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Coordination of mandibular muscle activity in infants with Down syndrome during feeding

Catherine Blair Williams

To the Graduate Council:

I am submitting herewith a thesis written by Catherine Blair Williams entitled "Coordination of mandibular muscle activity in infants with Down syndrome during feeding." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Speech Pathology.

Jacki L. Ruark, Major Professor

We have read this thesis and recommend its acceptance:

Mark Hedrick, Gary McCullough

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

C W Minkel

Associate Vice Chancellor and
Dean of The Graduate School

COORDINATION OF MANDIBULAR MUSCLE ACTIVITY IN INFANTS WITH DOWN SYNDROME DURING FEEDING

A Thesis
Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville

Catherine Blair Williams
May 1999

DEDICATION

This effort is lovingly dedicated to my precious family Mrs. Mary Eubank (grand-mother), Mr. and Mrs. W. Earl Williams (parents), and Katelyn V. Williams (sister). Their endless support, encouragement, and belief in me have led me to this accomplishment.

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ABSTRACT

Normally developing infants produce adult-like mandibular muscle activity during chewing by 12 months of age. However, infants and children with Down syndrome may exhibit delays in obtaining the typical mandibular motor patterns for feeding. Some reports have hypothesized that these patterns may even be deviant. Little quantitative data exists regarding the development of mandibular muscle activity in infants and children with Down syndrome.

The present EMG study describes the coordinative muscle patterns of infants with Down syndrome during feeding. This investigation allowed a comparison of the feeding patterns of infants with Down syndrome with normally developing infants. The crosscorrelation analysis yielded to points of interest: the peak correlation coefficient and the lag to the peak. A low to moderate degree of coupling was noted for the homologous and synergistic muscle pairs as well as relatively weaker coupling for the antagonistic muscle pairs during feeding. Mean absolute lag values demonstrated longer lags for the antagonistic muscle pairs and shorter lags for the homologous and synergistic muscle pairs.

Findings of this study suggest a nonlinear relationship between age and development of feeding skills. A linear relationship between gross motor feeding development, however, may be evident. Thus, feeding difficulties may stem from a developmental delay verses a distinct, deviant developmental pattern. The timing of muscle activity was found to be similar to the masticatory patterns of typically developing infants.

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CHAPTER I

Introduction and Review of the Literature

Introduction

Down syndrome is a chromosomal disorder that affects one in every 700 hundred live births (de Grouchy & Turleau, 1984). Infants born with Down syndrome are physically distinct and most frequently genetically characterized by an additional chromosome (Trisomy 21). Down syndrome, however, may also occur during the process of cell division in which the 21^{st} chromosome may be unequally paired or translocated (Monosomy 21). Manifestations of Down syndrome include: mental retardation, hearing disorders, speech and language delays, and delays in gross and fine motor development. More salient characteristics of infants with Down syndrome include: generalized hypotonia, hyper-extensible joints, brachycephaly, flat facial profile, up-slanting palpebral fissures, epicanthal folds, speckling of the iris, small nose, small oral cavity due to the disparity of size between the mandible and the maxilla, tendency toward protrusion of the tongue, small anomalous auricles, excess skin on back of neck, cardiac malformation (in approximately 40%), and duodenal atresia. The degree of which these characteristics may impact their feeding skills is unknown. There is a great need for quantitative data regarding the feeding skills of infants with Down syndrome.

General Motor Development in Children with Down Syndrome

Typically developing infants achieve developmental milestones sequentially within certain time frames. It is known that feeding and swallowing skills in children mature along with anatomic and central nervous system growth, and general motor development. In infants with Down syndrome, general motor developmental patterns will be delayed or occur out of normal sequence (Sleight & Niman, 1984). Developmental delays in motor control appear to occur earlier than cognitive delays (Carr, 1975). Pathological factors which may influence motor development of infants with Down syndrome include neuromuscular, structural, visual, and cardiac deficits. Explanations for the delay in motor development of infants with Down syndrome focus on known congenital deficits of their central nervous system. For example, the brainstem and cerebellum of this population have been found to be consistently reduced in size (Anwar, 1981). Neuromuscular and musculoskeletal deficits which may interfere with motor development in this population include hypotonicity, joint hypermobility, decreased muscular strength, and depressed reflexes. Other physical deficits identified, which may also affect gross motor development, include lower levels of serotonin and heart defects (Pueschel, 1987). Examples of musculoskeletal deficits exhibited by this population can be found in Appendix A.

Children with Down syndrome have also been reported to exhibit lowered or absent responses to tactile, proprioceptive, and vestibular input. For example, Anwar (1981) reported that the most frequently occurring deviations in their sensory system are impairments in kinesthetic or proprioceptive abilities. According to Brousseau & Brainerd (as cited in Anwar, 1981), reduced ability in tactile, kinesthetic, or cutaneous judgement reflects a potential central nervous system disturbance in the sensory areas.

Dicks-Mireaux (1972) reported that motor development slows in children with Down syndrome at some point during the first year of life. In the child with Down syndrome, generalized low muscle tone has been reported to contribute to motor delays and has also been correlated with delayed cognitive development, decreased kinesthetic feedback, impaired stereognosis, and delayed speech acquisition. Further examples of hypotonia can be found in Appendix A (Harris, 1984; Anwar, 1981). Moreover, it has been suggested that hypotonic musculature of subjects with Down syndrome explains the decreased reaction time (e.g., tasks that require short rapid movements in response to an external stimulus) demonstrated by these children. Several researchers have proposed a connection between slow motor speed and muscle tone; however, no study has quantified the reaction time related to the degree of hypotonia (Anwar, 1981).

Other authors have proposed that generalized hypotonia in infants with Down syndrome may result in weakness of extensor muscles of the neck and trunk, which may delay the development of head righting skills (Sleight & Niman, 1984). This lack of neck and trunk flexion may make it more difficult for the infants to stabilize their head at midline and exhibit neck flexion with a chin tuck for effective chewing and swallowing (See Appendix A).

Hoffman, Peterson, and Van Dike (1990) conducted a study to assess gross motor development, fine motor development, and hand function in children with Down syndrome. These scientists found that cardiac involvement had a significant effect on gross and fine motor performance (as cited in Van Dyke et al., 1990). Children with cardiac involvement did show a significant statistical difference in performance between gross and fine motor skills, whereas those without cardiac problems did not. Children with Down syndrome in this study showed a decline in mental and motor development over time, but cognitive performance in both sexes was consistently higher than motor performance, even when there was cardiac involvement.

Oral Motor and Feeding Development in the Typically Developing Child

The development of well-organized, efficient feeding may involve the ongoing maturation of oral motor reflexes and motor/sensory patterns. Oral motor patterns during feeding involve complex organized movements of the jaw, lips, cheeks, palate, and tongue. Although the development of feeding may depend on neurophysiologic changes and anatomical growth, developmental changes in motor control also play an important role. A longitudinal developmental study of chewing in normal children (four subjects in all) from 12 to 48 months has been described using electromyographic (EMG) records (Green, Moore, Ruark, Rodda, Morevee, & VanWitzenburg, 1997). During this study, children were seated in a high chair and presented with familiar foods that each preferred as a part of their typical diet. The foods were solid in texture and included cookies, cheese, fresh fruit, candy (Gummy Bears and jelly beans), pretzel, tofu, potato chips, hard cereal, and raisins (Green et al., 1997).

EMG signals were obtained through the use of surface Ag/AgCl electrodes. The muscles targeted included right masseter, left masseter, right temporalis, left temporalis, and the anterior belly of the digastric (ABD). These muscles were recorded bilaterally with the use of a single electrode pair. Cross-correlational analyzes were used to determine the relative coupling and synchrony of activity of 10 muscle pairs; mandibular synergists and antagonists.

The findings from this study indicated that chewing efficiency improves through a variety of changes that occur throughout early development. These scientists found that, similar to adults, reciprocal activity among mandibular antagonistic muscles was found to characterize chewing across all developmental age levels. With maturation, the coupling and synchrony of the mandibular synergists (i.e., masseter and temporalis) increased and the coactivation of antagonistic muscles (i.e., masseter and digastric) significantly decreased. Green and colleagues suggested that the development of chewing appears to be identified by an increase in motor efficiency along with a decrease in the variability of chewing patterns. Evidence of increased chewing efficiency was derived from these maturational changes, as well as by a parallel decrease in EMG burst duration (Green et al., 1997). Chewing rate was not found to change significantly with age. Although the basic chewing pattern of jointly activated opposing muscle groups is basically established by 12 months of age, refinement in the chewing pattern continues at least to 48 months of age (Green et al., 1997).

Another experiment quantified chewing activity in children, by examining the chewing cycles of normally developing children, ages 2- to 8-years (Gisel, 1998). Specifically, Gisel (1998) examined the chewing movements of children as measured by the time to chew one bite of food(measured from the moment the food was placed into the mouth until the final swallow), the number of chewing cycles (one cycle includes one downward and upward movement of the chin), and the time/cycle ratio (time divided by the number of chewing cycles/average cycle length) per bolus intake. Gisel (1988) found that overall the time to chew one bite of food decreases with age as well as the number of cycles per bolus intake. It has been suggested that this phenomenon occurs due to the change from primary to secondary dentition that occurs during these ages. With the exception of the graham cracker, significant effects of age on the time variable were shown for all food textures. The results from this study indicate that children's skills for eating solid food mature before the skills for eating "viscous" (a sticky, fluid consistency) and pureed foods. There was a significant decrease in time for chewing solid food from age 2 to 3 years of age and a further decrease from 3 to 4 years of age. Continuous drops in chewing time occurred up to the age of 8 years. Chewing of viscous food exhibited a different developmental pattern. The decrease in chewing time was less for viscous than solid foods. For pureed consistencies major decreases in time occurred through the age of 6 years and continued to decrease thereafter.

Other studies of normally developing children have compared the chewing cycles of children with three distinct food textures (Schwaab, Niman, & Gisel, 1986; Gisel & Stolovitz, 1991). These studies concluded that chewing time (measured from the moment the food was placed into the mouth until the swallow) in children ages 12 months to 5 years of age decreased with increased age and that food texture has a significant effect on the chewing time of children. It was also found that as children develop, their feeding behaviors mature, which was characterized by increased mobility of the tongue, better lip control, and decreased movement of the circumoral structures in swallowing. In addition, findings from these studies indicated that children ages 6 months to 2 years of age also began to display a more mature lateralization of the tongue, rather than the immature positioning of the tongue at midline for both solid and viscous textures. Pressing lips together and drawing in of the lower lip during swallowing for all food textures was seen frequently in these children. However, this more immature response of drawing the lower lip in decreased with age (Stolovitz & Gisel, 1991).

Feeding Skills in Children with Down Syndrome

In a retrospective study on feeding difficulties in children with Down syndrome, chart reviews of 49 children with Down syndrome, ages 6 months to 6 years, indicated that 80% of the children had problems related to food or feeding (Pipes & Holm, 1980). A smaller percentage of these children refused anything but strained food, even when they were developmentally ready for more viscous foods (more evident in the children between 25 & 36 months of age). The authors suggested that the delayed development of feeding skills in children with Down syndrome may be the consequence of problems with sucking, swallowing, chewing, and self-feeding. It may also be related to inappropriate feeding practices on the part of the caregivers who do not recognize when the child is developmentally ready to acquire a new skill. A nutritional and feeding intervention program was established and in 21 of these children, most nutritional, behavioral, and developmental problems surrounding food were eliminated. It was noted that children with Down syndrome demonstrated a reluctance to chew food and a preference to suck on items until swallowed. The finding of this study is similar to others that also found that children with Down syndrome exhibit difficulty with feeding, especially difficulties in eating meat or chewing food, sucking, regurgitation/gagging, and cup drinking (Calvert et al., 1970; Cullen et al., 1981& Van Dyke et al., 1990).

Difficulty in advancing textures has long been reported to be an issue for some children with Down syndrome. This difficulty has been related to the following: (1) poor control of tongue movement resulting in gagging and the rejection of textured foods (Rogers & Coleman, 1992), (2) low muscle tone, decreased jaw strength, and delays in acquisition of the tongue movement needed for chewing and efficient swallowing (Klein

& Delaney, 1994), and (3) the small oral cavity, "laxity of supportive musculature," and enlarged tonsils making swallowing solids difficult (Cooley & Graham, 1991).

