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Treatment of articulatory impairment in a child with spastic dysarthria associated with cerebral palsy

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Abstract

Background: A comparative study of treatment modalities for improving articulation in a 13-year-old child with severe spastic dysarthria associated with spastic cerebral palsy (SCP) was conducted.

Method: A multiple treatment design examined the effect of phonetic placement therapy (PPT) and sEMG-facilitated biofeedback relaxation therapy over a 6-week period. Treatment outcomes were measured using acoustic and perceptual analysis.

Results: Results revealed significant improvement in single word intelligibility following PPT with the improvements maintained following sEMG treatment. sEMG-facilitated biofeedback relaxation treatment indicated the occurrence of a pre-cursor skill in increased motor control. Intelligibility at paragraph or sentence level did not change following either treatment. Perceptually, there was no change to any parameters of articulation following either treatment. However, subtle changes were observed on acoustic analysis. Functionally, the participant reported no changes to feelings of well-being or distress regarding her speech disorder over the period of intervention.

Conclusions: Clinically, the PPT and sEMG treatments demonstrated improvement in single word articulation, despite no perceptible changes to overall intelligibility. It is likely that the severity of the participant's dysarthria was a factor in the minimal changes observed following treatment. Future studies examining the treatments in children with mild and/or moderate dysarthria are required.

Keywords*: Spastic dysarthria*, *sEMG biofeedback*, *articulation*, *speech disorder*, *cerebral palsy*

Antecedentes: Se desarrolló un estudio comparativo de modalidades de tratamiento para mejorar la articulación en un niño de 13 años con disartria espástica severa asociada a parálisis cerebral espástica (SCP).

Métodos: Se diseño un tratamiento múltiple a través del cual se examinó el efecto de la terapia fonética (PPT) y la terapia de relajación por medio de bioretroalimentación facilitada por electromiografía (sEMG) a lo largo de un periodo de seis semanas. Los resultados del tratamiento fueron medidos utilizando análisis perceptuales y acústicos.

Resultados: Los resultados revelaron una mejoría significativa en inteligibilidad de palabras únicas después de la PPT manteniéndose las mejorías después del tratamiento sEMG. El tratamiento de relajación a través de bioretroalimentación facilitada por sEMG indicó la presencia de de una capacidad pre-cursor en el aumento del control motriz. La inteligibilidad a nivel del párrafo o de la oración no cambió después de ambos tratamientos. Perceptualmente no hubo cambios en alguno de los parámetros de la articulación después de ambos tratamientos. Sin embargo hubo cambios mínimos en el análisis acústico. Funcionalmente el participante no reportó cambios en cuanto a la sensación de bienestar o de tensión en relación a la alteración en el habla durante el periodo de la intervención.

Conclusiones: Clínicamente los tratamientos con PPT y sEMG mostraron una mejoría en la articulación de palabras únicas, a pesar de no haber cambios perceptibles en general en cuanto a la inteligibilidad. Es posible que la severidad de la disartria del participante fuera un factor determinante en los cambios mínimos que se observaron después del tratamiento. Se requieren estudios a futuro que examinen los tratamientos en niños con disartria leve y/o moderada.

Palabras clave: *Disartria espástica*, *bioretroalimentación*, *sEMG*, *articulación*, *alteración en el habla*, *parálisis cerebral*

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Introduction

Spastic cerebral palsy (SCP) results from bilateral damage to the pyramidal and extra-pyramidal tracts of the central nervous system and produces increased tone (spasticity or hypertonus), weakness and reduced range of volitional movement to muscles of the limbs and orofacial region [1]. Children with SCP commonly exhibit dysarthria of varying severity. Articulatory imprecision is one of the primary characteristics of this dysarthria [2–5] and, for children with severe speech disorders, this contributes to increased disability, with subsequent social isolation, impaired social development and prejudice [6]. Surprisingly, few studies have investigated treatments for improving articulation in children with SCP. In addition, no studies have documented the outcomes of speech articulation intervention for children with SCP and severe articulation disorder.

Clinically, behavioural intervention generally focuses on improving oral articulatory function, by improving muscle tone and coordination of orofacial muscles and maximizing intelligibility using phonologic and phonetic training. One form of behavioural intervention is phonetic placement therapy (PPT). PPT aims to develop and repair disordered speech sounds by providing instructions on how to produce correct movement patterns in order to produce an appropriate speech sound [7]. Children with SCP and speech disorder have impaired motor execution abilities due to the underlying spasticity of their orofacial musculature which prevents exposure to the correct movement patterns required to execute accurate speech sounds [2–4, 8–11]. Therefore, PPT may facilitate, via direct instruction, correct movement patterns and improve the articulation of disordered sounds and, potentially, articulatory accuracy. Whilst PPT has been utilised widely, only one study has investigated its use with children with CP, reporting improved articulation of affricates and fricatives following a 4-month intervention period in a single child with moderate dysarthria and moderate CP [12]. Unfortunately, the authors did not discuss the effect of results in relation to intelligibility. Interestingly, whilst spasticity of the orofacial musculature is widely hypothesized as the basis for articulatory impairment in children with SCP [2–4, 8–11], few studies have reported attempts to reduce orofacial spasticity as a component of speech intervention.

