Hippotherapy with Neurological Disorders
Why do we Apply Hippotherapy in Neurological Diseases? A Brief Overview and Future Perspectives

**Introduction**

As a multidisciplinary approach, hippotherapy is a kind of rehabilitation that stimulates the patient both emotionally and physically. In fact, equine-assisted activities and therapies are effective means for improving many features of physical health in several neurological conditions such as mood disorders, attention deficit hyperactivity disorder, post-traumatic stress disorders and Down’s syndrome [1-6] (Figure 1). Among the natural gaits of the horse (pace, trot and canter), the most used in equine-assisted therapy (EAT) is the pace, thanks to its intrinsic characteristics of cyclicity in cadenced and rhythmic beats, and to three-dimensional movements imposed to the patient in the saddle, perfectly simulating (for amplitude and frequency) the human gait. The rhythm of the horse at pace, about 60 oscillations per minute, allows the relaxation of muscle tone, whilst the sinusoidal shape reproduces the bascule of normal walking movement. In the three-dimensional sinusoidal horse's movement at pace, the back of the horse becomes an "afferent" pacing bridge particularly important for the person riding: back and forth, from side to side, top and bottom. This requires the compensation of muscular reactions of readjustment to promote balance and postural correction, necessary to effectively remain on the saddle. The horse's movement is transmitted to patient's central nervous system through many afferent nerve terminations; the brain, in turn, sends this information to the whole body so that the adjustments are made by an adaptive behavior aimed at rebalancing [7]. The three-dimensional horse's movement at pace is a sinusoid acting on the patient.

**Horseback movements** (Table 1) allow the patient to find a right posture, balance stabilization and straightening [8].

| Types of horse back movement | Effects on patient |
|-----------------------------|--------------------|
| Back and forth               | An anteroposterior movement of the sagittal plane due to the constant accelerations and decelerations during pace acts with a high concentration in patient's straightening |
| From side to side           | Because of the centrifugal force, the patient loses balance on the left and right in rhythmic alternation. At pace, the pushing action of the horse's rear legs determines an associated lateral flexion of the animal's spine. A rotational component in the horizontal plane during pace stimulates the dissociation of the shoulder girdle from the pelvic bone. |
| Top and bottom              | Stimulation on the vertical plane is particularly effective in the trot, due to the different characteristics and symmetrical skipped gait |

Table 1: Type of horse back movement and their effect on patients.

The parallelism between the three-dimensionality of the human walking and the horse's gait gives the opportunity to the patient who have never walked or who walked with improper motor patterns to experiment the effects of EAT at the pelvis, trunk, girdle, upper limbs and head levels, resulting in stimulation of righting reactions and equilibrium [8].

In this perspective, it is fundamental how and who will choose the right horse, having the ideal morphological and disposition characteristics for the EAT; this choice requires a serious and progressive work plan and a proper training aimed to make the horse as safe and properly trained as possible.

The key variables that become so indispensable to ensure a high level of EAT are:

- The amplitude of pace movement, which varies in relation to the height of the animal (the more the horse is high, the more extensive will be the changes in balance), the amplitude of the chest (the more the chest is wide, the more extensive will be the wave movements) and the length of the trunk (the most the trunk is long, the more the movement will be large);
- The frequency of the movement, which depends on the length of the horse limbs in an inversely proportional manner;
- The age of the horse: an older horse feels more pain than a younger one and will tend to be more rigid and with reduced movements compared to a young animal; however, the older horse has usually more calm nature and less energy. Finding a right balance between these characteristics is one of the most important aspects to get the best benefits from EAT;
- The line that ideally links the hip points to the upper third of the scapula should be parallel to the ground.

The saddle is on its own able to select and filter reflex movements on the patient.
The horse movement is transmitted to the ischial bones of the patient, at the same time the hemipelvis are alternately forwarded and right and left rotated (Figure 1).

Figure 1: The horse movements.

The position on the horse allows a drastic broken of pathological postural patterns and riding plays a motion pattern that can be repeated over a longer period, at the similar rate of the human step.

The set of all the reported components allows:

1. The regulation of muscle tone
2. Pelvic mobilization/stabilization
3. The reinforcement or the appearance of righting mechanisms and trunk control
4. The improvement of the equilibrium reactions (especially in relation to changes of pace and direction).
5. Reduction of involuntary movements

Furthermore:

1. The visual and spatial stimulation provided by the special atmosphere of the stables with changes in color and brightness in relation to the movement of the horse stimulates a visual finalized attention, thus facilitating the acquisition of the size of the space;
2. The environments where the horses live have typical odors and noises, that are very evocative;
3. The intense tactile stimulation due to the contact with a large animal helps the awareness and knowledge of both oneself and horse's body;
4. The horse is a being expressing emotions like fear in which the patient can recognize and where he/she can hire a reassuring role; at the same time, riding a big and powerful animal offers protective feelings, self-esteem and self-confidence;
5. The horse has a lot of qualities such as warmth, softness, smell, smooth movements, big and intense eyes that may stimulate the important aspect of the attachment process for human development;
6. The relationship established with the horse is also an extraordinary element to recover the consciousness of patients’ psychomotor skills, reactions and emotions.

All the reported features are favored by the involvement of specialized therapists who, thanks to their “therapeutic” experience, make possible that the patient obtains the best goals from this rehabilitative treatment.

On the other hand, to get the best results, it is important that the patient attends regularly the rehabilitation program and that there are no other contraindications to apply EAT (i.e. cardiac problems, epilepsy, hip dysplasia).

However, several controlled trials are still needed to strengthen the current knowledge, to establish dose-response characteristics of equine-assisted activities and therapies, and to better explore the physiologic basis of EAT.

**Future Perspectives**

In the near future, hippotherapy exercise program should be fostered to assess movement reaction time, muscle activation, functional mobility, muscle strength and balance and to provide objective clinical data on the role of sensory integration in maintaining postural stability and in the quantification of the subject’s center of gravity. In this framework, gait analysis and stabilometric tools may play a major role in evaluating the effects of EAT in several neurological disorders.

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Postural Stability after Hippotherapy in an Adolescent with Cerebral Palsy

Abstract

Objectives: To investigate whether hippotherapy has short- and long-term effects on postural control in an adolescent with cerebral palsy (CP).

Design: Pre-and post-treatment follow-up with 5-week intervention. Quantitative stabilometry and a modified sensory organization test were performed to determine the subject’s response after hippotherapy (HT). The total path length and the lengths of the mediolateral and anteroposterior centre of pressure (COP) movements were calculated.

Settings: Measurement system from the Health Faculty research laboratory in centre for HT.

Participant: Adolescent with CP.

Intervention: 5 weeks’ hippotherapy, 3 times per week for 30 minutes.

Measures: Modified sensory organization test, stabilometry and gross motor function measure.

Results: The results of measurement of the short-term effect of HT on the parameters of movement of the COP on a firm surface with eyes open show that the total path length decreased by 20.94%, the path length in the mediolateral direction decreased by 24.30%, and in the anteroposterior direction by 17.91%; the area of the stabilogram decreased by 55.54% and the individual variance index (IVI) decreased by 9.95%. After completion of HT, the total path length decreased by 33.70%, the path length in the mediolateral direction decreased by 30.48%, in the anteroposterior direction by 35.06%; the stabilogram area decreased by 59.82% and IVI decreased by 15.10%.

Conclusion: In our case study the modified sensory organization test on the force plate was sufficiently sensitive to detect fluctuation changes in the COP; therefore it is appropriate for continued use. Similarly, HT was found to have a positive effect on postural control.

Keywords: Cerebral Palsy; Diplegic; Postural Control; Hippotherapy; Stabilometry

Abbreviations: CP: Cerebral Palsy; HT: HippoTherapy

Introduction

CP

The term “cerebral palsy” is used when the cerebral insult has occurred before birth, around the time of birth or up to the age of about 3 years, while the brain is still undergoing rapid development [1,2]. Disorders of movement and posture are caused by damage to the motor cortex. In addition to postural and motor abnormalities, which are always present, people with CP may exhibit learning disabilities, other cognitive and sensory impairments, hearing and visual loss, speech and language disorders, emotional problems, orthopaedic complications and epilepsy [3-6]. The consequences of chronic muscle imbalance and the resultant deformities can cause increasing disability with age [7,8]. One of the most significant problems in children with CP is defective postural control.

