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Neuromuscular activation analysis of the trunk muscles during hippotherapy sessions☆

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ABSTRACT

Introduction: Hippotherapy allows the development of affective, sensory, motor, and cognitive areas, besides providing the practitioner with several movements and stimuli necessary for therapeutic progress. However, there is a limited amount of scientific evidence regarding the suitability of the mount material, mount type, and hippotherapy session duration, as well as regarding the activation of specific muscle groups during the practice and its applicability to activities of daily living.
Objective: This study aimed to study the neuromuscular activation behavior of the iliocostalis, longissimus, multifidus, and upper trapezius muscles of children during four hippotherapy session time points using a functional task. It also compared two different mount materials for riding.
Methodology: A total of 30 children were randomly assigned to one of three groups: Saddle Hippotherapy Group, Blanket Hippotherapy Group, and Control Group. Data were collected with an electromyograph in a functional task that comprised trunk movements to pick up an object. Assessments took place at four times during the session.
Results: There was a significant increase in the neuromuscular activation of the iliocostalis, longissimus, and multifidus muscles after a 30-min session. The trapezius muscle showed increased neuromuscular activation after only 10 min. It continued to increase (but without a statistical difference) after and 20 and 30 min.
Conclusion: Hippotherapy promoted neuromuscular activation of the trunk muscles in children, assessed through a functional task, and was influenced by both session time and mount material. Specifically, the greater neuromuscular performance occurred when an exercise was performed using saddle and stirrup and lasted 30 min.

1. Introduction

The use of the equine as a physiotherapeutic resource, a practice known in Brazil as hippotherapy, has been increasingly widespread in health rehabilitation programs (Wood and Fields, 2019). Research has highlighted good results after interventions with hippotherapy in motor functions, especially walking, running, and jumping (Champagne et al., 2017; Pohl et al., 2018; Stergiou et al., 2017), as well as the symmetry of trunk muscle activity (Lakomy-Gawryszewska et al., 2017). It also promotes muscle balance, muscle mobility, and muscle strength in children (Champagne et al., 2017; Martín-Valero et al., 2018) and aging people (Ferriero et al., 2019; Hilliere et al., 2018). Other hippotherapy benefits include better proprioception and vestibular function, which contribute to correction and postural balance reactions (Champagne et al., 2017; Koca and Ataseven, 2015).

The potential benefits of hippotherapy are justified by the three-dimensional movement that the horseback riding rhythmically reproduces during the gait, which strengthens the practitioner's trunk muscles by improving postural control and balance. This animal's movement promotes the displacement of the

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practitioner's center of gravity in the transverse, sagittal, and frontal planes of the body. It is similar to the human pelvic movement during gait and provokes automatic reactions of postural correction that enable people to assume a more adequate orthostatic position and maintain the stability of the trunk when there are changes in position (ANDE-Brasil, 2016; Koca and Ataseven, 2015). Approximately 21,600 tonic adjustments, with activation of intrafusal proprioceptive receptors, contribute to the increased neuromuscular activation during a 30-min session (ANDE-Brasil, 2016). Given the benefits of these stimuli, researchers created machines that simulate the three-dimensional movement to replace the equine presence (Kim et al., 2014a; Noh et al., 2019).

The mount materials required for a hippotherapy session may include the use of a saddle or blanket, with or without a stirrup. The literature, despite highlighting the importance of the influence of mount material on neuromuscular activation during the practice of hippotherapy (Ribeiro et al., 2018), is scarce and contradictory as to the influence of these materials on the neuromuscular activation promoted by this activity (Espindula et al., 2012; 2014; Ribeiro et al., 2018).

