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Humeral external rotation handling by using the Bobath concept approach affects trunk extensor muscles electromyography in children with cerebral palsy

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ABSTRACT

This study aimed to investigate the electromyographic activity of cervical and trunk extensors muscles in children with cerebral palsy during two handlings according to the Bobath concept. A crossover trial involving 40 spastic diplegic children was conducted. Electromyography (EMG) was used to measure muscular activity at sitting position (SP), during shoulder internal rotation (IR) and shoulder external rotation (ER) handlings, which were performed using the elbow joint as key point of control. Muscle recordings were performed at the fourth cervical (C4) and at the tenth thoracic (T10) vertebral levels. The Gross Motor Function Classification System (GMFCS) was used to assess whether muscle activity would vary according to different levels of severity. Humeral ER handling induced an increase on EMG signal of trunk extensor muscles at the C4 ($P = 0.007$) and T10 ($P < 0.001$) vertebral levels. No significant effects were observed between SP and humeral IR handling at C4 level; However at T10 region, humeral IR handling induced an increase of EMG signal ($P = 0.019$). Humeral ER resulted in an increase of EMG signal at both levels, suggesting increase of extensor muscle activation. Furthermore, the humeral ER handling caused different responses on EMG signal at T10 vertebra level, according to the GMFCS classification ($P = 0.017$). In summary, an increase of EMG signal was observed during ER handling in both evaluated levels, suggesting an increase of muscle activation. These results indicate that humeral ER handling can be used for diplegic CP children rehabilitation to facilitate cervical and trunk extensor muscles activity in a GMFCS level-dependent manner.

1. Introduction

Cerebral palsy (CP) is the used term to describe non-progressive syndromes of posture and motor impairment that result from an injury to the developing central nervous system (Moreno-De-Luca, Ledbetter, & Martin, 2012). Spastic diplegic CP

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children are characterized by paresis, increased muscle tone, and deficient motor control that affect primarily the lower limbs instead of other parts of the body (Ju, Hwang, & Cherng, 2012; Saether et al., 2014). Despite the deficiency in trunk control, many of their functional activities may be done in sitting position, since they have difficulty maintaining their balance while standing (Heyrman et al., 2014; Ju et al., 2012; Pavão, dos Santos, de Oliveira, & Rocha, 2014b).

Spastic diplegic CP rehabilitation is based on these motor problems, and different approaches are used. The lack of clear and detailed description of rehabilitation programs, associated with the insufficiency of suitable validated evaluation tools, often make difficult to prove and reproduce research results.

One approach used for CP rehabilitation is the Bobath concept. This method of rehabilitation, known as "neurodevelopmental treatment" (NDT), aims at maximizing the child's potential to improve motor competence and prevent musculoskeletal complications (Tsorlakis, Evaggelinou, Grouios, & Tsorbatzoudis, 2004). Bobath concept comprehends specific handling techniques, focusing on the normalization of muscle tone, improvement of postural alignment, and inhibition of abnormal reflexes through sensory input to encourage child's active participation on development and practice of functional skills (Mayston, 2008). Using handlings through "key points of control" (as head, shoulders, elbows, hips, knees and ankles, for instance), the therapist aims to facilitate the desired muscle action (Veličković & Perat, 2005).

Through these "key points of control", it is possible to conduct movements, influence muscle tone, improve postural alignment and postural self-organization, as well as to increase active participation in the proposed functional tasks (Howle, 2002). Self-organization facilitated by handlings using "key points of control" induces posture and movement integration, allowing the use of anticipatory strategies contributing for motor learning and motor control improvement. Normal movements are facilitated and abnormal patterns are inhibited to allow appropriated active reactions when the therapist is not controlling the movement (Ju et al., 2012). The therapist induces an expected motor response by means of the stimulation of sensory pathways, that are the gateways to motor control and motor learning (Tsorlakis et al., 2004).