Posture

Posture involves orientation of the body in space so that muscles work efficiently against gravity. Postural control is dependent on proper functioning of righting, equilibrium and protective reactions, which are controlled by the central nervous system [9,10]. A certain degree of postural control is essential for controlled and coordinated movement of the extremities, head and trunk control, functional trunk mobility, maintaining symmetry, displaying the ability to weight shift and bear weight in all directions, and coordinated and voluntary limb movements [11-13]. Individuals with central nervous system damage may show signs of disrupted postural mechanisms [10,13] “Postural control is organized at two functional levels. The first level consists of a direction-specific adjustment when the equilibrium of the body is endangered, or the generation of direction-specific patterns of postural adjustment, while the second level fine-tunes the basic, direction-specific adjustment with input from the somatosensory, visual, and vestibular systems” [9]. Hippotherapy, in which equine movement is used for its therapeutic effect, is one of the approaches for improving postural control [15].

Hippotherapy (HT)

HT is defined as the therapeutic use of a horse as part of an integrated treatment strategy for children and adults with movement dysfunction [16-18]. The primary goal of HT is to improve the individual’s balance, posture, function, and mobility. The horse’s gait provides a precise, smooth, rhythmic, and repetitive three-dimensional pattern of movement to the rider [19-23]. In general, the movement of the horse provides a variety of inputs to the rider, which may be used to facilitate improved contraction, weight shift, and postural equilibrium and balance responses, and improve strength,
coordination, muscle tone, joint range of movements, weight bearing, gait, and sensory processing [19,24-26].

Stabilometry

Stabilometry is one of the most commonly used methods for measuring the parameters of postural steadiness. It determines the movement of the body’s COP within the support base during upright stance [27].

The dual purpose of our study was to:
1. Verify the suitability and feasibility of the modified test of sensory organization
2. Establish the short and long-term effects of HT in a person with cerebral palsy on the stability of posture, which are inferred from parameters of movement of the centre of pressure.

Methods

Participants - subjects

The University of Ljubljana, Faculty of Health Studies and the Centre for Education and Rehabilitation for Children and Adolescents with Special Needs approved the pilot study. Inclusion criteria for the subject included: (1) adult; (2) CP, (3) no previous hippotherapy. The participant signed a consent form approved by the Centre for Education and Rehabilitation for Children and Adolescents with Special Needs. No attempt was made to limit participation in other activities. The participant continued to receive physiotherapy and occupational therapy.

The subject of the case study was an 18-year-old male with a diagnosis of cerebral palsy and epilepsy. The subject suffered from spastic diplegia, with greater impairment on the left side. The asymmetry of muscle tone and increased muscle tone on the left side of the body resulted in mild asymmetry of the ribcage, an asymmetrical position of the pelvis and adduction and internal rotation of the left lower limb with knee flexion and inversion of the left foot. Asymmetry of muscle tone causes asymmetry of the whole body and perception of the body in space, which is reflected in the change in control of body posture in the standing position, with the asymmetry being even more pronounced when walking. The degree of functional motor ability, expressed by the GMFM test (Gross motor function measure), was 79% before hippotherapy.

Procedures and design

Intervention: The adult participated in a 30 – minute hippotherapy intervention 3 times a week for 5 weeks HT intervention. HT was individualized according to the adult’s needs and administered by one physiotherapist with support from riding instructors. During a 30-minute session the therapist encouraged a symmetrical body position, additional pelvic movement, especially to the left and right, and stimulated lateral trunk flexion and rotation between the pelvis and the shoulder girdle.

Measurements on the force platform, on which movement of the COP was measured, were performed before the commencement of HT, immediately after the first HT session and after the five-week period. Besides stabilometry, a modified sensory organization test [12], which comprised six measurements in quiet standing on the force platform, was performed before hippotherapy. Immediately following HT the same six measurements were repeated. The first two movements comprised standing on a firm base with the feet 17 cm apart, with eyes open and closed. For the next two measurements the subject had his feet together with eyes open and closed. In the third two measurements the subject stood on a soft base with his feet 17 cm apart, with eyes open and closed.

Table 1: Results of the modified sensory organization test before HT and after 5 weeks’ HT; data on the paths, area and IVI. Data are classified according to when hippotherapy was performed.

Before hippotherapy

| Measurements | Path (cm) | M-L path (cm) | A-P path (cm) | Area (cm²) | IVI |
|--------------|-----------|---------------|---------------|------------|-----|
| After the first HT | FB EO | 120.89 | 56.46 | 95.75 | 7.29 | 1.93 |
| FB EC | 153.13 | 85.29 | 109.45 | 18.92 | 2.05 |
| SB EC | / | / | / | / | / |

Feet together

Before the first HT

| Measurements | Path (cm) | M-L path (cm) | A-P path (cm) | Area (cm²) | IVI |
|--------------|-----------|---------------|---------------|------------|-----|
| After the first HT | FB EO | 132.23 | 75.51 | 91.63 | 14.39 | 1.83 |
| FB EC | 182.23 | 94.16 | 136.91 | 18.47 | 2.01 |

After the first HT

| Measurements | Path (cm) | M-L path (cm) | A-P path (cm) | Area (cm²) | IVI |
|--------------|-----------|---------------|---------------|------------|-----|
| Before the last HT | FB EO | 114.66 | 63.05 | 82.92 | 12.50 | 2.09 |
| FB EC | 166.04 | 109.82 | 102.51 | 19.36 | 1.83 |

Before the last HT

| Measurements | Path (cm) | M-L path (cm) | A-P path (cm) | Area (cm²) | IVI |
|--------------|-----------|---------------|---------------|------------|-----|
| After the last HT | FB EO | 101.14 | 45.51 | 81.14 | 16.43 | 2.10 |
| FB EC | 150.48 | 89.00 | 102.59 | 18.92 | 2.05 |
| SB EC | 169.91 | 101.30 | 114.47 | 16.52 | 1.74 |

Feet together

Figure 1: COP movement and area described by the platform with the subject’s feet in the spontaneous position, 17 cm apart on a hard surface with eyes open.

Figure 1: COP movement and area described by the platform with the subject’s feet in the spontaneous position, 17 cm apart on a hard surface with eyes open.
apart with eyes open and closed (Figure 1). The demand for postural control was increased by standing with feet together, thus decreasing the support base, and by closing his eyes.

Data analysis: Stabilometry was used to assess the amount of postural sway. Data were collected at a 50 Hz sampling rate for 60 seconds using a portable force platform (Kistler 9286 AA, Wintherthur, Switzerland). The raw data were stored on the disk of a PC-type computer using Kistler’s BioWare programme. For the analysis they were later uploaded to a server running under the Linux (Fedora 12) operating system. Data analysis was performed using web-based software that had been specially developed for our stabilometric measurements [27].

Analysis of the stabilometric data was begun by smoothing the acquired COP positions in the mediolateral and anteroposterior directions using moving averages over 10 adjacent points. From the resulting data standard statistical parameters of standard deviation and the averages of the absolute values of COP displacements and velocities, total path length and the lengths of the mediolateral and anteroposterior COP movements and the frequency distributions of the positions and velocities were calculated. Finally, we determined the outline of the measured data and calculated its Fourier coefficients, area and other related parameters.

Results

The 18-year-old adolescent, despite impaired movement due to CP, was able to stand on the force platform for 60 seconds with feet together or apart with eyes open and closed. On the soft base, before the first hippotherapy session, he stood with feet apart and eyes open for 60 seconds and in the same position with eyes closed for only 25 seconds, while after 5 weeks’ therapy he also stood for 60 seconds under the same conditions (Table 1).

The results of measurements with the force platform were analysed on two levels. Initially, we observed the short-term effect of a 30-minute hippotherapy session on the parameters of movement of the COP on a firm base and eyes open: the total path length decreased by 20.94%, the path length in the mediolateral direction decreased by 24.30% and in the anteroposterior direction by 17.91%; the stabilogram area decreased by 55.54% and IVI decreased by 9.95% (Figure 2). Later, we compared the results before hippotherapy and after five weeks’ therapy, which revealed that the total path length decreased by 33.70%, the path length in the mediolateral direction...
decreased by 30.48%, in the anteroposterior direction by 35.06%; the stabilogram area decreased by 59.82% and IVI decreased by 15.10%. All the results for the total path length of the COP, path length in the mediolateral and anteroposterior directions, stabilogram area and IVI of the subject are presented in Table 1. The pretest GMFM score was 79% compared to 86% at the conclusion of the test period after five weeks' hippotherapy. The 7% improvement was found only in parts D (standing) and E (walking, running and jumping).

