Relationship between Chewing Skills and Speech Intelligibility in Korean Children with Spastic Cerebral Palsy

Su Jeong Chang1), Hyun Sub Sim1) and Miseon Kwon2)

Abstract: The present study investigated the relationship between chewing skills and speech intelligibility of nonsense one-syllable utterances in Korean children aged 3-8 with spastic cerebral palsy. Twenty-five children with spastic cerebral palsy participated in the study. Chewing skills were examined using the biting and chewing portions of the Pre-Speech Assessment Scale (PSAS), which provides a format with guidelines and scoring procedures for the assessment of normal and abnormal components of pre-speech functioning. Oral movements were observed while chewing food of different consistencies. Speech intelligibility was examined via perceptual analysis of consonant-vowel (CV) syllable production. The study showed (1) a significant and positive correlation between normal chewing scores and speech intelligibility scores, and (2) a significant and negative correlation between abnormal chewing scores and speech intelligibility scores. The current study is consistent with previous studies that found a significant relationship between non-speech oral movements and speech acts. The results of the present study are discussed from the point of view of motor controls of speech and non-speech behavior, and their clinical applications are suggested.

Key words: chewing, speech intelligibility, cerebral palsy, oral motor function, Korean language

韓国の痙直型脳性麻痺児における咀嚼機能と発話明瞭度の関連

要　約：韓国の3〜8歳の痙直型脳性麻痺児における咀嚼機能と無意味1音節の発話明瞭度との関連を検討した。対象は25例の痙直型脳性麻痺児。咀嚼機能は、プレスピーチ機能の正常・異常の両面の評価のためのガイドラインと得点化の手続きが示されているPre-Speech Assessment Scale（PSAS）の、“biting”と“chewing”の領域を用いて評価され、異なった固さの食物を咀嚼しているときの発語器官の動きが観察された。発話明瞭度は子音－母音（CV）音節の産生時のそれが評価された。その結果、（1）正常咀嚼得点と発話明瞭度得点との間には有意な正の相関が認められ、（2）異常咀嚼得点と発話明瞭度得点との間には有意な負の相関が認められた。これは、発話を伴わない発語器官の動きがスピーチの機能と有意に関連するという先行研究に一致した。本研究の知見は、スピーチ動作と非スピーチ動作の運動コントロールの観点から論じられ、その臨床への応用が示唆された。

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2011年5月13日受理 2011年9月1日受理
Introduction

Human oral mechanisms serve two different functions: eating and speaking. The relationship between these two activities has not been clearly understood. Some studies have suggested that the non-speech oral motor function works as the precursor of speech development\(^1\)\(^-\)\(^3\). MacNeilage and Davis\(^3\) argued that speech evolved from simple non-speech behavior, based on the finding that vocal output from 7 to 18 months can be performed by mandibular oscillation alone. The authors suggested that this simple mandibular oscillation needs to be elaborated as children acquire different consonants and vowels. Based on the findings, it was assumed that motor skills are the essential predictor of speech development, and their improvement leads to the improvement of speech abilities\(^4\)\(^-\)\(^6\). However, two EMG studies have revealed that they have different control systems and develop independently\(^7\)\(^,\)\(^8\). Moore and Ruark\(^7\) compared the coordinative organization of the mandibular muscles of 15-month-old infants during spontaneous production of chewing, sucking, babbling, and speech. They found that couplings among all mandibular muscles were stronger during speech compared to earlier-emerging chewing and sucking. Ruark and Moore\(^8\) compared activities of the upper and lower lips during productions of chewing, syllable repetition, lip protrusion, and speech tasks (repeated two-word utterances) in seven 2-year-old children. The study found task-specific differences in the levels of the coupling of upper and lower lip activities in 2-year-old children.

Children with cerebral palsy showed both speech and eating problems. Therefore, non-speech oral skills as well as speech abilities are important skills considered in the assessment of children with cerebral palsy. Especially for young children with cerebral palsy, readiness for speech movement should be evaluated by examining (1) oral movements such as biting, sucking, and chewing; (2) pre-speech vocalization; and (3) speech posture\(^9\). Feeding activities are commonly included into the speech therapy program to facilitate oral motor function in children with cerebral palsy because it is very natural, functional, and easy to engage children\(^10\). This therapy program pays more attention to improving chewing activity because it is the major element of feeding activity and is accomplished by the coordinated movements of the jaw, lips, and tongue simultaneously. These kinds of speech therapy program are based on the assumption that treatment of oral motor control will be generalized to speech motor control\(^11\)\(^,\)\(^12\). Although empirical data about the relationship between oral motor activities and speech are not sufficient, many clinicians have the notion that training non-speech behaviors in children with cerebral palsy would facilitate speech by transferring the non-speech skills to impaired speech behaviors. Therefore, the current study investigated whether there are any significant correlations between chewing skills and intelligibility of nonsense one-syllable utterances in children with spastic cerebral palsy.