Neuromuscular activation can be measured by non-invasive surface electromyography, which uses electrodes on the skin in the muscle region of interest. The recordings reveal the potential that the muscle generates in spontaneous or voluntary actions to realize movements and stabilizations of the trunk and limbs (Ghofrani et al., 2016; Kienbacher et al., 2015; Wang et al., 2016; Wei et al., 2019). Used for more than 40 years, this method provides an objective and accurate assessment and determines the electrical characteristics of muscle contraction as the neuromuscular activation frequency in the time domain. Currently, electromyography is used for neuromuscular disease diagnosis, together with nerve conduction studies, as well as for other diverse research areas, such as sports science, neurophysiology, and rehabilitation. Its ability to analyze is trustworthy even during complex movement executions, a feature in contrast to electromyography that uses needles (Ghofrani et al., 2016).

Studies demonstrated that children with chronic non-progressive encephalopathy and Down syndrome have increased electromyographic signals of the trunk muscles and lower limbs depending on the mount (Espindula et al., 2012; 2014, 2015; Ribeiro et al., 2019). However, there are few findings on hippotherapy about healthy children's neuromuscular activation. These data would allow a more reliable analysis of the practice effects (Eckert, 2013; Stergiou et al., 2017). According to Wood and Fields (2019), further research into complex interventions that integrate hippotherapy is necessary and will help identify the most promising interventions worthy of replication, evaluation, and wide adoption. Additionally, these hippotherapy studies may consider the subjective improvement of practitioners' quality of life, as reported by the families and professionals, as well as the scarcity of scientific evidence regarding the choice of mount material, mount type, and the appropriate hippotherapy session duration (Stergiou et al., 2017). Considering the kinesiotherapeutic potential produced by the wealth of stimuli triggered by equine movement, the present research proposes to analyze the behavior of trunk neuromuscular activation for performing a functional tasks during four pre-defined time points in a hippotherapy session in healthy children. This endeavor will evaluate whether, as expected, we can also observe in this population the neurophysiological activation that provides the benefits widely demonstrated in patients with diverse neurological disorders. Furthermore, investigating the minimum time required for substantial physiological activation is critical for sessions to become more appropriate for patients and therapists alike. This goal also meets one of the pillars of the ethical principles of patient care. Finally, identifying which mount material is best suited for neuromuscular activation is crucial for enriching the scientific knowledge about hippotherapy and providing the best possible results for its practitioners.

The present research hypothesized that a session of hippotherapy in healthy children can promote greater or lesser neuromuscular stimulation due to the use of a saddle with stirrup or stirrup-free blanket, and with different activation levels as a function of session time. Thus, the present study aimed to investigate the neuromuscular activation of the iliocostalis, longissimus, upper trapezius, and multifidus muscles of healthy children using two different mount materials in the hippotherapy session—stirrup saddle and stirrupless blanket—at four times during the session: before beginning, after 10 min, after 20 min, and at the end of the 30-min session.

2. Materials and methods

2.1. Research design

This research was a cross-sectional, randomized, quantitative study. 2.2.Research subjects.

This research was performed at a hippotherapy center located in Ponte Nova, Brazil. All children enrolled in a private school in Ponte Nova (Brazil), who attended the third, fourth, and fifth years of primary school at the data collection time, were invited to participate (90 children total). Of these, only 33 accepted the invitation to participate in the research. All participants and parents or tutors were informed about the procedures and signed the Assent Term and the Free and Informed Consent Term, approved by the Human Research Ethics Committee of the Federal University of Viçosa (UFV) - CAAE: 3197018.8.0000.5153. This research was also approved by the UFV Ethics Committee on Animal Use, under protocol 722/2017. The National Hippotherapy Association – Brazil guidelines were followed (ANDE-Brasil, 2016) with regards to security procedures for the appropriate clothing and equipment use. The research was also approved and registered in the Brazilian Clinical Trials Registry, with primary identifier RBR-8ww6vs.

The children were evaluated by a physical therapist to participate in the study sample according to the following inclusion and exclusion criteria.

