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Original Research

Analysis of the electromiographic activity of lower limb and motor function in hippotherapy practitioners with cerebral palsy

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ABSTRACT

Objective: Investigation of the effects of hippotherapy treatment on lower limb muscle activity and gross motor function in subjects with cerebral palsy (CP), comparing them to a group of subjects with adequate motor development.

Methods: Evaluation was made of seven individuals with spastic diparetic CP, average age 9.3 (±3.3) years (CP group), Gross Motor Function Classification System (GMFCS) levels I and II, and eight individuals with adequate motor development, average age 10.9 (±3.2) years (control group). The groups were submitted to 25 sessions of hippotherapy, each lasting 30 min, on a weekly basis, and the muscle activity of the lower limbs was evaluated using surface electromyography during the 1st, 10th, 20th, and 25th sessions. For the CP group, Gross Motor Function Measurement (GMFM-88) was performed before and after hippotherapy treatment.

Results: There was higher muscle activity in the 10th session, compared to the other sessions, with greater activity of the tibialis anterior muscles, for both groups studied. After treatment, the CP group showed significant improvement in the GMFM total score, and in the scores for dimensions D and E.

Conclusion: Hippotherapy sessions improved the muscle responses in both groups, and improved the gross motor function of the subjects with CP.

1. Introduction

Chronic non-progressive childhood encephalopathy, known as cerebral palsy (CP), is a movement or posture disorder caused by non-progressive multi-factor brain lesion occurring during the period of brain development in the first years of life (Cargnin and Mazzitelli, 2003; Gomes and Golin, 2013). This cerebral lesion results in alterations in movement and posture control, with impaired balance, muscular changes, and difficulty of movement, which compromise the performance of normal daily activities (Souza and Alpino, 2015).

Global motor development in children is normally accompanied by the acquisition of specific abilities, such as walking. A child with CP can be recognized by delayed global motor development and by the presence of abnormal patterns of movement and posture (Beckung et al., 2007).

Hippotherapy is a useful intervention strategy that can be used to improve the functional performance of children with CP, who require continuous and repeated treatment employing a variety of stimuli (Cunningham, 2009; Jang et al., 2016). The rhythmic three-dimensional movement of the horse can help to increase the flexibility, posture, balance, and mobility of the rider (Park et al., 2014). The benefits of hippotherapy that have been described in individuals with CP, associated with the stimulation of sensorimotor activity and active control of posture during riding, include improvements in postural balance, dynamic balance, and functional activity (Moraes et al., 2016), gross motor function (Drnach et al., 2010),

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postural control (Tseng et al., 2013), postural control and equilibrium (Fernández-Gutiérrez et al., 2015), and spatio-temporal relationships, with improvement in gait symmetry (Manikowska et al., 2013).

Riding stimulates postural reflex mechanisms involving dissociation of the pelvic and scapular girdles, with constant adjustments of tone resulting in the development of balance and coordination abilities (Sanches and Vasconcelos, 2010). Studies have shown satisfactory results of hippotherapy employed as a treatment for children with CP, especially in terms of gross motor skills, with important improvements in walking, running, and jumping. The technique develops functional ability with the active participation of the child, based on the continuous adaptive response of the body, in a motivating environment (Casady and Nichols-Larsen, 2004; Araujo et al., 2011; Menezes et al., 2013; Park et al., 2014; Jang et al., 2016).

However, there have been few evaluations involving children with varying levels of impaired motor functionality, as in the case of individuals with CP. Further studies are needed of the benefits of using hippotherapy with this population, given the importance of therapeutic approaches that combine functional evaluation with muscular activity. Objective evaluation of the electrical activity of a muscle during its contraction can be achieved using a non-invasive technique such as surface electromyography (EMG) (Espindula et al., 2015).

This study contributes to scientific knowledge concerning the practice of hippotherapy, using EMG to characterize the lower limb muscle activity of CP subjects during therapy sessions, as well as the clinical effects on the functional motor potential. The hypothesis adopted was that hippotherapy can induce beneficial changes in lower limb muscle control and activation, and can improve gross motor function in these individuals.

The objective was therefore to evaluate the effects of hippotherapy on lower limb muscle activity and gross motor function in a group of subjects with CP, and to compare them to a group with adequate motor development.

2. Material and methods

This study is longitudinal, descriptive, and quantitative in nature. The project was approved by the Research Ethics Committee of the Federal University of Triângulo Mineiro (protocol 2686), and the evaluation and intervention methods employed followed the norms of Resolution #196/96 of the National Health Council for research involving humans. Those responsible for the research subjects received explanations regarding the objectives of the study and the procedures to be adopted, and those who consented signed the informed consent form as well as the terms for release of images.

2.1. Participants

Prior to the treatments, analysis was made of the records of students from a special education institution, in order to select individuals with diagnosis of cerebral palsy and slight intellectual retardation, but adequate motor development. The students needed to be correctly enrolled at the school, attending clinical sessions with speech and hearing therapists and psychologists that were provided by the institution. Data acquired for the study groups included age, weight, height, gender, medications used, the time attending hippotherapy sessions, and other therapeutic techniques applied. The individuals included in the study had no previous experience of hippotherapy, did not receive conventional physiotherapy, had diagnosis of spastic diparetic CP, were classified as level I or II according to the Gross Motor Function Classification System (GMFCS), were aged between 6 and 16 years, and had medical referral authorizing the use of hippotherapy.

Non-inclusion criteria were inability to walk independently, other type of CP (quadriplegia/quadriparesis, hemiplegia/hemiparesis), application of botulinum toxin in the last year, existence of other associated syndromes, epilepsy (uncontrolled), acute cardiopathies, spinal instabilities or other conditions, shoulder or hip dislocations, scoliosis of 30° or more, and hydrocephalus. Also excluded were those who showed uncontrollable fear of horses, presented behavioral alterations that prevented performance of the evaluations and the proposed sessions, needed to perform dual riding, and did not complete the planned number of sessions. Initially, 108 students with diagnosis of CP were identified, with individuals subsequently being selected according to the inclusion, non-inclusion, and exclusion criteria, as shown in Fig. 1.

The participants were allocated to two different groups. The cerebral palsy group (CPG) consisted of seven individuals (five males and two females) with spastic diparetic CP, mean age of 9.3 ($\pm$3.3) years, and with two subjects at GMFCS level I and five at GMFCS level II. The control group (CG) consisted of eight individuals (four males and four females), mean age of 10.9 ($\pm$3.2) years, with mild intellectual retardation and adequate motor development, without physical disability. Both groups were submitted to evaluations and hippotherapy sessions. There were no statistically significant differences between the groups in terms of the sample characterization parameters evaluated, as shown in Table 1.

