Effects of Strength Training Aided by Electrical Stimulation on Wrist Muscle Characteristics and Hand Function of Children with Hemiplegic Cerebral Palsy

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ABSTRACT. Nine children with spastic hemiplegic cerebral palsy underwent 24 sessions of wrist muscles strengthening in the extended wrist range aided by electrostimulation. Isometric strength of flexors and extensors was registered in three wrist positions (30° of flexion, neutral, and 30° of extension) to infer on angle–torque curves. Passive stiffness...
of wrist flexors and wrist flexion angle during manual tasks and hand function were also documented. Significant strength gains were observed at 30° of wrist extension for flexors ($p = 0.029$) and extensors ($p = 0.024$). No gains were observed at 30° of flexion. The difference in extensor strength between the three test positions changed after intervention ($p < 0.034$), suggesting a shift in the angle–torque curve. No changes were observed in passive stiffness ($p = 0.506$), wrist angle ($p < 0.586$), or hand function ($p = 0.525$). Strength training in specific joint ranges may alter angle–torque relationships. For functional gains to be observed, however, a more aggressive intervention and contextualized task training would probably be needed.

**KEYWORDS.** Hemiplegic cerebral palsy, wrist, strength, passive stiffness, hand function

Functional movement patterns are currently understood as resulting from the interaction of the many resources available to the organism in face of task demands and environmental conditions (Fonseca, Holt, Fetters, & Saltzman, 2004; Holt, Obusek, & Fonseca, 1996). According to this view, atypical motor patterns as those seen in cerebral palsy (CP) should not be considered pathological but rather adaptive to a primary disorder that changes the intrinsic resources of the organism (Holt et al., 1996; Latash & Anson, 1996). This notion has led to the idea that therapeutic approaches should intervene directly the altered resources which entail compensatory movement strategies instead of trying to “normalize” the movement pattern itself (Holt et al., 1996).

In this context, the contribution of biomechanical variables to motor performance of children with CP has been increasingly recognized (Holt, Butcher, & Fonseca, 2000; Holt, Fonseca, & LaFiandra, 2000). Among other factors, muscle weakness has been pointed out as a significant primary deficit related to the motor behaviors observed in patients with neurological disorders (Gowland, deBruin, Basmajian, Plews, & Burcea, 1992). Altered movement patterns, in turn, can influence the use of available resources, establishing a relationship of interdependency. Some studies demonstrate adaptations of muscles to atypical patterns of limb use in children with CP, with alterations in the angle–torque relationships (Tardieu, Huet, Bret, & Tardieu, 1982; Brouwer, Wheeldon, Stradiotto-Parker, & Allum, 1998; Vaz, Mancini, Fonseca, Vieira, & Pertence, 2006) and increases in passive muscle stiffness (Vaz et al., 2006; Friden &
Lieber, 2003). During development, these alterations in biomechanical properties can constrain performance, favoring the use of specific atypical patterns, possibly contributing to functional limitations. Thus, intervention with a focus on changing resources necessary for functional movements could be a way to promote the fit between the organism’s capabilities and task demands, which may result in improvement in children’s performance.

According to Vaz et al. (2006), children with hemiplegic CP demonstrate signs of tissue remodeling that are coherent with the wrist flexion pattern observed during manual activities, which maintains flexors and extensors in shortened and extended positions, respectively. The authors observed decreased strength of wrist flexors and extensors with the wrist in extension, possibly reflecting shifts in the length–tension relationships due to functioning in altered muscle lengths, and excessive passive stiffness of flexors, probably due to the maintenance of this muscle group in shortened positions (Vaz et al., 2006). These characteristics could hinder the use of the wrist in extended movement amplitudes in children with CP, and contribute to the observed posture of their upper limbs and to their functional limitations. In fact, weakness of extensors in the extended wrist position and increased flexor stiffness were associated with poorer manual function (Vaz et al., 2006).