2.2. Inclusion criteria

- Children of both genders, between 8 and 11 years old
- Enrolled in the third, fourth, or fifth year of primary school in Ponte Nova (Brazil)

2.3. Exclusion criteria

- Present any orthopedic or neurological dysfunction
- Present any joint pain, musculoskeletal dysfunction, or other disease at the moment of the session
- Involved in any other physical activity program
- Equinophobia
- Refusal to sign the Free and Informed Consent Form and/or the Assent Term.

2.4. Division of groups

Participants were randomly assigned to one of three groups. A researcher generated a sequence from 1 to 30 and performed a computerized draw that defined the interventions to be performed by each participant according to the following groups:

Fig. 1. The hippotherapy arena, with a horse-riding participant accompanied by a driver and two side aides. In addition to these individuals, a physical therapist fully followed all sessions.

1 – Saddle Hippotherapy Group (SHG): composed of 10 participants who performed a session with a saddle mount with Australian stirrups for 30 min.
2 –Blanket Hippotherapy Group (BHG): composed of 10 participants who performed a session with a blanket mount without stirrups for 30 min.
3 - Control Group (CG): composed of 10 participants who walked alongside the horse for 30 min.

2.5. Hippotherapy sessions

The hippotherapy sessions were performed with the aid of two *Equus caballus* mares of the Mangalarga breed, trained for the hippotherapy practice. They exhibit docile behavior, voice obedience, are not disturbed by noises, were trained to lean on the individuals' access ramp, like children, and accept all harness types. One of the mares is 1.5 m tall and 17 years old, while the other one is 1.6 m tall and 15 years old. Both live in individual airy bays with dimensions of 3–4 m, located on a farm in the city of Ponte Nova (Brazil), where they receive *ad libitum* feed with hay and grass, as well as piped water. They can perform three regular gaits: gallop, trot, and walk. To accomplish this research, the walk was used in a 30-min session.

All sessions were performed in a covered and rectangular arena, with an area of 20 x 50 m. The hippotherapy session involved only maintaining the participant on the horseback riding while walking, with no other movement of upper and lower limbs of the participant, and no rotational movements and linear acceleration and deceleration of the equine step. A driver, two side aides, and a physical therapist accompanied the participant, who remained supporting him- or herself at all times (Fig. 1).

2.6. Data collection

Neuromuscular activation of the trunk muscles in the SHG, BHG, and CG was assessed in a room beside the arena at four time points during the hippotherapy session: before the session began, 10 min after the session began, 20 min after the session began, and at the end of the session.

At each of these times, the participant was asked to get off the horse, go to the assessment room, and perform the following functional task: stand upright with his or her knees extended (shoulder-to-foot width) and lift a 0.5-m-high satin vinyl foam roll on the floor 0.1 m in front of him or her (Fig. 2A). For this task, the participant flexed the lumbar spine to touch the roller (Fig. 2B), raised it to head height (Fig. 2C), and returned to the starting position after placing the roller on the floor again (Fig. 2D). This task lasted approximately 8 s.

2.7. Neuromuscular activation recordings

A four-channel electromyograph (Miotec Equipamentos Biomédicos Ltda®, model Miotool - Porto Alegre - Brazil) and a notebook computer (ASUS®) were used for recording the neuromuscular activation. Each channel was coupled to a bipolar electrode (Miotec), adhesive, disposable, in disc format, 10 mm in diameter, and 20 mm apart. A reference electrode was also attached at the elbow (Hermens et al., 2000).

The bipolar electrode placement points were located by palpation in the dorsal region, in the iliocostalis, longissimus, upper trapezius, and multifidus muscles, following recommendations and references used by the European Union Biomedical Health and Research Program (BIOMED II; Hermens et al., 2000). The body region selected for the electrode arrangement was previously sterilized with gauze and 70% alcohol.

2.8. Signal and data analysis

The spectrum of the electromyographic recording was treated using Miograph 2.0® software, and the value obtained for analysis of the neuromuscular activation was the root mean square (RMS) in μV of the action potential amplitudes evoked in the muscle fibers during the task performance. A 20–450 Hz bandpass filter was applied, and signal peak normalization was used to evaluate the electromyographic signal activity level for each individual (Ghofrani et al., 2016).