**Discussion**

The presented case study provided information on the suitability of the proposed measurement protocol for the assessment of the effects of hippotherapy on the stability of posture or improvement in balance in people with sensorimotor disturbances. We established that it is possible to carry out the proposed modified sensory organization test in its entirety before and after hippotherapy in a person with the spastic form of CP. The subject was able to maintain the position for the 60 seconds required to obtain the data under all measurement conditions, in the spontaneous feet position, with feet together, with eyes open and closed and on a soft base. Sixty seconds represents the period for obtaining data that provides greater reliability and reproducibility of obtained stabilometric data [28]. We found that the parameters of COP movement after hippotherapy decreased when the subject had his eyes open, as did parameters for the total path length of the COP and individual components, that is anteroposterior and mediolateral components of the path length and the area described by the COP. They increased if the subject closed his eyes, and further increased if he stood on a soft base. The increase in postural sway is characteristic of the fluctuation in sensory input and conflicting information, resulting in a significant increase in the stabilogram area [27,28]. Since the path length of the COP and average speed are correlated, the results of our study can be compared with those of Kuczyński and Słonka [29], who reported a decrease in average speed and extent of sway in the anteroposterior and mediolateral direction and their standard deviations, which means decreased variability between attempts or a smaller number of larger excursions towards the edge of the force platform. Similarly, speed of movement decreased. There was no change in movement frequency in children with CP after 3 months' therapy that consisted of riding on the Brunel active balance saddle twice weekly for 20 minutes. The difference between people with CP and a comparable group of healthy children was statistically significant in this study.

Knowledge of equine-assisted therapies, especially hippotherapy, and their efficacy is continually increasing and becoming more reliable and precise [30]. Most studies focus on researching the effects on the Gross Motor Function Measure (GMFM), muscle tone, temperospatial parameters of walking and energy use during walking. One of the rare studies to use stabilometry as a measurement tool is the above-mentioned study of Kuczyński et al. [29]. In addition, in meta-analyses with systematic reviews a detailed analysis of studies that influence the effect of HT on postural control and balance has been performed [31]. These results show that hippotherapy, which transmit stimuli across the pelvis and thus elicit the righting and equilibrium reactions are effective improving postural control in people with CP.

**Conclusion**

With this case study we verified the feasibility and suitability of the modified test of sensory organization and stabilometry and the short-term effects before and after hippotherapy in a person with CP. We established that the modified sensory organization test on the force platform is sufficiently sensitive to detect changes in oscillation of the COP on the force platform. A longitudinal study is planned to analyse the long-term effects of hippotherapy. This will enable us to answer the question as to how hippotherapy influences postural control in a larger sample of adolescents with CP. Analysis of obtained data showed that the protocol is suitable for obtaining answers to the hypothesis posed prior to the case study.
Combination of Hippotherapy with Technical Bobath Method in Body Extensor Control of a Patient with Tetraplegia due to Cerebral Palsy

Abstract

The hippotherapy is a therapeutic method based on the practice of horsemanship activities that uses the horse as main kinesitherapeutic agent. Already the Neuroevolutive concept of Bobath consecrated there are years, it is used of specific techniques of inhibition, facilitation and neuromuscular stimulation, objectifying to modify standard postural tone and abnormal movements, facilitating standard motors of more appropriate movements. Therefore, this study has as objective to verify the evolution of an experimental protocol through exercises, associating the hippotherapy to Bobath’s techniques. It was used as study object an individual of the seven year-old masculine sex, with spastic tetraplegic diagnosis due to cerebral paralysis. The apprentice presented thoracic hyperkyfosis, hypertonic flexor reaction associated to the extending hypotonic thoracic reaction of the musculature, time delay in the recovery and rectification side, deficit of lateral balance, without capacity of executing March. The procedures were accomplished in the section of hippotherapy of Unisep, in two neighbors, PR, Brazil. The apprentice accomplished fifteen sessions with maximum duration of 30 minutes on the horse. The activities were structured seeking to stimulate motive coordination, proprioception, vestibular and motor-sensory system, they provided alterations of 20% in the thoracic cifosis, it improves in the time of the lateral reactions of protection in up to 700%, it improves of the muscular force of upper extremities passing of the degree 3 for 4 according to the scale of Oxford and it improves of the muscular tonus of upper extremities of the degree 3 for 1, according to the modified scale of Ashworth.

Keywords: Hippotherapy; Bobath method; Cerebral paralysis; Postural correction

Introduction

Cerebral palsy is a chronic non-progressive encephalopathy, frequent and changeable of motor impairment (tone and posture) secondary to damage the developing brain [1,2]. The harmful event may occur in pre, peri or post-natal care, taking into account the semiology which is divided into quadriplegia, diplegia, paraplegia, triplegia, hemiplegia or monoplegia. As for the type of involvement it can be divided into spastic, ataxic, and mixed atetotic [3].

Neuro-Bobath treatment concept uses inhibition of specific techniques, facilitating and stimulating which can be adapted to all types of neuromotor dysfunction [4]. Since adjusted to the individual needs of each patient, aiming to modify patterns of postural tone and abnormal movements, facilitating more appropriate motor patterns of movement, prepare the child for a variety of motor skills, having the possibility of live experiences that are favorable for brain plasticity [5].

In rehabilitation, mounting means help individuals develop normal activities, and its purposes are: improvement in balance, adjustments, tonics, alignment and body awareness, spatial and temporal organization and coordination. Objectives are similar to those of the Bobath method [4] which aims to facilitate the reaction balance, correction and protection.

Thus this study aims to apply an experimental treatment in equine therapy techniques involving the Bobath method with exercises performed on the horse to a patient diagnosed with spastic quadriplegia from cerebral palsy.

Material and Methods

This case study on the effect of techniques combination of Bobath Method and hippotherapy through an experimental protocol was performed on a seven year old male patient diagnosed with spastic quadriplegia due to cerebral palsy, which has hypertonia in upper and lower limbs, extensor hypotonia of the trunk, legs crossed, thoracic kyphosis, generalized muscle weakness, body asymmetry, impaired protection in side reactions and preserved cognitive inability to perform gait, and presents level III by Gross Motor Function Classification System (GMFCS). The patient has a history of perinatal distress in cesarean section, where it received a score of 4 in APGAR bulletin, both in the first minute of life, and in the second and fifth minute after birth. During pregnancy there were no relevant events through information provided by the mother. The patient performs some kind of treatment through traditional physical therapy since birth.

Assessment tools

For this work we had a permission form signed by the parents, informed intervention protocols and the accompanying norms of Resolution 196/96 of the National Health Council on research involving humans. We used an evaluation form adapted to the physical therapy patient used by Hippotherapy industry, a platform with 1.85 m long and 1.38 m wide, the ISP brand, a digital Sony camera, model Cyber-shot DSC-W30, 6.0 mega pixels, manufactured by Sony Corporation, the mobile stopwatch model 125 Mg LG brand, neurological reflex hammer brand ISP, warm heating pad, ice, tape...
brand ISP, black marker Faber Castell Kraft paper, Pentium 4 PC, Windows Vista and AutoCAD software.

Then the patient’s physical evaluation was performed at the Unisep Therapeutic Hippotherapy Center using a platform and a horse, prior to the first and after the last session, with the purpose of identifying and characterizing it as well as its acquisitions and motor deficits. The upper limb muscle tone was assessed according to the modified Ashworth Scale based on the study of Shurtleff et al. [6]. This scale has a minimum degree of 0 and a maximum of 5. Zero is considered normal tone and 5 severe hypertonia, the passive motion is impossible. The degree of upper limb muscle strength was evaluated according to the Oxford Scale. This scale classifies muscle strength and ranges from 0 to 5, where 0 is the absence of muscle contraction and 5 normal strength.

**Ratings**

The evaluation took place on the platform as follows: The patient sat on the platform was shifted to the right to rest on his own forearm, then received a verbal stimulus to return to the starting position. The time the patient took to return to the starting position was recorded. The procedure was repeated systematically to the left.

After that, the patient in the initial cat position on the stage received a verbal stimulus to raise the right arm and was kept on three supports. The stay in this posture was timed and performed consistently with the left side. On the horse the evaluation was as follows: The student was put in the cat position on the horse and the stay in this posture was recorded. All reaction time and maintenance of posture was timed three times each. Time were added and divided by three to obtain the average of each.