Interventions aimed at modifying muscle characteristics associated with hand dysfunction, through the facilitation of wrist extension, could promote improvements in hand function of children with CP. Koh (1995) suggested that resisted exercises in specific muscle lengths can increase or decrease the number of series sarcomeres, that is, it can cause specific muscle remodeling which enables muscles to respond to the new demands of tension generation. Experimental evidence to support such a hypothesis has been provided by studies with animals. Muscular activity in lengthened positions has been shown to produce increased muscle excursion associated with an increase in the number of series sarcomeres (Koh & Herzog, 1998). On the other hand, reductions in the number of series sarcomeres and shifts of the length–tension curve to the left were observed after electrical stimulation in shortened muscle lengths (Williams, Catanese, Lucey, & Goldspink, 1988). Accordingly, strengthening exercises for wrist flexors and extensors in extended wrist amplitudes may promote improvements of strength in extended wrist positions through muscle tissue remodeling (shifts in the length–tension relationship) as well as neural adaptation. Furthermore, these exercises can decrease passive flexor stiffness due to an increase in the number of series sarcomeres. However, to date, the clinical application of such reasoning to rehabilitation in children remains
as a hypothesis to be investigated. Evidence in support of this argument may help the development of new intervention approaches for children with CP.

The objectives of this study were to evaluate the effects of resisted exercises aided by functional electrostimulation for wrist flexors and extensors in extended wrist positions on: (i) the strength of flexors and extensors in three wrist positions (30° of flexion, neutral, and 30° of extension), (ii) the passive stiffness of wrist flexors, (iii) wrist position during functional movement, and (iv) hand function of children with hemiplegic CP.

METHODS

Participants

The experimental setup consisted of a pretest/posttest design involving nine children with spastic hemiplegic CP, (five females; five left hemiplegia; mean age: 9 years 1 month, SD: 1 year 6 months, range: 7–11 years). Children used the wrist predominantly in flexion during manual activities, although they were able to actively extend the wrist and fingers at least 30° from the resting position. The affected hand participated in daily activities as an assist to the non-affected hand, with reduced quality and speed of movement to grasp and release objects. According to the manual ability classification system (Eliasson et al., 2006), eight children were classified as level II and one as level I. Exclusion criteria included: current participation in a rehabilitation program, more than 10° of limitation in passive wrist extension, history of medical or surgical interventions for the upper limb and associated pathologies. The Federal University of Minas Gerais Ethics Review Committee approved the study’s procedures and parents signed a consent form.

Instrumentation and Procedures

All measures used in this study were subjected to reliability analyses. Intraclass correlation coefficients (ICCs) were obtained from pilot study data in which all children were assessed two times, with measures taken 1 week apart.

After measures of body mass (ICC = 0.99) and affected hand length (Jensen, 1986) (ICC = 0.91), isometric strength tests of wrist flexors and extensors were performed at three wrist positions: neutral position, 30° of flexion, and 30° of extension. Test order was randomized and repeated for each child after intervention. A device for upper limb stabilization was used
FIGURE 1. Device for stabilization of the upper extremity and positioning of the dynamometer during isometric strength tests of wrist flexors and extensors.

for tests. The child was sitting and had the hand fastened with Velcro straps against a flat support that could be moved 180° around its axis, which was aligned with the wrist axis (Figure 1). The hand support was positioned against the palm for tests of flexors and against the dorsum of the hand for extensor testing. The child was asked to exert a maximum effort to flex or extend the wrist while the examiner resisted motion with a Microfet-2 dynamometer (Hoggan Health Industries, West Jordan, USA) positioned against the support, always in the same area identified by a marker. Only one maximum isometric contraction of 5 s was performed in each position due to the high level of agreement observed between three measurements in the same position in the pilot study (ICCs: 0.93–0.98). Children rested for 1 min between contractions. Force values (N) read in the dynamometer were multiplied by the length of the lever arm of the support device (0.095 m) and normalized by hand length (ICCs: 0.81–0.93, according to muscle group and position tested).

A Biodex System 3 Pro isokinetic dynamometer (Biodex Medical System, New York, USA) was used in association with electromyographic (EMG) monitoring (MP100 unit, Biopac Systems, Goleta, USA) of wrist flexors and extensors for flexor passive stiffness assessments. Active surface electrodes were positioned over both muscle groups after cleaning
the skin with alcohol. A reference electrode was placed on the acromion. Positioning is illustrated in Figure 2. Elastic bands were strapped to the arm and forearm to stabilize the hand palm and extended fingers against a metal plate attached to the lever arm of the dynamometer.

With the child resting quietly, EMG baseline data for flexors and extensors were collected in a frequency of 1000 Hz, 10-Hz highpass and 500-Hz lowpass fourth-order Butterworth filtered and rectified. To eliminate the effects of tissue viscoelastic accommodation on test results, 10 passive movement repetitions of maximum wrist flexion and extension at 10 deg/s were performed before the actual stiffness test. The test was performed at 5 deg/s to avoid eliciting the stretch reflex. To assure that measures referred to tissue passive stiffness, test trials were discarded if EMG mean activity 2SD larger than baseline values were registered in one or more periods of 250 ms of the test signal (Lamontagne, Malouin, & Richards, 2000). The procedure was interrupted when three successful repetitions had been obtained.