Initially, the Shapiro-Wilk test was performed to test data normality obtained for the four time points, as indicated for studies with small samples. Subsequently, the RMS averages obtained for each muscle, at each time, and in the different groups were compared using Student's t-test for samples paired with one

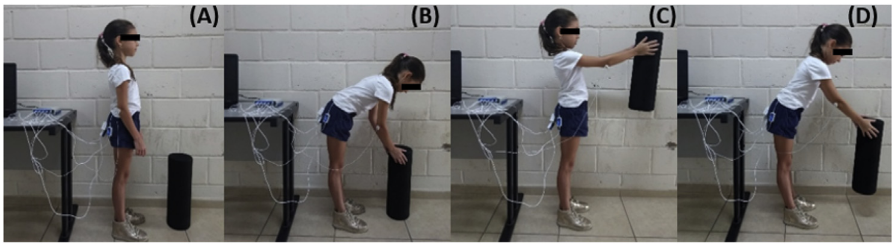

Fig. 2. Functional task in the assessment room. Moving from left to right, the participant is standing with knees extended (A), flexing the trunk to touch the roll (B), raising the roll to head height (C), and returning to the start position to place the roll on the floor (D).

Table 1
Mean of neuromuscular activation over time for the three groups evaluated.

Hippotherapy Saddle Group				
	Rest (μV)	10 min (μV)	20 min (μV)	30 min (μV)
Iliocostalis	27.40	28.60	31.08	39.72
Longissimus	26.67	28.51	27.73	31.74
Upper Trapezius	16.11	21.49	23.52	22.93
Multifidus	29.58	28.46	33.91	34.02

Hippotherapy Blanket Group				
	Rest (μV)	**10 min (μV)**	**20 min (μV)**	**30 min (μV)**
Iliocostalis	31.86	31.73	33.18	31.67
Longissimus	26.57	26.81	27.36	25.08
Upper Trapezius	22.11	26.72	31.47	22.47
Multifidus	28.74	27.13	27.05	29.12

Control Group				
	Rest (μV)	**10 min (μV)**	**20 min (μV)**	**30 min (μV)**
Iliocostalis	32.70	32.04	27.64	29.64
Longissimus	30.17	26.73	25.50	22.59
Upper Trapezius	27.15	22.90	25.24	20.33
Multifidus	31.78	31.23	30.12	25.93

Table 2
Statistical analysis of the mean difference in neuromuscular activation during the session in relation to rest for the three groups evaluated.

Iliocostalis	Saddle		Blanket		Control	
	Activation difference between session and rest (μV)	p-value	Activation difference between session and rest (μV)	p-value	Activation difference between session and rest (μV)	p-value
10 min	1.248	0.4177	0.2660	0.4599	0.659	0.5805
20 min	3.667	0.1500	1.0180	0.3313	5.062	0.9618
30 min	12.305	0.0136*	0.1959	0.5374	3.060	0.8182

Longissimus	**Saddle**		**Blanket**		**Control**	
	Activation difference between session and rest (μV)	**p-value**	**Activation difference between session and rest (μV)**	**p-value**	**Activation difference between session and rest (μV)**	**p-value**
10 min	1.838	0.2570	2.686	0.9104	3.403	0.9187
20 min	1.056	0.2758	2.138	0.9567	4.633	0.9623
30 min	5.076	0.0096*	4.417	0.9418	7.542	0.9782

Upper Trapezius	**Saddle**		Blanket		Control	
	Activation difference between session and rest (μV)	**p-value**	**Activation difference between session and rest (μV)**	**p-value**	**Activation difference between session and rest (μV)**	**p-value**
10 min	5.381	0.0433	4.610	0.0706	4.180	0.9072
20 min	7.411	0.0224*	8.359	0.0526	1.913	0.7161
30 min	6.822	0.0810	0.357	0.4580	8.346	0.9990