Despite the widespread use of NDT, studies of its effectiveness have reported conflicting or inconsistent findings (Knox & Evans, 2002; Tsorlakis et al., 2004). Thus, more accurate assessment tools are important for measuring the effectiveness of manual techniques used in CP rehabilitation. Surface electromyography (EMG) is a noninvasive technique to measure electrical muscle activity using closely spaced electrodes overlying a restricted area of the skin (De Luca, 1997). EMG recording during muscle activity can be used as diagnostic tool or rehabilitation research instrument, especially in patients with neuromuscular disorders (Bigongiari et al., 2011; Simon, Pinho, Grazziotin dos Santos, & Pagnussat, 2014).

Against this background, this study aimed to evaluate the effects of two handlings used to influence trunk control reactions, as recommended by the Bobath concept. Effects of humeral internal rotation (IR) and external rotation (ER) handlings on the activation of cervical and trunk extensors muscles were assessed by EMG in children with spastic diplegic CP. Furthermore, it was also evaluated whether muscle activity would vary according to level of severity, based on the Gross Motor Function Classification System (GMFCS) classification.

2. Methods

2.1. Participants

Seventy children were evaluated, and forty were selected based on inclusion and exclusion criteria. Forty children were eligible for inclusion if they were between 3 and 18 years of age, with spastic diplegic CP, and level 1–5, as evaluated using the GMFCS scale. The GMFCS is a valid, reliable tool that stratifies children into five groups based on gross motor function, with emphasis on sitting and walking (Palisano, Rosenbaum, Bartlett, & Livingston, 2008; Pavão, Barbosa, Sato, & Rocha, 2014a). Wide age range was possible because there is no comparison between subjects. Thus, comparisons between interventions were performed for each participant. Children with other physical abnormality, genetic syndromes, or severe comorbidities were excluded. Also, children with upper limb muscle shortening that could compromise range of motion did not participate of the study.

2.2. Design

A crossover trial was conducted between June 2011 and September 2012 at the Physical Therapy Department of Associação de Assistência à Criança Deficiente (AACD) (Porto Alegre, Brazil). Ethical approval was given by all health authorities involved and by the Ethics Committee of the Universidade Federal de Ciências da Saúde de Porto Alegre (Protocol no. 11-822). Written informed consent was obtained from children's parents prior to their enrollment. This study was conducted in compliance with the current revision of the Declaration of Helsinki and the Good Clinical Practice guidelines.

2.3. Intervention

We have examined the EMG signal of extensor muscles of cervical and upper trunk. Two handlings were used for the facilitation of trunk control, with 10 s of duration each. EMG recording was performed with children in the sitting posture during: sitting position, without any handling (SP), humeral internal rotation (IR) and humeral external rotation (ER) handlings through the elbow joint as "key point of control". Based on previous study, a 1-min interval for washout was provided between each handling (Bakhtiary & Fatemy, 2008). The sequence of handlings was randomly assigned for each participant (Fig. 1). Comparisons between muscle activation were made just between positions but not among children.

All children underwent the standardized handling, performed by the same researcher. Participants were sitting on a stable stretcher without back and feet support. The examiner's hands were positioned on the elbows of participants prior to the handlings. At SP, participants were instructed to keep their arms at their sides, keeping the support hand on the stretcher (as depicted in Fig. 1). Muscle activity was recorded along 10 s for each experimental situation (SP, IR, and ER). Total time for the procedure did not last more than 30 min for each child.

2.4. Data acquisition

First, a baseline test was conducted to ensure the quality of the EMG acquisition. To this end, participants have remained in the same sitting position, but with back support for their trunk to allow the total rest of the upper limbs, ensuring that the average baseline noise did not exceed 5 μV (De Luca, 1997).

EMG signals were recorded through circular neonatal surface electrodes of Ag/AgCl, with 20 mm diameter (MAXICOR Medical Products, Brazil), under bipolar configuration using interelectrode distance of 20 mm, as recommended by guidelines of the International Society of Electrophysiology and Kinesiology (ISEK) and the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) project (Merletti, 1999).