Sleight and Niman (1984) proposed that children with Down syndrome tend to be delayed or exhibit deviation from the predictable sequence of normally developing oral motor reflexes and the integration of immature oral motor patterns to mature motor skills. For example, oral reflexes which cause the normally developing infant to root, may be disturbed as may the response to touch pressure inside the infant's mouth by the nipple. Babies with Down syndrome may also react to touch pressure with hyper-responsive behavior by crying or moving away. In addition, the baby may avoid the nipple by protruding or retracting his/her tongue (Sleight & Niman, 1984). Hindered oral motor reflexes combined with depressed endurance may inhibit the baby from establishing an organized rhythm for sucking (Sleight & Niman, 1984).

Feeding time in the young infant with Down syndrome may be prolonged due to a delay in the ability to organize suckling/sucking and swallowing with breathing. During suckling the infant with Down syndrome may exhibit a flat tongue with inadequate grooving, and mandibular movement that is poorly grated and exaggerated. Subsequently, the infant may also be unable to elevate the tongue for a true suck, which causes the infant to retain a suckle pattern (Sleight & Niman, 1984).

According to Sleight and Niman (1984), decreased strength in infants with Down syndrome contributes to the delays of establishing postural control that is necessary for feeding. These authors also postulated that infants with Down syndrome are unable to control their tongue due to a small oral cavity, lack the fine muscular control necessary for tongue shaping, and protrude their tongue in an anticipation of food. Therefore, swallowing is accomplished with inappropriate movement patterns where the tongue goes forward and out of the mouth. After the initial swallow, there may be repeated anterior and posterior movements of the tongue demonstrating a delay in oral motor control.

Spender, Stein, Dennis, Reilly, Percy, and Cave (1996) examined feeding skills in children with Down syndrome ages 9 to 36 months. The Schedule for Oral Motor Assessment was used to record oral-motor skills and provide an objective rating of these skills during feeding. The children were observed and offered a range of foods consisting of different textures including puree, semisolid, solid, soft biscuits, medium biscuits, hard biscuits, dried fruit, and liquids. Each of the textures were presented four times. The video tape of these observations was rated for the presence of approximately 107 items relating to oral motor ability. Examples of these items include body and head positioning, refusal behaviors (e.g., head aversion), reactivity (e.g., anticipatory mouth opening), acceptance (e.g., food accepted within 2 seconds), food loss, drooling, sequencing (e.g., smooth coordination of sequential actions such as chew/munch/swallow), initiation (e.g., progressing from food placement in mouth to the start of sequencing), lips (e.g., lip closure), tongue (e.g., tongue protrusion), jaw movements, biting (e.g., control and effectiveness), and swallowing (e.g., lip closure and gagging). The findings of this study indicated that the sequence of oropharyngeal functions necessary to move puree and solid boluses from the lip region into the pharynx in children with Down syndrome is poorly coordinated. For example, jaw control was observed to be insufficient to enable small vertical jaw movements to manipulate puree and crackers (wide movements being unaffected) and was characterized by the need for external stabilization (e.g., by resting the jaw on the cracker) (Spender, et al.,1996).

There was a tendency for food to be pooled in the buccal cavities without being swallowed; it often reappeared on the tip of the tongue after the child consumed several boluses. These scientists also noted that children with Down syndrome appeared to exhibit difficulty in biting with adequate strength, partly because of interference by the tongue and partly because what appeared to be weak jaw control. In addition, intermittent lip closure (defined as lips being closed together for part of the sequence of chewing and munching) may also cause feeding difficulties for children with Down syndrome.

The study by Spender and colleagues has shown that young children with Down syndrome may have significant impairments in oral-motor function for feeding. The researchers concluded that the feeding impairments of children with Down syndrome are not just a function of developmental delay, but represent a distinctive developmental pattern, which appears to be unique to the syndrome. Certain aspects of oral-motor function were found to be more impaired than others (e.g., tongue position and jaw control). Although tongue protrusion during feeding is well recognized in children with Down syndrome (Gisel et al., 1984), this study demonstrated that other important elements of the feeding process may also be affected. Functional impairments may be a result of muscle hypotonicity (Limbrock et al., 1991). In addition, tongue protrusion has been attributed to the reduced size of the oral cavity, reduced palatal length (Shapiro et al., 1967), and maxillary hypoplasia (as cited in Spender et al., 1996).

Difficulty With Mastication

Gisel (1984) studied the chewing abilities of 4- and 5-year-old children with Down syndrome and compared their chewing movements to those of typically developing children. Results of her study indicated that children with Down syndrome expressed a reluctance to chew and seemed to suck more on the food items until swallowing. These children also demonstrated a more forward tongue position on presentation of all food items, whereas the typically developing children exhibited a tongue position behind the teeth in anticipation of food. The tongue position exhibited by the typically developing subjects appeared to be a more mature response, as indicated by the age-by-position effect in normal children (Shwartz, Niman, & Gisel, 1984). Gisel reported that the forward tongue position in the children with Down syndrome may have been caused by their breathing patterns and the configuration of oral structures. In addition, Gisel described the jaw movements of children with Down syndrome as slower than those of normal children during chewing. The duration of their chewing patterns were prolonged per bite of food. Gisel concluded that the increase in duration of chewing time in children with Down syndrome may reflect their reluctance, or inability, to chew food vigorously (Gisel, 1984; Klein & Delaney, 1994; Rogers & Coleman, 1992; Cooley & Graham, 1991).

Only one study has employed modified barium swallow studies to quantify the feeding difficulties in children with Down syndrome. Frazier and Friedman (1996) conducted a study on swallowing in children with Down syndrome ages 3 months to 11 years. These children were referred to the Swallowing Disorders Clinic of The Children's Hospital (TCH) of Denver to identify possible factors that may influence the respiratory health in this population. The group studied consisted of 19 children with Down syndrome. A speech-language pathologist, occupational therapist, and a dietician conducted pre-videofluroscopic assessments on each child which consisted of: (1) a parent/caregiver interview; (2) an oral motor, oral sensory, and feeding assessment; (3) an analysis of the child's postural control; and (4) a nutritional evaluation.

During the videofluroscopic modified barium swallow (VMBS) the following five aspects of swallowing were evaluated: (1) oral preparation, (2) reflex initiation, (3) pharyngeal clarity, (4) aspiration, and (5) cricopharyngeal screening. The method of food presentation and food textures depended upon the feeding abilities of each child. Textures were selected to match as closely as possible those textures being consumed on a daily basis. Textures included thin liquids, thickened liquids, puree or paste, and solids. Methods of presentation included bottles, cups, spout-cups, cut-out cups, straws, bottle nipples with a single slash, personal utensils, and a shallow-bowled spoon. Frazier and Friedman (1996) reported that three of the children exhibited normal oral muscle tone (normal muscle tone was defined as no oral open mouth posture and no tongue protrusion at rest) and developmentally appropriate oral motor abilities (no oral motor difficulties that impacted their feeding ability). The remaining 13 children demonstrated oral motor problems that affected their feeding ability. Oral motor difficulties in young infants exhibited during the VMBS consisted of fatigue, decreased suction on the nipple, difficulty with suck initiation, weak lip seal, and difficulty coordinating suck, swallow, and breathing patterns.

Oral motor difficulties in the older infants and children consisted of difficulty grading jaw movements resulting in wide jaw excursions, inefficient lip closure, and poor bolus control (e.g., transitioning the bolus within the oral cavity in preparation for swallowing). Oral sensory problems were exhibited in seven of the children. These problems were diagnosed by evaluating behaviors commonly associated with oral sensory dysfunction such as aversive or exaggerated response to touch in, or around, the mouth, hyperactive gag response, and lack of age-appropriate mouthing of toys/hands. Slow initiation of a swallow response occurred in 15 of the 19 children on thin liquids, thickened liquids, and puree textures. In regards to aspiration, no child aspirated on puree or solid textures. Ten children aspirated during the VMBS, six on thin liquids, two on thickened liquids, and two on both thin and thickened liquids. Thin liquids were deemed inappropriate for seven of the children, and it was recommended that oral feeding be discontinued for one child. The findings of this investigation concur with previous studies that found sucking and chewing difficulties in this population and suggest that aspiration should be considered as an additional factor contributory to the high incidence of respiratory illness in children with Down syndrome.

This study concluded that the oral phase of children with Down syndrome may be impacted by oral hypersensitivity which can interfere with their acceptance of textured foods. The difficulty of advancing textures has been reported to be related to a small oral cavity, low muscle tone, decreased jaw strength, and poor control of tongue movement resulting in gagging and the rejection of textured foods (as cited in Frazier & Friedman, 1996).

Conclusion

Since it is known that normally developing children by 12 months of age produce the basic masticatory patterns seen in adults, it can be suggested that feeding time for children with Down syndrome also decreases with maturity. It is widely known that children with Down syndrome exhibit delays in the motor patterns needed for chewing. Some reports indicate that these patterns may even be labeled deviant. However, there has been no quantitative data obtained on the motor patterns exhibited by children with Down syndrome. It has also been suggested that food textures will effect the coordination of chewing in children with Down syndrome, because they affect the chewing patterns in normally developing children. Many researchers discuss the relationship between oral-motor coordination and chewing; nevertheless, there is a great need for quantitative data regarding this relationship.

The proposed study will describe the coordinative muscle patterns of children with Down syndrome during feeding. The description of these motor patterns in children with Down syndrome will allow a comparison of their feeding patterns to the feeding patterns of normally developing children. This research will permit speech-language pathologists and other professionals working with these individuals to have a greater understanding of various aspects of normal and disordered mastication in children. More specifically, this comparison will enable the investigator to determine if the masticatory patterns in children with Down syndrome are more deviant or delayed.

Research Questions

The purpose of this EMG study is to gather quantitative data on children with Down syndrome ages 15 to 24 months of age, to describe and compare their coordinative muscle patterns during feeding to those of normally developing children. This study will determine the following:

(1) What coordinative patterns (relative timing and coupling) of mandibular muscle activity do children with Down syndrome exhibit during sucking?

(2) What coordinative patterns (relative timing and coupling) of mandibular muscle activity do children with Down syndrome exhibit during oral manipulation of

pureed foods?

(3) What coordinative patterns (relative timing and coupling) of mandibular muscle activity do children with Down syndrome exhibit during chewing of semi-solid or solid foods?

CHAPTER II

Methods

Purpose of Study

The purpose of this study was to compile descriptive and quantitative data for approximately two males and females with Down syndrome ages 9 to 18 months of age with regard to mandibular muscle activity during feeding activities (e.g., chewing, sucking and drinking). The degree of coupling between EMG signals from the right and left masseter, right and left temporalis, and the anterior belly of the digastric during chewing was determined. Research findings indicate that normally developing children produce adult-like mandibular muscle activity during feeding by 12 months of age. Children with Down syndrome may exhibit delays in obtaining the typical mandibular motor patterns for feeding. However, little quantitative data exists regarding the development of mandibular muscle activity in children with Down syndrome. Therefore, results from this study allow speech-language pathologists and other professionals working with these individuals to have a greater understanding of various aspects of normal and disordered feeding abilities in children. Additionally, therapies may begin to focus on the aspects of feeding that are most deviant. EMG data may also be utilized during therapy to identify normally developing chewing patterns when mastered.

Subject Recruitment

Subjects were recruited through contacts via The Down syndrome Awareness Group of East Tennessee, and by sending home parent-letters (letters that explain the study) via the University of Tennessee Pediatric Language Clinic (See Appendix B). The parent-letter informed the parent to contact the principal investigator if interested. At that time, the principal investigator provided the parent with additional information, answered questions, and completed a subject information form (See Appendix C) and a feeding history form (See Appendix D) to determine if the potential subject meets the subject selection criteria. When the potential subject was found to be appropriate for this study, a session time and date were agreed upon, and the principal investigator sent them an appointment letter. If a subject did not meet the subject-selection criteria, the parent received an explanation as to why their child was unable to participate in the study (e.g., we can only see toddlers with no severe respiratory difficulties) and was thanked for their time. An appointment letter was then sent to the parent with information regarding the tasks that their child performed (i.e., what food items that their child was asked to eat, and what foods could be brought from home) (See Appendix E).

