restricted/considerably restricted Regularity of movement: Normal/partially affected/markedly affected Involuntary movements: Present/absent. If present specify		
2.	**Is the movement of the soft palate normal during a gag reflex?**		

Total	

Sl. No.	Sub section	Score
1.	Palate at rest	
2.	Palate during sustained posture	
3.	Palate during movement	
	Total Score	

Severity rating for palate	Normal	Mild	Moderate	Severe

Part B: LIPS –JAW-TONGUE DIFFERENTIATION

Sl.No.	Questions	Yes	No
1.	Can the client open and close mouth without moving the head?		
2.	Can the client bite his upper /lower lip without moving the head?		
3.	Can the client alternately retract and protrude the lips with no accompanying jaw movements?		
4.	Can the client say /u/ or /i/ without additional head/jaw movements?		
5.	Can the client say /p/ without additional head/jaw movements?		
6.	Can the client protrude tongue out of mouth with no accompanying head movements or touching lips/teeth?		
7.	Can the client elevate tongue tip without overflow movements of head or jaw?		
8.	Can the client carry out lateral movement of tongue without head/jaw movements?		
9.	Can the client retract tongue back to pharynx without curling the tip of the tongue?		
10.	Can the client say /t/ or /k/ without additional head/jaw movements?		
Total			

Severity rating for lips-jaw-tongue differentiation	Normal	Mild	Moderate	Severe

Part C: ASSESSMENT OF DIADOCHOKINETIC RATE (DDK)

Instructions: Instruct the client to repeat the target syllable (/pa/, /ta/, /ka/, /pataka/) as quickly as possible for a duration of 5 seconds. Model the sequence and allow the client to practice 2-3 times to ensure that the instruction is understood. Determine the DDK by counting the number of syllables produced in 5 seconds. Rate the rhythm and articulation accuracy and place a tick mark (√) under the column 'Normal' if both are normal and under the column 'Affected' if they are affected.

Task	Repetitions per second	Rhythm		Articulation Accuracy	
		Normal	Affected	Normal	Affected
Pa	/5 sec				
Ta	/5 sec				
Ka	/5 sec				
Pataka	/5 sec				

Score				
Total score				

Degree of impairment in DDK	**Normal**	**Mild**	**Moderate**	**Severe**

Summary of findings of the oromotor section

Oro motor assessment		**Score**
Part A	Jaw	
	Lips	
	Tongue	
	Palate	
Part B	Lips-Jaw-Tongue differentiation	
Part C	DDK assessment	
Total		

Mental status of the child during the assessment (place a tick mark on all that apply): alert /responsive /cooperative /confused /lethargic /impulsive /uncooperative /combative/ unresponsive

General Remarks:

Final findings:

Subsection	**Score**
Oro sensory assessment	
Oro motor assessment	
Grand total score	

Recommendations:

Signature of the examiner with date