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Effects of Short-Term Hippotherapy on Strength, Sensory-Motor Skills, and Attention in Adult Patients with Neuromuscular Dysfunction

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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 strength changes 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 neurosmuscular dysfunction.

Keywords: Dynamometry; Riding; Down syndrome; Disability

Introduction

Sensory-motor skills and muscle strength are essential in a persons' 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		162		169		157	
Body weight (kg)	48		71		78		50	
Performance measures	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Simple choice RT (s)	0,95	0,94	0,52	0,39	unable	0,89	unable	0,44
Multiple choice RT	1,19	1,02	0,96	0,77	1,19	0,94	1,91	1,73
Balance (%)	68	74	22	31	37	46	unable	18
Attention (%)	50	85	35	75	unable	80	unable	unable
Handgrip strength (N)	150	150	300	300	250	300	80	120
QF isometric strength (Nm)	88	95	106	95	42	74	74	68
QF dynamic strength (Nm)	64	83	124	120	unable	unable	47	30
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 testmulti-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.

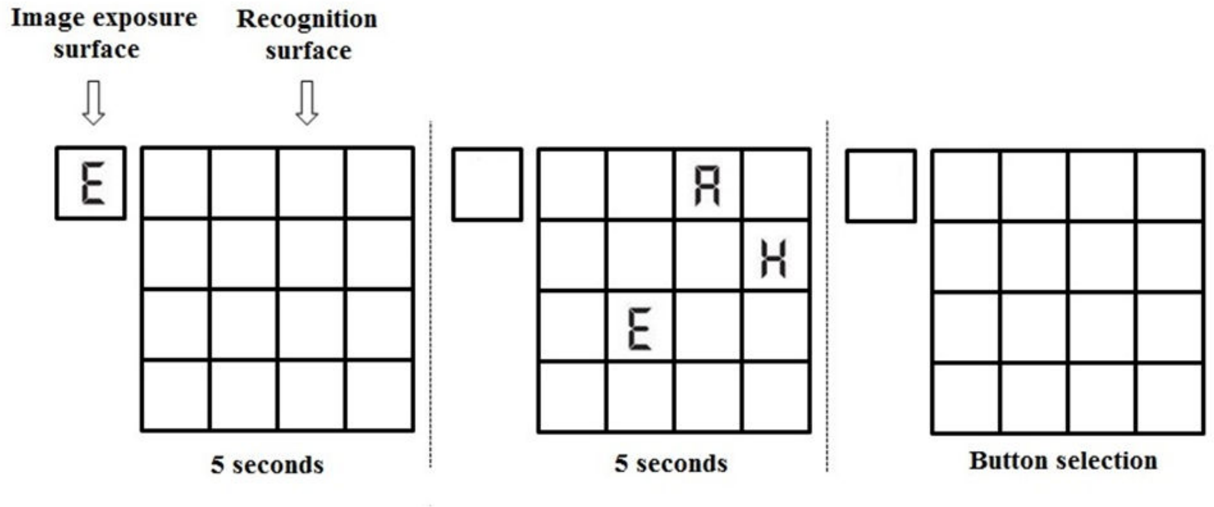

Figure 1. Sequence of image memorization, recognition, and location determination using digital tachistoscope for the examination of patients' attention.

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).

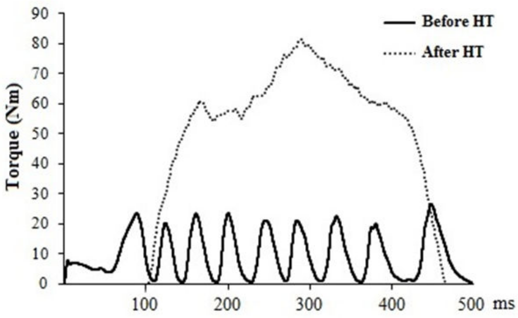

Figure 2. A representative torque-time curve recorded during maximal isometric quadriceps contraction in Patient 3 before and after HT.

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 theresults are in agreement with our findings [10,11,13]. Balance improvements are explained with the adaptation to the instable 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.

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