Selection Criteria

Items from the subject information sheet were presented verbally to the parent to assure that the subject met the following subject-selection criteria. Inclusion criteria required that the child exhibit mild to moderate mental retardation and have a diet of at least liquid and pureed consistencies. Exclusion criteria encompassed children with: (a) prolonged or traumatic oral intubation, (b) a tracheotomy, (c) oral, pharyngeal, and esophageal mechanisms that are atypical for toddlers with Down syndrome (e.g., cleft palate, esophageal atresia, tracheo-esophageal fistula), (d) deviant feeding difficulties (e.g., excessive coughing or choking, recurrent regurgitation/vomiting), and (e) known neurological deficits (e.g., seizures, cerebral insults).

Experimental Protocol

Each subject was seen individually, for one session, lasting approximately one hour in length. This session included: (a) the administration of an oral mechanism screening; and (b) the completion of the experimental tasks. The screening and experimental sessions took place in 443 South Stadium Hall on the University of Tennessee's campus. This sound-treated laboratory is child-friendly (all equipment are out of reach of the toddlers and small children) and contains children's furniture.

Before the screening session, each subject was given a few minutes to become acclimated to the environment. During that time, two sets of electrodes were shown to the parent and an explanation regarding application of electrodes was provided. Following the explanation, the parent gave verbal assent for their child to participate in the study, the parent then signed the consent form for subject participation (See Appendix F).

Oral Mechanism Screening Task

The screening task was administered prior to the experimental session. An informal oral mechanism examination (e.g., informal observations of facial muscle symmetry, range of movement of the speech articulators during speech and nonspeech movements) was performed (See Appendix G). Each subject was examined by a graduate student in speech-language pathology with supervision by a certified, ASHA accredited Speech-Language Pathologist to verify the inclusion criteria. This screening helped to assure that each subject's oral mechanism is adequate with respect to structure and function in toddlers with Down syndrome.

Experimental Session

Placement of surface electrodes:

Electrodes were placed on the child while he/she was sitting in a highchair or in the parent's lap. Seating was arranged to minimize extraneous movement and possible entangling of the electrodes. During the placement procedure, the toddler was encouraged to play with toys and to play games (e.g., patty cake). Both novel and familiar toys were used to amuse the child while the electrodes were being positioned.

Prior to electrode placement the subject's skin was lightly scrubbed with alcohol gauze pads followed by application of a hypo-allergenic antiperspirant skin lotion (Prep N' Stay, Pharmaceutical Innovations, Inc.). Ag/AgCl disk electrodes (In Vivo Metrics, 4 mm outside diameter) filled with hypo-allergenic electrode cream (Spectra 360, Parker, Inc.) were attached to the skin using adhesive electrode collars. Additional adhesive tape was placed over the electrodes to secure them in place. Any time the subject reached for the electrode wires, his/her hands were gently redirected to a toy or food item. A cordless microphone was placed on the child's blouse to record the description of the child's target behaviors, which may have also contained verbalizations from the child. EMG and audio signals were recorded continuously throughout the 60 minute session.

EMG recording sites

EMG activity was recorded from five sites: (1) right masseter; (2) left masseter; (3) right temporalis; (4) left temporalis; and (5) the anterior belly of the digastric (ABD). Placement of the masseter electrodes was based on the palpation of the main mass of the muscle, anterior and superior to the angle of the mandible. Temporalis electrodes were placed just superior to the zygomatic arch, which was identified with palpations. For both masseter and temporalis sites, the electrodes within each pair were aligned parallel to the orientation of the muscle fibers of the targeted muscle. The digastric was recorded bilaterally with the use of a single electrode pair and situated with one electrode over each belly (i.e., the right and left portions). The inter-electrode distance for all electrode pairs was ~0.5 cm. Additional adhesive tape was applied to secure all electrodes.

The electrode placement procedure, which was required to obtain adequate EMG signal recordings, is safe and effective with infants, children, and adults for several reasons (Ruark & Moore, 1992; Moore & Ruark, 1996, Green et al., 1997, Ruark & Moore, 1997). First, the electrodes are passive (signals are only amplified and recorded on a DAT recorder). Second, in past investigations, subjects (e.g., infants, children) have shown no adverse effects from electrode gel or collars (although after the removal of the collars, the skin surface of some individuals may show tiny red marks where the electrode collars contacted the skin; this disappears shortly). Third, passive electrodes are used with infants, children, and adults on a daily basis (e.g., in hearing clinics to record neural signals during auditory evoked response audiometry, in hospitals for monitoring heart rate). Because electrode preparation occurred prior to the experimental session, the placement procedure took less than ten minutes. Once the electrodes were in place, the experimental session began.

Signal recording

EMG signals were amplified using Grass P511K physiologic preamplifiers (bandpass = 30-3 kHz) and filtered to prevent aliasing. All channels were recorded on a TEAC RD-200T PCM DAT recorder for off-line digitization and analysis.

Channels that were recorded include:

1) right masseter

2) left masseter

3) right temporalis

4) left temporalis

5) bilateral anterior belly of the digastric

6) child's audio and on-line description of target behaviors by Experimenter #1

7) Experimenter #2 audio-commentaries regarding ongoing changes in experimental conditions

Experimental Tasks

Each subject was prompted to complete four experimental tasks. These tasks were selected for their potential to yield different degrees of mechanical coupling of the mandibular muscles during feeding (Moore & Ruark, 1996). These tasks were also selected to facilitate comparisons with tasks performed by infants and toddlers of the same age in similar EMG studies of developmental chewing patterns in normally developing children (Green et al., 1997; Moore & Ruark, 1996). Each toddler was presented with a familiar food item supplied by his/her parent (liquid, pureed, semi-solid or solid, which was determined by the child's abilities) along with verbal encouragement to eat or drink. As the child consumed a food item the principal investigator described the child's activity on audio Channel 1 (e.g., to describe whether the child's lips are open or closed). Task order was determined by the child's own interest and abilities, which varied across participants and resulted in a randomized data set.

The tasks included:

1) Sucking/drinking of liquids: Each child was presented with his/her "drink" (liquid that will be provided by his/her parent and part of the infant's normal diet) via bottle or sippy cup.

2) Oral manipulation of pureed foods from a spoon: The toddler was provided with his/her "snack" of a pureed consistency.

3) Chewing of semi-solid (a substance that is partially gaseous, liquid or hollow) or solid foods (a substance completely not gaseous, liquid, or hollow): The toddler was provided with food items that are consistent with semi-solid or solid consistencies (e.g., cereal, soft cracker, cheerio).

4) Oral manipulation of a teething biscuit. After the parent's consent each child was provided with a teething biscuit.

The child was encouraged to eat at least 5 to 10 "bites" of pureed items (~ 1/3 to ½ teaspoons each), eat 5 to 10 bites of food items of increased viscosity (thickened cereal, soft cracker, cheerio), and drink 1 to 2 ounces of liquid. The food items were provided by the child's parent. Additionally, all food items were familiar to each child and depended on his/her current stage of feeding behavior. If a child only consumed small amounts, refused to eat, or could not consume one or more food consistencies, his/her data was still used in the investigation.

Data Digitization

Target behaviors for each task were identified and parsed from the continuously taped 60-minute experimental session and stored in separate files for subsequent digitization and analysis. Each subject has three or four files (one for each task). Only those target behaviors that were free of movement artifact or other unacceptable instances (e.g., 60 cycle line noise, vocalizations mixed with chewing) were digitized.

EMG signals for each activity were digitized at a rate of 1,000 samples per second per channel and stored in a separate file. From the digitized files, each task was analyzed.

Data Analysis

A computer program custom-designed with MATLAB (The Mathworks, Inc., 1995) software was used to process and analyze the EMG data. Analysis began by displaying one entire file (e.g., EMG file of 60 seconds of sucking activity) on the computer screen. Next a cursor was used to mark the beginning and end points to be analyzed (e.g., the first 20 seconds of sucking activity). These marked portions were then full-waved rectified and low pass filtered to yield EMG activation "envelopes" per record. The EMG envelopes (of the five EMG records) were then analyzed in a pair-wise fashion (i.e., RM-LM, RM-RT, RM-LT, RM-ABD, LM-RT, LM-LT, LM-ABD, RT-LT, RT-ABD, and LT-ABD) using a cross-correlation function (ten pairs in all are analyzed, thus ten cross-correlation functions will be obtained), which correlated the rising and falling patterns of two muscles within a pair.

Finally, a "peak-picking" function designated the highest positive peak (peak coefficient) of each of the ten cross-correlation functions and provided the lag to each peak. The peak coefficient designates the level of muscle coupling (a coefficient of 1.0 indicates perfect coupling) and the lag indicates the synchrony of muscle activity. Data files were analyzed in 20 second intervals until the entire file was analyzed (e.g., 60 seconds of data would require three analysis). These analyses have been used in recent investigations to quantify the degree of coupling and synchrony between muscle pairs

(Moore & Ruark, 1996; Ruark & Moore, 1997).

Percent Agreement

Intrajudge and interjudge percent agreement was computed on data selection and data analysis. Pre-training occurred using data gathered outside of this study. The percent agreement included 10% of randomly selected tracings for one record file of each behavior across subjects. Random tracings were gathered using a random numbers table. Interjudge percent agreement was completed by the two experimenters. This percent agreement was considered acceptable if the reanalyzed data (i.e., peak coefficient) was within .10 of the original scores.

Data Description/Analysis

The objective of this investigation was to compare relative coupling among jaw muscles of infants with Down syndrome across a continuum of early developing feeding behaviors.

Findings of this investigation were described in the following manner: (1) coupling of each of the 10 muscle pairs (e.g., RM x LM) was compared across the four tasks and, (2) within a given task, coupling and timing of muscle pairs were compared. Data was presented in a descriptive format by reporting individual muscle pair means, and individual muscle pair ranges of the peak coefficients and absolute lags. Comparisons were made among mandibular synergist and antagonistic muscle pairs.

CHAPTER III

Results

This experiment was designed to describe and quantify the mandibular muscle activity of infants with Down syndrome during feeding activities (e.g., chewing, sucking and drinking). Subjects of this investigation included four infants with Down syndrome, two males and two females, 9 to 18 months of age. Additional descriptors are included in Table 1. A subject information sheet and feeding history form, completed by the parent, provided additional health history information.

All subjects completed the experimental protocol with the exception of one subject who was unable to complete one target behavior. Each infant was seen individually during lunch or snack time, accompanied by his or her mother. After a brief time, each subject easily acclimated to the researchers and the environment. All subjects tolerated the application of the surface EMG electrodes and readily sat in a highchair facing the mother and one of the researchers. A second researcher was positioned behind the infant throughout the experimental session to assure that electrode wires remained untangled; a third researcher monitored the physiologic equipment.

Each subject's experimental session lasted approximately 60 minutes. Target behaviors were elicited from the child while continuous FM tape recordings of the behaviors and audio signals were obtained. The experimental session contained four target behaviors which included the consumption of (1) liquid, (2) pureed, and (3) solid foods, and a (4) teething biscuit. Each subject was presented the consistencies by the parent via one or more of the following utensils: spoon, bottle, and/or sippy cup. There

Table 1. Subject characteristics.

Subject	Gender	Age	Foods Eaten	Gross motor milestones	Health history	Number of teeth	Feeding history
1	Female	9 months	cereal, purreed bannanas,cheerios, teething biscuit	crawling	heart surgery	0	no feeding tx
2	Male	9 months	pureed turkey, pureed fruit, crackers, teething biscuit	crawling	heart murmur	2	feeding tx
3	Female	15 months	pureed fruit, pureed vegetables, crackers	sitting	heart surgery	0	feeding eval
4	Male	18 months	applesauce, cheerios, crackers, teething biscuit	crawling	heart surgery	5	no feeding tx

was no attempt to control sampling order for the behaviors, rather, each child's interest dictated the order in which target behaviors were observed. The subjects orally manipulated a variety of foods provided by the mothers, depending on each child's normal diet (i.e., pureed fruit, pureed turkey, pudding, cheerios, crackers, teething biscuit). Three of the subjects drank from bottles and one drank from a sippy cup. At least 18 cycles of chewing of both solid and pureed textures were sampled for each child; the total sampling period consisting of approximately 360 seconds of data per subject. Data were collected for all consistencies for each subject, with the exception of the teething biscuit for Subject 3 due to this subject's inability to complete the task.