Methods

1. Subjects

A total of 25 Korean children (13 boys and 12 girls) who were diagnosed with spastic cerebral palsy aged 3 to 8 (mean=73.1 months, SD=20.08 months) participated; they were recruited from the Seoul and Gyeonggi areas. All participants were reported to have no history of hearing or cognitive disorders by their parents, teachers, or speech therapists. Twenty had cerebral palsy with spastic diplegia, four had spastic quadriplegia, and one had spastic hemiplegia.

2. Assessment of chewing skills and speech intelligibility

1) Chewing skills

Chewing skills were examined using the chewing portion of the Pre-Speech Assessment Scale (PSAS)\(^13\). The PSAS is an evaluation tool available now which provides a format with guidelines and scoring procedures for the assessment of normal and
abnormal components of pre-speech motor functioning in children with cerebral palsy as a comprehensive and widely used assessment tool\(^\text{14}\). A chewing section from the PSAS was administered for the purpose of the current study. However, jelly was used in the current study as a substitute for raisins used in the PSAS given that raisins are not relatively familiar food to Korean children.

2) Speech intelligibility

An open nonsense monosyllabic structure (CV) was used to evaluate speech intelligibility. Four consonant types were used in order to examine different kinds of articulatory movement: bilabial (/m/, /p/), alveolar (/n/, /t/), velar (/g/), and glottal (/h/) sounds. The stops used in this speech intelligibility test were lenis (basic form in Korean). Three different vowels —/a/, /i/, and /u/— were used in order to contrast the articulator movements. A total of 18 nonsense syllables (6 consonants x 3 vowels) were used as speech stimuli.

3. Assessment procedure

Assessment was conducted in a quiet location within the hospital and took approximately 15 minutes for each participant. The assessment consisted of two sessions. Prior to the first session, the examiner helped the children to keep an appropriate posture and seated them in a KAYE bench (Kaye Products, Inc. model S1A, S2A, or S5A) because posture may affect the oral movements or speech\(^\text{15-17}\). The assessment of articulator movements during chewing was conducted in the order of the jaw, tongue, and lips\(^\text{13}\). First, in order to observe jaw movements during chewing, a cookie or jelly was placed on the gums in the canine or molar area of both sides of the mouth. Second, foods with different consistencies, such as a cookie and jelly, were placed between the molars on both sides of the mouth, and then the child’s ability to lateralize the tongue was observed during chewing. Third, a cookie was placed on both the upper and lower lips and then lip movements were observed while chewing. All of the procedures were video-recorded using a video camera (Samsung VM-400 8 mm) during all assessment sessions.

After the first session, speech intelligibility was measured. Each speech stimulus was presented in turn to the child at a comfortable level of loudness in random order, and then the child was asked to repeat them. All sessions were audio-recorded to minidisk (Sharp MD-MT 831) using a headset microphone (Audio-Technica ATH-COM 1).

4. Data analysis

1) Chewing skills

Chewing skills were analyzed following the PSAS guidelines. Both abnormal behaviors score (ABS) and normal developmental range score (NDRS) for articulator movements were obtained based on the chewing activity for jaw, tongue, and lip movements.

ABS describes the severity of abnormal patterns of tone and movement in the pre-speech area which are not observed in normal children\(^\text{13}\). After observing the child’s chewing behaviors, an examiner (speech-language pathologist: SLP) with more than three years of experience in speech treatment for children with cerebral palsy rated and scored performance. The clinical judgment score of each articulator movement was made considering the frequency and severity of interference with chewing caused by abnormal patterns: i.e. the smoothness and precision of each articulator movement (see Morris\(^\text{13}\) for a detailed guideline). For clinical judgment of the severity of the abnormal movements, an ordinal scale from -1 to -9 was used. When abnormal behaviors were not present, it was scored zero.

NDRS is an indicator of the presence of movements in the pre-speech area in normal 1- to 24-month-old infants\(^\text{13}\). Normal behaviors were scored from 1 to 24, and the score corresponds to the last month at which the behavior appears. For example, a score of “1” indicates that the behaviors appear from birth to 1 month. When the behaviors were not present, zero was assigned.