In adults with spastic dysarthria, surface electromyography (sEMG) has been used to reduce orofacial spasticity, coinciding with improved speech production and intelligibility. sEMG biofeedback measures the strength and timing of muscle contractions via electrodes adhered to the skin above a target muscle or muscle group [13] and provides visual and/or auditory feedback offering a means by which to regulate muscle control and reduce orofacial spasticity. For individuals with SCP, sEMG has the potential to reduce muscle spasticity by facilitating muscle control using relaxation. Relaxation reduces muscle tone and facilitates improved range of orofacial movement and muscle functioning, which ultimately improves articulation and speech performance [14–18]. More studies investigating sEMG biofeedback for treating articulatory disorders are required to confirm these findings in children with SCP.

In a study investigating the treatment of dysarthria in CP, Finley et al. [15] reported improvement on speech measures, including breath support, phonation control and syllable production, following sEMG biofeedback intervention in a 14-year-old child with athetoid CP and mild–moderate dysarthria. The findings suggest that sEMG intervention facilitates a reduction in orofacial spasticity and may be an effective treatment modality for children with CP. In adults, several case studies have reported improved articulation and overall intelligibility following sEMG biofeedback treatment with severe spastic dysarthria [14–18].

Based on a limited number of studies both sEMG biofeedback and PPT treatments appear to have the potential to improve articulation disorder in children with SCP. Whilst sEMG biofeedback attempts to regulate and reduce orofacial spasticity via relaxation, allowing muscles improved ranges of movement and ultimately improved articulation, PPT aims to improve articulation via direct instruction on where and how to place muscles in order to correctly produce a sound. Given the potential promise of these techniques and the limited number of studies it is essential that further investigations examine treatment outcomes for improving articulation disorder in children with SCP.

Therefore, the present investigation will compare the treatment outcomes of sEMG biofeedback and PPT for a child with severe SCP on measures of speech articulation. The child, CB (fictitious initials), was referred for treatment as both she and her family ardently wanted to maintain speech as her primary means of communication despite the severity of her disability and previous speech treatment. Given the severity of the speech disorder, reported positive treatment outcomes for those with severe spastic dysarthria following sEMG treatment [14–18] and limited treatment outcomes of previous speech production treatment, it was hypothesized that sEMG biofeedback would facilitate a reduction in labial and lingual hypertonicity and thus result in greater improvements in articulation than PPT.

Method

Participant

A 13-year-old female with spastic hemiplegic CP participated in the study. CB exhibited: (1) a medical diagnosis of SCP, (2) speech therapy diagnosis of spastic dysarthria, (3) hearing and vision within normal limits, (4) speech as her primary means of communication (currently), (5) New Zealand English as her first language and (6) cognitively able to understand and complete the assessment and treatment procedures of the study. CB had not received speech and language therapy services for dysarthria for 1 year prior to participation. She was currently receiving training in the use of an augmentative communication device but was resistant to using it. She received continuous speech and language treatment for her communication disorder from the ages of 6–11 years with, according to CB's parents, limited success. Specific documentation regarding the nature of intervention undertaken was unavailable; however, treatment sessions with a speech pathologist occurred for 30 minutes only once per week. Based on parental report, it is thought that intervention focused on sound production drills, not specifically PPT. CB currently attends a mainstream school and employs spoken communication as her primary means of communication. While CB's speech disorder resulted in a high percentage of failed communication attempts with her peers and family, CB was adamant that she wished to continue using speech as her primary means of communication. As a result, both CB and her family were highly motivated to participate in the proposed treatment.

