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The Effect of Hippotherapy on Fatigue, Dynamic Balance, Walking Capacity and Energy Expenditure in Multiple Sclerosis: A Case Study

Christina Koutra[1,*], Maria Liga[2], Katerina Daskalaki[1], Manos Stefanakis[3], Georgios Godolias[1], Paraskevi Malliou[1,3], Thomas Kourtesis[4]

[1]Department of Physical Education and Sports Science, Democritus University of Thrace, Greece
[2]Hellenic Therapeutic Riding Center of Serres, Greece
[3]Department of Health Sciences, School of Life and Health Sciences, University of Nicosia, Cyprus
[4]Department of Early Childhood Education and Care, International Hellenic University, Greece

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Abstract Background: Secondary Progressive Multiple Sclerosis (SPMS) is a neurological disease of the central nervous system which presents a complex array of symptoms, including severe fatigue, compromised balance, diminished walking capacity, and increased energy expenditure. Although the positive effect of hippotherapy on aspects like balance and self-perceived fatigue in MS patients in a resting state has already been proved, research papers examining its effect on dynamic balance in both rest and fatigue states are lacking. Objective: The aim of the present case study was to investigate the effectiveness of hippotherapy in a male patient with SPMS and to examine its impact on dynamic balance in resting and fatigue states. Secondary outcomes include walking capacity, energy expenditure of walking and subjective perception of fatigue. Methods: A 38-year-old male with SPMS participated in 16 hippotherapy sessions, lasting 30-40mins each. Measurements included a baseline and a final measurement regarding dynamic balance in rest and fatigue states (mini-BESTest), walking capacity (distance and speed at Modified 6-Minute Walk Test), energy expenditure (Physiological Cost Index) and subjective perception of fatigue (MFIS). Results: Improvements were seen in the dynamic balance in rest (+8points) and fatigue state (+7points), walking distance (pre: 290m vs. post: 367m) and speed (pre: 48,3m/min vs. post: 61,33m/min), and self-perceived fatigue (pre: 33points vs. post: 22points). The energy cost of walking remained constant. Conclusion: Hippotherapy is shown to have positive effects on dynamic balance at rest and at fatigue, thus improving performance fatigability which is an objective measurement of fatigue in people with MS. Improvements in walking capacity and subjective perception of fatigue were also noteworthy. These findings mark an initial exploration of hippotherapy's impact on performance fatigability in MS, prompting further research inquiries.

Keywords Equine Assisted Physiotherapy, Performance Fatigability, Self-perceived Fatigue, Physiological Cost Index, Mini-BESTest, 6-Minute Walk Test

1. Introduction

Secondary Progressive Multiple Sclerosis (SPMS) presents a complex array of symptoms, including severe fatigue, compromised static and dynamic balance, diminished walking capacity, and increased energy expenditure [1]. Studies have consistently demonstrated that fatigue in MS is associated with compromised postural control and balance [2,3]. Despite fatigue being a prevalent symptom, there is a lack of universally accepted terminology for its various parameters. According to the taxonomy proposed by Kluger [4] there is a distinction between performance fatigability (i.e., the objective reduction in performance) and self-perceived fatigue (i.e., the subjective perception of fatigue, as it is self-referred by the individual). Thus, when discussing fatigue in the context of MS, it is important to distinguish between its objective and subjective manifestation while both need to be assessed and managed.

Numerous rehabilitation programs target self-perceived fatigue and impaired balance in individuals with MS [5-9], recognizing them as key symptoms that affect quality of life [10]. Self-perceived fatigue in MS is reported to be multidimensional, with various questionnaires [e.g., Modified Fatigue Impact Scale (MFIS), Fatigue Severity Scale (FSS)] differentiating between physical, cognitive, and psychosocial components [11]. On the other hand, performance fatigability is recognized as a distinct aspect of impaired motor function in people with MS. For example, during and/or after activities like walking, as assessed by the 6-minute walk test (6MWT), fatigability of motor performance is observed, e.g. decline of walking speed and worsening of balance [12,13] further predisposing individuals to risk of falls [14,15]. Additionally, compared to healthy controls, the energy cost of walking in patients with MS may increase by two to three times [1].