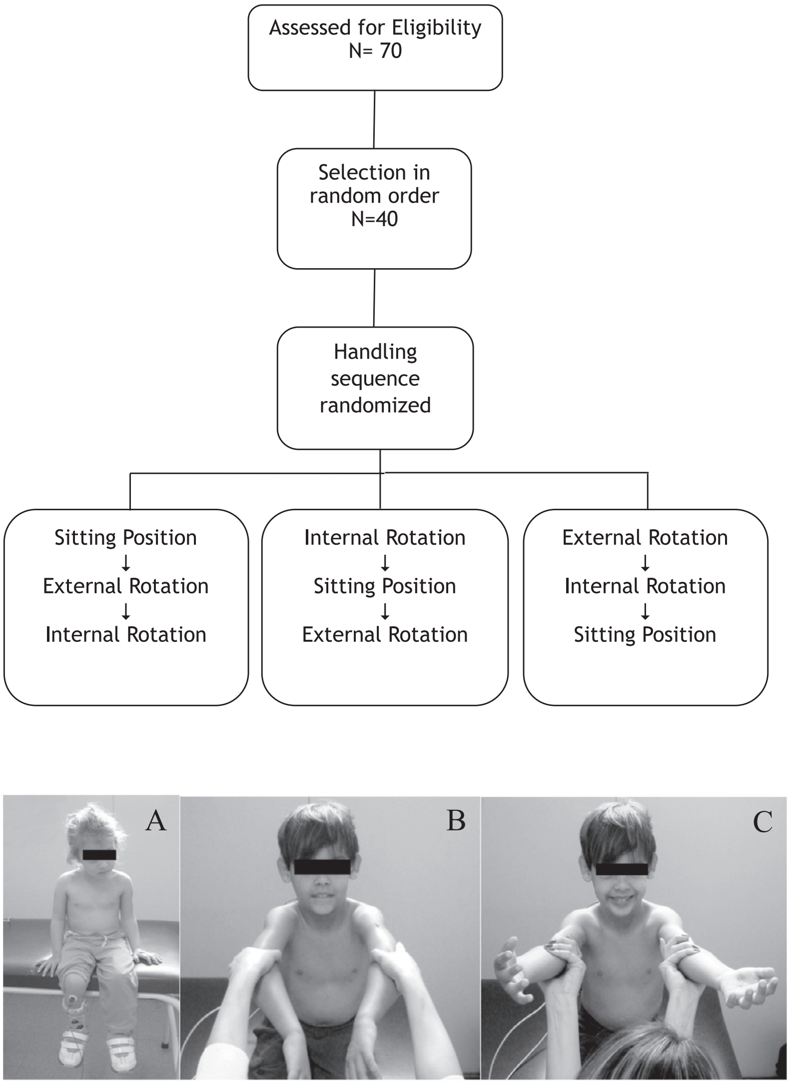


Fig. 1. Flow diagram of interventions and illustration for the three tested positions: (A) sitting position; (B) internal rotation; (C) external rotation.

As recommended, to monitor general muscle activity from cervical extensor muscles, electrodes should be placed at the fourth cervical vertebra (C4) level; to monitor thoracic extensor muscles, electrodes should be placed at the tenth thoracic vertebra (T10) level. Then, electrodes were placed at C4 and T10 levels, approximately 2 cm from the spine, longitudinally to the paraspinal muscles (Criswell, 2010). As placing the reference electrode close to the sensor may disturb the EMG signal, especially if multiple sensors are attached to the body (Roy et al., 2007), the reference electrode was placed on the right tibial tuberosity. Body hair was shaved away from the site of electrode placement, and the skin was gently abraded and cleaned with alcohol 70% to keep inter-electrode resistance low (De Luca, 1997). Electrodes and cables were fixed with adhesive tape (Transpore, Nexcare – 3M) to prevent EMG signal interference (De Luca, 1997).