2.2. Interventions

The interventions were performed at the Institute's own Hippotherapy Center, which has horses suitable for the activity, a cemented ring, and a grassed area. The hippotherapy sessions were performed with one Crioulo breed horse and one Persian Arab breed horse, randomly selected, with ages of 18 and 20 years and heights of 1.56 and 1.62 m, respectively. Despite the differences in terms of race, age, and height, both animals were extremely docile, trained for use in hippotherapy, and capable of different gaits. In this study, the horses proceeded at a walking pace, varying the gait during the sessions. The safety procedures adopted followed the guidelines of the Brazilian National Hippotherapy Association (ANDE, Brazil) concerning appropriate clothing and helmets. A blanket was used as the riding material, with the feet of the practitioner supported in the stirrups, since in previous work it was found that this condition provided greater activation of the lower limb muscles (Ribeiro et al., 2017).

The participants received 25 sessions of hippotherapy at intervals of one week, each lasting 30 min. In each session, the following sequence was adopted: for the first 10 min, the horse walked to the right side of the cemented ring, followed by walking in a straight line for 10 min on the grass, and finally 10 min to the left side of the cemented ring. During the 30 min of the session, no other activity or physical exercise was used for muscle activation, and the subject sitting on the back of the horse only received transmission of the three-dimensional movement provided by the animal. The evaluations and sessions were conducted by examiners who had been previously trained and licensed by ANDE (Brazil).

2.3. Evaluation procedures

The motor functions of the CP group participants were evaluated before and after the hippotherapy treatment, using the Gross Motor Function Measure (GMFM-88). The GMFM employs observation and quantitative evaluation to determine the degree of function displayed by the child, without considering the quality of the function. Its purpose is to assist in terms of the treatment strategy,

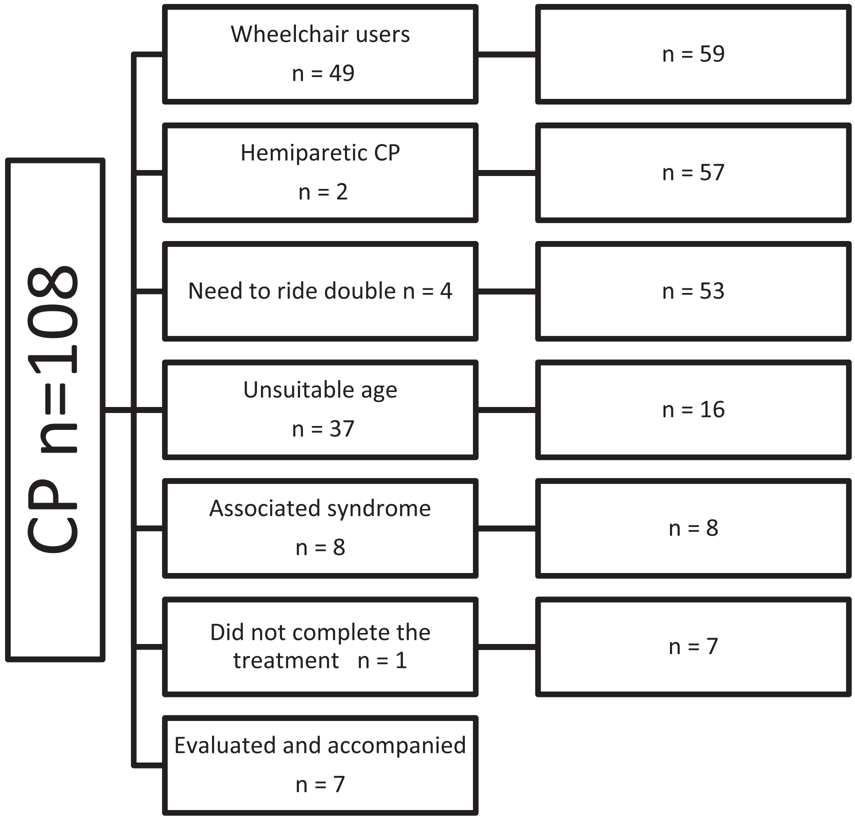

Fig. 1. Organogram showing the reasons for inclusion, non-inclusion, and exclusion of the individuals with cerebral palsy.

with the goal of improving function and the quality of life. It consists of 88 items divided into 5 dimensions: (A) lying down and rolling, (B) sitting, (C) crawling and kneeling, (D) standing, and (E) walking, running, and jumping. It is performed by observing the children and scoring them on an ordinal scale from 0 to 4 points. Within each dimension, the scores of each item are summed to obtain a total score, enabling determination of the percentage scores within each of the five dimensions. The final score is obtained as the average of the total percentage scores of each dimension (Pina and Loureiro, 2006; Park et al., 2014). Since the children were able to walk independently, this research employed a more detailed analysis of dimensions D and E, related to functional activity and gross motor function while standing, and while walking, running, and jumping, respectively.

Electromyographic (EMG) analysis was performed using a portable wireless 8-channel surface electromyograph (EMG800RF, EMG System do Brasil Ltda) with 14-bit signal acquisition resolution and 5000 V electrical isolation. The signal acquired by the electrodes was amplified 2000 times and filtered with 5–500 Hz bandpass filters and common mode rejection >120 dB. The electromyograph was connected to a USB port of a notebook computer (CCE brand), and the data were recorded and analyzed using software developed by EMG System do Brasil (Belo et al., 2009; Ribeiro et al., 2017). After trichotomy and cleaning of the location with cotton soaked in 70% alcohol, self-adhesive disposable bipolar electrodes (Ag/AgCl foam surface and solid gel), in the form of 1 cm diameter disks that were connected to the preamplifiers, were positioned with center-to-center distances of 2 cm (Espindula et al., 2015). The procedure followed the recommendations of the SENIAM project (Surface Electromyography for Non-Invasive Assessment of Muscles) (www.emgsystem.com.br) (Belo et al., 2009; Hermes et al., 2000; Ribeiro et al., 2017). The electrodes were placed bilaterally on the following lower limb muscles: rectus femoris, vastus lateralis, vastus medialis, and tibialis anterior.

Table 1
Sample characterization.

	CPG (n = 7)	CG (n = 8)
Sex M:F	5:2	4:4
Age (mean ± SD)	9,3 (±3,3)	10,9 (±3,2)
Weight (Kg)	28,4 (±11,2)	39,8 (±14,8)
Height (cm)	125 (±0,19)	144 (±0,15)
Diagnosis	Spastic diparetic CP	Adequate motor development
GMFCS level I:II	2:5	–

Electromyographic data were collected during the 1st, 10th, 20th, and 25th hippotherapy sessions. All 25 sessions were standardized, using a course sequence lasting 30 min, based on clinical criteria, performed on cemented and grass surfaces, as described in Table 2. In each session, electromyographic measurements were made for six different conditions. Two were with the subject sitting on the back of the static horse, at the start and end of the session, denoted the initial seated (IS) and final seated (FS) measurements, respectively. Four measurements were made with the horse at a walking pace, after the first (T1), tenth (T10), twentieth (T20), and thirtieth (T30) minutes. The electromyographic data were presented in the form of RMS (root mean square) values (in microvolts). The procedure involved intra-comparison of an individual during the course of all the sessions, so standardization of the data was unnecessary.