Preliminary oromotor analysis indicated that CB demonstrated severely restricted lingual and labial movement, including inadequate tongue elevation, tongue lateralization, tongue retraction, lip pursing and lip seal. This appeared to result primarily from significant orofacial muscle spasticity. Whilst restricted movements do not necessarily prohibit articulation, preliminary assessment results also revealed a significant articulatory impairment which appeared to result, in some part, from the orofacial spasticity demonstrated. Results of the Goldman-Fristoe Test of Articulation [20] indicated significantly impaired consonant accuracy, particularly in the production of fricatives and affricatives. Perceptual analysis of CB's speech by a listener experienced in dysarthria research further indicated a severe spastic dysarthria characterized by excessively slow rate, strained-strangled phonation and imprecise consonant and vowel articulation. Examination of expressive language using the Language Assessment Remediation and Screening Procedure (LARSP) [21], conversational analysis profile (CAP) [22] and profile in semantics (PRISM) [23] revealed a severe language delay (please contact the author for full results). Whilst the LARSP analysis indicated a severe syntactic delay, it was noted that attempts at more complex sentences became highly unintelligible and were unable to be analysed, suggesting that the speech disorder has significantly affected syntactic development. During conversational exchanges, CB's speech intelligibility was profoundly compromised and communicative breakdowns were frequent, resulting in simplified sentences (as shown by LARSP analysis) and repetition and rephrasing of utterances. Communication partners frequently needed to clarify CB's utterances, which increased the occurrence of responsive utterances and reduced the frequency of attempts at communication in CB's language, resulting in laboured conversations.

Procedure

The assessment and treatment timeline is detailed in Table I. A single-subject case study using an ABACA paradigm was undertaken. The case study consisted of three main stages: baseline, PPT treatment and sEMG biofeedback-facilitated relaxation treatment separated by a 2-week no treatment period. During each assessment, identical speech recordings were undertaken for later perceptual and acoustic analysis and physiological recordings of sEMG amplitude measures were completed. A total of 6 weeks was required to complete the study.

Speech assessment and data analysis

All assessment sessions were undertaken in a quiet room at CB's home or school. On average, 75 minutes were required to complete all investigations. For speech recordings, a Sony ECM-MS903 microphone was positioned in front of CB at a constant mouth-to-microphone distance of 30 centimetres. Speech was recorded using a Sony MZ-NHI

Table I. Timeline.

Time	Assessment phase
Day 1	Baseline assessment
Day 2	Baseline assessment
Day 3	Baseline assessment
Days 4–13	PPT treatment (five times per week over 2 weeks)
Day 14	Post-PPT assessment
Days 15–24	Treatment withdrawal (2 weeks)
Days 25– 34	sEMG treatment (five times per week over 2 weeks)
Day 35	post-sEMG intervention assessment

PPT = Phonetic placement therapy, sEMG = surface electromyography.

Minidisk recorder, set to Linear PCM (non-compression) mode. Audio-recordings were acquired for the word intelligibility sub-test from the Assessment of Intelligibility of Dysarthric Speech (AssIDS) [24], reading of the'Grandfather Passage'[25] and a DDK assessment including repetition of three consonant-vowel (CV) syllables (/pə/,/tə/ and /kə/). The distress/well-being scale of the AusTOMs was also completed to provide a measure of the effect of the treatment programme upon the individual [26]. The AssIDS was chosen to provide a measure of single word intelligibility and was completed as per test manual instructions. Two independent judges, both qualified speech-language therapists with experience in the perceptual analysis of dysarthric speech, analysed the results of the AssIDS. Grandfather passage samples were analysed to provide a measure of perceived articulation and intelligibility across treatments. Again, the two independent judges rated CB's articulation and overall intelligibility using the perceptual rating scale of Duffy [27]. The parameters of articulatory function rated included: imprecise consonants, distorted vowels, length of phoneme productions and overall intelligibility; a 5-point rating scale was used to rate articulation and overall intelligibility with a score of 0 representing no impairment and 4 severe speech deviance. Recordings of the AssIDS and Grandfather passage samples were randomized and analysed by the judges to avoid listener familiarity or test–re-test bias. Intra-judge reliability was 0.916 for judge A and 0.984 for judge B; inter-judge reliability coefficient was 0.842.

Acoustic analysis was undertaken for (1) vowel production using the first two sentences of the Grandfather passage ('You wish to know all about my grandfather' and 'Well, he is nearly 93 years old yet he still thinks as swiftly as ever') and (2) diadochokinesis (DDK). For vowel production, the three corner vowels/æ/,/i/and/u/were taken from the grandfather passage sample and the acoustic param eters of first (F_1) and second (F_2) formant frequencies were measured. Due to the noted centralization of vowel formant frequencies in CP [28], the corner vowels were chosen for analysis as any changes post-treatment would be more salient. Given the severity of CB's dysarthria, any instance in which a 50 ms segment of periodicity was evident was analysed for the three vowels. Analysis was conducted using PRAAT, a specialized acoustic analysis programme [29]. During analysis, both a waveform and a wideband spectrogram were displayed. Visual judgement determined the midpoint of the vowel segment and marked points at 25 ms from either side of the midpoint provided average F_1 and F_2 values across a 50 ms vowel segment and were extracted and recorded.