2) Speech intelligibility

The examiner listened to the nonsense one-syllable utterances of the participants in random order and evaluated their speech intelligibility. A 7-point scale (0 for not intelligible to 6 for normal intelligibility) was used for more detailed assessment\(^\text{18}\). Intelligibilities of a whole syllable and the consonant part of a syllable were evaluated separately.
5. Reliability

1) Intra-examiner reliability

Scores of chewing skills and speech intelligibility for 20% of the total participants (N=5) were randomly selected and retesting was performed to obtain intra-examiner reliability. The percentages of intra-examiner agreement were 97% for chewing skills and 93% for speech intelligibility.

2) Inter-examiner reliability

For the purpose of obtaining inter-examiner reliability, scores of chewing skills and speech intelligibility were taken for 20% of the total participants (N=5), who were randomly selected, and evaluated by two SLPs with more than three years of experience in treating children with cerebral palsy in clinical settings. Prior to the evaluation, the examiners had a practice session using 2-3 video and audio tapes so as to be fully aware of the assessment method. The percentages of inter-examiner agreement were 93% for chewing skills and 91% for speech intelligibility.

6. Statistical analysis

After checking reliability, statistical analyses of the original data were carried out using the SPSS (Statistical Package for Social Science) version 11.5 for Windows. Spearman’s rank correlations were computed to examine (1) the relationship between NRDS and speech intelligibility and (2) the relationship between ABS and speech intelligibility.

Table 1  Descriptive information of the normal developmental range scores for jaw, tongue and lip movements (N=25)

<table>
<thead>
<tr>
<th>Normal chewing score</th>
<th>Jaw movements</th>
<th>Tongue movements</th>
<th>Lip movements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>60.48</td>
<td>30.84</td>
<td>14.76</td>
</tr>
<tr>
<td>SD</td>
<td>20.94</td>
<td>10.59</td>
<td>6.96</td>
</tr>
<tr>
<td>Range</td>
<td>22-96</td>
<td>10-48</td>
<td>6-24</td>
</tr>
</tbody>
</table>

Table 2  Descriptive information of speech intelligibility scores for each place of articulation (N=25)

<table>
<thead>
<tr>
<th>Whole syllable</th>
<th>Bilabial</th>
<th>Alveolar</th>
<th>Velar</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>79.84</td>
<td>26.88</td>
<td>26.68</td>
<td>13.36</td>
</tr>
<tr>
<td>SD</td>
<td>27.00</td>
<td>9.99</td>
<td>9.28</td>
<td>5.87</td>
</tr>
<tr>
<td>Range</td>
<td>0-104</td>
<td>0-36</td>
<td>0-36</td>
<td>0-18</td>
</tr>
</tbody>
</table>

Figure 1  Scatter plot between NDRS and nonsense one-syllable intelligibility

Results

1. Correlation between normal developmental range score and speech intelligibility

Descriptive information on the NDRS and speech intelligibility for each articulator movement is provided in Tables 1 and 2, respectively. Normal chewing score is the sum of three articulators’ scores.

There was a significant and positive correlation between the NDRS and nonsense one-syllable intelligibility in children with spastic cerebral palsy (r=.813, p<.01), indicating that those who had higher scores in the NDRS showed better speech intelligibilities in nonsense one-syllable speech production. The scatter plot is shown in Figure 1.

The correlation coefficients were computed between the articulator movements according to the NDRS and intelligibility of each phoneme, and the results are provided in Table 3. All of the three articulators’ movements during chewing were significantly and positively correlated with the intelligibility of bilateral, alveolar and glottal sounds within a range of r=.793 (p<.01) to r=.454 (p<.05). However, the production of velar sounds was significantly correlated only with jaw movement (r=.458, p<.05).
2. Correlation between abnormal behaviors scores and speech intelligibility

Means and standard deviations of abnormal chewing behavior scores in children with spastic cerebral palsy are shown in Table 4. Abnormal chewing score is the sum of the three articulators’ abnormal movement scores.

There was a significant and negative correlation between ABS and speech intelligibility ($r=-.505$, $p<.01$), indicating that those who had abnormal chewing behaviors generally had lower speech intelligibility. The scatter plot is provided in Figure 2.

Discussion

The purpose of the current study was to examine the relationship between speech intelligibility at the syllable level and normal chewing skills/abnormal chewing behaviors in order to find out to what extent non-speech oral movements affect speech intelligibility.

