Effects of Neuromuscular Electrical Stimulation on the Wrist and Finger Flexor Spasticity and Hand Functions in Cerebral Palsy

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ABSTRACT

PURPOSE: To evaluate the effects of neuromuscular electrical stimulation on wrist range of motion, wrist and finger flexor spasticity, and hand functions in patients with unilateral cerebral palsy. METHOD: Twenty-four children with unilateral spastic cerebral palsy (14 boys and 10 girls) between the ages of 5 and 14 years were randomized into neuromuscular electrical stimulation and control groups. Conventional exercises were applied, and static volar wrist-hand orthosis was administered to all patients 5 days a week for 6 weeks. Additionally, 30-minute neuromuscular electrical stimulation sessions were applied to the wrist extensor muscles in the neuromuscular electrical stimulation group. Patients were evaluated by Zancolli Classification System, Manual Ability Classification System, and Abilhand-Kids Test. RESULTS: Compared with baseline, a significant increase was evident in active wrist extension angle at the fourth and sixth weeks in both groups (all \( P < 0.001 \)), more prominent in the neuromuscular electrical stimulation group at the fourth and sixth weeks (\( P = 0.015 \) and \( P = 0.006 \), respectively). A decrease was observed in the spasticity values in the neuromuscular electrical stimulation group at the fourth and sixth weeks (\( P = 0.002 \) and \( P = 0.001 \), respectively) and in the control group only at the sixth week (\( P = 0.008 \)). Abilhand-Kids values improved only in the neuromuscular electrical stimulation group (\( P < 0.001 \)). CONCLUSION: Neuromuscular electrical stimulation application in addition to conventional treatments is effective in improving active wrist range of motion, spasticity, and hand functions in cerebral palsy.

Keywords: cerebral palsy, hand functions, functional electrical stimulation, spasticity

Introduction

Cerebral palsy is the most common motor disability in childhood with an incidence of two to three per 1000 live births. \(^1\) Several upper extremity problems affecting activities of daily living are observed in patients with cerebral palsy, and these problems require prolonged rehabilitation. \(^2\) In this context, neuromuscular electrical stimulation (NMES) is an alternative method used for upper extremity disorders in patients with cerebral palsy. \(^3\) It is imperative to apply the best available evidence-based interventions to children with cerebral palsy. Novak et al. \(^4\) therefore classified the interventions in cerebral palsy into three main categories, whereby NMES has been reported to have lower level/inconclusive evidence.

Regarding NMES treatment for the upper extremity functions in patients with cerebral palsy, there are only a few studies in the pertinent literature. Only use of NMES has been reported in two case reports, \(^5,6\) a pre-test and post-test design including nine children, \(^7\) a baseline-intervention follow-up study including eight children, \(^8\) and a baseline-intervention study including eight children. \(^9\) Moreover, combined use of NMES treatment and splinting have been described in case reports or series, \(^10,11\) a retrospective study comprising 19 children \(^12\) and only one randomized trial consisting 24 children. \(^13\) Xu et al. \(^3\) documented the effects of constraint-induced movement therapy and NMES in 68 children with unilateral cerebral palsy. Overall, all these studies have described useful

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effects of NMES; however, they have yielded conflicting results for a standard NMES protocol with small sample sizes. Nevertheless, the combination of splinting, NMES treatment, and conventional exercises has not been studied yet. Therefore, the aim of this study was to investigate the effects of the combination of NMES, conventional rehabilitation program, and splinting on wrist and finger flexor spasticity, wrist extension, and hand functions of patients with spastic cerebral palsy.

**Methods**

**Patients**

Twenty-four unilateral cerebral palsy children (14 boys and 10 girls) with wrist and finger flexor spasticity who underwent inpatient rehabilitation were included in this study. Patients who had concomitant sight/hearing disorders, previous history of hand surgery or contracture in upper extremities, and dependent sitting balance were excluded. Informed consent was obtained from each patient’s parents, and the study protocol was approved by the local ethics committee.