From the DDK tasks, the following parameters were calculated using an amplitude-by-time waveform display and spectrogram (Figure 1). Analysis was conducted as per Kent and Read [30] using the following parameters: (1) alternate motion rate (AMR), (2) CV syllable durations and (3) inter-syllable gap duration. These analyses were selected to determine the speed and regularity of movements

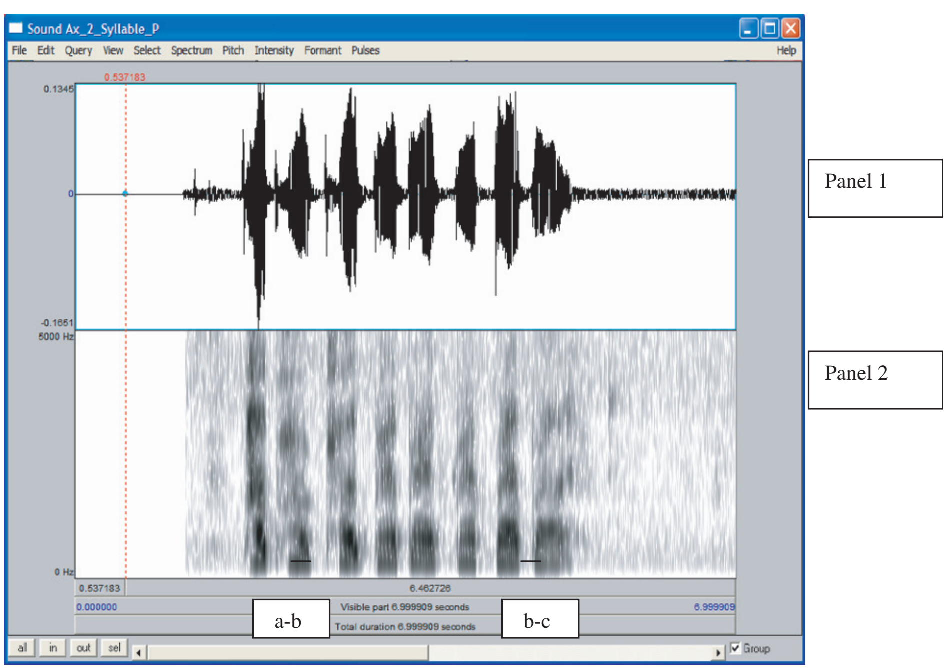

Figure 1. Waveform and spectrogram displaying the acoustic pattern for the syllable/pə/produced by a non-dysarthric speaker.
Note: Panel 1 = waveform, Panel 2 = narrow-band (70 Hz) spectrogram, a–b = syllable duration and b–c = inter-syllable gap duration.

of the jaw, lips and anterior and posterior tongue. AMR was calculated by dividing the total duration of breath group by the number of syllables per breath group to provide a value in syllables per second for each CV combination at each assessment phase. Duration of syllables was calculated from the start of the stop burst through to offset of the vowel at the level of the first formant [31]. Inter-syllable gap duration was calculated from the offset of the vowel formant (F_1) through to the beginning of the subsequent stop burst of the following syllable [30].

sEMG assessment and data analysis

The Myotrac-3™ (Thought Technology)[1] portable biofeedback device was employed to obtain sEMG amplitude, in microvolts (μV), of submental (floor of mouth) and orbicularis oris (lip) muscle activity during assessment. For assessment, the participant was seated in an upright position. The computer screen was positioned away from CB. Two centimetre silver–silver chloride surface EMG electrodes were attached to CB's skin, using an adhesive-backed patch. The electrodes were placed in three separate locations: (1) overlying the collective submental (floor of mouth) muscles under the chin, to indirectly assess floor of mouth and lingual amplitude measures, (2) above the left superior orbicularis oris muscle (left top lip), to indirectly assess left labial amplitude measures, and (3) above the right superior orbicularis oris muscle (right top lip), to indirectly assess right labial amplitude measures. The electrode locations were chosen as they represented muscles identified as contributing significantly to consonant and vowel misarticulations in the speech of children with cerebral palsy [2–4]. Therefore, it is likely that any change in tone and function of these muscles as a result of sEMG treatment would demonstrate change in articulation. The ground electrode was placed on CB's earlobe. A small mark had been placed on the skin surface to ensure the exact placement of the submental electrodes overtime. To avoid the social discomfort of a facial marking, consistent placement of orbicularis oris electrodes was facilitated using a photograph taken during the initial session.