Multifidus	**Saddle**		**Blanket**		**Control**	
	Activation difference between session and rest (μV)	**p-value**	**Activation difference between session and rest (μV)**	**p-value**	**Activation difference between session and rest (μV)**	**p-value**
10 min	0.679	0.4438	1.61	0.6661	0.544	0.5757
20 min	6.126	0.1096	1.69	0.6327	3.196	0.8317
30 min	6.237	0.0321*	0.383	0.4584	6.618	0.9752

variable. Throughout the analysis, a 95% level of statistical significance ($p < 0.05$) was considered using Stata® software.

3. Results

After exclusion of three volunteers for nonspecific back pain complaints, the sample included 30 children, 15 females and 15 males, with a mean age of 9.4 ± 1.14 years.

The neuromuscular activation mean over time for the three groups is shown in Table 1. The SHG showed an increase in this neuromuscular activation after 10, 20, and 30 min in all studied muscles compared with initial rest. For the BHG, the iliocostalis, longissimus, and trapezius muscles exhibited an increase in the neuromuscular activation after 20 min of intervention before it decreased, whereas the multifidus muscle presented a slight increase only at the end of the session. The CG showed a progressive

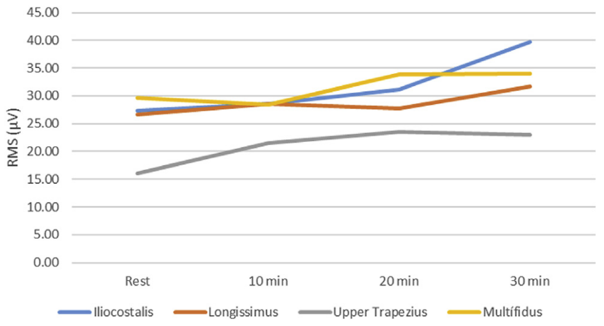

Fig. 3. Mean neuromuscular activation for each assessed muscle over time in the Saddle Hippotherapy Group (SHG).

decrease in neuromuscular activation of all muscles during the activity.

When the difference between the means of the neuromuscular activation of the studied muscles during the sessions was calculated in relation to the initial rest, there was a significant increase in neuromuscular activation of the iliocostalis (12.3 µV; $p = 0.0136$), longissimus (5.07 µV; $p = 0.0096$), and multifidus (6.23 µV; $p = 0.0321$), in the trunk movements of extension and flexion only after 30 min of hippotherapy (Table 2). The trapezius muscle presented significant differences, with increased activation only after 20 min, (7.41 µV; $p = 0.0224$). However, there was no significant difference after 30 min (6.82 µV; $p = 0.081$).

In the BHG and CG, there were no statistically significant differences between the activation means of any assessed muscle. For the SHG, Fig. 3 shows curves with an upward trend. All final time averages were greater than the initial ones.

Muscle activation in the BHG showed variable behavior during the riding time, with resting values similar to those at the end of the session (Fig. 4).

In the CG, muscle activation presented a downward trend in neuromuscular activation throughout the stages (Fig. 5). The data revealed that gait did not increase trunk muscle activation in the movement of trunk flexion and extension from the standing position after 30 min.

4. Discussion

The neuromuscular activation analysis of the children's trunk muscles during hippotherapy presented positive and accumulative effects over the session time when using the saddle mount and stirrups. These data are consistent with the literature for people with motor control deficiency of the trunk (Espindula et al., 2012; 2015) and healthy individuals (Ribeiro et al., 2018). The blanket mount without stirrup and the CG showed no increase in neuromuscular activation over time, and thus it is possible that there is an association between the significant increase of the neuromuscular activation in the SHG and the sensorial stimuli provoked in the soles of the feet by the stirrup. This association may cause a response that results in the foot automatic extension forward of the support surface, an action that would increase the postural tone and adapt balance to each movement (Eckert, 2013; Kim et al., 2014b; Menezes et al., 2013; Stergiou et al., 2017). The somatosensory stimuli of the neck and vestibular system, activated by changes in the head orientation, can also influence the postural tone distribution in the trunk and limbs (Espindula et al., 2015).