The results revealed that the speech intelligibility of children with spastic cerebral palsy has (1) a significant positive correlation with chewing skills and (2) a significant negative correlation with abnormal chewing behaviors. The results suggest that articulator movements during non-speech movement, such as chewing behaviors, are related to speech intelligibility at the syllable level in children with spastic cerebral palsy. The current study is consistent with other studies which found significant relationships between non-speech oral movements and speech acts\(^2\)\(^{-2}\)\(^{-2}\). Specifically, jaw movements were highly correlated with the intelligibility of all consonants. As Davis and MacNeilage\(^2\)\(^{-2}\) indicated, the results suggested that jaw movement is the basic frame of speech.

Though the relationship was not clear, there was a correlation between articulator movements during chewing behavior and speech intelligibility. Previous research indicated that subjects with articulation problems such as dysarthrias showed significantly low functions in oral movements\(^1\)\(^9\)\(^{-2}\)\(^{-2}\)\(^{-2}\). Generally there is a consensus among SLPs treating children with cerebral palsy that their abnormal oral behaviors interfere with speaking behaviors\(^6\)\(^{-2}\)\(^{-2}\). For example, while a child who shows tongue retraction has a problem producing alveolar sounds, a child with tongue thrust may have difficulty in producing velar sounds. Based on the results, it can be thought that speech intelligibility may be improved by training related articulator movements of children with cerebral palsy. Physiological factors have a superior role in babbling or early speech\(^2\)\(^{-2}\). Given the importance of physiological factors in early speech development, early treatment at the

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Correlation between articulator movement and speech intelligibility for each phoneme during chewing activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jaw</td>
</tr>
<tr>
<td>Bilateral</td>
<td>.793**</td>
</tr>
<tr>
<td>Alveolar</td>
<td>.624**</td>
</tr>
<tr>
<td>Velar</td>
<td>.458*</td>
</tr>
<tr>
<td>Glottal</td>
<td>.607**</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Descriptive statistics of abnormal behavior scores (N=25)</th>
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<tbody>
<tr>
<td></td>
<td>Abnormal jaw movements</td>
</tr>
<tr>
<td>Mean</td>
<td>6.12</td>
</tr>
<tr>
<td>SD</td>
<td>7.85</td>
</tr>
<tr>
<td>Range</td>
<td>0-32</td>
</tr>
</tbody>
</table>

| Figure 2 | Scatter plot between abnormal behavior score and intelligibility of nonsense one-syllable intelligibility |
beginning of speech development has been recommended in order to facilitate improvement of speech intelligibility by normalizing the oral movements.

Oral motor exercise has been widely used in Canada, Great Britain, and the United States. Beckman\textsuperscript{27} and Boshart\textsuperscript{28} recommended that non-speech motor training needs to be a part of the treatment regimen. Furthermore, Pierce and Taylor\textsuperscript{29} suggested that non-speech oral motor training should be included in coursework at the graduate level. However, the effects of oral motor training on speech need supportive evidence\textsuperscript{30} and questions concerning its use have been raised by many studies\textsuperscript{31,32}. The usefulness of non-speech oral motor treatments has been questioned because they target non-speech motor movements and oral postures for the purpose of developing motor patterns required for speech sound production\textsuperscript{32}. For example, because the musculatures of the speech and swallowing mechanisms differ in terms of fiber types and attachment patterns\textsuperscript{33-35}, they may respond to training in different ways.

Considering the specificity of speaking behaviors, non-speech movement training may not result in significant functional changes in either speech or swallowing movement because speaking behavior is “a fine motor skill which every healthy child acquires over an extensive learning period, with practice sessions on every day, and life-long adaptation\textsuperscript{36}.” This perspective takes the position that speech motor control is not related to the control of non-speech oral movements. Ziegler\textsuperscript{36} argued dissociation exists between involuntary acts that make use of the oral motor system, such as smiling and crying, and voluntary acts such as speaking behaviors based on clinical evidences. For example, patients with certain types of brain lesion may not disrupt involuntary acts such as breathing and yawning while impairing voluntary acts including speech. Conversely, involuntary movements can be impaired without speaking behaviors being disrupted.

Given the fact that one-syllable tasks were used for the purpose of measuring speech intelligibility in the current study, the findings of this study should be interpreted carefully because simple tasks to produce nonsense syllables reflect “the integrity of brain structures involved in early motor learning” rather than “motor representations acquired through long-term learning process\textsuperscript{30}. Therefore, the results of the study may be used carefully as basic data concerning the relationship between speech motor control and non-speech motor control and the validity of intervention by oral motor training on the speech of children with cerebral palsy. Furthermore, the findings suggest that SLPs should question the belief that the practice of non-speech oral motor training is transferred to speech tasks.

\textbf{References}

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