2.4. Data analysis

Statistical analysis of the RMS and GMFM data was performed using GraphPad Prism® software. The normality of the electromyographical data was checked using the Shapiro-Wilk test. When

Table 2
Sequence of the electromyographical measurements in all the evaluations.

Electromyographical measurement[a]	Time	Surface/condition	Direction
IS	0′	Halted	Halted - initial
T1	1′	Cemented	Right side of the ring
T10	10′	Cemented	Right side of the ring
T20	20′	Grassed	Straight line
T30	30′	Cemented	Left side of the ring
FS	30′	Halted	Halted - final

[a] IS: initial seated; T1: after 1 min; T10: after 10 min; T20: after 20 min; T30: after 30 min; FS: final seated.

the distribution was normal, paired one-way ANOVA followed by the Tukey post-test was used in the analyses, while the Friedman test followed by the Dunn post-test was used for non-normal data. In the comparisons between two groups, the variables that presented normal distributions were analyzed using the Student's t-test, while the Mann-Whitney test was used when the distribution was not normal. For analysis of the GMFM scores, the paired *t*-test was used for normal data and the Wilcoxon test was used for non-normal data. Differences were considered statistically significant when the p-value was less than 0.05.

3. Results

3.1. Analysis of gross motor function

In the evaluation of the gross motor function of the subjects with spastic diparetic CP using GMFM, the total score obtained after the 25 sessions of hippotherapy was significantly higher than before treatment ($p = .0012$), with an increase of 7.9%. For dimension A (lying down and rolling) the scores were 100% both before and after the intervention, while slight improvements ($p = .1250$) were observed for dimensions B (sitting) and C (crawling and kneeling). The results obtained for dimensions D (standing) and E (walking, running, and jumping) were statistically significant, with increases of 19.33% for dimension D (standing) ($p = .0104$) and 11.7% for dimension E (walking, running, and jumping) ($p < .0001$) (See Fig. 2).

Comparisons were made of the electromyographic results obtained for muscle activations at the same moment in different sessions, as well as at different moments of the same session.

3.2. Analysis of muscle activity between 4 sessions

The activity of the right rectus femoris (RRF) muscle showed a significant difference between the CG and CPG groups at time T30 in the 1st ($p = .0389$) and 10th ($p = .0440$) hippotherapy sessions, with the CPG group presenting greater muscle activity in both cases (See Fig. 3). In addition, for both groups, muscle activity at time T30 increased from the 1st to the 10th session, but was then lower in the subsequent evaluations. This muscle showed no statistically significant intra-group differences between the sessions at the moments evaluated. However, both groups showed greater activity of this muscle at moments IS and FS in the 10th session.

The right vastus lateralis (RVL) and right vastus medialis (RVM) muscles did not show any significant differences between the sessions at the moments evaluated, or in the intra- and intergroup analyses. The behavior for these two muscles was similar to that of the RRF, with greater activation shown at moment IS in the 10th

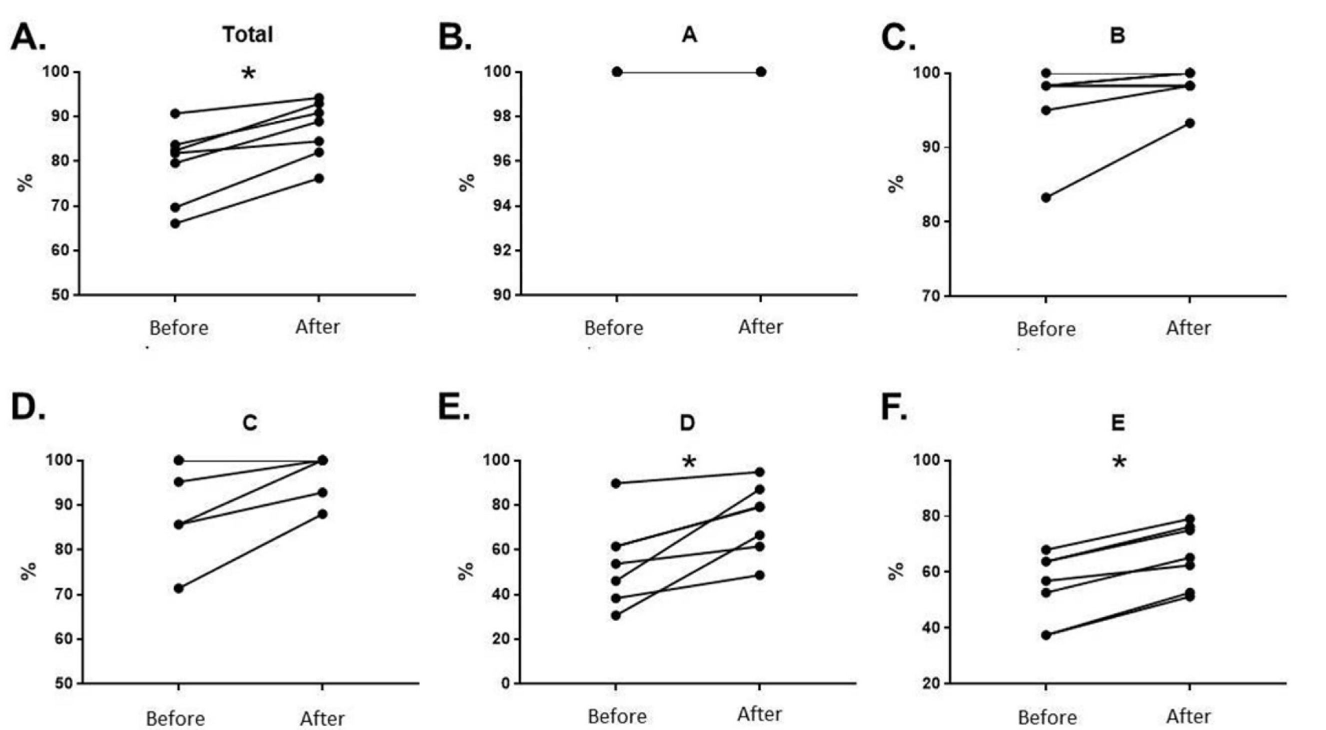

Fig. 2. (A) Total GMFM score for the CPG group, before and after 25 sessions of hippotherapy; (B) Score for dimension A; (C) Score for dimension B; (D) Score for dimension C; (E) Score for dimension D; (F) Score for dimension E. * $p < .05$.