Figure 1 illustrates one set of EMG records obtained during 20 seconds of chewing. Although computational limits required analysis of only 10 seconds of data at a time, all of the data in the figure were included in the analysis. Figure 2 illustrates how 10 seconds of a raw EMG signal was parsed for analysis. These results have been full-wave rectified and lowpass filtered (8-pole Butterworth, $f_c = 30$ Hz). The data in Figure 2 illustrates a typical reciprocal organization pattern of mandibular antagonists, as well as the synergistic organization pattern of mandibular homologous muscle pairs. These organizational patterns characterize the well-known mandibular coordinative organization for chewing (Moller, 1966).

The degree of coupling between muscle pairs was based on a pairwise cross-correlational analysis of timing and amplitude of the EMG signals obtained. Each crosscorrelation function resulted in two data points of interest: the peak correlation coefficient and the lag correlated with the peak coefficient. The peak correlation coefficient provided a quantitative measure of the degree of coupling for each muscle

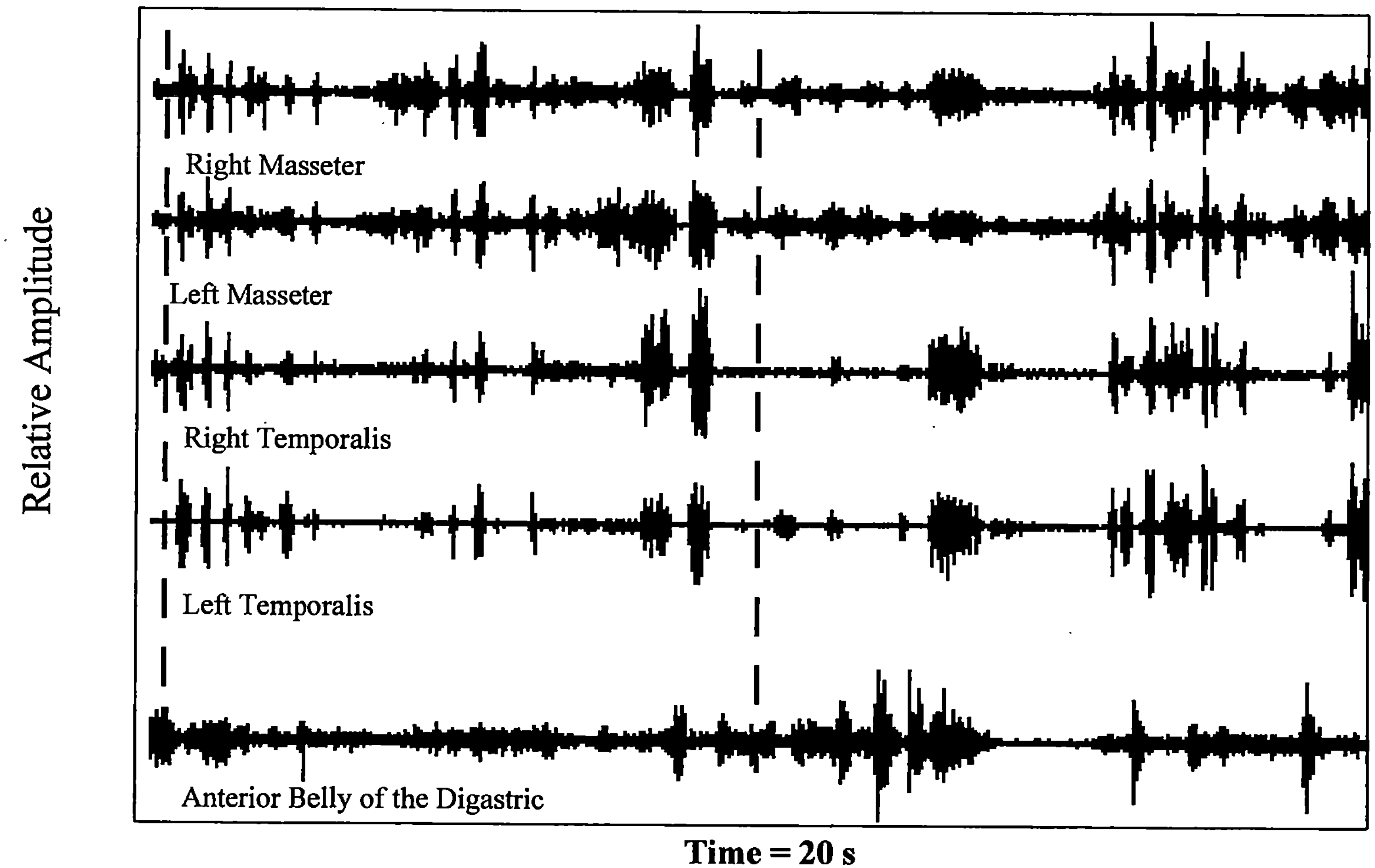

Figure 1. Electromyograms recorded from the five mandibular muscles of a 9-month-old infant with Down syndrome as he chewed solid food.

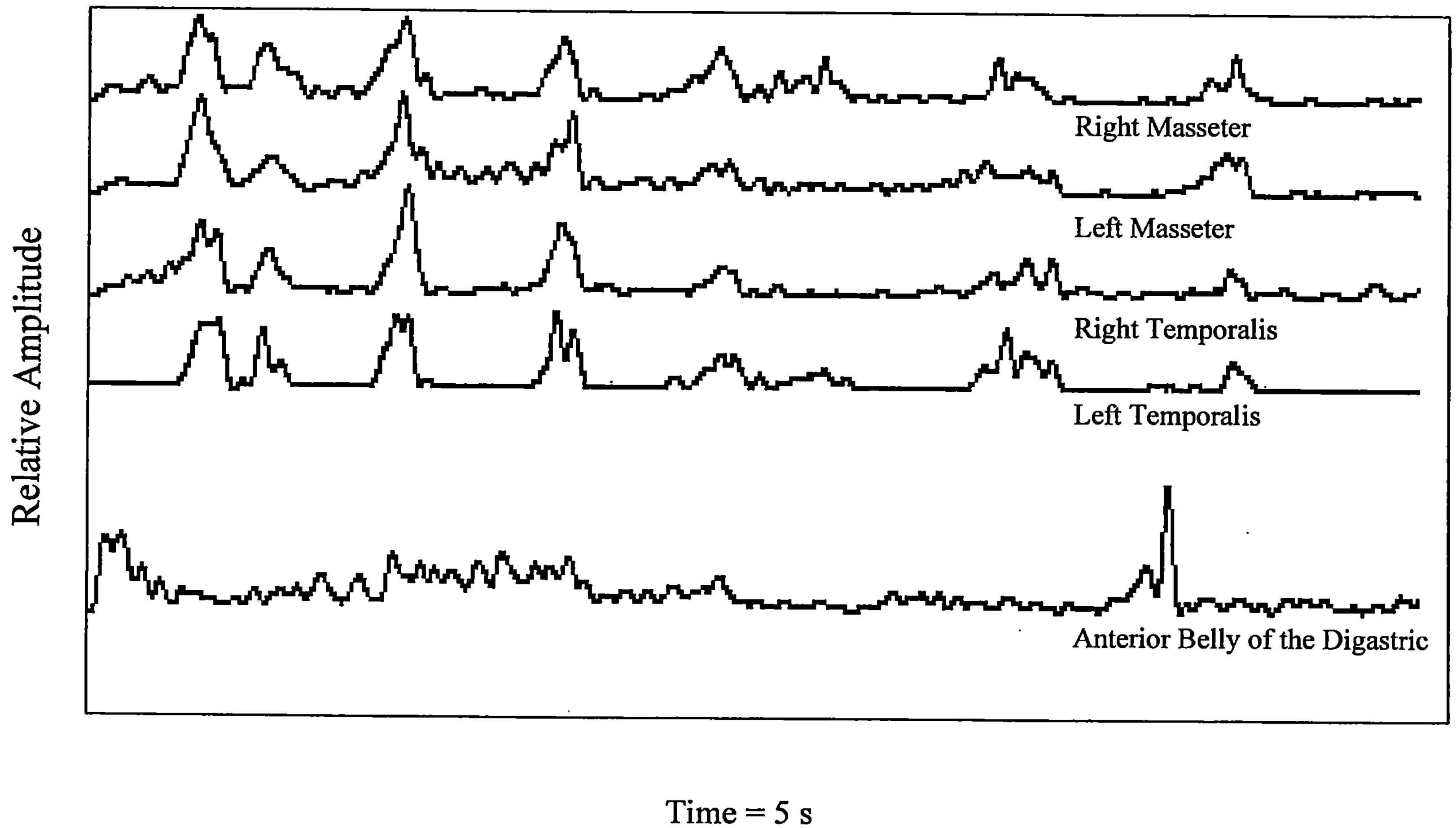

Figure 2. Rectified and Filtered EMG records of mandibular muscles of a 9 -month-old infant with Down syndrome while chewing a solid consistency.

pair, while the lag to the peak coefficient resulted in the timing of the delay between the coupled activity for each muscle pair. Crosscorrelation functions (as compared to simple zero-lag correlation coefficients) allows strongly coupled activity from opposing muscles (such as the reciprocal activation of the jaw depressing and jaw elevating muscles during chewing) to be described (in terms of the peak coefficient) and the delay (typically 200 ms for chewing) between the correlated activity is known (Moore & Ruark, 1996).

A total of 10 paired comparisons were computed for each data set (e.g., 10 seconds of chewing data). Figure 3 illustrates the crosscorrelation function obtained for the right and left masseter in Figure 2. The presence of the peak coefficient at .62 indicates a moderate level of coupled activity between this muscle pair. A lag to the peak of zero indicates that activity of the right and left masseters are highly synchronous during this trial of chewing. These values (peak coefficient and lag to the peak) can be used to compare coupling strength and synchrony of muscle pairs across behaviors (differences in the lags of the peak coefficients).

<u>Coupling strength of muscle pairs across tasks</u>

Table 2 shows each subjects' mean peak coefficient for each of the ten muscle pairs for the four target behaviors. To facilitate the comparison of the relative coupling among jaw muscles along a continuum of feeding behaviors, the results as depicted in Table 2 (mean peak coefficients for individual muscle pairs) were combined into groups of muscles that were chosen to represent biomechanical relationships. These muscle groups included: homologous pairs (RM x LM and RT x LT), ipsilateral pairs (RM x RT and LM x LT), contralateral pairs (RM x LT and LM x RT) and antagonist pairs (RM x ABD, LM x ABD, RT x ABD, and LT x ABD). Table 3 shows the collapsed data set for