The upper trapezius muscle was the only examined muscle without increased activation in the movement of trunk flexion and extension after 30-min hippotherapy in the SHG. These data may be justified by the modulation that exists in the postural response amplitudes. With repeated movement exposure, individuals can increase body balance and demonstrate lower amplitude postural responses by refining the response characteristics to optimize task effectiveness. The cranial extremity is most spatially displaced during three-dimensional movements by the horse, and thus the upper trapezius muscle can enter into a feedforward state, defined as preventive actions that occur prior to the sensory detection of a homeostasis rupture, based on previous experiences. The adjustments of postural anticipation, which are motor development patterns, support the ability of the nervous system to neutralize the reaction forces that are induced by a focal movement before performing the movement (Kobesova and Kolar, 2014). However, the neuromuscular activations presented by the BHG, which were not statistically significant, can be justified by the absence of the saddle and especially the stirrups, which may have led to the manifestation of muscle fatigue due to the greater request for tonic adjustments in the extensor musculature (Kienbacher et al., 2015).

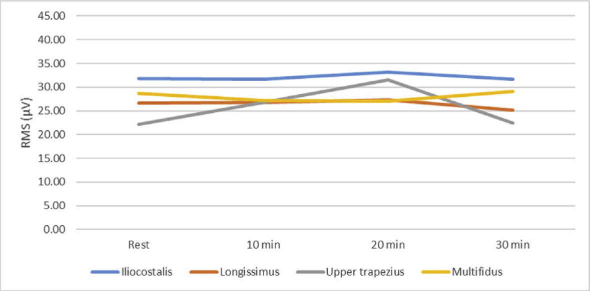

Fig. 4. Mean neuromuscular activation for each assessed muscle over time in the Blanket Hippotherapy Group (BHG).

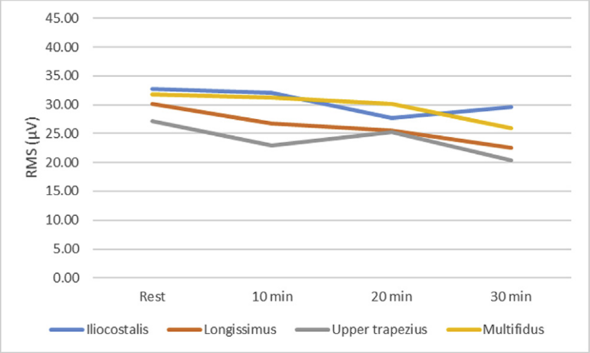

Fig. 5. Mean neuromuscular activation for each assessed muscle over time in the Control Group (CG).

The data obtained from the CG evaluation showed a slight reduction in erector muscle activation. Although Koca and Ataseven (2015) and Uchiyama et al. (2011) highlighted that there are similarities between the human gait and the horse gait—for example, in the losses sequence and balance resumption, three-dimensional movement, and dissociation of pelvic and scapular waists—the decrease in neuromuscular activation in the CG can be explained by the anticipatory postural control, which adjusts the posture before voluntary movements to minimize the possible balance disturbances that the movement can cause. This postural control requires attention processing and can reduce the performance of a second task performed simultaneously or reduce the postural task (Claudino et al., 2013; Kienbacher et al., 2015).

Dynamic tests such as the one performed in the present study, namely picking up and lifting a roll, promote an increased myoelectric activation of the trunk erector muscles due to their function in controlling the descent in favor of gravity (an eccentric contraction). This task can be classified as functional because it simulates an integral movement of daily living activities. The combination of the hamstring and trunk muscles in a standing trunk flexion and extension task is called the lumbopelvic rhythm and should be evaluated because it resembles several activities of daily living; their proper control will increase functional independence (Kienbacher et al., 2015).