EMG signals acquisition was performed using an electromyograph device with four channels (Miotec®, model Miottol400, 14-bit resolution, and electrical isolation of 5000 V and 2000 Hz per channel, common mode rejection ratio of 110 db). Data were collected and analyzed using the software Miograph 2.0. A battery-powered laptop was used to collect and process data.

Signals were filtered to a fourth-order Butterworth filter and band-pass with cut-off frequencies between (10 Hz and 400 Hz). Signals were clipped to exclude the ‘delay’ between the initiation of recordings and the execution of the handling. Therefore, the first and the last 2s (of the total 10s) were excluded, and the average root mean square (RMS) for the three muscles regions of interest (C4 and T10) was calculated based on a total of 6s. For data analysis, RMS values were normalized by the dynamic mean method because children had abnormal movement patterns and muscle action, due to CP (Burden & Bartlett, 1999). Thus, the average of three maximum values of RMS for data was calculated. Normalization using the Maximal Voluntary Contraction (MVC), which is usually used to analyze the EMG signal, was considered inappropriate because children's cognition levels were quite varied, impeding a request for an effective MVC.

2.5. Statistical analysis

To detect a Cohen's effect size (E/S) = 0.5 with a statistical power of 90% and a 2-sided significance level (α) of 0.05, a sample size of 40 patients was required. Continuous data were described using mean and standard deviation whereas for categorical data we used counts and percentages. For each outcome, we fitted a repeated-measures mixed-effects model with handling treatment as independent variable, testing for sequence and treatment-sequence interaction effects, and adjusting for age, and GMFCS-levels. Additionally, interaction effect of handling and GMFCS-level was also tested.

For post hoc comparisons we used the Sidak's multiple comparisons procedure. To evaluate the magnitude of the effects of handlings, we used the Cohen's effect size statistic (E/S) taking the overall resting EMG signal's standard deviation as the reference under the homogeneity of variances assumption. Significance level was set at $\alpha = 0.05$. Data were analyzed using SPSS version 18.0.

3. Results

Considering the crossover design of this study, we initially tested sequence and treatment by sequence interaction effects on responses. We found no significant influences of these two factors. Patient's characteristics are shown in Table 1.

3.1. Muscle activity at C4 level

At C4 level, there was an overall response of change in the EMG signal under handlings ($P = 0.023$), as presented in Fig. 2. Comparing SP with ER, there was increased of EMG signal during the handling, suggesting activation of the target muscles ($P = 0.007$). No significant effects were observed between SP and humeral IR handling, or between humeral IR and humeral ER handling (Fig. 2).

3.2. Muscle activity at T10 level

At T10 level, the overall response of change in the EMG signal under handlings was also significant ($P = 0.039$). Humeral ER handling has caused an increase of EMG signal when compared to the SP position ($P < 0.001$) and to humeral IR ($P = 0.019$). No significant effects were observed between humeral IR and humeral ER handling (Fig. 2).

