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Assessment of the Development of Hand and Mouth Coordination When Taking Food into the Oral Cavity

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ABSTRACT

The purpose of this study was to establish an assessment method for evaluation of hand and mouth coordination during self-feeding. The subjects were four normally developed infants. Their feeding behavior was videotaped at two or four week intervals (from age eight months to thirty-six months). The items analyzed were nine viewpoints for finger feeding and eight viewpoints for spoon-feeding. The results obtained included: finger feeding - development of cylinder and pinch grasp, two patterns of hand in relation to neck and trunk, placement of food into the mouth, developmental aspects of neck rotation when taking food with the lips; spoon feeding - holding technique, flexion of elbow and shoulder, taking food from the spoon bowl by the lips, patterns of neck rotation. From the results of these observations, we conclude that the items analyzed in this study can be useful for the assessment of the developmental process of hand and mouth coordination in self-feeding.

KEY WORDS:

feeding functions, hand to mouth coordination, early childhood, orofacial myology

INTRODUCTION

During the developmental process of feeding functions, healthy infants acquire hand and mouth coordination for self-feeding after acquiring the oral functions of swallowing, ingestion and mastication. Hand and mouth coordination is the bases of using utensils and the infant acquiring independent feeding functions. The feeding action is supported by the jaw, the condition in the oral cavity region and the condition of the arm area.

Previous research on the arm function of healthy infants and toddlers has been reported by Gesell (1937), Piaget (1952), Halverson (1931), Holle (1981) and Erhaedt (1983). Hohlstein (1982) analyzed the hands of infants and toddlers aged 7 to 14 months regarding the method and accuracy of a grasp, and the elements that supported arm function. Kaneko et.al. (1987), Mukai (1995) and Stevenson (1991) reported on motor development of the oral cavity region that was related to eating function. Although these sources provide information on both oral cavity function and arm function, as far as the authors know there are no reports on the developmental process of hand and mouth coordination during self-feeding.

While many reports were available about self-feeding functions of disabled subjects, no objective criteria was available for evaluating the developmental process of coordination during

self-feeding. The purpose of this study was to establish an assessment method for the evaluation of coordination during self-feeding.

METHOD

The subjects were two normally developed infants (A, B) for finger feeding and four (A, B, C, and D) normally developed infants for spoon-feeding. As subject A and B were living in the same infant home, they had a similar daily lifestyle. Subject C and D were living with their parents who were authors of this study. All of the subjects started weaning at five months. The subjects' food for finger feeding was bread crusts, and for spoon feeding it was an appropriate type according to the subjects' age. The utensils used were teaspoons or spoons for infants and toddlers.

The subjects sat in a baby chair until eleven months and after that sat in an infant chair. The height of the table kept the arm unsupported, as it was set lower than their elbows. Their feeding behavior was videotaped at two- or four- week intervals (from age eight months to thirty-six months). The movement of the mouth and hand and the positional relationship between the mouth and hand as the subjects ate was observed by viewing a video image of the self-feeding action.

The items analyzed were nine viewpoints for finger feeding and eight viewpoints for spoon-

feeding (Nishikata, 1999; Chigira, 1998; Ishii, 1998; Tamura, 1998;) (Table 1). Two dentists and two occupational therapists carried out the analysis of the data under identical calibration.

RESULTS

Finger Feeding

The change in holding methods is shown in Figure 1. At the beginning, all the infants could hold food by cylinder grasp, using their entire palm. At fourteen months, they could hold food by pulp pinch.

Upper extremity movement when picking food up to the mouth is shown in Figure 2. Although initially the infants brought food to their mouths mainly by flexion of their elbows, at nine or ten months they did it by multiple movements including: flexion; supination or internal rotation of the shoulder; flexion of the elbow; supination or pronation of the forearm; and flexion or extension of the wrist joint.

The upper extremity position when taking food is shown in Figure 3. At first, all of the infants demonstrated that for the upper extremity position when taking food, the upper arm contacted the body, with maximum flexion of the elbow joint, some supination or pronation of the forearm, and extension of the wrist joint. Subject A showed adjustment of the position of the upper extremity by shoulder flexion from nine months, and subject B did it from ten months.