**Study protocol and design**

The patients were randomized into NMES and control groups. Conventional exercises and occupational therapy were applied, and static volar wrist-hand orthosis was administered to each patient 5 days a week for 6 weeks. Additionally, 30-minute NMES sessions were applied to wrist and finger extensor muscles of the patients only in the NMES group.

**NMES protocol**

A NMES device with a stimulator (SAMMS Mod. Professional; BEAC Bio-Medical, Italy) and two surface electrodes that have properties of adjustable on-off stimulation loop, stimulation density, and stimulation start and end were used. Electrical stimulation was applied with a tolerable and comfortable density (10-25 mA) and a pulse width of 300 μseconds, frequency of 30 Hz, an on-time of 12 seconds (includes a ramp-up of 1 second and a ramp-down of 1 second/an off-time of 5 seconds). To achieve maximum contraction of wrist and fingers, NMES was applied because the children were in a sitting position with their elbow, forearm, and hands in 90° of flexion, pronation, and neutral position, respectively. An inactive electrode was placed on the dorsal side of the wrist and an active electrode was placed on forearm’s lateral side under the elbow. The same physiatrist (M.T.Y.) applied the NMES to all patients.

**Neurophysiologic/conventional exercises**

The conventional rehabilitation program consisted of neurophysiologic exercises using Bobath approach; active/passive range of motion (ROM) and stretching exercises were applied to all patients five times a week for 6 weeks (each session of 20-30 minutes).

**Assessment/classification tests**

All patients were evaluated before the beginning (baseline) and at the end of the third, fourth, and sixth weeks of the treatment. At each evaluation, active wrist extension, wrist and finger flexor spasticity, and hand functions were assessed. The affected side active wrist extension was measured using a goniometer after asking the patient to extend his/her wrist as much as he/she could do when the elbow was in 90° flexion and forearm was in pronation. The wrist and finger spasticity were rated by Zancolli Classification system in which hand grabbing and releasing functions were classified (Table 1).

To evaluate the hand’s functional activities and skills, five of six components of Jebsen Hand Function Test (JHFT, except for eating with a spoon simulation) were used. JHFT is a test measuring the time (seconds) spent on daily activities. In our study, children were tested while sitting comfortably around a table. The same test was performed three times, and the mean duration was recorded. The maximal time allowed to complete each subtest was 120 seconds. The following five subtests were performed:

1. Turning over five cards (12.7 × 7.5 cm)
2. Picking up small common objects (two paper clips, two coins and crown caps)
3. Stacking four checkers
4. Picking up and displacing five large light cans
5. Picking up and displacing five large heavy cans.

Moreover, patients were classified by Manual Ability Classification System, and they were assessed by Abilhand-Kids test. Abilhand-Kids test is a valid and reliable test to evaluate hand skills in children with upper extremity involvement. This test was completed by interviewing with the mothers of the patients at baseline and after sixth week of the treatment.

**Statistical analysis**

SPSS for Windows 11.5 program was used for statistical analysis. Shapiro-Wilk test was used to determine if the continuous variables were normally distributed. Descriptive statistics are indicated as mean ± standard deviation or median (minimum-maximum). Student t or Mann-Whitney U test (for continuous variables) and Pearson chi-square or Fisher exact test (for categorical variables) were used for the measurements between the groups, where appropriate. Mean or median values of the repetitive measurements within each group were calculated using two-way (for continuous variables) and Fisher exact test (for categorical variables). A P value of < 0.05 was considered statistically significant.

**Results**

The demographic and clinical features of the patients are given in Table 2. Age, sex, involved side, Manual Ability Classification System levels and baseline values of Zancolli spasticity, JHFT periods, and Abilhand-Kids levels were similar between the groups (all P > 0.05). Both groups’ changes in active wrist extension angles after the treatment are illustrated in Fig 1. Compared with baseline values, active wrist extension angle was increased in both groups at the fourth and sixth weeks (both P < 0.001), more prominent in the NMES group (P = 0.015 and P = 0.006, respectively).

Fig 2 displays the median Zancolli spasticity values of the patients. Compared with the baseline values, a decrease was observed in the NMES group at the fourth (P = 0.002) and sixth (P = 0.001) weeks and in the control group only at the sixth week (P = 0.008). The decrease levels according to the baseline values were significantly higher in the NMES group.