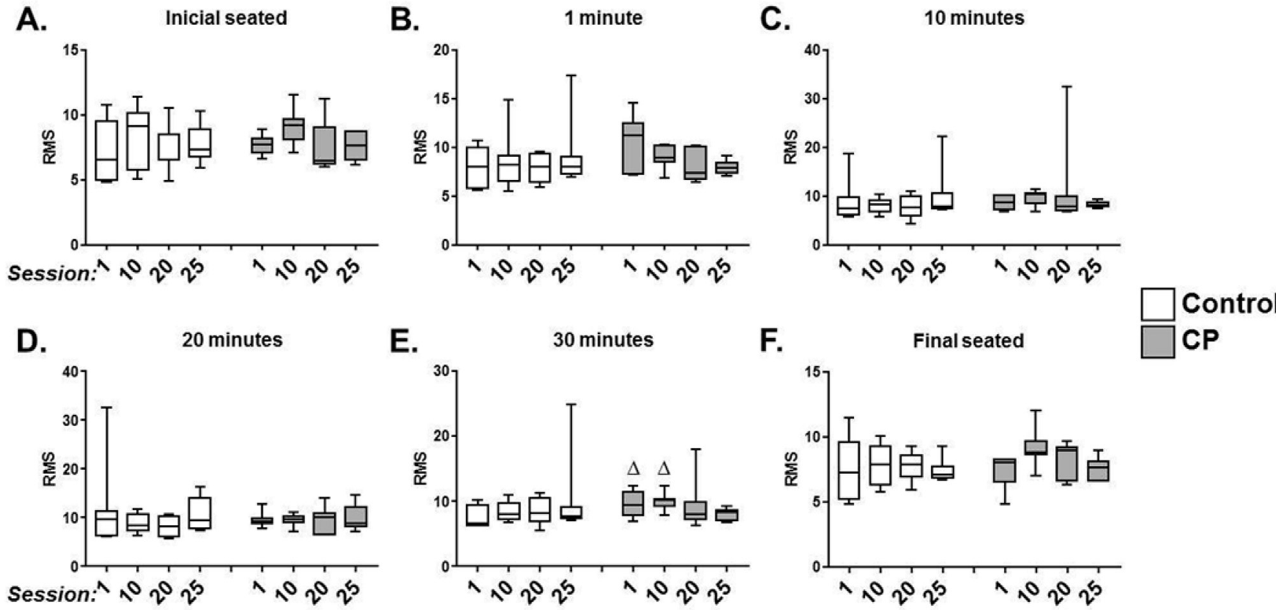

Fig. 3. RMS electromyographical activity of the right rectus femoris (RRF) muscle in the 1st, 10th, 20th, and 25th hippotherapy sessions, at the different moments evaluated. Δ p < 0,5 between groups.

session. For T30, the RVL presented increasing activity from the 1st to the 10th session, followed by a decrease in activity, for both groups, which was statistically significant ($p = .077$). For the same time T30, the greatest activation of the RVM muscles occurred in the 20th session.

The right tibialis anterior (RTA) muscle only showed a significant difference for CG, with greater activity in the 10th session, compared to the 25th ($p = .0306$) (See Fig. 4); at the same moment, for CPG, this muscle showed greatest activation (which was not significantly different) in the 20th session. CG showed a significantly greater activity of this muscle at T10 in the 10th session ($p = .0621$).

For CPG, the left rectus femoris (LRF) muscle showed a significant difference between the sessions at time T1, comparing the 1st to the 20th session ($p = .0003$) and the 10th to the 20th session ($p = .0316$). The muscle activity varied among the sessions, with the highest and lowest values obtained in the 1st and 20th sessions, respectively. CPG also showed a significant difference at time T10, with greater activation in the 1st session, compared to the 25th session ($p = .0398$). In comparison of the groups, there was a significant difference in the 10th session, with CPG showing greater muscle activity at T20, compared to CG ($p = .0339$) (See Fig. 5).

The left vastus lateralis (LVL), left vastus medialis (LVM), and left tibialis anterior (LTA) muscles did not present any statistically

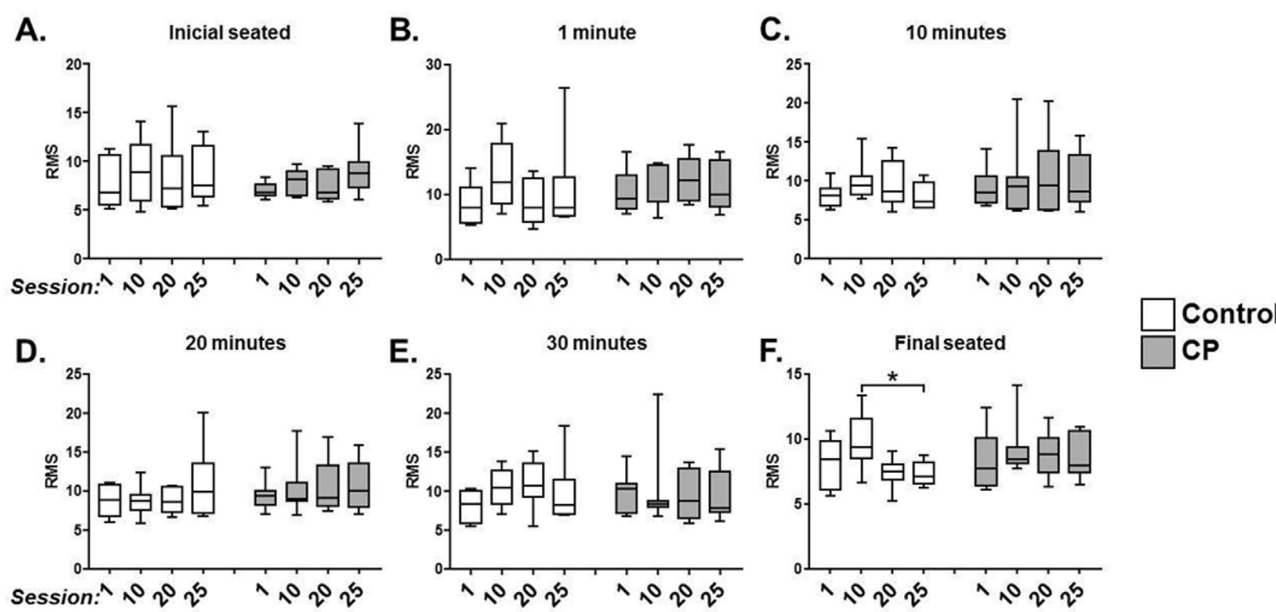

Fig. 4. RMS electromyographical activity of the right tibialis anterior (RTA) muscle in the 1st, 10th, 20th, and 25th hippotherapy sessions, at the different moments evaluated. *p < 0,5.