The hand in relation to the neck and trunk when taking food are shown in Figure 4. Though this showed two different patterns, all the infants came to bring the food from the outside to the center of the body.

The method of placing food in the mouth and the degree of lip involvement are shown in Figure 5. For the most part food was pressed into the mouth or torn off with the teeth. At eleven months, the movement changed to munching. At eight months, no lip involvement in taking food into the mouth was observed.

The relationship between neck rotation and the area of the lips involved when taking food into the mouth are shown in Figure 6. Both subjects showed different developmental aspects. At eleven months, however, the degree of development was identical.

When taking a piece of food, the fingers were placed in the mouth. This movement decreased as the subjects became older (Figure 7).

Spoon-Feeding

The method of holding the spoon is shown in Figure 8. Although the two infants sometimes held their spoons like a pen, they did not actually acquire this as an eating technique.

The infants initially brought their spoons to their mouths mainly by flexion of their elbows. Almost all of them showed horizontal flexion of the shoulder by the twenty-four month stage (Figure 9).

The position of the upper extremity when bringing the spoon to the mouth is shown in Figure 10. Three of the four infants showed adjustment in the position of the upper extremity due to shoulder flexion by the eighteen-month stage. All the infants brought their spoons to their mouths with their hands at angles within 45 degrees from the median by the end of twelve months of age (Figure 11).

All subjects started to take the bowl of the spoon into the mouth in conjunction with lip involvement at eighteen months. They completely established this skill at twenty-four months (Figure 12).

The degree of lip involvement during taking the bowl of the spoon into the mouth is shown in Figure 13. All subjects completely took the food on the bowl of the spoon with only lip movement at twenty-four months.

Neck rotation is shown in Figure 14. Neck rotation showed two patterns. One type of pattern demonstrated no neck rotation (subjects B and C). The other type of pattern exhibited frequent rotation at eleven months. As age increased, rotation of neck decreased (subjects A and D).

The area of the lip involved during taking the bowl of the spoon into the mouth is shown in Figure 15. Lip involvement of more than 45 degrees mesially during taking the spoon into the mouth was observed at twenty-eight months for the latest developing infant.

DISCUSSION AND RECOMMENDATIONS

Development of self-feeding function is based on previous feeding function. Food initially is carried to the mouth by a caregiver, with the infant itself then becoming able to perform independently the part that had been performed by the caregiver (Mukai, 1995). In attempting to view self-feeding from the development viewpoint, it is necessary that we analyze each characteristic movement of the mouth and hand. The mouth function, that develops first, is made to cooperate with the finger function. This evaluation takes into account the ample research on feeding operation. Research focused on finger function for the carrying process, however the movement of the mouth in receiving food has not been addressed. Since the oral cavity fulfills the main role of the eating function, it is very important to clarify the evolution of the process of hand and mouth coordination.

In the study by Mukai (1990) of 160 healthy infants and toddlers who were attending a day care center, most infants were able to eat by themselves at 3 years of age. As basic lifestyle habits of 3 year-olds differ due to variations in childcare environments such as day care centers and home, and the naturally individual differences in infant independence, an evaluation period of 36 months was considered adequate for this research.

Finger Feeding

The grasping or pinching food method

It has been clarified in research that the holding method changes developmentally (Gesell, 1937; Erhardt, 1983). However, the changes in the holding method have not been previously studied in terms of the necessary coordination of the oral cavity function and arm functions. Movement with the arm cooperating with the oral cavity is necessary to eat using the hand. "The holding method of the food" was set as an observation item in order to clarify how the holding method changes.

The upper extremity movement when carrying food to the mouth

The movement of the arm of infant A and B in carrying food to the mouth changed mainly in flexion at the elbow joint, with the compound motion of the forearm, elbow joint, shoulder joint and scapular joint moving together to compose

the simple operation. The movement is mainly in flexion of the elbow joint, and there is seldom moment in each of the shoulder joint, forearm, and wrist joint. The hand holding the object draws an arc with the elbow joint as the locus, and it is possible to move to the mouth by grasping the object in a compound motion that coordinates the circular motion of the joints of the forearm, elbow, shoulder, and scapular rectilinear. In the compound multi-joint operation, the adjustment of the direction of the object also becomes possible, and movement with high approach accuracy becomes possible.

