Chewing Cycles in 4- and 5-Year-Old Normal Children: An Index of Eating Efficacy

(eating evaluation, food texture, time/cycle ratio)

Eating movements in the preschool child undergo change between the ages of 2 and 5 years. There is a lack of objective clinical data from normal children against which eating movements of feeding-impaired children can be compared. In this study, chewing movements were measured to complement tongue movements described in an earlier study. The movements were monitored in 40 children: 20 were four years old and 20 were five years old. Each group had ten boys and ten girls.

Chewing movements were measured by time (sec), number of cycles, and a time/cycle ratio. A chewing cycle was defined as an upward and downward movement of the chin. Total time from the moment food was placed in the mouth until the final swallow occurred was divided by the number of cycles counted for the same period.

Age and sex did not affect time, cycles, or the time/cycle ratio. However, the measures were strongly affected by the type of food eaten. These findings suggest that the texture of food strongly influences both the number of chewing cycles performed and the time used for chewing.

The occupational therapist administering eating evaluations to children should carefully choose the foods offered for initial evaluations and use the same food consistently during re-evaluations.
Clinical observations suggest that jaw movements are different between normal children and children with eating difficulties. Jaw movements are crucial to the efficacy of chewing movements. Extensive work has been done with adults, but only a few studies describe chewing movements in children.

Ahlgren studied 35 children aged 9 to 16 years while they chewed carrots and gum (1). He found that the mean duration of the chewing cycle was 0.77 seconds for chewing gum and 0.58 seconds for carrots—a significant difference between the two foods. The child’s occlusion of upper and lower teeth did not affect the duration of the chewing cycle. Although the above difference might be attributed to differences in food texture, it is not clear how much any taste preference might contribute to such differences.

Chewing cycles of preschool children have not been studied. Our preliminary data from a study of normal 4- and 5-year-old children and children with Down’s syndrome of comparable age indicate that chewing cycles may provide a sensitive measure of differences in chewing abilities (7). The purpose of this study was to establish a baseline with normal children to supplement data on tongue movements described earlier (8).

To determine patterns of chewing movements, many techniques have been developed to study adults. Such techniques include cinematography (2), kinematograph-cinematography (2), electromyography (1-4), intraorally placed light-emitting diodes (5), and a sound transmission system (6).

For our purpose a simple non-invasive method was desired because preschool children are unable to sit quietly for more than a few minutes at a time. Chewing movements were videotaped so that the children did not need to be restrained.

Materials and Methods

Sample. Forty normal preschool children were observed, 20 children aged 4 years, ± 1 month, and 20 aged 5 years, ± 1 month. There were ten boys and ten girls in each group. The children attended preschool at least 2 half days per week. Parental consent was obtained for each child who participated in the study. These children were also part of a study on tongue movements (8).

Children were excluded from the study if they had medically diagnosed neurological difficulties, mental retardation, oral defects such as cleft palate or cleft lip, one or more obviously decayed teeth, or were receiving speech therapy. Only Caucasian children were included since it has been shown that oral structure measurements vary for different racial groups (9). Parents of the children were noncommissioned military officers, professionals, university faculty, and students.

Procedures. Testing was done between 9 A.M. and 11:30 A.M. Eating observations took place in a quiet room at the child’s school. There were few distractions.

The children were seated in a chair with their feet on the floor or on a support. During the observation session, the investigator sat in front of the child in a small chair. The video camera was placed to the left of the investigator, approximately 4 feet from the right side of the child’s chair. The camera lens was level with the child’s mouth. Time was recorded with a digital clock placed near the child. All children ignored the camera once they were shown the food. The flashing digital clock was distracting to some children, but they were easily brought back to the task.

Twenty raisins, 10 bites of graham cracker, and 10 small spoonfuls of unsweetened applesauce were fed to each child by the investigator. Raisins were fed twice to each child. First, the raisin was placed behind the lower incisors (raisin I) ten times. Second, the raisin was placed over the molars (raisin II) ten times. The order of all food presentation was randomized.

Chewing cycles were videotaped in profile view. Three sets of data were scored from the videotapes at a later time. First, the number of chewing cycles needed to swallow each mouthful of food was counted. A chewing cycle was defined as an upward and downward movement of the chin. Second, time (sec) was measured from the moment food was placed in the mouth until the last swallow was taken or when the mandible remained in resting position for 2 seconds. Resting position of the mandible was defined as a stable position maintained by the muscles of mastication. The occlusal surfaces of the teeth were not in contact while the mandible was in resting position (10). Third, time was divided by the number of chewing cycles to determine the average cycle length for each mouthful of food.