Although the beneficial effects of exercise are well-documented for this group of patients [16], the chronicity of the disease and the complexity of symptoms may contribute to reduced patient exercise adherence [17]. For this reason, it is of utmost importance to offer rehabilitation options to MS patients that could be both attractive and effective in improving the intended outcomes. Compared to other modalities, animal-assisted therapies (AAT) have demonstrated good patient adherence [18]. Hippotherapy, which falls within the scope of AAT, primarily incorporates the three-dimensional movements of the horse's pelvis during gait (anterior/posterior tilt, upward/downward tilt, and rotations) in a rhythmic, repetitive, and coordinated way, mimicking the movements of the human pelvis during gait [19,20] while moving in space and in different directions. All these impulses are transitioned to the rider, provoking neuromuscular and sensory inputs that affect the visual, vestibular, and somatosensory systems, inducing anticipatory and reactive postural adjustments [6,21]. The multisensory stimuli delivered by the horse, with varying intensity and frequency, align with the multifaceted needs of MS, often described as "the disease with a thousand faces" [22].

While recent reviews highlight the positive effects of hippotherapy on aspects like balance and self-perceived fatigue in MS patients in a resting state [23-25], to our knowledge, there are no research papers examining the effect of hippotherapy on dynamic balance in people with MS in both rest and fatigue states.

To address this gap, the aim of the present case study was to investigate the effectiveness of hippotherapy in a male patient with SPMS and to examine its impact on dynamic balance in resting and fatigue states. Secondary outcomes include its effect on walking capacity, energy expenditure of walking and subjective perception of fatigue.

2. Materials and Methods

2.1. Ethics Statements

Ethical approval was provided by the Committee on Ethics in Research of Democritus University of Thrace, Greece. Informed and signed consent was given by the subject in order to be included in the experimental intervention.

2.2. Patient Information

The participant was a 38-year-old man 1.75 m in height and 75 kg in weight with a resting heart rate (HR) of 77 beats per min (bpm) and blood pressure of 12.5/7 mmHg. The patient was diagnosed with SPMS at the age of 28 by an expert of neurologist according to McDonald's diagnostic criteria, although some symptoms (weakness and pain) were also present during childhood. His current Expanded Disability Status Scale (EDSS) was 3.5. The patient has been on stable medication at least for 6 months and followed a regular physiotherapy program once a week for the past year. There was greater impairment of movement on the right side of the body, accompanied by right foot drop and application of a hinged splint.

2.3. Outcomes and Measures

The baseline measurement was performed before the beginning of the intervention and the post-measurement two days after the last hippotherapy session (i.e., after 16 sessions).

The measurements were executed in the following order: First, the Mini-BESTest was performed (to assess dynamic balance in resting state). After that, a Polar chest band (Polar RS100, Finland) was applied to the participant (to measure his HR in the subsequent phases) and was connected to a mobile phone by the use of application POLAR BEAT 3.5.8. The participant then rested on a chair for 5 mins and immediately after the HRresting was recorded. Then, the Modified 6-MWT (M-6MWT) was performed during which HRwalking was also measured. After that, the mini-BESTest was performed for a second time (to assess dynamic balance in fatigue state). Finally, the Greek version of the Modified Fatigue Impact Scale questionnaire (MFIS-Greek) was completed. The Physiological Cost Index (PCI) (energy expenditure of walking) was calculated later.

2.3.1. Mini-BESTest

The mini-BESTest assesses dynamic balance, and it includes 14 items that are separated into 4 sections, namely: 1) Anticipatory postural adjustments (3 items), 2) Reactive postural control (3 items), 3) Sensory orientation (3 items) and 4) Dynamic gait (5 items). The duration of the test is 10-15 mins [26]. The score of each item is 0-2 points and its maximum total score is 28 points. This test was chosen because it does not show floor or ceiling effect as reported for the Berg Balance Scale (BBS) [27,28] as well as the fact that cognitive function [29,30] and reactive balance [31], parameters included in the mini-BESTest, are affected in fatigue state.