The images were standardized with actual measurements to be analyzed by AutoCAD Software. To take the photos we used a wall lined with kraft paper and this was marked forming a bounded numerical scale of ten centimeters. The horse was positioned on the side of this scale and the patient was placed in a sitting position on the horse without support. The procedures for all images were the same, being bounded a fixed distance of two meters and photographic records were made before the first, after the eighth and after the last session.

**Procedures**

Procedures were as follows: the patient held fifteen sessions of hippotherapy exercises associated with the Bobath method for at most 30 minutes on the horse, three times a week in a row. The activities were structured to stimulate tonic and postural adjustments, to increase resistance of the extensor muscles of the trunk and upper limbs, as hypotonia and muscle weakness are considered characteristic of cerebral palsy.

We used an 800 m² oval shape sand track, a creole breed horse with buckskin single coat, 1.15 m tall, gentle and trained for hippotherapy, basic saddlery - a saddle type Chincha, blanket with stirrups and pommel, halter and bridle, and protective riding helmet. Auxiliary devices used: cone, crisp ball, hula hoop.

The patient performed all the exercises in simple riding. The treatment program execution is as follows:

1st exercise: The patient in the sitting position without support, while the horse was led to perform movements of “coil” with use of six cones arranged in a linear distance of 2 m between each cone, in a total of twenty repetitions, leaving from the first cone and returning to the same.

2nd exercise: The patient in the sitting position without support, the horse was led to perform moves in a circle, clockwise and counterclockwise. Ten turns to each side.

3rd exercise: The student sat on the motionless horse performed bimanual movements associated with rotational movements of the trunk for both sides and throwed the ball into the basket. Ten repetitions for each side.

4th exercise: patient in inverted mount, bimanual supported on the horse’s back with elbows extended for four laps on the track. Two turns clockwise and two turns in the counterclockwise direction.

5th exercise: The student maintained a sitting posture with good alignment of trunk while were performed output movements and stop of the horse turn. For this exercise there were ten shifts of about five meters on a straight line.

6th exercise: The patient sat on the motionless horse, without support, holding the crisp ball of 15 cm with both hands, and held the position maintained flexion of both shoulders passing the ball into the hoop, handing it to the therapist (therapist holds the hoop). Fifteen repetitions. In order to the patient not lose interest in the session due to the repetitions during the exercise, the last five sessions of the hula hoop was replaced by a cone for the patient to fit the ball inside, just as a change of reference.

**Results and Discussion**

Over the patient physical examination before the equine therapy treatment it was observed that when the patient was sitting he kept the trunk forward flexioned due to mild hypertonia of this region and the anterior extension associated with hypotonia of the trunk, characterizing a marked thoracic kyphosis. The patient had no associated motor impairment, the upper and lower limbs showed a mild degree of bending stiffness with distribution in flexion.

He had no ability to perform gait, did not show any associated disorder relate to vision, hearing, speech or respiratory system.

In neurological examination was found that the patient did not show any abnormal primitive or pathological reflex activity, only a delay in time recovery and side recovery. Data analysis of the initial and final assessments was through comparative charts and photographs with the aid of AutoCAD software, shown below.

In Figure 1 the patient is in sitting position on the horse at the end of the outlined scale, with bilateral support of the forearms and hands.
severe thoracic kyphosis and cervical protrusion. The real value of column initial height measured by AutoCAD is 34.2 cm (marked in green).

As noted above, in Figure 2 after the eighth session the patient has the value of the column height increased to 35.25 cm, which gives an improvement rate of 3% compared to the initial value in Figure 1.

There was improvement in thoracic kyphosis and cervical protrusion, the support became only the pommel hand and forearm is not supported on the horse. From the eighth session the patient did not require consecutive verbal and sensory stimulation to keep the trunk posture in the midline and the head high, even without the continued support of the pommel he could use the arms to hold the ball, which agrees with a study by Duarte Barbosa [7], which reports improved trunk control, balance and postural adjustments from the eighth hippotherapic session for an individual with spastic cerebral palsy.

Figure 3 illustrates the final treatment after the fifteen sessions. Analyzing the thoracic kyphosis before and after execution of the protocol it is evident a spine gain extension, ie, the decrease of the thoracic kyphosis and improved cervical protrusion, increasing the value of the patient column height to 41.03 cm, which compared to the amount of Figure 2 we have an improvement rate of 16%.

Comparing Figure 1 (before treatment) as shown above (after fifteen sessions), there was a total improvement of 20%. Support remains only on the manual pommel and his forearm is not supported on the horse, showing improvement in thoracic kyphosis and the resistance of the trunk extensor muscles and improves static balance in a seated position, which is consistent with Meregillano [8] who reports improved posture and static balance in practicing hippotherapy.

Figure 3 shows positive resistance gain of the trunk extensor muscle by repositioning along the vertebral column at the end of fifteen sessions and through therapeutic exercises on the horse leading to an increase of 6.83 cm in the patient height position, which gives us an improvement rate of 20%, which in fact seems to agree with the findings of Silkwood-Sherer and Warmbier [9], who observed significant improvements promoted by hippotherapy in spine imbalances in patients with cerebral palsy.

Chart 1 compares in seconds the time of reactions recovery for left and right side, for cat position on the platform with four and later with three supports, before the first and after the fifteenth session. The average reaction time of recovery for right side went from 5.66 to 3.33 seconds, thus having a better percentage of 41.17%.

According to the results in the analysis of the cat position on the platform there was an improvement of 13.19% by comparing the initial value which was 12.66 seconds with the final value that resulted in 14.33 seconds keeping the position. According to the results obtained in the initial and final cat position on the platform raising the right arm, an increase in time from 2 to 6.47 seconds with an improvement rate of 223.5% can be observed.

However the left side as well as the left side reaction time there was a higher percentage of improvement than on the contralateral side, the initial value of permanence increased from one to eight seconds, which gives us a percentage of 700% improvement in time.

Chart 2 compares the time in seconds referring to the initial and final assessment of the patient’s permanence in cat position on the horse. After fifteen sessions his stay in the same position was increased to 5 seconds, obtaining an improvement of 500% compared to the average time.

Chart 3 shows initial and final evaluation of the MMSS muscle tone according to the Ashworth scale. Before the first session his tone was graduated in three and after the last session, was graduated in 1, thus obtaining an improvement of 40% over the MMSS muscle tone.

Chart 4 shows the initial and final assessment of the patient’s MMSS muscle strength. It’s possible to note that before the treatment
start the degree of force was 3 and after fifteen sessions it went to 4, with a 20% improvement in MMSS strength muscle.

Given that the sample participant had at the beginning of the experimental protocol improper placement of trunk anterior flexion, severe thoracic kyphosis and anterior head protrusion due to the hypotonia extensor and flexor hypertonia of the trunk, he did not remain in a sitting position without the support of the hands and forearms by global muscle weakness, and deficit of static balance due to spastic quadriplegia framework deriving from cerebral palsy [10-12], during the first visits it was noted moderate difficulty for the patient to remain sitting unsupported on the horse without missing balance and falling down. Another factor was about the difficulty in extending the trunk and keep his head up, due to trunk anterior flexor hypertonia and deficit of trunk extensor control.

From the fourth visit it was possible to observe improvement in thoracic kyphosis due to postural adjustments, improved trunk control to the imbalance even with the horse in motion [12]. It also showed better quality in the movement of raising the arms above the head. These same positions became spontaneous and without difficulty, because the patient held his head up so that the trunk remained extended longer. In this sense, the therapist has the function to lead and facilitate the achievement of normal movements, inhibit the realization of abnormal movements and encourage normal patterns of movement during the session [13,14].

These functions mentioned above were the basis for the treatment techniques association, which were held until the seventh session, i.e, beyond the protocol activities performed by the patient associated with the movements provided by the horse, the therapist had a sensory feedback through tapping on the dorsal region of the spine and forehead, besides verbal stimulation to the patient during treatment.

From the eighth session the patient did not require consecutive verbal and sensory encouragement to keep trunk posture in the midline and the head up, even without the continued support of the pommel and could use his arms to hold the ball, what is in accordance with the study by Zadnikar and Kastrin [7], which reports improved trunk control, balance and postural adjustments from the eighth equoterapic session for patients with spastic cerebral palsy.