Although different tasks evoke distinct trunk muscle activity (Wang et al., 2016), the neuromuscular effects obtained in a given activity can be observed in the performance of a different task performed by the same muscle group (Kobesova and Kolar, 2014). The proprioceptive and motor stimuli provoked during hippotherapy facilitate the practitioner's task of balancing while horseback riding, but performing a distinct motor task, as was done during the four assessment times, involves the activation of relatively distinct control mechanisms and movement regulation; these will be more complex the harder the task is (Kim et al., 2014b). Considering also that cortical reorganization is environment dependent (Arya et al., 2011), the fact that the practitioner balances the trunk during a mount does not necessarily elicit the same neuromuscular reaction when balancing his or her trunk during the assessment task. However, the analysis of dynamic trunk motor control patterns can be extrapolated for use in diagnosing and treating locomotor system dysfunction (Kobesova and Kolar, 2014) and understanding the various patterns of trunk muscle activity over time. It is presented as a possible relevant factor for the adequate design of therapeutic activities, as well as the materials used during their practices. Thus, the assessment of spontaneous motor behavior, reflexes, and postural reactions—as is the purpose of a functional assessment—can serve as an important clinical tool to reassess the child in a treatment and evaluate the effect of the implemented therapy. It provides feedback to therapists and parents and may also allow comparison of different types of treatment strategies (Morrell et al., 2002).

Finally, Wood and Fields (2019) published the largest systematic review of hippotherapy to date and concluded that to advance the evidence base of hippotherapy more effectively, researchers must address gaps in fundamental work. Furthermore, they must develop studies that integrate the use of equine movement by highly trained health professionals and link enhanced bodily functions with enhanced participation in everyday life and quality of life to help improve the functioning of people of all ages. The gaps about the influence of mount material and the session time of the hippotherapy, investigated by a physical therapist who sought to associate these effects with a specific musculature through functional activity, respond directly to these recommendations and provide a more appropriate scientific knowledge base for future interventions that utilize hippotherapy.

5. Limitations of the study

The primary limitation of the present research was the small number of participants per group. Although the research included 33 participants, the statistical analysis may have been impacted by limited comparisons to groups with only 10 participants. Nevertheless, we highlight that the sample is above the average reported the literature that involves this practice, possibly due to the technical difficulties for its accomplishment. Other important factors to consider include sample selection, which focused on only one school, and the lack of blinding of researchers and individuals. Although the researchers performed a randomized division of the groups and they were similar, the validity of the research may have been impacted by these factors.

6. Clinical relevance

Considering that continuing research of complex interventions that integrate hippotherapy, equine movement as a therapy tool is warranted, as highlighted by the systematic review of Wood and Fields (2019). The findings of the present research can contribute to the enrichment of the scientific knowledge on the subject and suggest that:

Healthy children may also benefit from the hippotherapy practice in view of their increased neuromuscular activation during the functional activity tested.

The gain in neuromuscular activation is increasing over the session time, since the highest activation was observed at the last assessment time point, i.e., after the 30-min session.

The methodological strategy for hippotherapy using the stirrup saddle is more efficient than using the non-stirrup blanket, especially when the clinical objective is to focus on neuromuscular activation of trunk muscles.

In short, these findings provide a better use of the sessions and stimuli that the horse transmits to the practitioner. The choice of mount material and the appropriate length of the session are key to achieving the best results.

7. Conclusion

The practice of hippotherapy can promote trunk neuromuscular activation in healthy children, and it is influenced by both session time and mount material. The 30-min saddle and stirrups practice produced higher levels of trunk neuromuscular activation during a functional task of flexing and extending the trunk compared to the blanket group without stirrups and the control group (walking). Multicentric research with a larger participant numbers are recommended to support these findings and to promote hippotherapy in the safest and most accurate manner.

Disclaimer

None.

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