3.3. Handlings and age

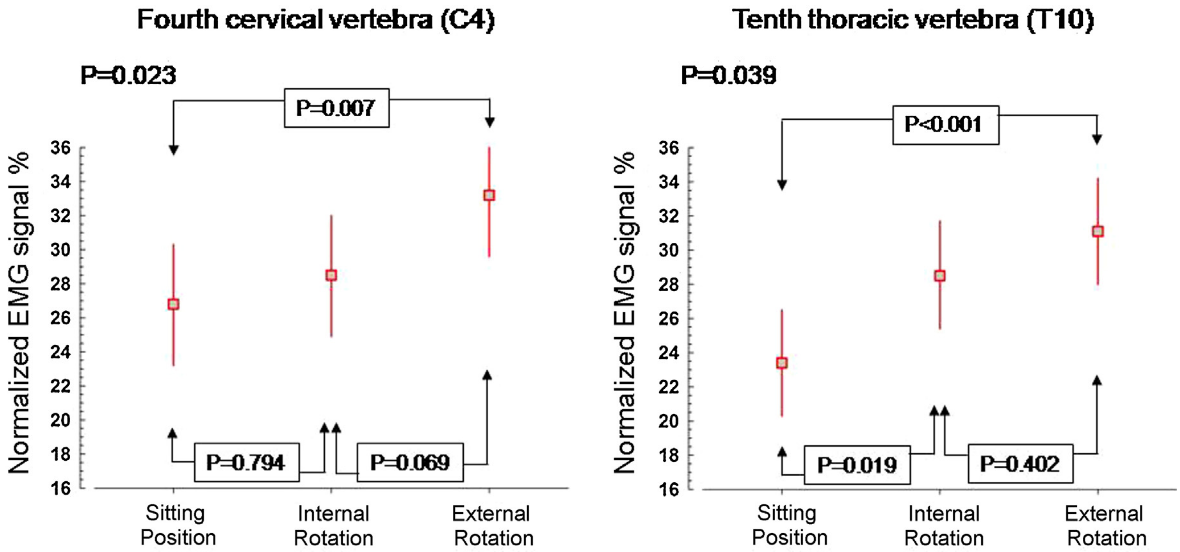
No significant difference was found between handlings and age in both analyzed points (neither at C4 level ($P = 0.298$) not at T10 level ($P = 0.699$)). Thus, all children were influenced by handlings independently of their age.

3.4. Handlings and GMFCS

At C4 level, results showed no significant difference between handling and GMFCS level ($P = 0.367$); however, at the T10 region, there was difference on EMG signal related to the GMFCS level (handling and GMFCS interaction; $P = 0.017$) (Fig. 3).

Table 1
Demographics characteristics of participants. SD: standard deviation; GMFCS: Gross Motor Function Classification Scale.

	(n = 40)
Age, mo, mean (SD)	82.8 (25.9)
Sex (female), n (%)	22 (55.0)
GMFCS, n (%)	
1	3 (7.5)
2	9 (20.0)
3	20 (52.5)
4	6 (15.0)
5	2 (5.0)



n = 40						
maximum	45.3	44.2	52.8	42.9	42.1	47.4
mean	26.7	28.5	33.2	23.4	28.5	31.5
minimum	13.0	6.6	20.2	9.4	11.0	16.1

Fig. 2. Mean values and their respective 95% confidence intervals of normalized EMG signals for three different handling interventions recorded on C4 and T10 vertebrae regions. Means were adjusted for age and GMFCS level in a linear mixed model followed by Sidak's adjustment for multiple comparisons. For each handling minimum and maximum individual values observed were also provided.

For data analysis, children classified as GMFCS levels 4 (four) and 5 (five) were combined in the same group due to small sample in each group.

Children classified as GMFCS levels 1 (one) and 2 (two) showed superior response for both humeral IR and humeral ER handlings. Muscle activation effect was reduced in those children classified as GMFCS level 3 (three), getting close to zero in those classified as GMFCS levels 4 (four) and 5 (five) (Table 2 and Fig. 3). Absolute mean differences between humeral IR handling and SP position (ΔIR-SP), and between humeral ER handling and SP position (ΔER-SP) and Cohen's effect size for mean differences were also showed in Table 2.

4. Discussion

The main purpose of this study was to investigate whether handlings recommended by the Bobath concept were able to cause an immediate effect on muscle activation of spastic diplegic CP children, as visualized by changing in EMG signal. The significance of investigating this approach refers to its widespread use in CP rehabilitation to inhibit primitive synergistic patterns of movement through humeral IR handling, as well as to facilitate the activity of the trunk extensor muscles by means of the humeral ER handling (Howle, 2002). Despite the theoretical preconization, there is no scientific evidence about the real effects of each handling, as recommended by Bobath concept.