According to Hamill et al. [15] the horse’s oscillations and movements stimulates balance reactions and a better control of the patient’s trunk and head position, a fact observed in Figure 2. The improvement in patient’s static balance in the sitting position, according to Santos [16] it is from an improving balance of the patient that the control can progress to cervical trunk control. It is also evident in Figure 2, the improvement thoracic kyphosis due to occurred muscular tonic adjustments and increasing of the column extended extension muscle resistance.

Figure 3 shows positive gain in resistance of the trunk extensor muscle by extending repositioning along the vertebral column at the end of fifteen sessions as well as through therapeutic exercises on the horse leading to an increase of 6.83 cm in the patient’s height position, which gives us an improvement rate of 20%, which actually seems to work according to observed significant improvements promoted by hippotherapy’s spine imbalances in patients with cerebral palsy [17].

With trunk organization it may perform its functions more easily. The trunk should be able to align the vertebral segments and stabilize them in static position as well as in weight bearing, perform flexion, extension, side inclinations and rotations according to Silva e Borges et al. [18] it can be combined thanks to spine mobility.

This dual purpose handling/stability is ensured by the trunk muscles. Fact observed at the end of treatment, greater control on the mobility of the shoulder girdle while performing bilateral shoulder flexion, trunk rotation when throwing the ball, reduction in time reaction of right and left side recovery and correction in the increase of the MMSS muscle strength to stay longer in cat position on three supports on the platform and cat position on the horse. According to the Oxford power scale, before the treatment start its graduation was 3, after the treatment the graduation went to 4, thereby obtaining an improvement rate of 20% after the treatment.

In his experience with hippotherapy Lisinski and Stryla [19] report that the walk was always described as the gait for excellence in activities that use the horse as a therapeutic means, which together with the work of Frank et al. [1] where the hippotherapy through the three-dimensional motion of the horse’s back and synergistic action of agonist and antagonist muscles will rescue the global postural mechanism reflex, maintaining posture and balance.
Neuromotor techniques used in the treatment associated with equine therapy, according to Klimont [20] help to stabilize the postural tone in the head organization, torso and limbs. We have observed that spastic muscle groups through the effect of movement of the horse received alternately the resulting posterior antero-lateral impulse with spasticity reduction under the effect of inhibition techniques, facilitating and gradual and symmetrical stimulation. According to Kwon et al. [21] spasticity is one of the causes of movements limitations in neurological patients, a fact observed in the patient during the first sessions, who had difficulties in performing movements such as raising his arms above the head to hold and play the ball, presented by spasticity in his MMSS, and was evaluated based on Lechner et al. [22] by the Ashworth modified scale in step 3.

From the eighth session these difficulties were reduced by adjusting tonic and postural correction. It was obtained a 40% improvement in the MMSS spasticity degree when the modified Ashworth scale went from the first level to level 3 at the end of one treatment using the gait as inhibiting pathological patterns and encouraging normal adding to the dissociation of the shoulder girdle through bilateral exercises with trunk rotation, shoulder flexion and making changes in position on the horse.

Lisiński and Stryla [19] reported that avoiding abrupt motions and resistance is important to encourage the application of selective movement with the maximum symmetry on both sides. This fact is in agreement with the experimental protocol performed in our work where bilateral exercises were performed avoiding sudden movements that could increase MMSS spasticity degree.

Shurtleff et al. [6] reported that the central nervous system uses automatic postural responses to provide quick reactions, but despite moves go quickly, Benda et al. [23] reported that they are not so quick to the point of not being understood by the human brain, and their repetition, symmetry, rhythm and cadence in making their responses arise very quickly, what makes this a great advantage of horse using.

For balance disorders equine therapy provides a better balance in the patient by the constant stimulation of the horse three-dimensional motion that is performed on the vestibular system, cerebellum and reticular patient [24]. This fact can be observed by decreasing recovery time and side rectification and maintenance of the cat posture on the horse on the platform shown in Charts 1 and 2.

In this sense, the techniques associated with hippotherapy Bobath method becomes a method of rehabilitation and mental motor, acting as a facilitator of teaching and learning [4,20,23,25], making the central nervous system to react at stimulations that converge from the outside and inside the body, inhibiting the uncoordinated activity and facilitating utility functions simultaneously promoting capacity of motor learning.

Therefore, according to the findings of this study, we observed that at the end of fifteen sessions, the patient showed significant improvement in thoracic kyphosis by quantifying torso alignment, improvement of static balance at sitting position adopted because of the taken position without support on the horse, improvement in time recovery and side recovery, improvement of MMSS muscle strength through increased time in the cat position on the horse and on the platform, and tonic adjustments enabled by the benefits favored by the Bobath method techniques combination and hippotherapy.
Neurological Rehabilitation after Severe Traumatic Brain Injury, New Tools
New Hopes: The Hippotherapy Approach

Abstract

Traumatic brain injury is an unexpected and heavily disabling event occurring mostly in young adults, frequently leading to devastating consequences for the individual and his relatives. Therapeutic alternatives are limited and neurological rehabilitation remains relatively confidential. Besides, therapeutic success when noticed is mostly empirical and need to be scientifically clarified. Hippotherapy is a rather novel therapeutic approach where by the therapist uses the horse’s movement as a therapeutic intervention or support. Multimodal sensory inputs generated by the horse’s rhythmic walk generate adaptive responses in the patient that conceivably promote plastic changes in brain circuits. The consolidation of motor and non-motor improvements depends partly on the congruence of the session frequency and content. In this paper, we describe the improvements noticed during a two-year’ series of short programs of hippotherapy in a patient that suffered a severe traumatic brain injury in 2010 that generated permanent serious neurological and neurobehavioral sequelae.

Keywords: Traumatic brain injury; Neurological impairment; Cognitive; Sensorimotor; Brain plasticity; Hippotherapy; Neurorehabilitation.

Introduction

Worldwide, traumatic brain injury (TBI) is the leading injury cause of death and permanent disability. In the United States, there are about 1.4 million cases of TBI known per year while in France, for the same period, 155,000 cases are treated in the emergency services. Among the later, 8500 will be severely injured and will have an identified permanent disability. The high prevalence of chronic neurological and neuropsychiatric sequelae can devastate the lives of survivors and their family caregivers.

From a mechanistic point of view, there are broadly two types of forces that result in brain trauma: contact and inertial. Both of these forces are associated with two main categories of brain damage: focal damage and diffuse injury. Focal harm includes cortical and/or subcortical severe contusions and lacerations, as well as intracranial bleeding (subarachnoid hemorrhage and subdural hematoma). Diffuse injury, mainly diffuse axonal injury (DAI), is due to acceleration/deceleration forces that lead to shearing of axons and doesn’t need any skull fracture nor direct impact neither crush injury to the brain surface [1].

Brain trauma generates a complex cascade of neurochemical changes that affects brain function: deregulation of ion flux, including efflux of potassium and influx of calcium, release of excitatory neurotransmitters, mainly glutamate, further depolarization, influx of calcium ions, and widespread suppression of neurons with glucose hypometabolism. Increased activity in membrane pumps in order to restore ionic balance, raises glucose consumption, depletes energy stores, causes calcium influx into mitochondria, and impairs oxidative metabolism and consequently anaerobic glycolysis with lactate production, resulting in acidosis and edema [2,3].

After TBI of any severity, a substantial amount of patients exhibits cognitive and emotional difficulties that, even without motor or sensory deficits, may prevent returning to work and other social activities. Rehabilitation after TBI is a complex process because patients’ individual needs evolve with time and depend upon the severity and type of TBI, pre-morbid functional status and levels of medical and social support. Intensive intervention appears to lead to earlier gains and prompt transfer to rehabilitation services can potentially improve functional outcome and lower global hospitalization costs. However, access to neurorehabilitation services remains restricted [4].

Few laboratory studies have examined the beneficial effects of physical therapy on recovery. Emerging strategies implement specialized training protocols, such as constraint-induced movement therapy for the arm and hand [5], behavioral shaping using robotic devices [6], bilateral arm training [7], body weight-supported treadmill training [8], task oriented physical therapy [9], and music therapy [10]. Nevertheless, the reasons for the effectiveness of these treatments remain unclear. Improvement is presumably the result of synaptic changes/remodeling in response to the different inputs [11].