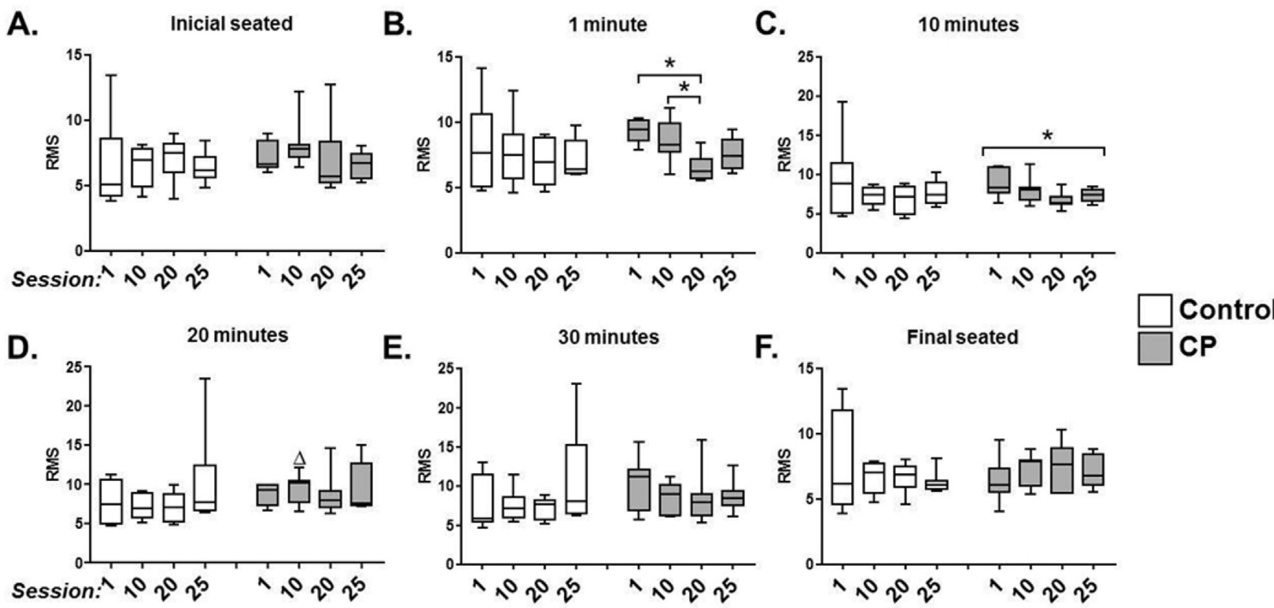

Fig. 5. RMS electromyographical activity of the left rectus femoris (LRF) muscle in the 1st, 10th, 20th, and 25th hippotherapy sessions, at the different moments evaluated. *p < 0,5 e Δ p < 0,5 between groups.

significant differences in RMS muscle activity among the sessions, for the different moments. For both groups, in general there was increased muscle activity in the 10th and 20th sessions, with the increase being lower in the latter case.

3.3. Analysis of muscle activity between the different moments studied

In the analysis of the differences in muscle behavior among the moments of data collection during a single session, all the muscles presented significant differences in some sessions.

For CG, the RRF showed significant differences among the moments of the 1st session, from IS to T20 ($P = .0098$), while CPG showed differences between T20 and IS and FS ($p = .0215$). In the 25th session, CG showed a difference between T20 and FS ($p = .046$). In all cases, the greatest muscle activity was obtained at T20.

The RVL muscle showed a significant difference among the moments of the first session for CG ($p = .0156$) and CPG ($p = .0096$), with greatest activity at T20 for both groups. In the 10th session, CPG showed greater activation of this muscle ($p = .0001$) at T10 and T20, compared to IS. CG showed the greatest activation at T20 in the 20th session ($p = .0014$), while CPG showed the greatest activation at T20 in the 25th session ($p = .0064$).

The RVM muscle showed statistically significant differences between the moments in all the sessions and in both groups. In the 1st session, greatest activation was obtained at T20 for CG ($p = .0156$) and CPG ($p = .0096$). In the 10th session, greatest activation was obtained at T20 for CG ($p = .0156$) and at T10 for CPG ($p < .0001$). In the 20th session, greatest activation was obtained at T20 for CG ($p = .0014$) and CPG ($p = .0145$). In the 25th session, greatest activation was obtained at T20 for CG ($p = .0493$) and CPG ($p = .0064$).

In the case of the RTA muscle, CPG showed a statistically significant difference at T10, with greater activation, compared to FS, in the 1st session ($p = .0110$). CPG showed greater activation of this muscle at T20, compared to the other moments, in the 25th session ($p = .0470$).

For CPG, in the 1st session, the LRF muscle was more activated at T30, compared to the activation at FS ($p = .0056$), while in the 10th and 20th sessions, greater activation was obtained at T20 ($p = .0131$ and $p = .0208$, respectively). In the 25th session, CPG showed greater activation of this muscle at T20 and T30, compared to FS ($p = .0135$), with the highest value at T30. Similarly, for CG, greater activation was obtained at T30, compared to T20 and FS ($p = .0008$).

In the case of the LVL muscle, CPG showed a significant difference in the 1st session ($p = .0240$), with greater activation at T10 and T20, compared to moments IS and FS; in the 10th session, this group showed lower activity of this muscle at IS, compared to T10, T20, and T30 ($p = .0016$); in the 20th session, lower activity was obtained at IS and FS, compared to T20. CG also showed differences for this muscle in the 20th session, with lower activation at IS and FS, compared to T1, T10, and T20, with the greatest activation at T20 ($p = .0007$). In the 25th session, CG showed a significant difference between IS and T20 and T30, with greatest activation at T20 ($p = .0002$).

For the LME muscle, only CPG showed differences among the moments of the same session. In the 1st session, greater activation was obtained at T30, compared to IS ($p = .0085$); in the 10th session, activation was greater at T10 and T20, compared to IS, with the greatest activity at T20 ($p = .0010$); in the 25th session, there was greater activity at T20, compared to IS ($p = .0153$).

The LTA muscle only showed a significant difference among the moments of the 20th session for CPG, with greater activity at T20, compared to IS ($p = .0362$), and in the 25th session, for which greater activity was also obtained at T20 ($p = .0482$).

3.4. Comparison of muscle activity among studied muscles

In the grouping of the 25 sessions (See Fig. 6), it can be seen that there were statistically significant differences in the activities of the muscles evaluated, for both CG ($p < .0001$) and CPG ($p < .0001$). In both groups, the LTA muscle was the most stimulated, followed by the RTA, RRF, and LVL muscles. The other muscles showed similar activities, and the LVM muscle was the least stimulated during the sessions. Although the degree of muscle activation may have varied, the only muscle that showed a statistically significant difference between the right and left sides was the rectus femoris, for