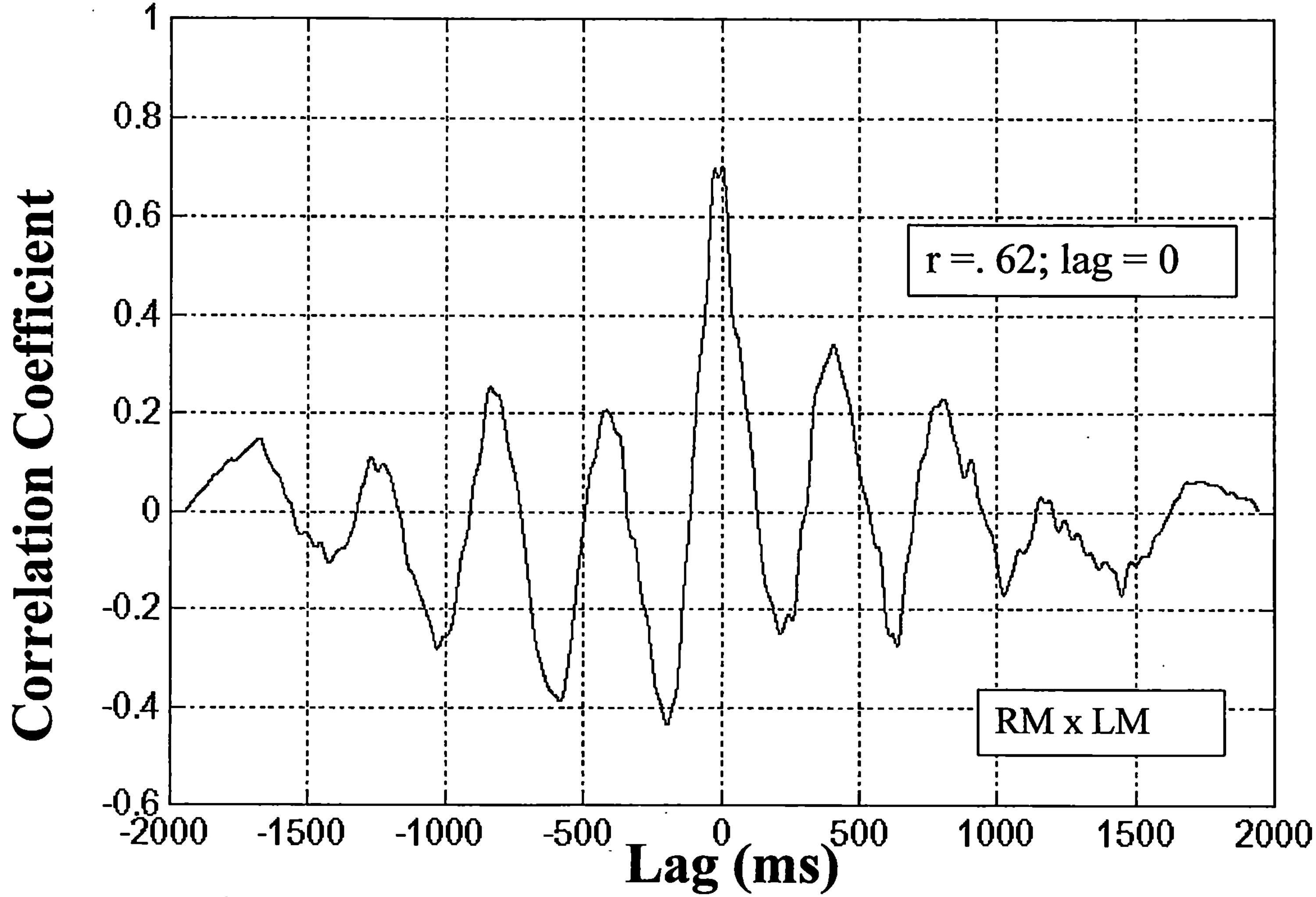

Figure 3. The crosscorrelation function obtained for the right masseter and left masseter records in Figure 1. The peak coefficient of .62 indicates a moderate level of coupled activity between this muscle pair. The lag of 0 ms indicates high synchrony of the right and left masseters.

Table 2. Subject's mean peak coefficients and mean peak coefficient ranges across tasks for each of the 10 muscle pairs.
Note: RM - right masseter, LM - left masseter, RT - right temporalis, LT - left temporalis, and ABD - anterior belly of the digastric.

Muscle Pairs:		RM x LM	RT x LT	RM x RT	LM x LT	RM x LT	LM x RT	RM x ABD	LM x ABD	RT x ABD	LT x ABD
Tasks	Subjects										
liquid	Subject 1	.43 (.11 to .62)	.39 (.08 to .56)	.50 (.37 to .69)	.53 (.44 to .69)	.28 (.14 to .69)	.33 (.24 to .55)	.39 (.29 to .59)	.44 (.37 to .47)	.21 (-.07 to .37)	.27 (.08 to .44)
	Subject 2	.81 (.77 to .89)	69 (.46 to .88)	.72 (.50 to .86)	.66 (.51 to .79)	.71 (.56 to .87)	.66 (.47 to .82)	.43 (.31 to .54)	.40 (.23 to .54)	.34 (.17 to .45)	.36 (.14 to .48)
	Subject 3	.47 (.33 to . 59)	.44 (.29 to .50)	.39 (.23 to .49)	.39 (.19 to .56)	.26 (.12 t0 .33)	.36 (.29 to .49)	.49 (.35 to .62)	.45 (.29 to .59)	.27 (.14 to .46)	.26 (.02 to .43)
	Subject 4	.58 (.44 to .74)	.51 (.39 to .63)	.47 (.24 to .73)	.51 (.33 to .69)	.34 (.07 to .50)	.50 (.35 to .67)	.37 (.25 to .45)	.35 (.15 to .48)	.28 (.08 to .55)	.27 (.17 to .37)
pureed	Subject 1	.41 (.20 to .54)	.49 (.27 to .64)	.48 (.37 to .56)	.47 (.33 to .62)	.35 (.07 to .65)	.31 (.13 to .49)	.35 (.26 to .53)	.32 (.26 to .53)	.27 (.14 to .50)	.27 (.11 to .43)
	Subject 2	.75 (.64 to .85)	.56 (.31 to .94)	.66 (.50 to .87)	.57 (.47 to .76)	.55 (.30 to .86)	.59 (.46 to .74)	.27 (-.11 to .48)	.27 (-.17 to .62)	.37 (.12 to .64)	.26 (-.08 to .53)
	Subject 3	.49 (.28 to .71)	.41 (-.09 to .73)	.58 (.45 to .78)	.36 (.13 to .76)	.31 (-.12 to .69)	.39 (.16 to .70)	.28 (.04 to .47	.26 (.07 to .43)	.23 (.00 to .45)	.16 (-.09 to .39)
	Subject 4	.48 (.37 to .56)	.41 (.21 to .75)	.35 (.21 to .43)	.57 (.51 to .65)	.36 (.27 to .46)	.38 (.28 to .58)	.24 (.04 to .39)	.27 (..10 to .47)	.18 (-.05 to .33)	.23 (.00 to .50)
solid	Subject 1	.51 (.39 to .59)	.31 (.06 to .59)	.35 (.08 to .51)	.27 (.06 to .66)	.20 (.06 to .48)	.51 (.43 to .59)	.34 (.23 to .41)	.48 (.41 to .56)	.49 (.39 to .59)	.17 (.06 to .39)
	Subject 2	.74 (.59 to .83)	.76 (.54 to .86)	0.66 (.39 to .80)	.66 (..47 to .80)	.68 (.43 to .85)	.66 (.42 to .80)	.22 (.05 to .33)	.24 (.12 to .39)	.22 (.05 to .31)	.20 (.02 to .31)
	Subject 3	.58	.29	.22	.41	.58	.14	.23	.41	.42	.08
	Subject 4	.27 (.11 to .43)	.48 (.24 to .68)	.34 (.29 to .41)	.57 (.42 to .79)	.28 (.13 to .41)	.35 (.20 to .57)	.31 (.10 to .53)	.19 (-.05 to .37)	.22 (.07 to .40)	.19 (.05 to .34)
teething biscuit	Subject 1	.59 (.29 to .76)	.60 (.34 to .75)	.62 (.46 to .76)	.64 (.43 to .80)	.61 (.51 to .80)	.53 (.74 to .22)	.42 (.30 to .50)	.41 (.26 to .55)	.31 (.19 to .55)	.41 (.19 to .58)
	Subject 2	.79 (.77 to .81)	.32 (.26 to .37)	.57 (.54 to .60)	.58 (.50 to .67)	.49 (.41 to .57)	.59 (.53 to .66)	.20 (.05 to .34)	.17 (.04 to .31)	.08 (.03 to .12)	.33 (.25 to .42)
	Subject 3										
	Subject 4	.43 (.27 t0 .63)	.51 (.34 to .75)	.44 (.21 to .64)	.62 (.52 to .71)	.49 (.37 to .58)	.44 (.22 to .64)	.14 (.05 to .29)	.16 (.08 to .26)	.07 (-.14 to .17)	.13 (.05 to .18)

Table 3. Mean peak coefficients of collasped muscle groups for each subject across tasks.

Tasks	Subjects	Homologous	Ipsilateral	Contralateral	Antagonistic
liquid	Subject 1	0.41	0.51	0.31	0.33
	Subject 2	0.75	0.69	0.68	0.38
	Subject 3	0.45	0.39	0.31	0.37
	Subject 4	0.55	0.49	0.42	0.32
pureed	Subject 1	0.45	0.47	0.33	0.31
	Subject 2	0.65	0.62	0.57	0.29
	Subject 3	0.45	0.47	0.35	0.23
	Subject 4	0.45	0.46	0.37	0.23
solid	Subject 1	0.41	0.31	0.35	0.37
	Subject 2	0.75	0.66	0.67	0.22
	Subject 3	0.44	0.32	0.36	0.28
	Subject 4	0.37	0.46	0.31	0.23
teething biscuit	Subject 1	0.59	0.63	0.57	0.39
	Subject 2	0.55	0.58	0.54	0.19
	Subject 3				
	Subject 4	0.47	0.53	0.47	0.12

each behavior for all subjects. General observations of this table indicates (1) a low to moderate degree of coupling of the homologous and synergistic muscle pairs, and (2) relatively weaker coupling of the antagonistic muscle pair. This pattern is seen within each target behavior (except the teething biscuit yielded higher coupling of the mandibular synergists) across all subjects (although Subject 2 demonstrates relatively high coupling of mandibular synergists across tasks). These results are noted to be similar to the pattern of mandibular muscle activity of normally developing infants during feeding tasks (Moore & Ruark, 1996). Coupling of the homologous muscle pairs ranged from .37 to .75. The range of peak coefficients for the ipsilateral muscle group was .31 to .69, and .31 to .68 for the contralateral muscle group. The antagonistic muscle group revealed the lowest range of peak coefficients, .12 to .39.

Through parental report, it was found that the gross motor development of the infants varied and did not appear to correspond to chronological age. Figures 4 and 5 illustrate how the mean peak coefficients within groups of muscles, across tasks, varied between one infant who demonstrated relatively advanced motor skills and another infant whose motor skills appeared slightly delayed. Figure 4 represents the data set of mean peak coefficients across tasks, for Subject 2. The highest degree of muscle coupling for this subject was found for the homologous and synergistic muscle pairs. Though subject 2 is one of the youngest infants of the four, his chewing activity was characterized by motor patterns that are seen in older typically developing infants and children (e.g., high degree of coupling for homologous muscle pairs). In contrast, Figure 5 displays the mean peak coefficients for Subject 3, an infant who exhibited a delay in obtaining gross motor milestones in comparison to the other three subjects. In fact, this subject was only able to

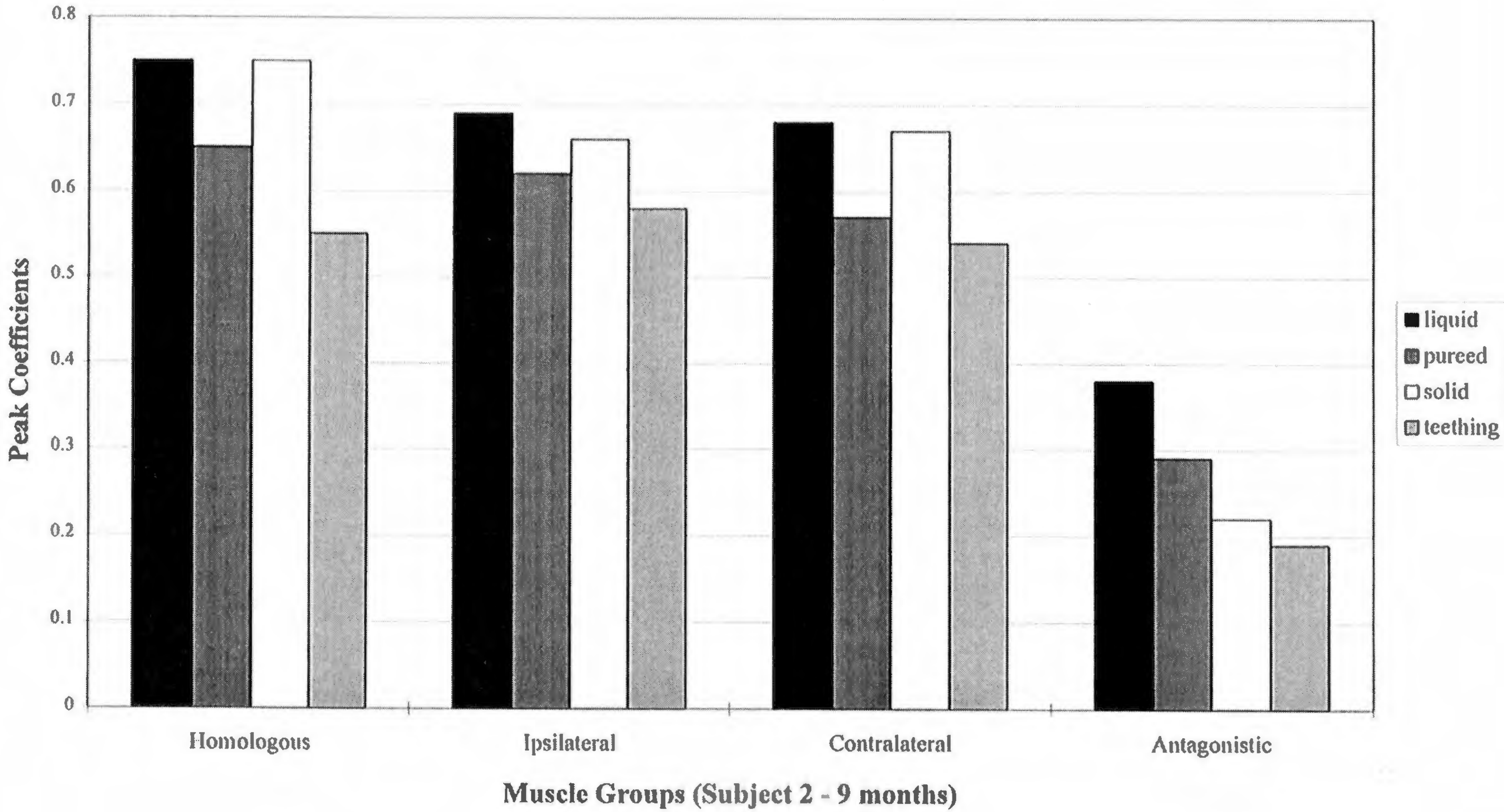

Figure 4. Absolute lags of collapsed muscle groups for Subject 2 across target behaviors.