CB completed two tasks for each sEMG assessment. Task one assessed muscle activity at rest and provided a resting baseline average of muscle activity while task two assessed muscle activity during non-speech postures, namely tongue protrusion and lip pursing. Whilst non-speech related tasks may not directly influence speech performance [32], non-speech tasks were assessed to determine whether any improvement in muscle control functioning could occur during different muscle positions in isolation. During task one CB was instructed to close her eyes, sit quietly and try to relax as much as possible. Two minutes after this command was given an average resting measure of amplitude was calculated at intervals of 10, 20 and 30 seconds. This task was repeated for both submental and labial electrode placements. During task two, CB was instructed to maximally protrude her tongue during submental electrode placement and maximally purse her lips during labial electrode placement. CB was instructed to maintain these postures for 30 seconds. An average measure of amplitude was also calculated at intervals of 10, 20 and 30 seconds. Approximately 15 minutes was required to complete all sEMG tasks.

Treatment programme

Two therapy programmes were trialled during the period of the study: (1) PPT and (2) sEMG biofeedback-facilitated relaxation treatment. The therapy programmes were designed to adhere to the principles of motor learning. Multiple opportunities for practise of the desired motor movement, appropriate feedback regarding the nature of the movement, explanations regarding why the movement is important and adapting the rate of the movement to the ability of the individual are key principles of motor learning [19]. Treatment programmes were comprised of 10 daily sessions conducted over a 2-week period (Monday–Friday). On average, 45 minutes was allowed for each therapy session. The therapy sessions were conducted in a quiet location at either CB's school or home. The aims and tasks of the session were explained to CB. CB was asked to respond to simple questions regarding the purpose and instruction of treatments to ensure that she understood what was being asked of her. Appropriate feedback was provided on completion of each task.

Phonetic placement therapy

Phonetic placement therapy was used to improve articulation. The five consonants chosen for intervention included/t/, /s/, /f/, /ð/and/ʃ/. These sounds were chosen based upon: (1) responses on the Goldman Fristoe Test of Articulation (sounds in words sub-test) utilised during preliminary oromotor analyses, (2) developmental stage of CB, (3) the frequency of phoneme occurrence within words and (4) effect of the sound upon intelligibility. Furthermore, whilst it is acknowledged that these consonants require complex motor speech demands in their production, fricatives and affricates have clearly been identified as the most frequently misarticulated sounds in the speech of children with CP and contribute significantly to reducing intelligibility [2–4]. It is hoped that in selecting these sounds for intervention any improvement in production will provide salient changes in articulation outcomes. As it is common for children with CP to voice voiceless consonants [33], which contribute to reduced intelligibility, the target consonants are all voiceless to maximize speech production outcomes. It is assumed that improvement in the production of these sounds will generalize to the voiced pair.

During each session all sounds were targeted; however, one sound was selected as the main focus of each session and received 30 minutes of treatment to ensure that all sounds received the same amount of practise time during treatment. At the beginning of each session the therapist would inform CB which sound was being targeted and provide both visual and auditory representation of the sound to develop letter-name knowledge and to provide a model of how the consonant should sound. A mirror was also utilised during therapy to assist CB as to where and how to place her articulators. Speech drills were employed and specific feedback was provided for each of CB's productions. To maintain motivation, games were also used during therapy; both therapist and CB were required to make five sound productions before receiving a turn in the game and feedback was also provided. At times CB was also asked to provide feedback regarding her sound productions to enhance self-awareness. Treatment progressed as per traditional articulation hierarchies with speech sound production tasks that increased in complexity from sounds produced in isolation through to sounds produced in sentences and phrases. Once an 80% accuracy rate for a specific target (e.g. isolated sounds) was achieved, CB progressed onto the next level of task complexity (e.g. sounds in words). CB progressed only to sounds in words level for all speech sounds targeted.

sEMG biofeedback- facilitated relaxation therapy

sEMG biofeedback-facilitated relaxation treatment was used with the aim of inhibiting muscle tension within the orofacial muscles using relaxation therapy. A portable device, the Procomp^{TM} biofeedback device (Thought Technology), was employed during therapy. During all treatment sessions, CB was seated in an upright position in a quiet room, either at home or at school. As in the assessment stages, surface electrodes were adhered to the CB's skin, using paired 2 cm silver–silver chloride electrodes. Electrode placement was again ensured via markings under the chin for the submental electrode and via a photograph for the superior orbicularis oris electrode placements. Treatment sessions were divided into two 20-minute phases, thus allowing for focused relaxation of the two target muscle groups, namely submental and bilateral superior orbicularis oris muscles. Whilst specific outlines for managing speech disorders are limited, it is generally accepted that treatments initially focus on improving oromotor functions that support speech, including modifying muscle tone and range of movement [7]. The submental and orbicularis oris muscles were selected for biofeedback-facilitated relaxation treatment to determine if a reduction in muscle tone results in improved articulation of consonant and vowels.