2.3.2. HRresting

HRresting was used as the average heart rate recorded every 10 s for 2 mins.

2.3.3. M-6MWT and HRwalking

The M-6MWT was used for the assessment of walking capacity (walking distance and walking speed), while it also served as an aggravating factor in order to induce fatigue to the participant. The participant was wearing a hinged splint to avoid right drop foot. The modification to the simple 6MWT involved the initial instruction asking "walk quickly and safely, considering that you will be walking for 6 minutes" [32]. Subsequent interim instructions and the protocol followed were those recommended by the American Thoracic Society [33].

The space used to perform the test was an indoor corridor 23 m long and 2 m wide, well-lit, with side handrails on the left and right walls. At the two longitudinal ends of the corridor, adhesive strips were placed on the floor, defining a distance of 20 m, and this distance was further divided into 2.5 m intervals with colored sticky tape.

An observer recorded the participant's overall walking distance during the M-6MWT which was also used to compute his walking speed. The whole walking process was recorded with a video camera.

During the whole procedure of the M-6MWT, the HR of the participant was measured every minute in order to define the HRwalking. According to O'Brien [34], during continuous exercise, there is a normal HR variability of 3 to 4 beats per minute (bpm). Taking that into account, in the present study, the steady-state walking condition was defined as the time period where the HR variability was below 4 bpm. This occurred after the 3rd minute and lasted for at least two minutes (in both measurements, i.e., pre- and post-intervention). Therefore, the HRwalking was the average HR of the 4th and the 5th minute.

The minimal detectable change (MDC) for the 6MWT in MS patients is according to Learmonth [35] 76.2 m but according to Decavel [36], there must be an increase of 31.7% (MDC95). The minimal important change for improvement is 19.7 m (95%CI 9.8–30.9 m) according to Oosterveer [37].

2.3.4. MFIS-Greek

The subjective perception of fatigue was measured by the questionnaire MFIS-Greek. MFIS is recommended by the Multiple Sclerosis Council for Clinical Practice Guidelines [38] for research and its Greek version is a valid and reliable tool for the assessment of fatigue in MS patients [39]. Higher scores reflect greater problems due to fatigue. The maximum score is 88 points. MFIS was analyzed according to two factors (physical and cognitive) as proposed by Bakalidou [39] for the Greek version. As stated by Rooney [40], a difference of at least 4 points constitutes a clinically significant difference in fatigue on the MFIS.

2.3.5. Physiological Cost Index

According to McGregor[41], the formula for calculating Physiological Cost Index is as follows: PCI (beats/meter) = (HRwalking – HRrest)/Speed, where HRwalking is the HR at walking (bpm), HRrest is the resting HR (bpm) and Speed is the walking speed (m/min). The HRwalking and HRrest had already been calculated, as previously described. The Speed was measured later, based on the video that had been recorded during the M-6MWT. Specifically, the walking distance covered during the two minutes of steady-state HR gait (i.e., between the 4th and 5th minute) was calculated, using the distances marked with tape at 2.5 m intervals as a point of reference for this measurement. The measurement unit of PCI is beats per meter (beats/m).

2.4. Intervention

Two experienced physiotherapists with knowledge of hippotherapy led the treatment sessions and procedures. The protocol's main goal was to gradually put the rider's motor skills to the test. Both an arena covered with sand and an outside grassy space were used. There was a ramp available to make mounting easier. With the horse constantly moving, each hippotherapy session included a warm-up and stretching phase (5 mins), exercises to improve balance, mobility, and functional performance (23 mins), and a cool-down phase (2 mins). The rider was not involved in any of the horse preparation tasks. After dismounting, the participant engaged in gait, balance, coordination, and other activities for about 10 mins in order to apply the acquired abilities of the horse (Table 1). After familiarization and progression, some exercises were performed with a metronome or/and closed eyes under close supervision by the therapists.