Two independent investigators scored all scorable trials of 13 subjects to determine inter-scorer reliability.
Table 1
Effect of Food on Chewing Cycles in 4- and 5-Year-Old Children

<table>
<thead>
<tr>
<th>Food</th>
<th>Time (sec)</th>
<th>Cycles (sec)</th>
<th>T/C (sec/cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>11.6 ± 4.1 (39)</td>
<td>15.5 ± 5.2 (39)</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>RII</td>
<td>11.5 ± 3.6 (38)</td>
<td>15.9 ± 5.0 (39)</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>GC</td>
<td>11.4 ± 2.7 (40)</td>
<td>15.0 ± 3.4 (40)</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>A</td>
<td>3.4 ± 1.4 (40)</td>
<td>2.9 ± 1.6 (39)</td>
<td>1.3 ± 0.5</td>
</tr>
</tbody>
</table>

Data represent Mean ± SD.
RI—raisin I; RII—raisin II
GC—graham cracker, A—applesauce, T/C—time/cycle
Cycles—see text for definitions.

manner: For applesauce, the investigator started timing when the spoon tip was observed above the lower lip. Timing was stopped when the jaw was in resting position for 2 seconds or after the last swallow. The investigator counted the number of times the chin moved down while applesauce was in the mouth. When the raisin was placed behind the lower incisors, the investigator started timing when her fingers were outside the mouth and stopped when the jaw was in resting position or after the last swallow. The number of times the chin moved down was counted while the raisin was in the mouth. The same procedure was followed for molar placement of the raisin. For graham cracker, timing started when the cracker was broken or the bite was finished, and stopped when the jaw was in resting position or after the last swallow. The number of times the chin moved down was counted while the cracker was in the mouth.

No data were collected when the child moved out of the video picture, when the child turned away from the camera, when the view of the jaw was blocked by the child’s right arm, or when the child talked sporadically throughout the trial.

To analyze the data, computer program BMDP-2V was used for an analysis of variance with repeated measures (11). This analysis provided the investigator with 3-way associations of the data. Comparisons were made among sex, age, and food types. Orthogonal contrasts were used to compute post-hoc F-scores.

For interscorer reliability, intraclass correlations were computed by using the method of Ebel (12).

Results
It was hypothesized that there would be no difference in the time/cycle ratio between different food textures in both age groups. One outlying score each in cycles and time from three children for raisin I, raisin II, and applesauce was deleted from the analyses of cycles and time. The outlying scores did not affect the time/cycle ratio. Thus, all data were included for analysis of ratios.

Data for the effects of food, sex, and age on chewing cycles can be found in Tables 1 through 3. Note that the time/cycle ratio was almost twice as long for applesauce as for raisins and graham cracker (see Table 1). Although time and cycles were slightly longer in males than females for graham crackers and raisins, time and cycles were slightly less in applesauce. Time cycle ratios were slightly less in males than females on all foods (see Table 2). Four year olds had slightly longer times and cycles than 5 year olds on all foods, with the exception of time on applesauce. Time cycle ratios did not vary with age (see Table 3). Summary analyses can be found in Table 4. Time, cycles, and time/cycle ratios were not affected by the age or sex of the child. The type of food strongly affected time, cycles, and time/cycle ratios (p < .001). Applesauce was different from raisin I, raisin II, and graham cracker for time (p < .001), cycle (p < .001), and time/cycle ratio (p < .011). Raisin I, raisin II, and graham cracker were not different from one another.

Reliability between two independent observers ranged from 0.78 to 0.95 in 4-year-old children for the average of all four foods. Numbers represent time and cycles, respectively. Reliability was 0.82 and 0.81 for the 5 year olds on the same measures. In general, ratings for applesauce were less, due to the fact that when time averaged less than 5 seconds there was less reliability between observers.