Prior to the initial session of sEMG treatment, CB received a single training session to ensure she was able to utilise the equipment. Before each session CB was informed about the purpose of the activity and the researcher ensured that CB understood the aims of the session. The first 20 minutes of treatment focused on reducing submental amplitude measures during rest and non-speech postures. An animated character (a component of the equipment's software) was employed to provide visual feedback to facilitate motor learning and achievement of target levels. Instructions were'I want you to make the man sit on his chair for 10 seconds. Remember, to do this you need to try and stay relaxed'. A target visual threshold, determined by the clinician and based on session behaviour, was also displayed on the computer screen to aid in task execution. If CB was unable to consistently achieve the task the target threshold was increased to ensure success and maintain motivation. Once CB demonstrated a consistent response below the threshold the threshold was then lowered. This process was repeated multiple times for all lingual and labial postures, including tongue protrusion, tongue elevation and depression, tongue lateralization, lip pursing and lip retraction.

Reliability analysis

Inter-judge reliability for F_1, F_2, AMR, CV duration and inter-syllable duration was 0.825, 0.865, 0.998, 0.987 and 0.998, respectively. Average absolute differences were 26 Hz, 92 Hz, 0.03 s, 0.05 s and 0.04 s, respectively for the same measures. Intra-judge reliability for F_1, F_2, AMR, CV duration and inter-syllable duration was 0.925, 0.947, 0.999, 0.956 and 0.964 with absolute difference values of 15 Hz, 72 Hz, 0.02 s, 0.02 s and 0.05 s for the same measures.

Statistical analysis

As the aim of the current investigation was to examine and describe changes in speech production in a single participant rather than to generalize results to a given population, visual inspection of the data was performed to examine the trends of each treatment phase [34]. The mean and standard

Table II. Mean and standard deviation (SD) of sEMG amplitudes in microvolts (μV).

	Baseline		Post-PPT		Post-sEMG	
Measures	*M*	SD	*M*	SD	*M*	SD
At rest						
Orbicularis oris at rest (L)	29.20	11.03	25.85	8.12	19.68	0.54
Orbicularis oris at rest (R)	17.91	10.66	18.02	11.05	17.10	3.67
Submental	16.22	12.97	23.22	10.25	9.85	1.48
Non-speech postures						
Lip pursing (orbicularis oris L)	–	–	72.53	5.93	38.98*	3.98
Lip pursing (orbicularis oris R)	–	–	54.21	11.00	25.66*	9.14
Tongue protrusion (submental)	–	–	43.65	14.49	13.58*	2.00

* ±1 SD from baseline measure, PPT = phonetic placement therapy, sEMG = sEMG biofeedback treatment.

deviation (SD) values for each speech parameter were calculated and are reported. Consistent with the single case intervention study of Sapir et al. [34], results were considered significant if their mean value was greater than 1 SD from the baseline value.

Results

sEMG amplitude measurements

Results of the sEMG amplitude measurements during rest and non-speech postures are displayed in Table II. Examination of sEMG amplitudes at rest indicated no significant differences across the treatment phases. However, a trend towards reduced submental amplitude was observed post-sEMG treatment. Furthermore, the SD results also reflected greater stability as evidenced by the considerably smaller SDs post-sEMG for all submental values. sEMG amplitude values were not recorded across all three baseline assessments during non-speech postures, therefore, a single baseline measure taken pre-PPT treatment was used as a baseline measure. During non-speech postures, amplitude measures significantly decreased for both the tongue protrusion and lip pursing tasks post-sEMG, when compared to those attained following PPT.

Perceptual measures

Intelligibility. Results of the AssIDS for single word intelligibility are presented in Table III. The results revealed a significant increase in single word intelligibility post-PPT that was maintained following sEMG-facilitated biofeedback.

Perceptual rating scale of Duffy [27]. Analysis revealed no change to any articulatory parameters or overall intelligibility following treatment. Imprecise consonants and overall intelligibility were rated as being severely deviant across all treatment conditions. Vowel distortions were generally judged to be markedly deviant and did not change over the duration of the treatment programme. Ratings of prolonged phonemes were maintained as mildly impaired at both the post-PPT and post-sEMG phases.

Table III. Mean and standard deviation scores for percentage intelligibility as measured on the Assessment of Intelligibility of Dysarthric Speech [24].