Method

Hippotherapy (from Greek hippos = horse) is an emerging specialized rehabilitation treatment, performed on a horse under the direction of an accredited health professional (e.g. physical therapists, occupational therapists, psychomotoricians, speech-language pathologists, clinical psychologists, and others). The movement of the horse at a walk is used as a therapeutic intervention or support by the therapist. During Hippotherapy, the patient has no intentional control over the horse’s movement [12].
During Hippotherapy, the center of gravity of the horse at a walk describes a three-dimensional movement similarly to humans when walking. The adaptation of the patient to the pace rhythm is one of the key pieces of Hippotherapy. The inputs coming from the smooth and rhythmic movements made by the horse facilitate and improve patient’s muscle co-contraction, joint stability, weight shift, and postural and equilibrium responses, directly targeting gross motor function [13]. The tonic rhythmic adjustment of the osteoarticular movement facilitates the transmission of a great deal of proprioceptive information. Thus the new information, determined by the horse inputs, allows the creation of new motor schemes and/or the reinforcement of existing ones [14].

A typical Hippotherapy session consists of an initial period of passive muscle relaxation and postural adjustments solely in response to the horse’s movement, followed by position changes and active exercises directed by the therapist. Thus, by introducing figures such as circles or serpentines the therapist can challenge lateral weight shift and midline postural control; by lengthening the horse’s stride he allows the transmission of greater movement amplitude through the patient’s pelvis and trunk; by accelerating/decelerating the walk he challenges anticipatory or feedback postural control; by walking on uneven terrain he incorporates predictive visual environmental cues to the session; and so on. Moreover, the powerful thrusts of the horse’s legs provide strong vestibular and proprioceptive stimulation and heighten body awareness, while repeated small postural adjustments help the patient gain a more normative sense of midline, symmetrical weight-bearing and body-image [15]. As a whole, the strong solicitation of the sensorimotor sphere promotes and interacts with mechanisms related to the executive functioning linked to the cognitive (memory, attention, executive function, speed of information processing ...), and social spheres (social comportment, motivated behavior.) [16].

**Case Report**

MM is a 26 years-old man who suffered a severe traumatic brain injury in September 2010 (car accident). He was initially hospitalized in an anoxic comatose state and was in a coma for 10 days. At the admission GCS scored 6 and evolved to 9-10 during the first month. The initial MRI (10/08/12) report stated important parenchymal supratentorial lesions consisting of signal abnormalities of white matter in the semiolateral centers of the posterfrontal region, parietal region and corpus callosum (most likely post-anoxic, non hemorrhagic), and some degree of atrophy of the hippocampus (CA, gyrusdentatus and para-hippocampal gyrus) associated with an enlargement of the temporal horns of the lateral ventricles.

Initially hospitalized in an Intensive Care Unit for two months, he was transferred to a Physical Medicine and Rehabilitation Service for eight months and was finally managed in a community Medical and Social Center for one year. As a whole, he remained hospitalized until June 2012 when he returned home. MM presents neurological signs of a frontal syndrome:

Behavioral changes and dysregulation of motor activity characterized by (i) psychomotor slowing accompanied by initiative loss in the activities of daily living (ADL), default of gesture initiative and spontaneity, deficit in the mirroring of a series of gestures and rhythms; and (ii) disorders of posture and gait consisting on occasional static and dynamic loss of balance, slow and asymmetrical locomotor movements, slow gait cadence, and permanent flexion of the hips and knees in the upright position.

Cognitive changes characterized by (i) attention and concentration deficit, short term memory deficit, absence of logic organization of data to be memorized and limitation of the field of interest; (ii) difficulty with reasoning and judging; and (iii) reduction of verbal communication associated to a lack of verbal spontaneity/initiative.

**Hippotherapy intervention**

The therapeutic program started in August 2012 and initially consisted of three sessions of Hippotherapy per week during three weeks. Since then, he has followed five short therapeutic programs at a rate of a session per day for one week (June 2013, August 2013, November 2013, March 2014 and July 2014).

Initially, each therapeutic program started with an evaluation session to observe the patient’s current psychological state, executive coordination, walking pattern, postural control, static and dynamic balance and sensory integration. Subsequently, the therapeutic team oriented each activity towards a specific target, therefore, once the aim accomplished, the program was retuned to the next target.

A typical session started with grooming, equipment of the horse and self-equipment. Then, the therapeutic team conduct the patient in riding tracks with or without reins in a rectangular 2,000 sq.m indoor arena, trick riding exercises in a round track in the indoor arena, and/or on foot workout in a 18m diameter round pen. All sessions started with the horse preparation in order to enable the patient to connect with and to warm up before the session. Each exercise was designed with a specific target in mind:

Riding tracks were aiming at stimulating the cognitive functions in charge of attention, memory, anticipation, and movement initiation. Simultaneously, the horse movement provided multiple inputs that passively stimulated gait, balance, postural control and coordination. Active workout was conducted by the physiotherapist and oriented to bettering postural control, upper and lower limb coordination, static and dynamic balance, muscle reinforcement and walking pattern. Track complexity was gradually raised.

Trick riding was utilized to develop body’s spatial orientation and balance reactions. The therapist progressively added complexity to the exercises in order to stimulate in the patient more accurate movements.

Round pen work focused on self-awareness and was used to observe patient’s ability to check and respond to his own errors. This helped remove potential barriers to the rehabilitation.

**Results**

Based on the intermediate evaluations, we can state an encouraging evolution of MM’s condition on different levels of the sensorimotor and cognitive spheres such as coordination and balance control, fine motor control, attention and working memory, self-initiative and self-awareness (e.g. he is capable to adjust his upper limb movements and thus, to effectively guide his horse through more complicated courses). Furthermore, we can also notice a progression on trick riding exercises: the gain in postural control benefits upper and lower limbs movement. Likewise, static and dynamic balance has gradually improved. By the end of each short therapeutic program the progression has been clear. However, a continuous improvement of
his neurological condition has been hindered by the limited access of MM to Hippotherapy.

**Discussion**

As in the case of MM, subsequent long-lasting disability occurs frequently after TBI. Much of this arises from cognitive and psychomotor impairment and treatment of these drawbacks is often ineffective, but when beneficial, the mechanisms of action are frequently unclear. TBI often produces diffuse injury of white-matter connections resulting from DAI which would disconnect brain regions, and could mainly determine clinical outcome. Complex processes involve distributed neural networks and functional impairment reflect disruption of these networks. Interestingly, the network-based hypothesis emphasizes an impairment in anticipatory control which rather than associate this process to a single neural region such as the frontal lobe, consider how this aspect of brain function emerges through the interactions of several regions including frontal lobe, parietal lobe and cerebellum [17]. The anticipatory control needs both appropriate “before-the-action” motor and cognitive skills which are highly altered in the case of our patient’s ADL. Interestingly, during the Hippotherapy session on the horse, the co-activation of different brain regions by means of simultaneous multimodal inputs (visual and auditory cues, sensory cues, cerebellar cues) outwardly promotes the organization of adapted responses during the exercises.

It must be emphasized that a fundamental property of the brain consists on its capacity to change in response to a broad range of inputs, including injury situations. In the latter, although there are spontaneous reparative mechanisms which follow an injury, these mechanisms are hardly ever sufficient to support substantial functional recovery even though the brain is inherently capable of changing to enable at least some behavioral restitution. The degree of plastic changes is related to both the relevance of an experience and the intensity or frequency of its constituent events [11]. According to previous works, experiences that are highly relevant are likely to produce much more rapid neuronal changes than less relevant ones. In contrast, experiences that are perceived as irrelevant may not lead to neural changes. In the same way, intensity or frequency of the experience is also crucial [18,19]. Since self-awareness is not deeply altered in the case of MM, one can reasonably assume that strong psychological cues are playing a key role in making relevant the experience on the horse [20]. Indeed, the multisensory inputs that generate a balanced, stable and regular independent locomotion-like perception in the disabled patient are thought to be strong building blocks for the reconstruction of a self body-image and the idea’s reinforcement of the experience’s relevance.