Discussion
It was hypothesized that there would be no difference in the time/cycle ratio among different food textures in both age groups. This hypothesis was rejected. The time/cycle ratio of applesauce was different from raisin I, raisin II, and graham cracker in 4- and 5-year-old children. These findings...
Table 2
Effect of Sex on Chewing Cycles in 4- and 5-Year-Old Children

<table>
<thead>
<tr>
<th>Food</th>
<th>Time (sec)</th>
<th>Cycles</th>
<th>T/C (sec/cycle)</th>
<th>Time (sec)</th>
<th>Cycles</th>
<th>T/C (sec/cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>11.4 ± 4.0</td>
<td>16.1 ± 5.5</td>
<td>0.7 ± 0.1</td>
<td>11.1 ± 3.7</td>
<td>14.8 ± 4.6</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>RII</td>
<td>11.5 ± 3.4</td>
<td>16.4 ± 5.4</td>
<td>0.7 ± 0.1</td>
<td>11.4 ± 3.9</td>
<td>15.7 ± 4.9</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>GC</td>
<td>11.2 ± 2.8</td>
<td>15.5 ± 3.2</td>
<td>0.7 ± 0.1</td>
<td>11.1 ± 2.3</td>
<td>14.8 ± 3.6</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>A</td>
<td>3.1 ± 0.8</td>
<td>2.7 ± 1.4</td>
<td>1.2 ± 0.4</td>
<td>3.7 ± 1.8</td>
<td>3.0 ± 1.7</td>
<td>1.3 ± 0.5</td>
</tr>
</tbody>
</table>

Data represent Mean ± SD.
RI—raisin I, RII—raisin II
GC—graham cracker, A—applesauce, T/C—time/cycle

reflect the fact that pureed food was chewed fewer times but that the food was held in the mouth for a relatively longer period than when solid food was chewed. In contrast, a bite of solid food was chewed more quickly and with more chewing cycles than pureed food.

Our measures indicate that the chewing movements of 4- and 5-year-old children are consistent with the chewing movements of older children and adults. The number of cycles needed to chew raisins and graham cracker was consistent with the work of Gibbs and collaborators (6), who found that adults averaged 15.5 chews per mouthful of food. The time/cycle ratio was also consistent with Ahlgren's work (1) where the average chewing cycle was 0.77 seconds for chewing gum and 0.58 seconds for carrots. It is interesting to note that carrots, which have a harder texture than gum, elicit a shorter chewing cycle than gum, which has a more viscous texture and would seem easier to chew. Our results support these findings by showing shorter time/cycle ratios for solid foods compared to the pureed texture of applesauce. If raisins and applesauce are assumed to be similarly appealing in their taste qualities of sweetness, the results would indicate that the length of chewing cycles may be controlled by the texture of the food rather than its taste.

The possibility of using the time/cycle ratio as a measure for identifying children with eating difficulties should be explored further. Although scores for time and cycles varied greatly among individuals, the time/cycle ratio was constant. It was not affected by the age or sex of the child, as tongue movements were (8). Preliminary results of time/cycle ratios from children with Down's syndrome

Table 3
Effects of Age on Chewing Cycles in 4- and 5-Year-Old Children

<table>
<thead>
<tr>
<th>Food</th>
<th>Time (sec)</th>
<th>Cycles</th>
<th>T/C (sec/cycle)</th>
<th>Time (sec)</th>
<th>Cycles</th>
<th>T/C (sec/cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>11.8 ± 3.6</td>
<td>15.5 ± 3.2</td>
<td>0.8 ± 0.2</td>
<td>10.6 ± 4.1</td>
<td>15.3 ± 6.5</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>RII</td>
<td>12.1 ± 3.1</td>
<td>16.4 ± 3.7</td>
<td>0.8 ± 0.1</td>
<td>10.8 ± 4.0</td>
<td>15.7 ± 6.3</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>GC</td>
<td>11.2 ± 2.0</td>
<td>15.3 ± 2.6</td>
<td>0.8 ± 0.1</td>
<td>11.1 ± 3.0</td>
<td>14.9 ± 4.1</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>A</td>
<td>3.3 ± 0.9</td>
<td>2.9 ± 1.5</td>
<td>1.2 ± 0.4</td>
<td>3.6 ± 1.8</td>
<td>2.8 ± 1.6</td>
<td>1.3 ± 0.5</td>
</tr>
</tbody>
</table>

Data represent Mean ± SD.
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indicate markedly elevated ratios for solid foods (7). Thus the measurement is highly discriminative of differences in chewing movements between normal and feeding-impaired children. The high time/cycle ratio in children with Down's syndrome seems to reflect their reluctance or inability to chew solid foods vigorously. To what extent sensory abilities of the oral structures influence chewing vigor is not known. However, this measure will eventually provide the clinician with a range of normal performance against which eating impairment can be objectively determined.

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REFERENCES

The American Journal of Occupational Therapy 175