	Baseline		Post-PPT		Post-sEMG	
Measures	*M*	SD	*M*	SD	*M*	SD
Single word intelligibility	35.00	1.15	44.00*	0.00	44.5*	9.19

* ±1 SD from baseline measure. During post-PPT analysis, both judges attained identical single word percentage intelligibility scores resulting in a SD of 0.

Therapy outcome measures. There was no reported difference in the participant's self-perception of her speech impairment across the intervention phases. CB had moderate concern regarding her speech disorder and this did not alter with treatment.

Acoustic-articulatory measures

Vowel articulation. Results of F_1 and F_2 frequencies for three vowels, /æ/, /i/ and /u/, are presented in Table IV. The mean data indicate a significant increase in F_2 for/æ/productions post-PPT. A significant reduction in F_2 was observed for/u/ productions post-sEMG. No changes were identified for the remaining formant values.

Consonant articulation. Results revealed a significant decrease in AMR post-sEMG for/kə/only (see Table IV). Results of the CV durational measures revealed no significant differences across any of the syllables (Table V). Results of the inter-syllable gap durations revealed a significant decrease

Table IV. Mean and standard deviation (SD) of F_1 and F_2 frequencies (Hz) for vowels/æ/, /i/ and /u/.

	Baseline		Post-PPT		Post-sEMG	
Measure	*M*	SD	*M*	SD	*M*	SD
F_1 Frequency/æ/	695	82	736	147	691	274
F_2 Frequency/æ/	1369	145	1578*	196	1491	32
F_1 Frequency/i/	521	35	539	17	514	67
F_2 Frequency/i/	2023	419	2351	534	1900	383
F_1 Frequency/u/	560	111	545	81	559	60
F_2 frequency/u/	1819	248	1821	362	1291*	293

* ±1 SD from baseline measure.
For details of normal vowel production in NZ English please refer to Maclagan and Hay [36].

Table V. Mean and standard deviation (SD) of Alternative Motion Rates (AMR) (syllables per second), duration of consonant-vowel (CV) in seconds and inter-syllabic (inter-syll) gap duration in seconds.

	Baseline		Post-PPT		Post-sEMG	
Measure	*M*	SD	*M*	SD	*M*	SD
AMR						
pə	4.29	1.08	4.60	0.98	4.75	0.39
tə	3.46	1.86	5.03	1.01	4.47	0.76
kə	5.21	1.85	4.38	1.86	1.72*	0.74
CV duration						
pə	0.27	0.07	0.30	0.08	0.28	0.07
tə	0.32	0.10	0.32	0.06	0.27	0.09
kə	0.28	0.06	0.27	0.08	0.30	0.09
Inter-syll gap						
pə	0.22	0.05	0.10*	0.06	0.09*	0.03
tə	0.36	0.19	0.12*	0.04	0.14*	0.12
kə	0.18	0.04	0.17	0.08	0.19	0.12

* ±1 SD from baseline measure.

in duration for /pə/ and /tə/ following both treatments (see Table IV).

Discussion

sEMG amplitude findings

The current study revealed a non-significant trend in sEMG amplitude at rest with a concomitant reduction in variability of recording EMG activity post-treatment. This suggests that, although substantial relaxation was not achieved, CB perhaps demonstrated a pre-cursor skill of increased motor control. This is an important result as it suggests that sEMG facilitated greater consistency in lingual and labial muscle functioning, which with further training could potentially facilitate improved motor control and articulation.

Results of the non-speech postures revealed significant reductions in submental and orbicularis oris amplitudes post-sEMG treatment. Whilst sEMG reductions may represent improved lingual and labial muscle regulation they were not sufficient to result in salient perceptual changes given the severity of the speech disorder. Thus, whilst results show that sEMG treatment, as it was provided in this study, was not effective in improving articulation for a child with severe speech disorder, sEMG treatment did facilitate improved muscle control during different postures in isolation. It may be likely that articulation did not improve as non-speech learning tasks do not generalize to speech performance [32]. Therefore, speech production tasks may have provided more accurate data regarding articulation outcomes. These results are consistent with the findings of Finley et al. [15] who also reported no perceptible changes to articulation and overall intelligibility in individuals with severe speech disorder following sEMG treatment. However, it should be noted that those participants in the Finley et al. [15] study with severe speech disorder did not have speech, whereas CB used speech as her primary means of communication.