Resistance torques registered from 0° to 60° of wrist extension were treated with a fourth-order Butterworth filter with a low cut-off (1.25 Hz) and considered for the calculation of flexors passive stiffness. Body mass,
age, and hand length were considered in a biomechanical model used to estimate the torques generated by the weight of hand (Jensen, 1986). Torques generated by the hand and the metal plate were deducted from the torques registered by the dynamometer. Resulting resistance torque was considered to be produced by the soft tissues. Simple regression analyses between joint angles and soft tissues resistance torques were performed for each of the three successful trials. Passive flexors stiffness was calculated as the mean of the three regression slopes (Nm/rad) (ICC = 0.96).

Three tasks based on the Jebsen–Taylor Hand Function Test (Taylor, Sand, & Jebsen, 1973) were used to assess manual dexterity. Adaptation of the tasks was necessary because they were too difficult for some of the children to complete. For the first task, larger objects were used. Instead of picking up two coins, two paper clips, and two regular pencils, children picked up two thicker pencils, two correction fluid bottles, and two erasers and put them in a can. The second task was not modified from the original test and consisted of stacking four wooden checkers. The third task involved picking up five round containers. The containers were smaller in diameter (diameter: 4.8 cm, height: 10.6 cm) than the cans used in the original test (diameter: 7.4 cm, height: 8.0 cm) to facilitate prehension. Children had to place the containers on a board on the table. Children were instructed to complete each task as fast as possible. They were allowed a maximum time of 40 s to complete each task (Wright & Granat, 2000). Hand function score was calculated as the sum of the time (in seconds) spent in each task (ICC = 0.98).

Wrist angle during manual activities was obtained from three-dimensional position data captured with the Qualysis ProReflex MCU movement analysis system (Qualisys Medical AB, 411 12 Gothenburg, Sweden) while each child picked up a correction fluid bottle, a wooden checker, and a round container. Reflective markers were positioned on the second and fifth metacarpal heads, bilaterally on the wrist joint line, on the middle portion of the forearm, on the lateral epicondyle, middle and lateral upper portion of the arm, and on the acromion. Data were collected at a rate of 120 Hz. The beginning and the end of each manual activity were defined as the moment after initiation of movement when the marker of the second metacarpal head reached a predetermined distance from the object to be grasped. The software Visual 3D (C-Motion Inc., Rockville, MD, USA) was used to define a separate coordinate system for each segment of the upper limb, from which the mean wrist angle used during each activity was calculated.

The intervention protocol started 1 week after initial assessments and was comprised of three weekly sessions of resisted exercises performed
in the extended wrist range for flexors and extensors for 8 weeks (24 sessions). A two-channel functional FESMED electrostimulator (CARCI, São Paulo, Brazil) was used as an adjunct stimulus to facilitate muscle contractions. Optimum electrode positioning was determined before the beginning of each session according to maximum flexion and extension responses. Electrodes were placed over the bulk of flexors and extensors and distally next to the wrist. Intensity was increased gradually according to tolerance, until visible contractions producing movement were obtained. Current was set at 300 $\mu$s pulse width, frequency of 30 pps, rise and decay time of 3 s, and ON time of 5 s (Carmick, 1993). Current was alternated between muscle groups, with a duty cycle of 1:3. Physical therapists offered graded manual resistance against wrist flexion and extension in extended wrist ranges according to each child’s capability. The objective was to always offer the maximal resistance the child was capable of overcoming. Children were encouraged to compete with the therapist by moving the wrist forcefully against resistance in both movement directions during the application of current, and always increasing maximal extension achieved. Movement was not allowed to occur past neutral in flexion ranges. Final measures were performed 1 week after the last intervention session in order to minimize the influence of possible transient effects of treatment on study results.

**Statistical Analysis**

After analysis of normality of data distribution, paired $t$-tests were used to compare muscle strength, passive stiffness of flexors, wrist angle during manual activities, and hand function scores before and after intervention. Analyses of variance (ANOVAs) with one repeated measure were used to compare strength values between test positions for flexors and extensors in each assessment moment (before and after intervention). Significance level was set at 0.05.