Finally, we hypothesize that one of the main targets of the Hippotherapy approach is the cerebellum which is massively interconnected with the cerebral cortex. Conventionally, it was established that the cerebellum receives information from widespread cortical areas, including portions of the frontal, parietal, temporal, and occipital lobes. It is nowadays clear that outputs from the cerebellar nuclei project to a myriad of cortical areas, including regions of frontal, prefrontal, and posterior parietal cortex via the ventrolateral thalamus. This influences more widespread regions of the cerebral cortex than was first thought. It provides the anatomical substrate of cerebellar influence in nonmotor as well as motor areas of the cerebral cortex. Accordingly, abnormal activity in these circuits leads not only to motor deficits but also to cognitive, attentional, and affective deficits. The outputs of the cerebro-cerebellar loops provide the cerebellum with the anatomical substrate to influence the control of movement and cognition. The range of tasks associated with cerebellar activation is remarkable and includes tasks designed to assess attention, executive control, language, working memory, learning, pain, and emotion [21]. During Hippotherapy, effective use of multisensory inputs related to posture and movement would provide the basis for a reinforcement/remodeling of the cerebro-cerebellar circuits.

**Conclusion**

A more solid scientific groundwork for restorative neuroscience is needed. This would improve our understanding of the basis for cognitive and psychomotor integration after TBI and potentially facilitate the development of novel approaches. Understanding the effect of this injury at the level of large-scale brain networks will provide important insights for the elaboration of tailored neurorehabilitation programs. Hippotherapy represents an exciting new support both for rehabilitation of neurological disorders and for carrying on targeted research programs in neuroscience.
Effects of Short-Term Hippotherapy on Strength, Sensory-Motor Skills, and Attention in Adult Patients with Neuromuscular Dysfunction

Abstract

The purpose of the present study was to quantitatively assess the effects of hippotherapy on sensory-motor skills, strength, and attention in four adult patients with neuromuscular dysfunctions (two with Down syndrome, one with laesio cerebri, and one with mental disorder). Patients participated in hippotherapy once a week, for 8 weeks. Before and after the intervention, strength components such as hand-grip strength, vertical jump force, and knee extensor torque were assessed. Balance, simple-choice foot and multiple-choice hand reaction time, and attention with a short-term memory task were also measured. Balance and both types of reaction times improved in all patients, but change strengths were inconsistent. The greatest improvement was found in attention. The present data provide evidence that short-term hippotherapy is an effective treatment strategy in the development of sensory-motor and cognitive skills of patients with neuromuscular dysfunction.

Keywords: Dynamometry; Riding; Down syndrome; Disability

Introduction

Sensory-motor skills and muscle strength are essential in a person’s ability to quickly adapt to the environmental changes with coordinated movements. Patients with movement disorders (originating from either inherent disease or birth-related injury) are characterized by reduced motor function [1], postural control [2], visual perception and visual-motor performance [1], balance [3], and movement speed [2]. In addition, the neuromuscular deficit is often accompanied by reduced cognitive abilities (Lee et al.), which exacerbate movement disability.

Various useful physical therapy modalities exist to target motor performance deficits, including aerobic exercise [4], neuromuscular training [5], movement control exercise training [6], and neurodevelopmental therapy [7]. Alternatively, it has been demonstrated that horseback riding can improve functional task performance by reducing reaction time [8]. Hippotherapy (HT) has been recently used as a specific technique to provide sufficient exercise stimuli to enhance functional improvements in patients with neuromuscular dysfunctions [9-11]. During HT, the therapist targets the rider’s weaknesses to facilitate sensory-motor and perceptual-motor skills by using various postural movements on the horse [12]. Balance improvements in patients are reported in several studies using HT [10,11,13]. Lee et al. [10] used quantitative and qualitative balance tests and found that HT remarkably improved both dynamic and static balance in children with cerebral palsy. Others demonstrated that balance can improve in as short as 6 weeks (two sessions per week) after HT [13], suggesting early adaptation in proprioception. In addition, a 10-week-long HT enhanced gait speed and mobility in adult patients with chronic brain disorders [11].

Muscle strength is an important component of movement quality, however, only few data are available on strength changes after HT. In a case study, it was shown that gait speed, and muscle strength evaluated by functional tests (sit-ups, hip extensions, plantar flexion, and jumps) improved after 12 HT sessions in a boy with traumatic brain injury [14]. Furthermore, increased muscle activation during a chair stand-up test was demonstrated after 14-week HT in intellectually disabled adolescents; however, no strength measurements were taken in the experiment [8].

The Gross Motor Function Test is often conducted for the demonstration of the favourable effects of HT, and it was found that all of its components (lying and rolling, sitting, crawling and kneeling, standing, and walking) improved after 8 weeks [9]. Furthermore, increased daily activity and life quality evaluated with the Pediatric Evaluation of Disability Inventory are also frequently reported in patients. Park et al. [9], for example, found that HT improved self-care, mobility, and social functioning in children. Others demonstrated positive changes in functional performance of daily life skills assessed with the self-administered 30-item Activities Scale [13].

While previous research evaluated mostly qualitative measures before and after HT, which are based on subjective scores, there is a lack of quantitative data on the effectiveness of HT. Furthermore, little information is available about whether HT is effective in developing muscle strength. Here we quantitatively investigated the short-term effects of HT on strength, balance, reaction time, and attention in four adult patients with neuromuscular dysfunction. Using laboratory tests and equipments with consistent methodology and environment during pre- and post-treatment measurements, it was expected to accurately quantify HT-induced changes in the selected variables.
Cases and Methods

Patients

Four adult patients were recruited in the study. Table 1 shows patients’ descriptive characteristics. Patient 1 and 4 were diagnosed with Down syndrome, and have middle severity mental disorder. Imbecillitas was also documented in Patient 4. Patient 2 was diagnosed with laesio cerebri, imbecillitas, and epilepsy. Patient 3 had severe mental disorder. Patients were recruited from a local institution for individuals with mental disabilities. Before any testing and intervention, patients’ guardians signed an informed consent to agree to participate in the study. Patients participated in a familiarization session in order to get accustomed to the test exercises and equipments. On a separate day, patients were tested on muscle strength, reaction time, balance, and attention, which were repeated after the HT intervention. At the time of the experiment, none of the patients participated in any other rehabilitation program.

| Descriptives                        | Patient 1     | Patient 2     | Patient 3     | Patient 4     |
|-------------------------------------|---------------|---------------|---------------|---------------|
| Diagnosis                           | DS, MD        | LC            | MD            | DS, MD        |
| Gender                              | female        | female        | male          | female        |
| Age (years)                         | 19            | 42            | 18            | 32            |
| Height (cm)                         | 157           | 182           | 169           | 157           |
| Body weight (kg)                    | 48            | 71            | 78            | 50            |
| Performance measures                | PRE           | POST          | PRE           | POST          |
| Simple choice RT (s)                | 0.95          | 0.94          | 0.52          | 0.39          |
|                                   | unable        | 0.39          | unable        | 0.89          |
|                                   | 0.94          | 0.94          | 1.19          | 1.91          |
|                                   | 1.73          |               |               |               |
| Balance (%)                         | 68            | 74            | 22            | 31            |
|                                   | 37            | 46            | 46            | 18            |
| Attention (%)                       | 50            | 85            | 35            | 75            |
|                                   | 80            | 0            | 80            | 120           |
| Handgrip strength (N)               | 150           | 150           | 300           | 300           |
|                                   | 300           | 250           | 300           | 80            |
|                                   | 250           |               | 120           | 47            |
|                                   | 47            | 30            |               |               |
| QF isometric strength (Nm)          | 88            | 95            | 106           | 95            |
|                                   | 95            | 42            | 74            | 74            |
|                                   | 74            | 68            |               |               |
| QF dynamic strength (Nm)            | 64            | 83            | 124           | 120           |
|                                   | 120           | 47            | 47            | 16,8          |
|                                   | 30            |               | 18            |               |
| Vertical jump force (N/kg)          | 23,5          | 21            | 21,4          | 21,7          |
|                                   | 27,9          | 29,2          | 16,8          | 18            |

Table 1: Descriptive data of patients, and changes in the performance measures. RT=reaction time, QF=quadriceps femoris, DS=Down syndrome, LC=laesio cerebri, MD=mental disorder.

Strength measurements

Before strength testing, patients warmed up by riding a stationary cycle ergometer for 3 minutes at a self-selected speed and by stretching the lower extremity muscles. On Multicont II isokinetic dynamometer (Mediagnost, Budapest and Mechatronic Ltd, Szeged, Hungary), three maximal bilateral isometric knee extensions were performed in a sitting position, at 70° knee angle. Patients were instructed to generate force to the lever of the dynamometer, while giving visual feedback about their efforts. This followed three maximal dynamic knee extensions, between 80° and 20° knee angle. From the torque-time curves (sampling rate: 1000 Hz) we determined knee extensor peak torque for both isometric and dynamic contractions.