The upper extremity position when taking food

The upper extremity position when taking food changed from being initially at the fully extended limit of joint motion, to move away from the fully extended joint position, and finally the position of the forearm became varied, and extension of the wrist joint was observed. The range of motion is regulated by the extension condition of the outer joint structure including the muscle, chorda, ligaments, and skin. The position in which the tension of muscle and ligament matches is optimal as a preparation position for the next motion, and the motion area is maximized (Castaing, 1986). That is to say, keeping the range of motion away from the boundary of joint motion seems to become a factor for carrying out a smooth motion. Additionally, the forearm and wrist joint are related to the adjustment of hand orientation. In the present investigation, the involvement of the forearm and wrist joint was observed along with the development. It seemed that it became possible for the arm to adjust so that food was easily taken into the mouth.

The relationship between hand location in relation to the neck and trunk, and neck rotation when taking food

In infant A and B, there was a difference in movement of hand position in relation to the neck and trunk, and in neck rotation when taking food. In infant A, feeding was in the form of bringing the mouth close to the hand by initially winding the neck rotation when taking food from the hand. However, this winding in the neck rotation was not observed in infant B who ingested food from the hand into the corners of the mouth.

The relationship between the method of placing food into the mouth and the degree of lip involvement when taking food into the mouth

The main movement of placing food into the mouth by finger function does not address the function that the front section of the oral cavity performs in taking in food. In other words, it is a form where food is released into an open mouth. Only at the developmental stage of oral cavity function is it possible for food to be taken into the mouth by closing the lips if feeding assistance is received at a few months of age (Mukai, 1995). However, in the present observation, the ingestion function is not sufficiently demonstrated due to the lack of coordination between the mouth and hand during self-feeding. In addition, according to research into lip pressure during assisted feeding by spoon, 0 to 2-year-olds are still in a developmental process (Chigira, 1991) and from the perspective of strength it is difficult to say they are acquiring the feeding function. For children in the same age range, a difference that can be seen between assisted feeding and self-feeding is that when the undeveloped finger function is made to cooperate in self-feeding with the oral cavity function acquired during assisted feeding, the function of the oral cavity on the receiving end is not displayed.

Therefore, we considered that evaluating the method of placing the food into the mouth, which is the receiver side, is appropriate for evaluating the coordination of both finger function and oral cavity function. Although "tearing" involves the subject trying to bite food with the front teeth, it is still a feeding movement composed mainly by the pulling force of the fingers and the rotation of the head to take in the food. Adults are able to bite off food with the hardness of bread, but a certain period of practice is necessary to reach this stage of development. It is assumed that lip pressure during taking in food is influenced by the eruption period of deciduous anterior teeth. The influence of this on feeding function ought to be examined in future.

The state of involvement by the lip during taking in food is thought to be strongly related to the method of placing the food into the mouth. For lip movement during taking in food, lip closure is of particular interest. Since the eruption period of front teeth is not investigated in this study, it is not possible to observe its relevance. However, it was observed that at the initial stage when lip

cooperation in supporting the food becomes possible, gnawing by the front teeth occupied the mainstream of taking in food. This fact indicates that before the effect of the eruption of the front teeth, the acquisition of lip movement that plays the role of a bridge between the hand and mouth is important.

The relationship between neck rotation and the area of the lips involved when taking food into the mouth.

In the stage of immature development in infant A, movement was frequently observed where food was held by the fingers, and the mouth moved to meet the food through rotation of the neck. In infant B it was observed that the neck did not rotate, and food was taken in from the corners of the mouth. However, though the evolution process differed between infant A and B, with the progress of time the food came to be taken in from the center of the mouth. Ayano (1997) studied the relationship between the motion locus distance from pick up to taking in food by the lips and the distance from the food on the tray to the lips. She found that the locus of movement for finger feeding is nearly always the same. It is presumed that this type of locus comes to be shown as adult feeding functions continue to develop.