**RESULTS**

Paired $t$-tests revealed increased strength of extensors in the extended ($p = 0.024$) and neutral ($p = 0.013$) wrist positions after intervention. No significant increase in extensor strength was observed in the flexed position ($p = 0.548$). Wrist flexors demonstrated increased strength only in the extended wrist position ($p = 0.029$). Differences in the neutral ($p = 0.223$) and flexed ($p = 0.071$) positions before and after intervention were
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FIGURE 3. Means and 95% confidence intervals for wrist extensor strength. ○, wrist extended 30°; □, neutral wrist; ×, wrist flexed 30°; *, significant gains after intervention, compared to the same position before intervention; a, b, c, and d, same letters indicate nonsignificant difference between positions, different letters indicate significant differences between positions.

Before intervention, repeated measures ANOVA revealed significantly lower strength with the wrist at 30° of extension in comparison with the other two test positions for extensors (p < 0.001) and flexors (p < 0.005).

not significant for wrist flexors. These results are illustrated in Figures 3 and 4.

Before intervention, repeated measures ANOVA revealed significantly lower strength with the wrist at 30° of extension in comparison with the other two test positions for extensors (p < 0.001) and flexors (p < 0.005).
FIGURE 4. Means and 95% confidence intervals for wrist flexor strength. ○, wrist extended 30°; □, neutral wrist; ×, wrist flexed 30°; *, significant gains after intervention, compared to the same position before intervention; a, b, c, and d, same letters indicate nonsignificant difference between positions, different letters indicate significant differences between positions.

No differences between 30° of flexion and neutral were observed for flexors ($p = 0.30$) or extensors ($p = 0.37$). After intervention, extensors strength at neutral was significantly higher than at 30° of flexion ($p = 0.034$) and 30° of extension ($p = 0.001$). Extensor strength at 30° of extension was still lower than at 30° of flexion, with the difference approaching significance.
TABLE 1. Strength Results (N) in Different Test Positions

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Comparisons Between Wrist Positions</th>
<th>Before Intervention Difference Between Means (95% CI), p-Value</th>
<th>After Intervention Difference Between Means (95% CI), p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensors</td>
<td>30° of extension vs. neutral</td>
<td>11.86 (5.52, 18.19), p = 0.001</td>
<td>12.86 (9.63, 16.09), p = 0.001</td>
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<td></td>
<td>30° of extension vs. 30° of flexion</td>
<td>9.11 (4.16, 14.06), p = 0.007</td>
<td>6.08 (−2.98, 15.15), p = 0.054</td>
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<td></td>
<td>30° of flexion vs. neutral</td>
<td>2.74 (−6.03, 11.52), p = 0.370</td>
<td>6.77 (0.13, 13.42), p = 0.034</td>
</tr>
<tr>
<td>Flexors</td>
<td>30° of extension vs. neutral</td>
<td>16.13 (4.17, 28.10), p = 0.005</td>
<td>10.86 (5.92, 15.81), p = 0.016</td>
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<td></td>
<td>30° of extension vs. 30° of flexion</td>
<td>21.50 (8.51, 34.50), p = 0.001</td>
<td>17.97 (7.84, 28.09), p = 0.001</td>
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<td>30° of flexion vs. Neutral</td>
<td>5.36 (−4.37, 15.11), p = 0.303</td>
<td>7.10 (−4.61, 18.81), p = 0.100</td>
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</table>

95% CI: 95% confidence interval for means.

(p = 0.054). Flexors demonstrated the same differences between positions observed before intervention, with decreased strength at 30° of extension (p < 0.016) compared to the other two test positions and no differences between neutral and 30° of flexion (p = 0.100). Results of comparisons between test positions can be found in Table 1 and Figures 3 and 4.

After intervention, no significant differences were observed for passive stiffness of wrist flexors (p = 0.506), hand function (p = 0.525), or mean wrist angle during the three manual tasks (p < 0.586).

Means, standard deviations, confidence intervals, and significance values for all before and after comparisons can be found in Tables 2 and 3.