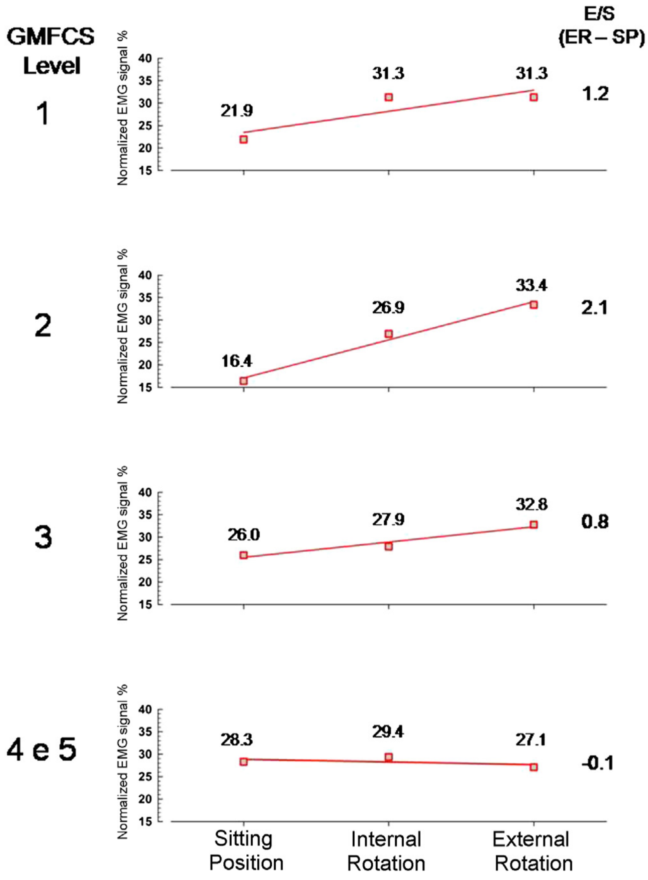


Fig. 3. Mean values of normalized EMG signals for three handling interventions record on T10 vertebra region showing different response according to GMFCS level (handling-by-GMFCS interaction; $P = 0.017$), adjusted by age. *E*/*S*: Cohen's effect size statistic, ER: external rotation, SP: sitting position.

Table 2
EMG signals for handlings according to the GMFCS levels at T10 vertebra. EMG (%) ± SE: mean of normalized EMG signal ± standard error; ΔIR–SP: absolute mean difference between internal rotation handling and sitting position; ΔER–SP: absolute mean difference between external rotation handling and sitting position *E*/*S*: Cohen's effect size for mean differences.

GMFCS	Sitting position	Internal rotation			External rotation		
	EMG (%) ± SE	EMG (%)	ΔIR–SP	*E*/*S*	EMG (%)	ΔER–SP	*E*/*S*
1	22.5	29.8	7.3	0.9	31.2	8.7	1.1
2	17.0	26.9	9.9	1.2	33.5	16.5	2.0
3	25.7	28.3	2.6	0.32	32.8	7.1	0.9
4–5	28.5	29.1	0.6	0.07	27.1	−1.3	−0.2

Our results have shown that electromyographic activity at cervical and thoracic levels were increased when humeral ER was induced by means of elbow joint as a key point of control, suggesting activation of extensor muscles. Since humeral ER allows to place the scapula in a retracted position, keeping it depressed, this handling would be useful for facilitating trunk position against gravity, without abnormal or pathological movement synergies (Bly & Whiteside, 1997; Winters, Takahashi, Lieber, & Ward, 2011). Extensor muscles control is expected at the beginning of typical motor development for allowing first motor acquisitions, such as head control. Furthermore, extensor patters, specially in prone position, are essential either to development cervical and lumbar curvatures or for pelvis mobility.