**Table 1. Zancolli Classification**

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>Complete finger extension when the wrist is in neutral position or less than 20° flexion</td>
</tr>
<tr>
<td>Type IIA</td>
<td>Active wrist extension when the fingers are in more than 20° flexion</td>
</tr>
<tr>
<td>Type IIB</td>
<td>No active wrist extension when the fingers are flexed</td>
</tr>
<tr>
<td>Type III</td>
<td>No active finger extension when the wrist is in maximum flexion</td>
</tr>
</tbody>
</table>
than the control group at the fourth \((P = 0.001)\) and sixth \((P = 0.016)\) weeks. Although all patients indicated improvement in Zancolli stages in the NMES group, five of 12 patients stayed at the same Zancolli stage in the control group. Zancolli stages changed from IIB to IIA (\(n = 4\)), from IIB to I (\(n = 2\)), and from IIA to I (\(n = 6\)) with NMES treatment. In the control group, one patient improved from III to IIB and six patients improved from IIB to IIA, whereas four patients stayed as IIA and one patient as IIB.

Abilhand-Kids values of the groups are depicted in Fig 3. Although the Abilhand-Kids values increased in both groups, it reached significantly only in the NMES group \((P = 0.002)\). There was improvement in JHFT times in both groups; however, this improvement was not statistically significant (all \(P > 0.05\)). Besides, there were no significant differences between the groups regarding time changes (all \(P > 0.017\)).

### Discussion

In this study, we aimed to explore whether NMES treatment had an additional effect on rehabilitative treatment methods in children with cerebral palsy. Our results demonstrate that NMES treatment applied for at least 6 weeks in addition to conventional rehabilitation program and splinting had favorable effects on spasticity, wrist extension, and hand functions for the first time in the literature.

Novak et al.\(^4\) have categorized the 64 discrete interventions in cerebral palsy into three lights (green, yellow, and red) according to “traffic light system.” Effective interventions (24%) have been described as green and interventions that have uncertain effects (70%) have been described as yellow. Furthermore, interventions proven to be ineffective (6%) have been described as red. NMES treatment, neurophysiologic exercises, and splinting that we used in our study have been categorized under yellow lights.

According to our results, the increases in wrist extension after the 6 weeks were 34.6° (NMES group) and 16.7° (control group). These findings demonstrated that the NMES group had indicated more improvement than the control group. Improvement of the wrist extension values in the control group was similar to that of the results of the study conducted by Kamper et al.\(^9\). Kamper et al.\(^9\) reported that NMES treatment applied to seven patients with unilateral cerebral palsy (aged between 5 and 15 years) for 3 months indicated an improvement in wrist extension angle (14° at 6 weeks and 38° at 3 months). Increased active wrist extension after 6-week NMES treatment (about 10°) and decreased spasticity after 6-week NMES treatment applied to wrist extenders have also been reported.\(^5\) Our findings and those of the aforementioned studies revealed that NMES treatment is more effective in increasing the ROM when it is combined with exercise and orthosis. Additionally, the effects of NMES were observed after 4 weeks of treatment.

NMES stimulates an agonist muscle contraction and inhibits the antagonist spastic muscle via the reflex arc. It also provides muscle re-education and strengthening without any significant side effects.\(^8,9,13,19\) In this regard, NMES is a convenient application used for reducing spasticity, and it has been used in several studies.\(^8,9,13,19\)

In a study whereby the effects of a 5-week NMES treatment in 12 patients with hemiplegic cerebral palsy were evaluated, it has been revealed that Zancolli stages changed from IIA to I in seven patients and from IIB to I in five patients.\(^15\) In another study (retrospective) in 19 patients with cerebral palsy, all patients’ Zancolli stages improved one to three levels after the NMES treatment and a dynamic orthosis.\(^12\) Ozer et al.\(^13\) randomized 24 patients with hemiplegic cerebral palsy into only NMES treatment, only orthosis, or NMES plus orthosis treatment groups. After 6 months of follow-up, NMES plus orthosis combination was found to be more effective than the others. In our study, Zancolli stages changed from IIB to IIA (\(n = 4\)), from IIB to I (\(n = 2\)), and from IIA to I (\(n = 6\)) with NMES treatment. According to our results, in the