DISCUSSION

After the intervention protocol, children with hemiplegic CP demonstrated increases in strength with the wrist in extended position for both extensors and flexors. Wrist extensors also demonstrated increases in strength at the neutral position. These gains are consistent with the study hypothesis of specific gains in extended wrist positions after specific training. Before intervention, the highest wrist extensors torque values were produced at 30° of flexion and neutral, possibly reflecting shifts in the length–tension relationships due to functioning in altered muscle lengths (Vaz et al., 2006).
TABLE 2. Means, Standard Deviations, and 95% Confidence Intervals for Muscle Strength (N)

<table>
<thead>
<tr>
<th>Muscle Group and Wrist Position</th>
<th>Before Intervention Mean ± SD (95% CI)</th>
<th>After Intervention Mean ± SD (95% CI)</th>
<th>Difference Between Means (95% CI), p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensors, wrist extended 30°</td>
<td>7.37 ± 3.07 (5.01, 9.74)</td>
<td>13.11 ± 7.53 (7.32, 18.90)</td>
<td>5.73 (0.96, 10.50), p = 0.024</td>
</tr>
<tr>
<td>Extensors, wrist at neutral</td>
<td>19.23 ± 9.77 (11.72, 26.75)</td>
<td>25.97 ± 7.99 (19.82, 32.12)</td>
<td>6.74 (1.81, 11.66), p = 0.0135</td>
</tr>
<tr>
<td>Extensors, wrist flexed 30°</td>
<td>16.49 ± 7.55 (10.68, 22.29)</td>
<td>19.19 ± 13.87 (8.53, 29.86)</td>
<td>2.70 (−7.25, 12.66), p = 0.548</td>
</tr>
<tr>
<td>Flexors, wrist extended 30°</td>
<td>31.02 ± 13.89 (20.35, 41.70)</td>
<td>42.01 ± 14.70 (30.70, 53.31)</td>
<td>10.98 (1.42, 20.54), p = 0.029</td>
</tr>
<tr>
<td>Flexors, wrist at neutral</td>
<td>47.16 ± 20.61 (31.31, 63.01)</td>
<td>52.87 ± 17.08 (39.74, 66.01)</td>
<td>5.71 (−4.26, 15.69), p = 0.223</td>
</tr>
<tr>
<td>Flexors, wrist flexed 30°</td>
<td>52.53 ± 16.37 (39.95, 65.11)</td>
<td>59.98 ± 9.80 (52.44, 67.52)</td>
<td>7.44 (−0.82, 15.71), p = 0.071</td>
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</table>

SD: standard deviation, 95% CI: 95% confidence interval for means.
TABLE 3. Means, Standard Deviations, and 95% Confidence Intervals for Flexors Stiffness, Wrist Flexion Angle, and Hand Function

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Intervention</th>
<th></th>
<th>After Intervention</th>
<th></th>
<th>Difference Between Means (95% CI), p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD (95% CI)</td>
<td></td>
<td>Mean ± SD (95% CI)</td>
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<tr>
<td>Flexors stiffness (Nm/rad)</td>
<td>0.30 ± 0.19 (0.15, 0.45)</td>
<td></td>
<td>0.24 ± 0.30 (0.01, 0.48)</td>
<td></td>
<td>−0.06 (−0.24, 0.13), p = 0.506</td>
</tr>
<tr>
<td>Wrist flexion angle, Task 1</td>
<td>22.80 ± 18.87 (8.29, 37.31)</td>
<td></td>
<td>20.05 ± 14.20 (9.14, 30.97)</td>
<td></td>
<td>−2.74 (−13.91, 8.42), p = 0.586</td>
</tr>
<tr>
<td>Wrist flexion angle, Task 2</td>
<td>19.34 ± 27.25 (−1.59, 40.29)</td>
<td></td>
<td>17.80 ± 19.50 (2.81, 32.79)</td>
<td></td>
<td>−1.54 (−14.88, 11.79), p = 0.797</td>
</tr>
<tr>
<td>Wrist flexion angle, Task 3</td>
<td>27.01 ± 18.30 (12.94, 41.08)</td>
<td></td>
<td>25.51 ± 16.19 (13.05, 37.96)</td>
<td></td>
<td>−1.50 (−15.26, 12.26), p = 0.808</td>
</tr>
<tr>
<td>Hand function (s)</td>
<td>59.98 ± 20.26 (44.41, 75.56)</td>
<td></td>
<td>58.46 ± 21.11 (42.23, 74.69)</td>
<td></td>
<td>−1.51 (−6.78, 3.75), p = 0.525</td>
</tr>
</tbody>
</table>

SD: standard deviation, 95% CI: 95% confidence interval for means, Task 1: picking up objects and putting in a can, Task 2: stacking four checkers, Task 3: picking up five round containers.
After intervention, extensors produced the highest torque values at the neutral position. These modifications in torque production over different angles suggest a probable shift of the wrist extensor length–tension curve to the left, favoring production of greater tension in more shortened muscle positions. The area of peak torque in the extensors’ angle–torque curve may have moved away from flexed positions to become more centralized around the neutral wrist position, and this would explain the significant inferior strength values in the flexed position compared to neutral after intervention, in opposition to nonsignificant differences between the two positions before intervention. This effect is in accordance with that expected after resisted training in shortened lengths (Koh, 1995).