Degree of finger entry when taking food into the mouth

There was some change in the method of processing food portions as age increased. Before twelve months, movement with the fingers entering the oral cavity was observed, but by around fifteen months it had generally stopped. This movement in which the fingers enter the oral cavity when food is taken in means that the intake of food in the oral cavity only by ingestion through the lip function is not possible, underdeveloped, or that coordinated movement has not developed. The progression from finger-feeding to eating with utensils, as well as a clinical instruction method should be examined in the future.

Research on early promotion of feeding using utensils has been done (Shimizu, 1988; Seto, 1991). However, finger-feeding during meals is generally not desired, and research on the finger-feeding developmental stage, though it has been made, is slight as was mentioned earlier. To avoid neglecting consideration of the

development of oral cavity form and function, in conjunction with the difficulty in development of hand and mouth coordination, it is necessary to take a viewpoint of finger feeding and utensil feeding that links the development process of feeding function and movement. Another aspect that cannot be forgotten is psychological development. Without the volition to take external objects into the body, feeding function cannot be self-supporting (Mukai, 1990). Therefore, it is additionally necessary to evaluate and consider the developmental process of hand and mouth coordination in concert with psychological development and development of the sensory experience during thumb sucking, sucking on soothers and while playing.

Spoon-Feeding

The spoon-holding method

Research carried out by Connolly (1989) on two groups of children at 11 months and 17 months of age classified the holding method of the spoon into eleven different types. In this study it was observed that spoon holding developed to the radial side from the ulnar side in order, and that it gradually changed to the finger periphery. Five kinds of holding methods were observed. None of the 4 infants reached the highest developmental stage of acquiring the pen grip function. Erhardt (1983) reported that development of the method of holding a crayon or pencil begins with the ulnar side-palm grasp in 1 to 2 year old children, then shifts to the finger grasp at 2 to 3 years, and finally at 3 years the static grasp with three fingers appears. In this study, the relationship with the drawing movement did not evaluate any finger function other than for spoon operation. In the future, observation of the relationship between movement of the arm and the holding method of the pen seems to be necessary to more objectively evaluate the developmental process of hand and mouth coordination.

The relationship between how the spoon was brought to the mouth after scooping food and the position of the upper extremity

Movement resulting from food being scooped up to the mouth changed from a simple movement of the elbow joint to a compound movement in which the shoulder, elbow, forearm, wrist joint, and finger became involved. According to Alexandar (1997), at the 10 month to 12-month

stage the infant becomes good at eating using the hand and acquires the necessary precise coordination of mouth and hand. The infant then becomes able to combine complex movements involving the wrist joint, forearm, and elbow joint to decide the direction of the food. However, it is also stated that infants under twelve months of age are not able to manipulate a spoon as they intend. When using a utensil, attention to the operation of the utensil is needed. When using a spoon the food is farther from the fingers by the length of the spoon shaft when compared to finger-feeding. Accordingly, time is required to acquire the more complicated and precise elements of arm and finger function. After food is picked up, the operation of the arm in taking food to the mouth increases in complexity and precision by the addition of flexion of the shoulder joint to the operation. Shoulder joint flexion appears in the arm position as the spoon enters the oral cavity. Along with this development, the position of the hand as the spoon enters the oral cavity changes from initially moving along the corneal plane towards the mouth to eventually approaching the mouth within a range of 45 degrees to the outside from the surgical plane. From this fact, as the rough motion of the arm develops, the motion to the mouth after the food is grabbed was thought to take place perpendicularly in relation to the lips.

The relationship between the manner of inserting the bowl of spoon and the degree of lip involvement during entry into the oral cavity

Most spoons for infants and toddlers available on the market, including the spoon used in this study, tend to have thick shafts designed for easy holding. However, it is presently difficult to say that the growth of the mouth opening has been given consideration regarding the bowl section. In research by Xia (1992) studying 53 two-year-old children and 190 three-year-old children, the distance between the corners of the mouth was reported to average 30.39mm to 33.36mm. Comparison with this result is not possible as the distance between the corners of the mouth in the subject children was not measured in this study. When the width of the bowl of the spoon was too large compared to the distance between corners of the mouth, it was difficult for the subjects to apply force with the lips, and food entered the mouth by licking the tip of the bowl. Conversely, in the period when feeding skills are undeveloped, when there was

a large increase in mouth size along with growth of the infant, the bowl of the spoon can become too small, with the spoon being inserted deep into the oral cavity. In both cases, taking in food inevitably seemed to become difficult, and it seemed that the method of taking food from the bowl by the lips was affected.