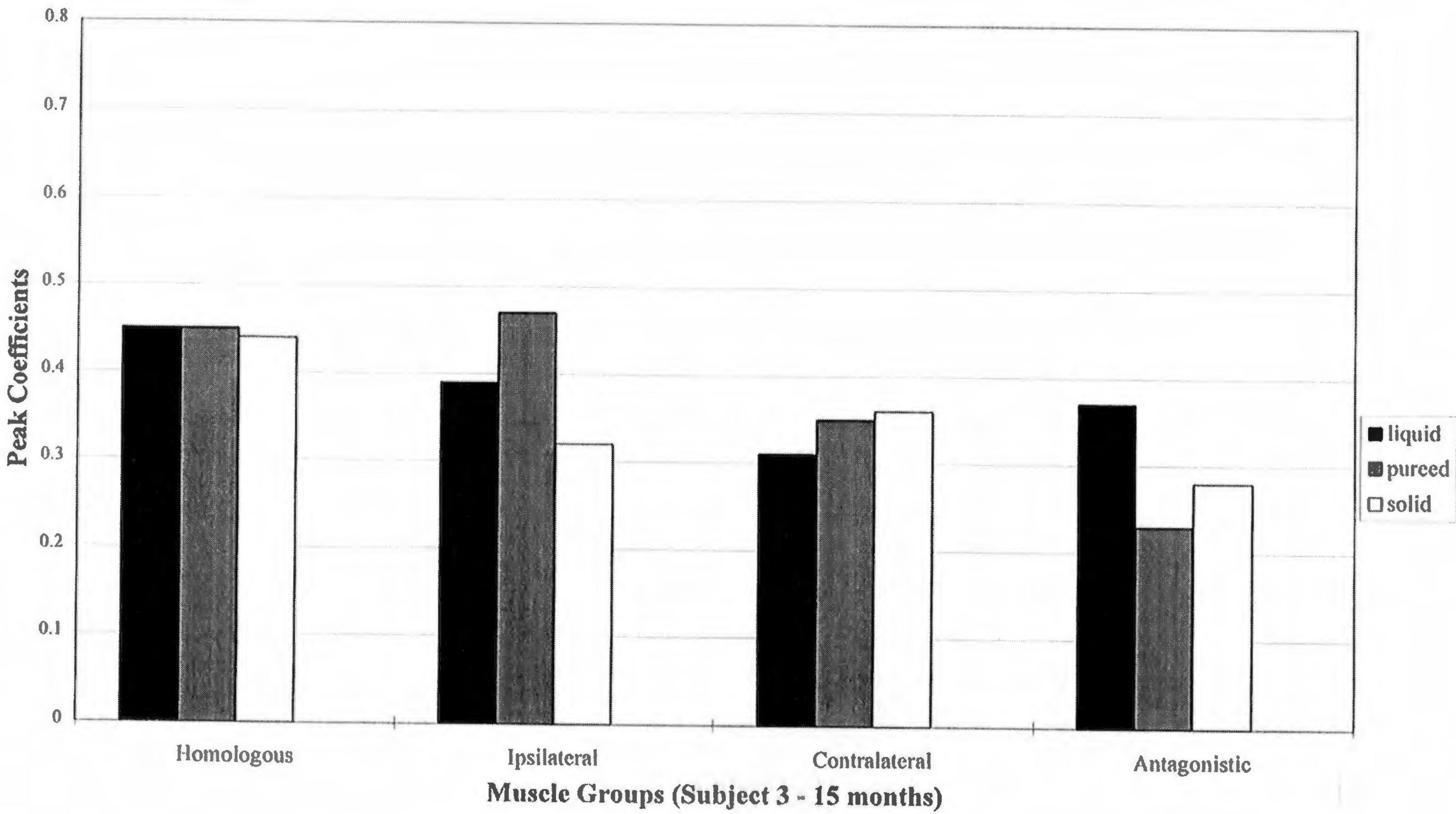

Figure 5. Mean peak coefficients of collapsed muscle groups for Subject 3 across target behaviors.

orally manipulate liquid and pureed consistencies, and a solid consistency with much difficulty. A lower degree of coupling is seen for all muscle pairs across target behaviors.

Timing of muscle pairs across tasks

The lag to the peak coefficient for each crosscorrelation function was extracted and converted to its absolute value to permit averaging. Table 4 shows each subject's mean absolute lag values for each of the ten muscle pairs for the four target behaviors. Once again, to facilitate comparison of the timing of muscle activity across tasks, the results depicted in Table 4 were combined into groups of muscles that were chosen to represent biomechanical relationships. Table 5 shows the collapsed data set for each behavior for all subjects. Mean absolute lag values for the homologous muscle pairs ranged from 2 ms-to-87 ms. Mean lag values ranged from 1 ms-to-238 ms for synergists and 46 ms-to-378 ms for antagonists. Overall, chewing was characterized by longer lags for antagonistic pairs and much shorter lags for synergists, conforming to the fact that synergistic muscles coactivate during chewing. In reference to Table 5, lag values for chewing were typically under 100 ms for homologous and synergistic pairs, indicating a significant synchrony of activation among these pairs, whereas antagonistic pairs yielded lags as high as 378 ms. These findings are similar to those of normally developing children during chewing activities (Moore & Ruark, 1996).

Percent Agreement

The experimental protocol and recording conditions proved to be sufficient for the purpose of gathering descriptive samples of target behaviors from these young children. Intrajudge percent agreement was determined by analysis of one record file of each behavior across subjects. The mean percent of agreement was 93.4%.

Table 4. Subject's mean lags (in milliseconds) and mean lag ranges across tasks for each of the 10 muscle pairs.
Note: RM - right masseter, LM - left masseter, RT - right temporalis, LT - left temporalis, and ABD - anterior belly of the digastric.

Muscle Pairs:		RM x LM	RT x LT	RM x RT	LM x LT	RM x LT	LM x RT	RM x ABD	LM x ABD	RT x ABD	LT x ABD
Tasks	Subjects										
liquid	Subject 1	64 (2 to 427)	63 (1 to 281)	4 (2 to 8)	8 (1 to 14)	106 (2 to 479)	87 (2 to 478)	14 (1 to 58)	42 (6 to 152)	142 (2 to 367)	242 (20 to 499)
	Subject 2	3 (2 to 6)	4 (1 to 8)	6 (2 to 12)	7 (0 to 13)	8 (3 to 16)	4 (0 to 10)	124 (14 to 477)	108 (2 to 431)	117 (40 to 398)	118 (6 to 449)
	Subject 3	6 (2 to 12)	6 (2 to 17)	29 (1 to 152)	5 (1 to 14)	40 (1 to 152)	3 (0 to 7)	16 (1 to 48)	12 (2 to 31)	42 (24 to 57)	114 (12 to 414)
	Subject 4	4 (2 to 6)	9 (0 to 37)	4 (0 to 10)	6 (2 to 15)	13 (1 to 32)	5 (1 to 21)	260 (6 to 477)	228 (4 to 499)	303 (214 to 474)	281 (185 to 470)
pureed	Subject 1	46 (1 to 248)	17 (1 to 77)	48 (2 to 18)	5 (0 to 16)	40 (5 to 205)	138 (4 to 451)	68 (2 to 294)	137 (1 to 384)	293 (3 to 440)	281 (11 to 493)
	Subject 2	13 (2 to 56)	8 (2 to 17)	13 (2 to 43)	10 (3 to 17)	16 (2 to 45)	27 (0 to 80)	299 (2 to 501)	282 (29 to 501)	309 (16 to 501)	266 (15 to 501)
	Subject 3	3 (1 to 7)	93 (1 to 401)	26 (0 to 154)	236 (3 to 491)	133 (2 to 470)	204 (0 to 499)	71 (4 to 470)	61 (1 to 339)	123 (2 to 331)	215 (46 to 499)
	Subject 4	5 (1 to 16)	98 (1 to 465)	6 (0 to 22)	12 (2 to 31)	18 (0 to 58)	109 (2 to 54)	211 (2 to 499)	270 (5 to 499)	224 (124 to 352)	279 (121 to 501)
solid	Subject 1	5 (0 to 12)	170 (0 to 479)	3 (1 to 6)	81 (0 to 260)	105 (1 to 170)	3 (2 to 4)	148 (3 to 287)	5 (2 to 6)	7 (0 to 10)	216 (41 to 435)
	Subject 2	3 (1 to 9)	3 (0 to 8)	8 (3 to 14)	9 (6 to 14)	8 (2 to 13)	8 (3 to 20)	350 (237 to 487)	293 (173 to 454)	266 (47 to 492)	297 (136 to 414)
	Subject 3	39	24	2	0	2	473	54	5	499	499
	Subject 4	45 (1 to 195)	4 (2 to 10)	2 (1 to 4)	2 (0 to 6)	113 (3 to 499)	5 (2 to 9)	341 (224 to 499)	380 (237 to 491)	381 (319 to 499)	409 (231 to 485)
teething biscuit	Subject 1	5 (1 to 11)	20 (2 to 71)	5 (2 to 12)	2 (2 to 3)	26 (0 to 89)	7 (3 to 10)	198 (5 to 413)	191 (1 to 378)	244 (176 to 367)	233 (11 to 424)
	Subject 2	4 (1 to 7)	4 (2 to 5)	16 (7 to 25)	5 (3 to 7)	3 (2 to 3)	7 (2 to 11)	71 (21 to 120)	25 (2 to 48)	238 (59 to 417)	188 (74 to 302)
	Subject 3										
	Subject 4	4 (2 to 5)	1 (0 to 2)	7 (1 to 10)	5 (0 to 8)	32 (3 to 85)	20 (6 to 55)	204 (4 to 362)	254 (206 to 317)	252 (15 to 496)	302 (211 to 341)

Table 5. Mean lags (in milliseconds) of collapsed muscle groups for each subject across tasks.

Tasks	Subjects	Homologous	Ipsilateral	Contralateral	Antagonistic
liquid	Subject 1	64	6	96	110
	Subject 2	4	6	6	117
	Subject 3	6	17	22	46
	Subject 4	6	5	9	268
pureed	Subject 1	32	26	89	195
	Subject 2	11	11	21	289
	Subject 3	48	131	169	117
	Subject 4	52	9	63	246
solid	Subject 1	87	42	54	94
	Subject 2	3	8	8	301
	Subject 3	32	1	238	264
	Subject 4	25	2	59	378
teething	Subject 1	12	4	17	216
	Subject 2	4	11	5	130
	Subject 3				
	Subject 4	2	6	26	253

CHAPTER IV

Discussion

There exists a vast amount of literature regarding feeding difficulties of infants with Down syndrome. These difficulties have been mainly characterized as delays in developing the motor patterns that are needed for chewing. However, little data exists in regard to quantitative descriptions of the motor patterns required for mastication in children with Down syndrome. The present findings of this investigation revealed that the coordinative organization of mandibular muscle activity in children with Down syndrome appears to be diverse from, yet somewhat similar to, typically developing infants.