No changes in passive stiffness or in the difference in strength between test positions were observed for wrist flexors. Before and after intervention, flexors produced less torque with the wrist extended compared to other test positions, in accordance to previous findings, possibly due to tissue remodeling (Vaz et al., 2006). This result can be associated with the presence of histological alterations more severe in flexors such as increased variability in fiber length with significantly smaller fiber sizes when compared to extensors (Ponten, Friden, Thornell, & Lieber, 2005). Wrist flexors of children with hemiplegic CP would probably need more aggressive or prolonged intervention protocols in order to produce changes in characteristics such as passive stiffness and/or angle–torque relationship.

Lower limb strength is correlated to gross motor function (Damiano & Abel, 1998) and improvements in motor function are documented after strength training in children with CP (Dodd, Taylor, & Damiano, 2002). However, despite the observed increases in wrist extensors strength at 30° of extension after intervention, there were no concomitant improvements in hand function scores. Time to complete manual tasks may not have changed because alterations in muscle characteristics were probably not sufficiently expressive. Wrist flexor stiffness did not decrease and strength gains of wrist extensors may not have been enough to allow these muscles to produce sufficient torque at the extended position and support functional wrist extension. Additionally, although the difference between flexed and extended wrist positions did not reach significance, mean extensor strength in a flexed wrist position was still higher than in an extended position after intervention (Table 1). Therefore, wrist position during functional activities was not modified to a more extended position. After intervention, children with hemiplegic CP continued to use the wrist in an average position of 21° of flexion. Studies that document the effects of muscle training provide evidence for a change in angular position of the ankle (more dorsiflexion) after electrical stimulation (Comeaux, Patterson, Rubin, & Meiner, 1997) and

of the knee (more extension in crouch gait) after quadriceps strengthening (Damiano, Kelly, & Vaughan, 1995). Additionally, a study by Wright and Granat (2000) documented significant gains in hand function after electrical stimulation applied daily to the wrist extensors for 6 weeks. Therefore, it is possible that more aggressive or prolonged intervention could have caused more consistent changes in muscle characteristics, wrist angle during movement, and hand function. Future studies with longer follow-ups could address this hypothesis.

The lack of effects of an intervention aimed at modifying muscle characteristics on movement patterns and functional skills demonstrated by results of the present study can also be interpreted in light of contemporary approaches to motor learning, that point to the specificity of motor training interventions (Carr & Shepherd, 1998). Performance improvement is most pronounced in the specific movements trained (Morrissey, Harman, & Johnson, 1995), in the case of this study, isolated flexion and extension of the wrist. Although resolution or amelioration of primary deficits such as weakness would be essential to decrease the need for adaptive movement patterns (Latash & Anson, 1996), intervention at the level of impairments alone may not be sufficient to cause significant modifications in the final motor pattern. Evidence indicates that a direct relationship between impairment and activity levels is not always present, meaning that minimization of impairments do not lead unequivocally to improvements in functional performance (Case-Smith, 1995). Although children demonstrated increased extensors strength at the neutral and extended wrist positions, in order for these gains to be generalized to functional skills, additional specific task training would probably be needed. Children with hemiplegic CP would have to be given the opportunity to explore the newly acquired resources (i.e., increased wrist extensors strength at extended wrist positions) in the context of a specific task (i.e., with specific hand function training, such as that advocated in constraint-induced movement training, for example) for a modification of movement patterns and an improvement in performance to occur. The view of atypical movements as adaptive, however, suggests that the efficacy of contextualized task training could be enhanced by its association with intervention aimed at changing the resources available to the organism, which would minimize the need for compensatory movements. In other words, changes in motor patterns could be promoted by an association of modifications at the physical and behavioral levels of performance. Future studies should evaluate the effects of the association of more aggressive interventions, addressing multiple resources required for children with hemiplegic CP to improve functional performance, with specific task training protocols such as constraint-induced movement therapy.
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