According to research by Chigira (1994) that investigated lip pressure of 104 healthy 0 to 5-year-old children during taking in food, the development of lip function had matured to some extent around the 3-year-old stage. As age increased from that stage, children became able to execute stabilized and fixed force in an equal form every time for food of equal volume. This seemed to be reinforced by observation of infant C and D. When the bowl of the spoon touched the lip while entering the mouth, taking food from the bowl became possible by the participation of lips at 36 months. According to the research of the authors, it is felt that there is a need for evaluation of lip movement which includes the morphological change in the oral cavity. There is a relation shown between the lip pressure fluctuation coefficient that indicates the lips' proficiency in taking in food and eruption of deciduous anterior teeth 24. Though it was predicted that using the lips to take in food was influenced by the size of the spoon bowl, use of the same size spoon was infrequent. There were times when two different types of spoons were used. It is necessary to observe the method used for bowl entry into the mouth and the method used by the lips taking in food. However, it is important to first define the size of the bowl section of the spoon to be used.

The relationship between neck rotation and the area of the lip involved when taking the bowl of the spoon into the mouth.

There was a strong connection seen between neck rotation and horizontal positioning between the lip opening and the bowl of spoon which seemed to be largely affected by arm movement. When the infant began to use utensils for feeding, it was frequently observed that the elbow joint did not separate from the trunk in the forward direction. The head turned with neck rotation to face the spoon held in the hand, and the spoon was inserted into the mouth at the corners of the mouth. As the infant advances in age, a progression is observed:

1. During eating the elbow joint gradually separates from the trunk in the forward direction, the tip of the spoon comes to be inserted in the center of the lips, and almost no neck rotation is observed.
2. When using utensils, the distance of the food from the hand becomes greater than that during finger-feeding by the length of the utensil shaft. Since the motion of the upper-extremity joints becomes more and more complicated, it is anticipated that a longer period of time is required to acquire feeding functions equivalent to that of adults than for acquiring finger-feeding functions.
3. Eating with utensils is more difficult than eating by hand. To evaluate the operation of eating with utensils, it is necessary to first evaluate hand and mouth coordination.
4. Then observing the operation of neck rotation with the horizontal positioning between the lip opening and the bowl of spoon seems to be effective.

In self-feeding, it was not possible to carry out a quantitative analysis of the motion component of this dynamic phenomenon of progress to the mouth. However, it was possible to observe the kind of joint moment elements that are central, and the developmental changes occurring in them. It was possible to examine in detail the kind of position the joint takes regarding static phenomenon. And, it was also possible to observe the developmental changes in the position of the arm during taking in food. For the clinical application of these results to be effective with developmentally disordered children, or children in need of orofacial myofunctional therapy, it is necessary to quantitatively clarify and qualitatively analyze the detailed changes of the development of mouth and hand coordination.

In dysphagia, the non-coordination of hand and mouth is observed as a symptom in a great number of subjects. Reddihough (1991) reported on feeding training of cerebral infantile palsy children. This involved training that put emphasis on hand function for using modified utensils and carrying food to the mouth. However, Nomoto (1999) reported that the development of hand and mouth coordination in the self-feeding stage was stimulated by the team approach in self-feeding function therapy to disabled children, including occupational therapy in the clinic. Training and instruction is

expected mainly on the operation of the oral cavity.

CONCLUSION

For the present observations of movement, it can be said that 1) movements that were easy to compare were chosen, 2) special features of movement during this time period were included, and 3) the process of developmental change occurred gradually and was easy to observe and evaluate. These items are considered sufficient to evaluate the development process of feeding using utensils.

The method of self-feeding gradually changed to become more efficient as infants progressed in age, approaching more adult-like feeding

technique. In self-feeding, it was inferred that there were changes in the upper extremities and neck to more functional positions and movement. From the results of these observations, we conclude that the items analyzed in this study can be useful for assessment of the developmental process of hand and mouth coordination in self-feeding.

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