Table 1. Hippotherapy and exercise intervention protocol on and off the horse

ON THE HORSE PROGRAM (30 mins)
Warming up (5 mins)
1. Hand on rider's thighs
2. Hands on horse's neck
3. Hands cross over the chest – on shoulders – rotate arms
4. Straight line horse walking
Main program (23 mins)
1. Straight line horse walking
2. Alternating stop and go of the horse
3. Upper arm(s) loading, ex.: One hand on horse's neck while the other is moving or holding on various positions (in parallel to the ground, behind the lumbar, behind the neck etc.)
4. Closed eyes while the horse moves in straight line, curves, above low barrier
5. Short diameter cycles and eight figures
6. Standing on stirrups with the pelvis raised
7. Place and remove feet from the stirrups.
8. Dual task, ex.: keep balance in dynamic conditions while add numbers of a deck of cards
9. Trotting gait
10. Uphill and downhill rides
11. Leading the horse by the reins
Cooling down (2 mins)
Relaxation with deep breaths
OFF THE HORSE PROGRAM (10 mins)
1. Walking by pushing a chair on the sand
2. Walking on a narrow path marked on the sand
3. Walking with diagonal coordination movement of the opposite upper and lower limbs
4. Walking over low obstacles
5. Backward and side walking

Note: min: minutes, ex.: example

3. Results

After 16 sessions of hippotherapy, the patient showed improvement in almost all outcomes. Performance fatigability was obvious in both measurements (before and after the intervention) since the total score of dynamic balance as well as the partial scores were reduced in the fatigue state (after the M-6MWT) except the score of sensory orientation part which remained unchanged in pre-intervention measurement.

In the long term, performance fatigability was reduced, since dynamic balance was improved: all scores of mini-BESTest (total and partial) improved post-intervention compared to baseline in both resting and fatigue states, with the exception of the score of sensory orientation part in the fatigue state which remained the same. After the intervention the total dynamic balance score in the fatigue state (19/28) was better than the total dynamic balance in the rest state before the intervention (15/28). The dynamic gait part after the intervention was scored with the highest points (10/10) in the rest state and with 9/10 points in the fatigue state (Table 2).

Walking capacity improved, showing an increase in walking distance of 77 m and consequently in walking speed which improved by 13.03 m/min.

The PCI remained stable indicating no change in indirect measurement of energy expenditure in walking.

The subjective perception of fatigue was reduced: the initial total score was 33 points which were divided into 30 points for physical factor and 3 points for cognitive factor. After the intervention, the total score was reduced to 22 points, namely 20 for physical factor and 2 for cognitive factor (Table 3).

Table 2. Total and partial scores of Mini-BESTest pre- and post- intervention in rest and fatigue states

Measurements	Pre Intervention		Post Intervention	
Mini-BESTest	Rest State	Fatigue State	Rest State	Fatigue State
Total score	15/28	11/28	25/28	19/28
Anicipatory part	3/6	2/6	5/6	3/6
Reactive Postural Control part	2/6	1/6	5/6	4/6
Sensory Orientation part	3/6	3/6	5/6	3/6
Dynamic Gait part	7/10	5/10	10/10	9/10

Table 3. Scores of M-6MWT, PCI, and MFIS, pre-and post- intervention

Measurements	Pre-Intervention	Post-Intervention
M-6MWT	290 m	367 m
Speed (total M-6MWT)	48,3 m/min	61,33 m/min
PCI	0,91 beats/m (112-75)/40.5	0,9 beats/m (128-75)/58.75
Walking Distance (4th-5th min)	81 m	117.5 m
HRrest	75 bpm	75 bpm
HRwalking	112 bpm	128 bpm
Speed (4th and 5th min)	40.5 m/min	58.75 m/min
MFIS Total score Physical part Cognitive part	 33 30 3	 22 20 2

Note: M-6MWT: Modified- 6-Minute Walk Test, min: minute(s), m: meter(s), m/min: meters per minute, beats/m: beats per meter, PCI: Physiological Cost Index = (HRwalking – HRrest)/Speed, where HRwalking is the Heart Rate at walking (beats per minute), HRrest is the resting Heart Rate (beats per minute), and Speed is the walking speed (meters per minute), MFIS: Modified Fatigue Impact Scale

4. Discussion

Based on the findings of the present research, the protocol of hippotherapy used was effective in improving almost all outcomes. Additionally, the present case study shed light on significant findings regarding performance fatigability, investigating for the first time the effect of hippotherapy on the dynamic balance of a patient with SPMS in both rest and fatigue state.