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**TABLE 2. Demographic and Baseline Clinical Characteristics of the Patients**

<table>
<thead>
<tr>
<th>Variable</th>
<th>NMES Group ((N = 12))</th>
<th>Control Group ((N = 12))</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>8.2 ± 2.2</td>
<td>7.4 ± 2.6</td>
<td>0.455</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>7/5</td>
<td>7/5</td>
<td>1.000</td>
</tr>
<tr>
<td>Involved side (R/L)</td>
<td>6/6</td>
<td>5/7</td>
<td>0.682</td>
</tr>
<tr>
<td>Active wrist extension angle</td>
<td>27.5 ± 17.1</td>
<td>16.2 ± 14.3</td>
<td>0.095</td>
</tr>
<tr>
<td>Zancolli spasticity values</td>
<td>2 (1-3)</td>
<td>3 (2-4)</td>
<td>0.207</td>
</tr>
<tr>
<td>MACS values</td>
<td>3 (2-5)</td>
<td>3 (2-5)</td>
<td>0.974</td>
</tr>
<tr>
<td>Abilhand-Kids values</td>
<td>8.4 ± 2.5</td>
<td>7.7 ± 4.4</td>
<td>0.266</td>
</tr>
</tbody>
</table>

**Abbreviations:**

- \(F\) = Female
- \(M\) = Male
- \(L\) = Left
- \(R\) = Right
- \(MACS\) = Manual Ability Classification System
- \(NMES\) = Neuromuscular electrical stimulation

The values are given in mean ± SD, n, or median (minimum–maximum).
control group, one patient improved from III to IIB and six patients improved from IIB to IIA, whereas four patients stayed as IIA and one patient as IIB. Moreover, Zancolli values were found to be lower in the NMES group than in the control group on the fourth week and thereafter. Consequently, the improvement in Zancolli values was observed earlier and better when NMES treatment was combined with exercise and orthosis. Thus, we imply that NMES treatment in addition to conventional rehabilitation and static orthosis decreases the children’s hand spasticity.

Wright et al. applied NMES treatment to upper extremities and evaluated the efficiency by three subtests of JHFT (turning over cards, stacking checkers, and the six-object picking up test). The lowest improvement was observed in six-object picking up test. In our study, we used five subtests of JHFT. Eating with a spoon was excluded because it took too much time to concentrate children on simulating eating. At the end of the treatment, there was improvement in time spent on completing JHFT in both groups; yet this improvement was not statistically significant. We could attribute this to the wide range of impaired hand functions in cerebral palsy. The lack of writing task is one of the limitations in our study.

A recent study including 101 children with cerebral palsy concludes that the presence of hand deformities does not have a direct relationship with hand abilities. Clinicians should evaluate hand abilities apart from hand deformities. The Abilhand-Kids test could be used to evaluate manual ability for children with upper limb impairments. In this regard, we used Abilhand-Kids to evaluate the children’s hand abilities. Abilhand-Kids values increased after the treatment only in the NMES group. On the other hand, lack of bimanual performance assessment is a limitation of our study.

We have some limitations in our study. First, although our sample size is comparable to previous studies, the sample size could be larger. Second, children could be monitored longer than 6 weeks to better characterize the longer effects of NMES. Lack of only NMES treatment group and/or only orthosis group is a limitation of our study as well. The present study could be performed in a crossover design.

Conclusion

In light of our results, NMES treatment in addition to splinting and conventional exercises seems to be effective in improving active ROM, spasticity, and hand functions. Further studies should utilize a larger sample size including a crossover design and the effects of NMES along with other treatment modalities such as botulinum toxin

References

7. Vaz DV, Mancini MC, da Fonseca ST, et al. Effects of strength training aided by electrical stimulation on wrist muscle characteristics and

“In my experience” is a phrase that usually introduces a statement of rank prejudice or bias. The information that follows cannot be checked, nor has it been subjected to any analysis other than some vague tally in the speaker’s memory.

Michael Crichton, 1971