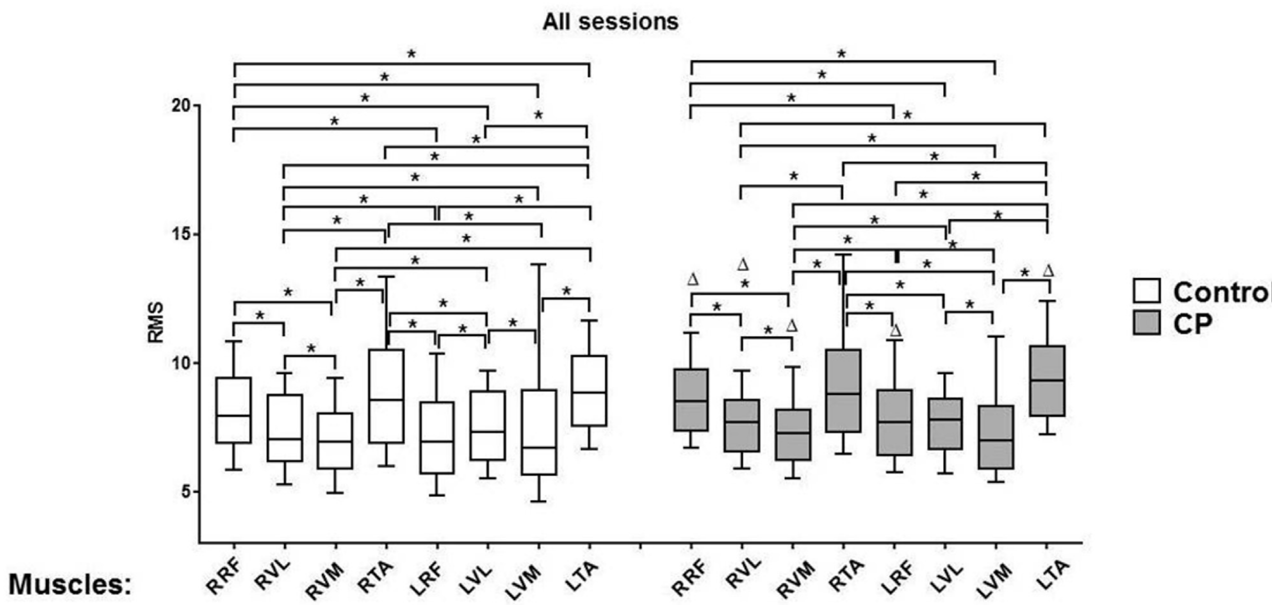

Fig. 6. Difference between muscle activity of muscles assessed in all sessions. *p < 0,5 e Δ p < 0,5 between groups.

both CG ($p < .0001$) and CPG ($p < .0001$). There were differences in muscle activity between the groups, with CPG showing greater activity, compared to CG, for the muscles RRF ($p = .0066$), RVL ($p = 0343$), RVM ($p = .0305$), LRF ($p = .0003$), and LTA ($p = .0085$).

4. Discussion

Considering the proposed objectives of this study, changes were identified in lower limb muscle activity during the course of the 25 sessions of hippotherapy, in the two groups evaluated. The findings revealed the influence of the technique on the gross motor function of the subjects with spastic diparetic CP, hence confirming the initial hypothesis.

The subjects with CP showed a significant improvement in global gross motor function after the hippotherapy sessions. The fact that dimensions A, B, and C did not show any substantial changes could be explained because the individuals involved had diparetic CP and were able to walk without using an assisting device. The subjects were classified as GMFCS levels I and II, and possessed adequate motor skills. Therefore, dimensions D and E, corresponding to activities requiring greater complexity of gross functional motor ability, such as standing, walking, running, and jumping, were those that the subjects found most difficult prior to the hippotherapy. Consequently, these activities showed the greatest improvement following the intervention.

Improvement in gross motor function of children with CP was reported previously, focusing on dimension E of the GMFM, with hippotherapy performed twice weekly during eight weeks of treatment (McGibbon et al., 1998). Drnach et al. (2010) reported that five weeks of therapeutic riding were sufficient to produce positive GMFM results in children with CP; however, the subjects of the study were more independent, and during the session were encouraged to perform motor tasks designed to improve balance, strength, posture control, and flexibility. Another study reported improvement in the GMFM dimension E score in children with spastic CP (GMFCS I and II), as well as improvements in speed, step length, and pelvic kinematics, after eight weeks of hippotherapy performed twice weekly (Kwon et al., 2011). In subsequent work by the same research group, it was found that after a period of eight weeks, hippotherapy had positive effects on the gross motor function and balance of children with CP, at various GMFCS functional levels: dimension E at level I; dimensions D and E at level II; dimensions C and D at level III; and dimensions B and C at level IV (Kwon et al., 2015).

Although most of the evidence reported in the literature indicates the beneficial effects of hippotherapy on the gross motor function of children with CP, some studies did not observe such an influence. Davis et al. (2009) evaluated the GMFM of children with CP (GMFCS levels I to III) and found no improvement after 10 sessions of hippotherapy. Herrero et al. (2012) observed no alterations in the motor function of children with GMFCS level V cerebral palsy after 10 weekly sessions of hippotherapy lasting 15 min. It is possible that the results obtained in the different studies may have been influenced by the number and duration of the sessions, as well as the specific conditions and heterogeneity of the subjects analyzed.

In the work of McGibbon et al. (2009), it was found that the rhythmic and symmetrical movement of the walking horse modified the midline axis of the child, while the circumference of the horse provided a sustained gentle stretching of the spastic adductor muscles, achieving better results than activities in conventional therapies. It was observed that after 12 weeks of hippotherapy, the children with spastic CP showed improved GMFM scores, and that this improvement was maintained for up to 12 weeks after the end of the treatment. The control of mediolateral and anteroposterior postural balance, adaptation of posture to changes in the environment, and the more effective use of multisensory stimuli related to posture and movement were identified as motor strategies that were benefited by hippotherapy.

In hippotherapy, the movement of the horse provides a unique type of stimulation, with a degree of complexity that is difficult to reproduce in other traditional therapy environments. The technique therefore offers a valuable means of developing strategies that can be used by the child during functional activities (McGibbon et al., 2009; Herrero et al., 2012). The electromyographic data obtained in the present work indicated that after the hippotherapy treatment, there was clinical improvement of the gross functional motor skills of the group of individuals with spastic diparetic CP. In some cases, when significant differences were found between the groups, the CPG group presented greater muscular activity, demonstrating the benefits of the stimulation of the lower limb musculature in this group.

Motor ability learning occurs when the individual succeeds in performing a motor activity with improved performance, due to practice or experience, stabilizing the behavior (Holmefur et al., 2009; Monteiro et al., 2010). In the initial phase of the motor learning process in children with CP, evaluated by means of a labyrinth task, there are many errors, inconsistency, and the need for a high level of attention. However, the activity subsequently becomes more consistent, with fewer errors and a decreased need for attention. With practice, there are fewer unnecessary movements, with consequent optimization of energy, resulting in the sequence of movements progressively gaining fluency and harmony. Furthermore, adaptation occurs when situations arise that challenge the movement capacity acquired previously, so that new action strategies must be developed in order to meet the demands imposed by the environment (Monteiro et al., 2010; Abswoude et al., 2015). In general, increases in functional ability and muscle strength can be achieved by neuromuscular training, while the practice of an exercise, activity, or task leads to improved ability and performance without the need to increase muscular strength (Monteiro et al., 2010).