Significance of age and gross motor skill development on feeding patterns

It is widely known that feeding and swallowing skills in children mature along with anatomic and central nervous system growth, as well as general motor development. Several research studies suggest that age may have a significant effect on the coordination of masticatory muscles during feeding (e.g., timing of muscle activity; Gisel, 1988; Shwartz, et al., 1984). Gisel (1991) reported that an increase in chewing efficiency was marked by a decrease in chewing duration for typically developing children between six and 24 months of age. As children developed, fewer chewing cycles (one up and down movement of the mandible) were needed to consume a standard size bolus (i.e., raisin). Similarly, Green and colleagues (1997) found that although the basic pattern of chewing is established by 12 months of age, the refinement of chewing patterns in infants and toddlers continues at least to 48 months of age (e.g., activity of mandibular synergists become more synchronous; activity of antagonistic muscles become more reciprocal;

Green et al., 1997). Because the present investigation contained a small sample size and a wide age-range of subjects, direct comparisons cannot be made to previous investigations. The findings of the present investigation however, showed that a nonlinear relationship between age and the development of feeding skills in infants with Down syndrome may exist. However, a linear relationship between the development of gross motor and feeding skills was evident. Age did not seem to be the only factor to have an effect on the degree of chewing efficiency in infants with Down syndrome. Thus, the present study demonstrated that gross motor skill development rather than chronological age of an infant with Down syndrome is more important in predetermining the accuracy of the infant's feeding skills.

Figure 4 depicts the data set of Subject 2 (9 month old) who demonstrates the greatest achievement of gross motor milestones. This subject displayed the most mature chewing pattern across all target behaviors characterized by a high degree of coupling and short lags for the homologous muscle pair and lowest degree of coupling and longer lags exhibited by the antagonists. Green et al., 1997, reported that with maturation, the coupling and synchrony of mandibular synergists (i.e., masseter and temporalis) increased and the coactivation of antagonistic muscles (i.e., masseter and digastric) significantly decreased. Green and colleagues (1997) also suggested that the development of chewing appears to be identified by an increase in motor efficiency. Notably, Subject 2 demonstrated the highest achievement of gross motor milestones across subjects.

In contrast Figure 5 shows that age does not appear to impact this subject's coordinative muscle patterns. Whereas, the current findings do suggest that the subject's delay in obtaining gross motor milestones coincides with her apparent delay in feeding skills. For example, the subject was unable to orally manipulate a teething biscuit and demonstrated refusal behaviors such as crying and head aversion. The findings of the present study reveal that feeding difficulties appear to stem from an overall developmental delay rather than a distinctive developmental pattern unique to the syndrome.

Significance of food consistency on coupling

There is a lack of research on the effect of food consistency on oral motor behaviors. Gisel (1991) found that in normal infants, solid textures were more difficult for these infants to orally manipulate compared to other food consistencies. However, she also concluded that in infants with Down syndrome, solid textures may be easier for these children to chew (increased sensory input). The data from the present investigation supports her findings in that mandibular muscle activity of infants in the present investigation is characterized by higher peak coefficients for the teething task than the other consistencies.

Overall, subjects of the present investigation demonstrated a degree of low to low-moderate coupling of the antagonistic muscle pairs across all consistencies. Coupling strength across all subjects for the homologous muscle pairs appeared to be the greatest for the liquid consistency with a range of .41 to .75, indicating a moderate degree of coupling. The weakest degree of coupling was noted for the solid consistency across subjects (with the exception of Subject 2), revealing a homologous muscle range of .37 to .75, indicating a moderate degree of coupling as well.

Feeding difficulties in children with Down syndrome appear to be common and are most often characterized by immature feeding behaviors (e.g., drawing in of the lower lip; positioning of the tongue at midline; tongue protrusion) and aversions to textured foods. Gisel (1984) described children with Down syndrome to demonstrate a more forward tongue position on the presentation of all food items, whereas typically developing children exhibited a tongue position behind the teeth in anticipation of food. Pipes & Holm (1980) report that children with Down syndrome often refuse anything but pureed food, even when they appear developmentally ready for more viscous foods. Developmental delays of feeding skills may be attributed to difficulties with sucking, swallowing, chewing, self-feeding, or inappropriate feeding practices on the part of the caregiver.

Overall, the subjects of this investigation demonstrated a willingness to chew all food consistencies with the exception of Subject 3, who demonstrated a reluctance to both the solid consistency and teething biscuit. This subject was able to orally manipulate solid textures, but demonstrated a more forward tongue position on the presentation of all food consistencies. Gisel et al., 1984 reported that children with Down syndrome expressed a hesitation to chew and seemed to suck more on the food items until swallowing. It may be proposed that Subject 3 demonstrated this hesitation on all food consistencies when looking at the peak coefficients (strength of coupling) for the homologous muscle pairs. The homologous muscle pairs exhibit comparable peak coefficients across all target behaviors. The subject also exhibited difficulties with postural control (i.e., holding head at midline). Sleight & Niman (1984) discussed the decreased strength in infants with Down syndrome and how it may contribute the postural control necessary for feeding.

Sensory awareness prior to a swallow may benefit these infants with Down syndrome due to oral hypersensitivity or reduced oral sensation. Both compensatory (controlled by the caregiver) and therapeutic (changing the timing of the swallow by reducing the oral onset time and pharyngeal delay time) techniques may be used to enhance pre-swallow sensory input (Logemann, 1998). These procedures all involve providing a preliminary sensory stimulus prior to the initiation of the patient's swallow attempt, and it is hypothesized that this will alert the central nervous system, resulting in lowering the threshold of the swallowing centers (as cited, Logemann, 1998).

Significance of medical and feeding history

Cullen et al., 1981 found that children with Down syndrome who exhibit moderate to severe heart defects attain some feeding milestones later than children with Down syndrome with mild to no heart defects. Evidence of the present study supports this finding. Subject 2 demonstrates the highest achievement of feeding milestones across subjects and also exhibits a milder heart condition (e.g., the only subject who has not experienced heart surgery) as compared with other subjects. He also demonstrated the most mature feeding behaviors evidenced by the strongest coupling observed for the homologous muscle pairs and synergists, with the antagonistic coupling appearing to be somewhat weaker. Heart defects may have contributed to the overall decreased coordinative mandibular muscle patterns of Subject 3 indicated by lower peak coefficients across target behaviors and longer lags revealing longer delays in the coupled activity of the muscle pairs.

Timing of muscle activity (absolute lags)

Moore & Ruark (1996) conducted an investigation to quantify the coordinative organization of mandibular muscles in normally developing infants (age 15 months) during speech and nonspeech behaviors. Because the synergistic muscles of their subjects coactivate during chewing and antagonists activate 180 ° out of phase with each other, chewing was characterized by longer lags for antagonistic muscle pairs and shorter lags for synergists, (as cited, Moore & Ruark, 1996). The typically developing infants also demonstrated a significantly shorter lag time during sucking activities. Results reported by Moore and Ruark (1996), indicated that homologous muscle pairs (i.e., RM x LM and RT x LT) produced very short lags regardless of the target behavior and that the timing of activity within these pairs appeared to be consistently coupled.

In comparison, the masticatory patterns of infants in the present study were also characterized by longer lags for the antagonistic muscle pairs (i.e., RM x ABD). In contrast, the infants with Down syndrome continued to display a longer lag time during the sucking behaviors. In reference to Table 5, results of the present study indicate that homologous muscle pairs produced very short lags regardless of the target behavior and that the timing within these muscle pairs were consistently coupled, which are concurrent with the findings of Moore and Ruark (1996).

Future research

The present investigation, describing the coordination of mandibular muscle activity of infants with Down syndrome, provides a quantitative description of possible delayed coordinative development. The present findings suggest that infants with Down syndrome follow a similar developmental pattern as exhibited by normally developing infants.

This study provides information regarding specific factors that may affect the feeding skills of children with Down syndrome (i.e., gross motor milestones, maturation of oral motor skills, heart defects, and caregiver roles). EMG signals may be used to in feeding therapy to determine the most beneficial food consistencies for children with Down syndrome. Results may alert clinicians to the most appropriate time to introduce a more difficult consistency to the infant. Future efforts, in addition to refining the description of delayed coordinative development within a longitudinal study, will be directed toward obtaining group findings for infants with Down syndrome.

Methodologic considerations

The results of this investigation were influenced by a number of methodologic factors. One of the most obvious factors is the small sample size. The small sample size as well as the wide age-range of subjects participating in this study, make it difficult to generalize the results of the present investigation to all infants with Down syndrome. This cross-sectional design makes it difficult to generalize these results to the developmental pattern of infants with Down syndrome. A longitudinal study will allow the researcher to document the subject's developmental masticatory patterns as their age increases and to compare these patterns to the normal population.

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APPENDICES

Appendix A

Oral Manifestations

Oral manifestations

Jack Jung (1989) reported that oral manifestations of children with Down syndrome may include: midface dysplasia with relative prognathism, open bite, posterior cross bite, enlarged tongue with fissuring and irregularities, relatively small oral opening, dry fissured lip structure, delayed eruption of teeth, and missing teeth. The primary palate is often narrow and high arched, and submucous clefts of the uvula and portions of the secondary palate may occur more often among children with Down syndrome. The short neck structure of this population is also associated with a more cephalic placed larynx, and shortened oral pharyngeal structures are associated with nasal airway breathing difficulties (Gorlin & Pindborg, 1964; Viglid, 1985). The multiple cranial skeletal differences in a child with Down syndrome may significantly influence his/her feeding skills (Van Dyke et al., 1989). Because of the short and narrow palate and midface dysplasia, the position of the muscles of mastication during chewing may be altered. The tongue in some individuals in normal in size, but may appear large due to the existence of a small oral cavity, secondary to midfacial hypoplasia (Gisel, Lange & Niman, 1984). Many children with Down syndrome are mouth breathers, due to a small oral cavity, enlargement of the tonsils, and/or decreased size of the nasal passages. General hypotonia has been reported to be a possible negative influence on jaw stability, lip closure, and tongue control. All of these factors may result in delays in oral motor skills (Gisel, Lange, & Niman, 1984).

Hypotonia

A longitudinal study by Cullen, Cronk, Pueschel, Schnell, and Reed (1981) evaluated the social and developmental feeding skills of children with Down syndrome. Social competence was evaluated using the Vineland Social Maturity Scale. An oral motor screening form was developed to assess oral control, muscle tone, and feeding milestones. A developmental feeding table was modified to relate feeding to developmental levels rather than chronological age. The participating investigators (a pediatrician, neurologist, and a physical therapist) recorded the muscle tone of the children at 3-month intervals using simple ordinal scales for rating muscle tone and a composite score based on four ordinal ratings of muscle tone in various parts of the body. The ratings were analyzed and scored using varimax rotation to assign the children to one of two groups: infants with "good" muscle tone and infants with "bad" muscle tone. These two muscle groups were compared and as a result of the Vineland scores, the "good" muscle tone groups scored significantly higher than those of the "bad" muscle tone group. This study found slight hypotonia of the oral region to be a common finding in children with Down syndrome, with 41% having some degree of hypotonia.

Appendix B

Parent Letter

Dear Parent(s),

This letter is to invite your child to participate in a developmental feeding study at the University of Tennessee, Knoxville. We are interested in how young children with Down syndrome move their jaw muscles during feeding (e.g., drinking from a cup or bottle, eating cereal from a spoon). Small electrode sensors are attached to the skin on your child's chin, cheeks and temple areas. These sensors allows us to record muscle activity onto a tape recorder as your child has a snack. Each child will participate in only one, 60 minute session. After the session, you will be reimbursed $30.00 for your time and travel expenses.

If you are interested in your child participating, or desire additional information, please call Blair Williams at the number provided. Thank you.