According to the Bobath concept, deeper trunk muscles would be activated to stiffen the spine irrespective of the direction that the upper limb moves in, but the more superficial trunk muscles are direction specific (Lee, Coppieters, & Hodges, 2011). The stable scapula on the thoracic cage allows the upper limb to move away from the body, freeing the hand to reach (Raine, Meadows, & Lynch-Ellerington, 2009). Considering humeral ER handling as a movement facilitator, it would bring benefits in anticipatory postural adjustments through stimulating the nervous system that uses these muscle synergies, or patterns of activation, to recruit trunk muscles in an efficient and automatic way before moving the arms (Raine et al., 2009). In long term, humeral ER facilitation would allow for achieving proximal trunk stability and provide the foundation for shoulder muscles to efficiently take the hand forward. It is well established that the shoulder complex position is critical for motor performance in the upper limb under neurological conditions (Buccino et al., 2012).

Handlings and movement facilitation aim to influence muscle length and range of motion to allow improved alignment for more effective muscle activation in order to incorporate the complex relationship between stability and mobility components (Raine, 2007). Our results suggest that therapeutic handling to keep shoulders in external rotation would be able to facilitate the activity of the extensor muscles at both cervical and thoracic levels.

Nonetheless, EMG activity of the selected extensors muscles did not decrease when humeral internal rotation (IR) was performed and compared to SP or ER. This lack of muscle inhibition was observed either at cervical or at thoracic levels. Additionally, and contradicting our initial hypothesis, IR handling increased muscle EMG activity at thoracic spine level when compared to SP recordings. This finding might be due to the motor profile of children with spastic diplegic CP. In these children, the most important motor impairment is observed in lower limbs, and the compromise of the trunk musculature is not always evident (Wolf et al., 2011). Considering the topography of CP children in this study, and their motor level classification (majority on the 1–3 GMFCS), it was hypothesized that these children could produce an active contraction of extensor muscles when IR was induced by means of the elbow as key point of control.

We have demonstrated a possible interaction between EMG muscle activity and GMFCS levels when therapeutic handling includes ER rotation, scapular retraction and depression. The absolute mean difference between IR and ER handling and SP (score delta) underwent a gradual increase in the 1–2 GMFCS levels and an important decrease from 3 to 4–5 levels (Fig. 3). GMFCS is a 5-level classification system that describes the gross motor function of CP children on the basis of their self-initiated movement in a crescent pattern of impairment (Rosenbaum et al., 2007). Thus, humeral ER handling would be more effectively used for increasing extensor muscle activity when children have slight motor problems.

With regard to the limitations of the study, the sample size was small and heterogeneous; therefore a larger, adequately powered study is necessary to answer these questions. Also, only an immediate evaluation was performed. Once verified the existence of handling influence on muscle activity, by changing the EMG signal, it is necessary to evaluate their effectiveness, using intervention protocols, follow-up and functional evaluation. Moreover, methods of normalization for special populations are not yet definitely reliable, which can compromise the reliability of the study.

The purpose of this investigation was to evaluate whether two handlings recommended by Bobath concept would cause changes in muscle activity through evaluation by EMG, aiming to contribute for the evidence-based physiotherapy practice on CP rehabilitation. According to the results we have concluded that humeral ER could be used for diplegic CP children rehabilitation to facilitate cervical and trunk extensor muscles activity in a GMFCS level-dependent manner. As far as we know, this is the first study that demonstrates the effects of muscle activation under this specific approach. Clearly, additional experimental works are needed to clarify the effectiveness of these handlings and to establish the most suitable rehabilitation treatment for spastic diplegic CP children.

5. Conclusion

Based on the presented results we have concluded that external rotation handling, using the elbow joint as a key point of control, facilitates activation of trunk extensor muscles and would be effective for achieving trunk stability in spastic diplegic CP children. Children with milder levels of impairment (classified as 1–3 GMFCS levels) seem to respond better than those more severely compromised (classified as 4–5 GMFCS level).

Conflict of interest

Authors declared no potential conflicts of interest with respect to the re-search, authorship, and/or publication of this article.

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