The above considerations help in interpretation of the findings of this work. Comparison of the muscle activities at the different moments of the hippotherapy sessions showed that in most cases, there was no pattern of gradual increase as the sessions progressed. There was an overall increase from the 1st to the 10th session, although at some moments in the 1st session the muscle activity could be greater, with a subsequent decrease up to the 25th session. This was observed for the subjects with CP, as well as for those with adequate motor development. Over the long term, there was evidence for motor learning during the course of the hippotherapy sessions, with the requirement for less activation of the musculature to remain on the horse, following the repeated experience during the 25 sessions.

On the horse, the subject is placed in a position that inhibits spasticity of the leg extensor and hip adductor muscles. This may be useful in reducing the typically high muscle tone of individuals with spastic CP, as well as in control of the trunk and in improving posture (Bertoti, 1988). It has been reported that motor recruitment dysfunction and impaired co-activation can affect the quality of postural adjustment in children with CP. In hippotherapy, muscle contractions can occur in response to unexpected external disturbances, generating self-control of movement, which makes this therapy beneficial for improving spasticity, balance, functional capacity, and postural control (Casady and Nichols-Larsen, 2004).

During a 30-minute hippotherapy session, the three-dimensional movement of the horse generates approximately 2700–3300 repeated stimuli of adjustments of posture and tone, with the rider responding to the impulses of the movement (Debuse et al., 2005; Kwon et al., 2015). It should be noted that the results obtained here were solely caused by the three-dimensional movement of the horse, since no other activity was performed during riding, and that the individuals had diparetic CP and could therefore benefit from the gain in strength. The action on the lower limb musculature during riding promoted an increase of muscle activity during the course of the treatment. In relation to the muscle activity at the different moments during the same session, the moments that corresponded to the horse moving at a walking pace were those associated with greater muscle activity, although even with the horse static (at IS and FS), there was an important muscle demand in order to maintain balance. It could be seen that in general terms, the statistically significant differences between the moments were associated with the horse either in motion or halted.

In the literature, there are few studies that have investigated whether the type of ground on which the horse walks can affect the muscle stimuli generated in the rider. In this study, both groups showed greater muscle activity at time T20 with the horse walking on a grassy surface. However, since there was no significant difference between the moments (T1, T10, T20, and T30) when the horse was moving at a walking pace, the type of surface did not appear to influence the muscle activity. These results were in agreement with the findings of a study of children with Down syndrome and children without physical impairment, where no differences in stimuli related to trunk and abdominal muscle activity were observed for level earth, gravel, cement, and grass surfaces (Espindula et al., 2015).

The movement of the horse provides a variety of stimuli to the rider, which can be used to facilitate and improve muscle activation and the responses to the movement (Giagazoglou et al., 2013). In a pilot study undertaken prior to this research, it was found that the quadriceps and tibialis anterior musculatures presented greater activity when the feet were positioned in the stirrups, rather than outside them, and that riding using a blanket, with the feet supported in the stirrups, provided greater stimuli of muscle activity in the lower limbs, so that the seated rider was able to maintain postural control during the ride (Ribeiro et al., 2017). In the same way, in the present study, the RTA and LTA muscles were more activated during the sessions, compared to the quadriceps muscles, for both groups, but were the ones that presented the smallest variation at different moments during a single session. It is likely that having the feet supported in the stirrups led to greater recruitment of this musculature when stimulated by the three-dimensional movement of the horse.

The alternating movement of the horse simultaneously exerts vertical, lateral, and horizontal forces on the body of the rider, and the walking pace is most used for therapeutic purposes, due to its symmetrical characteristics. All the movements produced on one side of the animal are reproduced similarly and symmetrically on the other side, providing the pelvis of the rider with sequential stimuli, inducing muscle recruitment and adjustments of tone in order to avoid falling (Pierobon and Galetti, 2008). In the present study, there were natural variations in the stimuli of the quadriceps and tibialis anterior muscles, but they followed a symmetrical pattern, and neither group showed any statistically significant differences between the right and left sides, with the exception of the rectus femoris muscle, which sometimes presented greater activation on the right side. This may have happened because all participants were right-handed.

A limitation in studies involving individuals with CP is related to the sample size, due to the difficulty in recruiting a representative number of individuals of this population (Moraes et al., 2016). It is also difficult to compose a homogeneous group, due to the various forms of manifestation of the condition and considerable variability in the functional capacity classification level (GMFCS) (Sterba et al., 2002; Davis et al., 2009). Furthermore, it is hard to control the therapies to which these children are exposed, including conventional physiotherapy (Tseng et al., 2013; Kwon et al., 2015). A limitation of the present study was the small sample number. However, the inclusion, non-inclusion, and exclusion criteria enabled a more homogeneous sample population to be obtained. This research can therefore be considered to provide a scientifically valid elucidation of the effects of hippotherapy in individuals with spastic diparetic CP, focusing on disorders related to the lower limbs.

5. Conclusions

Electromyographic analysis of the lower limb activity of subjects with spastic diparetic CP and others with adequate motor development demonstrated that the movement of the walking horse generated a series of stimuli capable of muscle activation. The practice of hippotherapy led to improved gross motor function of individuals with CP, especially in dimensions D and E. The group with CP presented greater muscle stimulation than the individuals with adequate motor development, while both groups showed greater activity up to the 10th session, followed by decreases in the subsequent evaluations, indicating that motor learning had occurred. The practice of hippotherapy led to better adaptation of the muscle responses to different tasks. The type of surface did not influence lower limb muscle activation. Finally, it can be concluded that the hippotherapy provided a series of muscle stimuli that resulted in improvements in ability and lower limb activity, and that this therapeutic technique can contribute to the active rehabilitation and enhanced motor ability of individuals with CP.