Researchers:	C. Blair Williams, Graduate Student (telephone # (423)-974-1787) Dr. Jacki L. Ruark (telephone # (423) - 974-1787)
Purpose:	The purpose of this study is to determine how young children with Down syndrome use their jaw muscles during feeding activities.
Participants:	**Males or Females ages 15 to 24 months**
Time Commitment:	Approximately 60 minutes in length (appointment times - early mornings, or late afternoon, & weekends). *Your child may cease to participate at anytime during the 60 minute session with no consequences; you will still receive the $30.00 reimbursement.*
Site:	443 South Stadium Hall - located at the Neyland Football Stadium on the University of Tennessee's campus.
Parking:	Parking will be made available at the stadium.
Your child will also:	Perform simple feeding tasks, which includes eating a snack provided by the parent. Your child's verbalizations will be audiotaped during the entire session and small round sensor electrodes will be placed on your child's cheeks, under the chin, and temple areas. These sensors have been used in several developmental studies, and the majority of children (99%) have not minded their presence.
Benefits:	You will receive the results of an oral mechanism screening at the end of the session. An informal oral mechanism examination will be performed by a certified, ASHA accredited Speech-Language Pathologist who has 15 years experience working with children with Down syndrome. This screening will include informal observations of you child's facial muscles and movement of the oral structures during nonfeeding activities. Information obtained from this study will be used to help other children who may have difficulty chewing. *Your child's name will remain confidential if this study is published, or the findings are presented at a research conference.*

Appendix C

Subject Information Sheet

SUBJECT INFORMATION SHEET

Researcher's name:______________________________
Date:________________________

A. Background History:

Name of child:_________________________________
Date of Birth:_____________ Age:____________
Address: ____
____
____
____

Parent(s) ____
Phone: (work)_______________ (home)_______________________
Child's school: ______________________________Grade:_____

B. Related Medical History

Check the following if the answer is YES; place comments next to sentence.

______ Child is without perinatal complications such as heart defect and prolonged anoxia at birth

______ Child has a history of severe respiratory illness (e.g. recurrent pneumonia)

______ Child has received prolonged or traumatic oral intubation

______ Child has received a tracheotomy

______ Child exhibits oral, pharyngeal, or esophageal mechanism that is atypical of toddlers with Down syndrome (e.g. cleft palate, esophageal atresia, fistulas)

______ Child is currently on medication that may affect movement (e.g. seizure medications)

C. Related Developmental History

Check the following if the answer is YES; place comments next to sentence.

_____Child exhibits no more than moderate to severe mental retardation

_____Child is able to sit independently and hold head erect

_____ Child babbles or speaks when spoken to or played with

_____ Child is ambulatory (e.g. crawls or walks with/without assistance)

_____ Child exhibits appropriate feeding skills (See Feeding History Form)

Appendix D

Feeding History Form

Feeding History Form

______ Child has a diet of at least liquid and pureed consistencies

______ Child exhibits no deviant feeding difficulties (e.g. excessive coughing or choking, consistent regurgitation/vomiting)

What types of foods does your child eat?

What types of liquids does your child drink?

What is the manner of food presentation?

How many meals does your child eat per day?
Amount per meal ____________

How many snacks does your child eat per day?
Amount per snack____________

What is the duration of your child's meals?

How is your child positioned during feeding?

Who is the primary "feeder"?

Which foods would you describe as "easy" foods?

Which foods would you describe as "difficult" foods?

Which foods are disliked by your child?

Which foods are liked by your child?

What types of self-feeding skills does your child exhibit?

Does your child eat the following foods?

a. pureed food (baby food)__________________________

b. pudding or applesauce __________________________

c. soft cookies or crackers__________________________

d. cheerios_________________________________

e. teething biscuits _________________________

f. other____

Appendix E

Appointment Letter

Appointment letter:

Dear ___________,

We are looking forward to seeing you and _______________ on _________________. Enclosed are a parent letter, parking instructions, and a map to Neyland Football Stadium (South Stadium Hall) where our room is located. I will meet you in Parking Lot 4/5, just in front of the stadium and will give you a parking permit for the day.

There are a few things that we would like for you to bring when you come for your visit:

1. Your child will be asked to drink a small amount of liquid and eat a snack that you bring from home. Below are a list of food items that you can bring with you. If possible we would like your child to drink at least 1-to 2- ounces of liquid from a bottle or sippy cup, and eat a pureed item (e.g., baby food, apple sauce), and (if appropriate) eat one item that requires them to chew more vigorously (e.g., cheerio, teething biscuit).

Liquid	water, juice, Kool-aid, etc.
Pureed	Applesauce, pudding
Foods that may require more chewing	cheerios, teething biscuit, thick cereal, etc

Your child will not be required to eat anything that she/he does not want to. She/he can still be in the study even if she/he chooses to eat only a small amount.

If you have any questions or concerns, please feel free to call me at (423) 974-1787.

Sincerely,

Blair Williams

Appendix F

Consent Form

Consent to Participate in a Research Study

Title: Coordination of Mandibular Muscles in Infants with Down syndrome During Feeding

Investigators: C. Blair Williams
Graduate Student
6315 Kingston Pike #1313
Knoxville, Tennessee 37919

Jacki L. Ruark, Ph.D.
444 South Stadium Hall
University of Tennessee, Knoxville
Knoxville, Tennessee 37996

Description

Infants and young children with Down syndrome frequently demonstrate delays in obtaining certain feeding skills, such as chewing puree and solid foods. These delays have been attributed to a delay in the development of jaw control. Jaw movements during chewing have been reported to appear slower in children with Down syndrome, resulting in prolonged feeding times.

Your child would be invited to participate in a study to help us understand how young children with Down syndrome move their jaw muscles during feeding. The procedure we use to measure jaw muscle movement is simple and causes no discomfort. We will simply measure the activity in your child's jaw muscles he or she eats a favorite snack and drinks from a bottle or a cup.

As your child sits in a highchair, or on your lap, small, surface sensor electrodes will be placed on your child's face (on cheeks, under chin, and on the temple areas). Your child will then eat a snack that you brought from home. During this time, jaw muscle activity will be recorded by the electrode sensors onto a multichannel tape recorder. In addition your child's vocal utterances will be recorded. The experiment will take approximately 60 minutes, however, your child may stop at any time if he or she wishes to discontinue the study.

Before participating in the study, your child will receive an informal oral mechanism screening by a certified speech-language pathologist. This screening will help to determine that your child's oral structures are intact.

Risk and Benefits

There are no known risks associated with this procedure. This procedure causes no discomfort to your child. We have used this procedure on other infants and small children with no difficulties. All equipment/toys are sterilized before each session.

Your child would not benefit directly from participating in this study. However, this information will help us understand how young children with Down syndrome use their jaw muscles during feeding activities. Your child, however, will receive an oral mechanism screening for no charge.

Cost and Payments

There will be no charge to you or your child. At your request, or at the request of your child, you may withdraw from the study at anytime. When your child completes the study, you will be paid $30 for your participation.

Confidentiality

Information regarding you or your child obtained for this research project will be kept confidential.

Right to Refuse or End Participation

You or your child are free to refuse participation in this research project or to withdraw at any time without penalty.

Voluntary Consent

I certify that I have read the preceding or it has been explained to me and that I understand its content. Any questions that I have regarding this research project have been answered by the investigator. A copy of this consent form will be given to me. My signature below means that I have freely agreed to allow my child to participate in this research study.

Name of child:________________________

Parent's signature __________________________________ Date:__________

Investigator's signature______________________________ Date:__________

Witness____________________________

I also verify that I have read the list of foods that are used in this study and that to my knowledge, my child does not have any known allergies of these foods.

Parent's signature __________________________________

Appendix G

Informal Oral Mechanism Screening

ORAL MOTOR / FEEDING CHECKLIST

1. General Tone Low ___ Normal ___ High ___

   Observations of facial features: Eyes ______
   Nose ______
   Ears ______
   Overall symmetry ______

2. Oral Motor Tone:

	Low	Medium	High
Lips			
Cheeks			
Tongue			

3. Usual head position: Midline - Upright ___ Tilted Back ___ Forward ___
   Turned Left ___ Right ___ Tilted Left ___ Right ___

4. Hyperextension of neck: Present ___ Absent ___

5. Oral Motor Movements:

Symmetrical	Yes ___	No ___
Lip Rounding	Yes ___	No ___
Smiling Lip Retract.	Yes ___	No ___
Tongue Protrusion	Present ___	Absent ___
	Normal ___	Abnormal ___
Tongue Lateralization	Present ___	Absent ___
Tongue Tip Elevation	Present ___	Absent ___

6. Mandible: Protruded ___ Retracted ___ Normal ___
   Size: WNL ___ Not WNL (specify) ___
   Position at rest: Open ___ Closed ___

7. Palate: Normal ___
   High: Mild ___ Mod ___ Severe ___
   Cleft: Midline ___ Lateral Right ___ Lateral Left ___
   Submucous ___ Fistula ___

8. Alveolar Ridge: Normal ___ Wide ___

9. Lingual and Labial Frenulums: Normal ___ Short ___

10. Posturing of Lips: Forward ___ Normal ___ Retracted ___

11. Posturing of Tongue: Thick & Bunchy ___ Thin & Cupped ___ Retracted ___
    Neutral ___ Protruded ___

12. Sensory Response in Oral Region:
    ___ Unusually irritable (hypersensitive)
    ___ Normal
    ___ Unusually apathetic (hyposensitive)

13. Hand to Mouth Movement: Present ___ Absent ___

14. Oral Reflexes:

	Present	Weak	Absent
Rooting (to 3 mos.)			
Sucking			
Suckle/Swallow (present at birth, disappears between 2 -4 mos)			
Bite (Birth to 5-6 mos)			
Gag (Present at birth, weaker after 7th month)			
Transverse Tongue			

15. Control of oral secretions: Normal ____ Abnormal ____

16. Present Feedings: PO ____ NG ____ G____

17. Type and amount of foods typically eaten: ____
____

18. Respiratory Control: Normal _____ Uncoordinated _____

19. Swallow: ____ Coordinated - Single Swallow
____ Consecutive Swallow
____ Gasping - Choking

20. Suck: Able to Latch to Nipple Yes ____ No _____
Organized ____ Disorganized ____
Seal: WNL ____ Abnormal ____
Liquid Loss: WNL ____ Excessive _____

21. Cup Drinking: _____ Suckle Pattern (6-8- mos.)
_____ Sucking Pattern (after 12 mos.)
_____ Uses tongue for stabilization (up to 18 mos.)
_____ Bites on cup (up to 24 mos)
_____ Liquid Loss: WNL _____ Abnormal ______

22. Spoon Feeding:
Clears spoon with upper lip Yes ____ No _____
Biting on spoon Present ____ Absent _____
Opens mouth for spoon (Orientation) Yes _____ No _____

23. Chewing: Munch _____ Diagonal _____ Rotary _____ Absent _____

24. Biting: _____ Phasic biting with rhythm
_____ Hold & break
_____ Controlled, sustained bite on soft solid (12 mos.)
_____ Controlled, sustained bite on hard solid (18 mos.)
_____ Absent

25. Textures Accepted: _____ Purees
_____ Lumpy purees
_____ Soft solids
_____ Hard Solids

26. Self-Feeding Skills: WNL _____ Abnormal _____

Other Observations:

VITA

Catherine Blair Williams, originally from Richmond, Virginia, graduated with Magna Cum Laude honors from Longwood College in Farmville, Virginia in May 1997 with a Bachelor of Sciences in Speech-Language Pathology and Audiology. She was a member of Phi Kappa Phi honor society. During her junior year she was named to Who's Who Among Students in American Universities and Colleges. Miss Williams also presented a case study on Developmental Verbal Dyspraxia in Infants and Children at the 1997 Speech-Language Hearing Association of Virginia Conference.

Presently, Miss Williams has completed the requirements for a Master of Arts in Speech Pathology. She will be graduating with honors from the University of Tennessee, Knoxville. She served as the secretary for the National Student Speech-Language and Hearing Association Chapter at the University of Tennessee, Knoxville in 1998. She has completed practicum experience in various settings including: public schools, the university clinic, a pediatric clinic, hospitals, and a rehabilitation center. Upon graduation in May 1999 she plans to pursue a career as a speech-language pathologist in an acute care setting.