Perceptual findings

Single word intelligibility outcomes demonstrated significant increase across treatment conditions, with a significant increase at the post-PPT phase maintained post-sEMG facilitated treatment. This supports the findings of Wu and Jeng [12] that PPT improved articulation. The improvement to single word intelligibility post-PPT can be related to the stage achieved in treatment. That is, treatment progressed to the word level and a resultant improvement in single-word intelligibility was observed. The further improvement to single-word intelligibility post-sEMG treatment cannot be attributed to biofeedback alone. Indeed, it is likely that the result indicates to some extent a maintenance effect post-PPT. Both PPT and sEMG treatments provide direct instruction regarding the function of orofacial muscles, PPT focuses on muscle placement and sEMG on muscle tone, which may explain similarities in treatment outcomes for single word intelligibility. Thus, the complimentary nature of the two treatments suggests that it may be efficacious to employ both techniques in treating articulation disorders. Furthermore, in this case both treatments were effective in treating CB's articulation disorder at a single word level.

Given the improvement to single word intelligibility observed, it was surprising that ratings of articulatory impairment (specifically consonant and vowel production) did not change following treatment. However, articulation was rated during the passage reading task. In hindsight, it would appear that the task employed and the rating scale used to examine articulation was too broad to perceive change. Specifically, it is possible that if raters were asked to judge the precision of consonant and vowel articulation in a single-word context only, improved results may have been observed. Future studies of children with severe dysarthria would benefit from the examination of perceptual changes to articulation in a single-word speaking task.

Acoustic-articulatory findings

Vowel articulation. Results of the acoustic analysis of vowel articulation generally concurred with the perceptual findings with minimal changes observed across the treatment phases. The exceptions were a significant increase in F_2 frequency for /æ/ following PPT and a significant decrease in F_2 frequency for/u/ post-sEMG treatment. The increased frequency of F_2 for /æ/ post-PPT may have reflected a subtle improvement in lingual range resulting from a vocal tract constriction or stabilization [35]. Regarding the finding of a decrease in F_2 for/u/, it is possible that improved lip-rounding occurred as a result of a reduction in labial muscle hyperfunction. This supports the observation following sEMG that there was a reduction in labial muscle constriction. Given that no changes were observed perceptually it is not surprising that few changes were observed acoustically. However, future studies of children with severe dysarthria are required to examine any change during single word productions.

Consonant articulation. Acoustic analysis of the DDK tasks revealed no changes to AMR post-PPT and a significant reduction in AMR for /kə/ following sEMG treatment. As PPT targets accuracy in labial and lingual placement and does not attempt to facilitate rate of movement, the lack of change post-PPT was not surprising. However, with the reduction in labial and lingual hyperfunction observed in non-speech postures, it was anticipated that some change may be observed post-sEMG treatment. The results indicated that, even though CB was able to voluntarily reduce sEMG amplitude levels, this did not serve to increase AMR during the DDK task. Only one change was observed and this was a significant reduction in the AMR for /kə/. It is possible that this result may reflect a high degree of intra-participant variability, previously observed in the maximum repetition rates of children with SCP [4].

While duration of the CV segment did not change following either PPT or sEMG-facilitated biofeedback intervention, a significant decrease in inter-syllable gap duration for /pə/ and /tə/ productions was observed subsequent to PPT and maintained post-sEMG. As stated by Kent and Read [30], the inter-syllable gap period is associated with acoustic silence and corresponds to articulatory occlusion of either the lips or tongue. The current finding of a reduction in the period of articulatory occlusion for /pə/ and /tə/ may represent improved articulatory occlusion following treatment. PPT focused exclusively on consonants produced using anterior lingual and labial movements, and not posterior tongue placement, which may account for lack of change to inter-syllable gap duration for /kə/. Whilst sEMG treatment maintained these reductions for /pə/ and /tə/ productions, sEMG results may also be attributed to the speech tasks involved in the sEMG intervention stage. These tasks targeted anterior lingual movements such as tongue elevation and labial movements such as lip pursing. Thus, it is likely a reduction in anterior lingual and labial muscle tone contributed to these findings.

Summary and directions for future research

This preliminary case study aimed to compare the speech outcomes of phonetic placement therapy (PPT) and sEMG biofeedback-facilitated relaxation therapy in a child with SCP and severe spastic dysarthria. Single word intelligibility significantly improved following PPT with the improvements maintained following sEMG treatment for a child with severe speech disorder. sEMG-relaxation treatment indicated the occurrence of a pre-cursor skill for increased motor control. However, both treatments failed to elicit improvement in sentence or paragraph level intelligibility. The efficacy of these treatments may be better understood for a child with a less severe speech disorder and SCP. Future studies are required to further examine treatments with individuals with differing severity levels to determine efficacy across different severity levels of speech disorder. Further case studies examining a number of individuals are also required using multiple baseline designs or alternating treatment designs.

Note

1. Please note that two different biofeedback devices were employed during assessment and intervention.

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