To test multi-joint strength, vertical jump force was determined by using a force plate (Tenzi, Pilisvorosvar, Hungary). Standing on the force plate, patients placed their hands on their hip and performed three maximum effort countermovement jumps. Peak ground reaction forces were measured and normalized to patients’ body weight.

Hand-grip strength was measured using a Jamar dynamometer (Bolingbrook, USA). Patients performed three attempts with both hands, and the best values for both hands were averaged.

Sensory-motor skill testing

Multiple-choice hand reaction time (RT) was measured with a complex sensory-motor tester (type EM-05.58K, STRUKTURA Instruments Ltd., Tura, Hungary). Coloured light lit up on the surface of the equipment, and patients selected and pressed the button with the corresponding colour as fast as possible. Four colours were used as stimuli in this test. Simple-choice foot RT was also measured with the same equipment. When a light lit up, patients pressed a foot switch as fast as possible. For both RT conditions, forty stimuli were delivered continuously, among which the time intervals ranged between two and seven seconds.

Balance was tested with a stabilometer (type EM-05.47M, STRUKTURA Instruments Ltd., Tura, Hungary). Patients were instructed to place their hands on their hip and maintain standing posture on the stabilometer. The test was performed with opened eyes and lasted for 30 seconds, and three trials were performed with one minute rest between trials. Patients received visual feedback on a screen about their postural position, and they were required to perform the task with the least postural sway by moving the center of gravity. Values were expressed in percentage (0% and 100% represent that the stabilometer is fully tilted and maintained in full stability, respectively).
Attention testing

A digital tachistoscope (type EM-05.74, STRUKTURA Instruments Ltd., Tura, Hungary) with multifunctional image exposure and recognition surface was used to evaluate patients' attention, applying a short-term memory task. The test started with a five-second exposure of an image stimulus (letter or number) on the image exposure surface. After this disappeared, three different images appeared on the recognition surface (also including the image stimulus to be recognized) for another five seconds. When these images disappeared, patients attempted to select the right button, which corresponded to the image stimulus (Figure 1). After five practice trials, forty stimuli were delivered, and the successful trials were counted and expressed in percentage.

![Image 1: Sequence of image memorization, recognition, and location determination using digital tachistoscope for the examination of patients' attention.](image)

Intervention

Hippotherapy was used as therapy intervention with one session per week for 8 weeks, conducted in an indoor riding arena. A 15-year-old mare served as therapy horse. A special education teacher was also present at each session to motivate the patient. Preparation of the horse (tooling and communication with the horse) was already performed in front of the patients, which is considered an important part of the therapy. The primary aim was to encourage patients to release the harness and make the hands free during riding. Later, the hippotherapist instructed the patients to perform various upper body movements to challenge balance, and to target sensory-motor, cognitive-motor, and muscular weaknesses. This included several arm position changes, trunk exercises such as forward and backward bending, as well as anterior-sitting, posterior-sitting, and side-sitting exercises. Patients wore a helmet, and rode without using a saddle in every session, which lasted 30 minutes. The therapist held the reins of the horse, and a side-walker was also present to assist the patients and prevent them from falling. The walking pace of the horse was approximately 5 km/h.

Discussion

The present case study provides quantitative evidence that short-term HT improves reaction time, balance, and attention in patients with neuromuscular dysfunction. However, HT induced inconsistent changes in the measured strength variables.

It is novel that in this study we measured HT-induced strength changes using force plate and isokinetic dynamometry. Vertical jump test was performed to evaluate patients' multi-joint force generating ability, while dynamometric strength testing allowed us to quantify single muscle strength parameters. Isometric and isokinetic maximal voluntary contraction torques, measured with the dynamometer, represent the muscle's static and dynamic contractility, the ability to activate the maximum number of motor units. We found inconsistent changes in quadriceps strength, vertical jump force, and hand grip strength in the four patients, suggesting that strength responses vary after HT (Table 1). Though patient 3 was unable to execute the dynamic knee extensions, he performed better in all other strength variables after HT. A few studies demonstrated that patients' strength improves after HT [14-16]; however, intervention duration and number of sessions could influence the results. According to previous data, an 11-week-long treatment is necessary to detect strength improvements [16]. Furthermore, increased rectus femoris and biceps femoris muscle activation was demonstrated after 14-week HT in intellectually disabled adolescents, leading to functional improvements [8]. It is important to mention that, though quantitative strength testing is useful, it may not be adequate to test patients with lower cognitive abilities because of their difficulty understanding the task. Still, with dynamometric testing, we found a notable qualitative change in patient 3, who suffered from severe mental disorder: before HT, the patient generated quadriceps torque with palpitation, while after the intervention he was able to maintain peak torque for several seconds, suggesting improvement in understanding the task (Figure 2).
In the present study, all sensory-motor variables improved consistently in all the four patients (Table 1). The greatest improvement (~25%, n=3) was found in balance, with one patient who was unable to maintain standing posture on the stabilometer before HT, but succeeded after HT. Balance is influenced by several factors such as vestibular system operation, visual inputs, proprioception, and muscle strength. Numerous studies investigated the effects of HT on balancing skills, and the results are in agreement with our findings [10,11,13]. Balance improvements are explained with the adaptation to the unstable situations provided by the horse when walking, especially when saddle is not used. Balance is further challenged when patients are instructed to change posture and perform arm movements on the horse, which shifts the rider’s center of gravity.

It was expected that RT improves after HT because of the necessity to react and maintain posture by adapting to sudden changes during riding. Simple choice foot RT reduced differently, 1% and 25%, in two patients. Before HT, the other two patients were unable to sufficiently press the foot switch; however, after HT, they performed similarly to the others. Multiple-choice RT reduced an average of ~16% (n=4), suggesting that patients improved the ability to selectively respond to various stimuli. Effects of HT on RT were measured in one study previously, and it found that lower extremity RT improved after 14 weeks of intervention [8]. Overall, HT creates unusual situations with a variety of stimuli that enhance proprioception as well as other sensory inputs in as short as 8 weeks, improving balance and RT.

We quantitatively assessed the impact of HT on attention, an important component of cognitive function. Attention was expected to indirectly improve after HT, because a quantity of literature demonstrates positive changes in cognitive skills after various types of exercise interventions, not only in patients but also in healthy individuals [17]. Furthermore, a positive relationship between motor behavior, especially coordination, and cognitive abilities were found previously [18]. We measured attention using a short-term memory test, which requires patients’ concentration on the task, and we found remarkable improvements in three patients: two patients improved 65% and 102%, and one patient was able to perform the post-intervention test only. One patient was unable to perform either of the pre- or post-test. There is a limited data on the effectiveness of HT on attention of patients with mental disabilities. Hession et al. [19] found improvement in general intelligence and reductions in cognitive, affective, and behavioral signs of depression in children with dyspraxia after only six riding sessions. The mechanism of how HT enhances attention development might be explained with the findings that exercise triggers improvements in neuronal plasticity such as neurogenesis, but changes in cerebro-vascular plasticity could also be a reason [17]. Furthermore, evidence from functional magnetic resonance image examinations show that 8 weeks of balance training improves attention during walking in ageing humans through improved brain function [20].

There are several important limitations in the present study. First, only four cases were investigated, therefore the results cannot be generalized for the entire population of patients. Furthermore, patients with different diagnosis and disabilities were tested, and individual differences in motor skills and intellectual abilities vary greatly among patients. This may have affected the magnitude of improvement in the selected measures after HT, and it also remains unknown whether improvements are attributed to intellectual or physical components or both. Still, we demonstrated consistent development in sensory-motor variables and attention. Finally, the lack of control subjects and/or control conditions did not allow us to test whether health status and/or therapy type influence the magnitude of changes in the selected variables.

**Conclusion**

In conclusion, the present case study provides quantitative evidence that HT improves sensory-motor skills such as balance and reaction time in as short as 8 weeks of HT, with one session per week. Furthermore, we demonstrated a remarkable improvement in patients’ attention, suggesting quick adaptation in brain function. Strength changes were inconsistent among subjects, probably because of the shortness of the intervention. These data are informative for the therapists in the development of patients with neuromuscular dysfunctions and mental disabilities.

![Figure 2](Image)

**Figure 2.** A representative torque-time curve recorded during maximal isometric quadriceps contraction in Patient 3 before and after HT.
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