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References

Abswoude, F.V., Santos-Vieira, B., Kamp, J.V.D., Steenbergen, B., 2015. The influence of errors during practice on motor learning in young individuals with cerebral palsy. Res. Dev. Disabil. 45–46, 353–364.
Araujo, T.B., et al., 2011. Efeito da equoterapia no equilíbrio postural de idosos. Rev. Bras. Fisiot. 15 (5), 414–419.
Beckung, E., Carlsson, G., Carlsdotter, S., Uvebrant, P., 2007. The natural history of gross motor development in children with cerebral palsy aged 1 to 15 years. Dev. Med. Child Neurol. 49, 751–756.
Belo, L.R., Lins, S.C., Cunha, D.A., Lins, O., Amorim, S.F., 2009. Surface electromyography of the suprahyoid muscles during deglutition of elderly people without neurological diseases and with Parkinson disease. Rev. CEFAC 11 (2), 268–280.
Bertoti, D.B., 1988. Effect of therapeutic horseback riding on posture in children with cerebral palsy. Phys. Ther. 68, 1505–1512.
Cargnin, A.P.M., Mazzitelli, C., 2003. Proposta de Tratamento Fisioterapêutico para Crianças Portadoras de Paralisia Cerebral Espástica, com Ênfase nas Alterações Musculoesqueléticas. Revista Neurociências 11 (1), 1–6.
Casady, R.L., Nichols-Larsen, D.S., 2004. The effect of hippotherapy on ten children with cerebral palsy. Pediatr. Phys. Ther. 16, 165–172.
Cunningham, B., 2009. The effect of hippotherapy on functional outcomes for children with disabilities: a pilot study. Pediatr. Phys. Ther. 21, 137.
Davis, E., Davies, B., Wolfe, R., et al., 2009. A randomized controlled trial of the impact of therapeutic horse riding on the quality of life, health, and function of children with cerebral palsy. Dev. Med. Child Neurol. 51, 111–119.
Debuse, D., Gibb, C., Chandler, C., 2005. An exploration of German an British physiotherapists' views on the effects of hippotherapy and their measurement. Physiother. Theor. Pract. 21, 219–242.
Drnach, M., O'Brien, P.A., Kreger, A., 2010. The effects of a 5-week therapeutic horseback riding program on gross motor function in a child with cerebral palsy: a case study. J. Alternative Compl. Med. 16 (9), 1003–1006.
Espindula, A.P., Ribeiro, M.F., Souza, L.A.P.S., Ferreira, A.A., Teixeira, V.P.A., 2015. Avaliação muscular eletromiográfica em pacientes com síndrome de Down submetidos à equoterapia. Revista Neurociencias 23 (2), 218–226.
Fernández-Gutiérrez, C., Apolo-Arenas, M.D., Martínez-García, Y., Cana-Pino, A., 2015. Efectos de la hipoterapia en la estabilidad postural en parálisis cerebral infantil: a propósito de un caso clínico. Fisioterapia 37 (3), 135–139.
Giagazoglou, P., Arabatzi, F., Kellis, E., Liga, M., Karra, C., Amiridis, I., 2013. Muscle reaction function of individuals with intellectual disabilities may be improved through therapeutic use of a horse. Res. Dev. Disabil. 34, 2442–2448.
Gomes, C., Golin, M., 2013. Tratamento Fisioterapêutico Na Paralisia Cerebral Tetraparesia Espástica, Segundo Conceito Bobath. Revista Neurociências 21 (2), 278–285.
Hermes, J.H., Freriks, B., Klug, C.D., Rau, G., 2000. Development of recommendations for SEMG sensors and sensor placement procedures. J. Electromyogr. Kinesiol. 14, 361–374.
Herrero, P., Trullén, E.M.G., Asensio, A., García, E., Casas, R., Monserrat, E., et al., 2012. Study of the therapeutic effects of a hippotherapy simulator in children with cerebral palsy: a stratified single-blind randomized controlled trial. Clin. Rehabil. 26, 1105–1113.
Holmefur, M., Krumlinde-Sundholm, L., Bergstrom, J., Eliasson, A., 2009. Longitudinal development of hand function in children with unilateral cerebral palsy. Dev. Med. Child Neurol. 52 (4), 352–357.
Jang, C.H., Joo, M.C., Noh, S.E., Lee, S.Y., et al., 2016. Effects of hippotherapy on psychosocial aspects in children with cerebral palsy and their caregivers: a pilot study. Ann. Rehabil. Med. 40 (2), 230–236.
Kwon, J., Chang, H.J., Yi, S., Lee, J.Y., Shin, H., Kim, Y., 2015. J. Alternative Compl. Med. 21 (1), 15–21.
Kwon, J.Y., Chang, H.J., Lee, J.Y., Há, Y., Lee, P.K., Kim, Y.H., 2011. Effects of hippotherapy on gait parameters in children with bilateral spastic cerebral palsy. Arch. Phys. Med. Rehabil. 92, 774–779.
Manikowska, F., JóŸwiak, M., Idzior, M., Che, P.B., Tarnowski, D., 2013. The effect of a hippotherapy session on spatiotemporal parameters of gait in children with cerebral palsy – pilot study. Traumatologia Rehabilitacja 3 (6), 253–257.
McGibbon, N.H., Andrade, C.K., Widener, G., Cintas, H.L., 1998. Effect of na equine-movement therapy program on gait, energy expenditure, and motor function in children with spastic cerebral palsy: a pilot study. Dev. Med. Child Neurol. 40, 754–762.
McGibbon, N.H., Benda, W., Duncan, B.R., Silkwood-Sherer, D., 2009. Immediate and long-term effects of hippotherapy on symmetry of adductor muscle activity and functional ability in children with spastic cerebral palsy. Arch. Phys. Med. Rehabil. 90, 966–974.
Menezes, K.M., et al., 2013. Efeito da equoterapia na estabilidade postural de portadores de esclerose múltipla: Estudo preliminar. Fisioterapia Pesquisa 20, 43–49.
Monteiro, C.B.M., Jakabi, C.M., Palma, G.C.S., Torriani-Pasin, C., Junior, C.M.M., 2010. Aprendizagem motora em crianças com paralisia cerebral. Rev. Bras. Crescimento Desenvolv. Hum. 20 (2), 250–262.
Moraes, A.G., Copetti, F., Angelo, V.R., Chiavoloni, L.L., David, A.C., 2016. The effects of hippotherapy on postural balance and functional ability in children with cerebral palsy. J. Phys. Ther. Sci. 28, 2220–2226.
Park, E.S., Rha, D., Shin, J.S., Kim, S., Jung, S., 2014. Effects of hippotherapy on gross motor function and functional performance of children with cerebral palsy. Yonsei Med. J. 55 (6), 1736–1742.
Pierobon, J.C.M., Galetti, F.C., 2008. Estímulos sensório-motores proporcionados ao praticante de Equoterapia pelo cavalo ao passo durante a montaria. Ensaios e Ciência: Ciências Biológicas. Agrárias e da Saúde 12 (2), 63–79.
Pina, L.V., Loureiro, A.P.C., 2006. O GMFM e sua aplicação na avaliação motora de crianças com paralisia cerebral. Fisioterapia em Movimento 19 (2), 91–100.
Ribeiro, M.F., Espindula, A.P., Bevilacqua Júnior, D.E., et al., 2017. Ativação dos músculos dos membros inferiores com diferentes tipos de suporte em hipnoterapia. https://doi.org/10.1016/j.jbmt.2017.03.020.
Sanches, S.M.N., Vasconcelos, L.A.P., 2010. Equoterapia na reabilitação da meningoencefalocele: estudo de caso. Fisioterapia e Pesquisa 17 (4).
Souza, N.P., Alpino, A.M.S., 2015. Avaliação de Crianças com Diparesia Espástica Segundo a Classificação Internacional de Funcionalidade, Incapacidade e Saúde (CIF). Rev. Bras. Educ. Espec. 21 (2), 199–212.
Sterba, J.A., Rogers, B.T., France, A.P., Vokes, D.A., 2002. Horseback riding in children with cerebral palsy: effect on gross motor function. Dev. Med. Child Neurol. 44, 301–308.
Tseng, S., Chen, H., Tam, K., 2013. Systematic review and meta-analysis of the effect of equine assisted activities and therapies on gross motor outcome in children with cerebral palsy. Disabil. Rehabil. 35 (2), 89–99.