In more detail, after 16 hippotherapy sessions, the dynamic balance of the participant improved in both the rest state (+10 points) and the fatigue state (+8 points) compared to baseline and scores are clinically significant since they surpass the MDC of 3.74 points for individuals with MS [42]. The improvement of balance in the resting state is in line with other hippotherapy interventions [5,8,21,27,43]. Regarding performance fatigability (as this was induced through the M-6MWT) this was obvious in both measurements (pre- and post-intervention) and had a negative impact on balance in the fatigue state. Specifically, in the fatigue state pre-intervention, there was a reduction of balance by 4 points, and post-intervention by 6 points, aligning with existing literature that sustains a reduction of balance due to performance fatigability [12,13]. However, the dynamic balance of the patient in the fatigue state post-intervention not only improved compared to baseline, but it was even better than his balance in the rest state pre-intervention by 4 points, indicating a clinically significant reduction of performance fatigability between measurements. This result aligns with existing literature which emphasizes the crucial role of addressing patient balance assessment and intervention efficiency in managing performance fatigability for comprehensive patient care strategies [13,44,45,46].

While overall improvements were observed across most parts of mini-BESTest in both state conditions, a unique finding emerged concerning sensory orientation, whose score post-intervention improved in the resting state (5/6) compared to baseline, but in the fatigue state, it was reduced to its initial pre-measurement score (3/6) again. This finding underscores the potential benefits of hippotherapy in a resting state in readjusting the processing and use of sensory stimuli for individuals with MS [21,27]. However, it also prompts consideration of the challenging conditions under which two of the three items in the sensory orientation part are being performed, i.e., with eyes closed, resulting in the exclusion of visual stimuli on which the majority of MS patients rely heavily to maintain balance [47], and on challenging surfaces like foam and a 10° sloped ground. The additional factor of physical fatigue, in the absence of visual stimuli, and on challenging surfaces, made it even more difficult to maintain balance. This observation is extremely valuable since it implies that maybe more exercises on uneven surfaces and/or with closed eyes are needed in order to overcome this barrier and impact more on sensory orientation.

In terms of secondary outcomes, walking capacity using the M-6MWT revealed an improvement of 77 m walking distance and an increase in speed of 13.03 m/min, indicating the positive impact of hippotherapy on walking capacity as it has been also demonstrated by other studies [48,49]. Although this was a very positive outcome, caution is advised in interpreting this finding due to the absence of published clinical standards or reference values for individuals with MS undertaking the 6MWT based on their EDSS level. Learmonth [35] considers a change of 76.2 m in the 6MWT to be clinically significant for patients with MS, while Decavel [36] proposes an MDC95 of 31.7%, which for the present study would correspond to an increase of 91.93 m based on the pre-measurement of 290 m. However, Decavel [36] utilized a 24-meter circular course for the 6MWT, ensuring a continuous test without interruptions or exogenous speed fluctuations, enabling participants to maintain a steady walking speed. In contrast, our study employed a 20-meter track, incorporating a 180° turn-around cones at the course ends, which may have necessitated our participant to walk more slowly at the track ends to ensure stability. Such variations in test setup can lead to substantial differences in the distance walked [50]. Consequently, the observed difference of 14.93 m between the post-measurement and the threshold considered clinically significant by Decavel [36] may be even smaller. Furthermore, the minimally important change of 19.7 m (95%CI 9.8–30.9 m) for improvement [37] was accomplished, indicating that the protocol used was beneficial for the participant, which is an important outcome considering that slower gait speed is a frequent deficit of patients with MS [1]. The unique benefits of hippotherapy for individuals with MS may be due to its task-specific nature, as the horse's pelvic movement simulates human pelvic movement during walking in a 3D, rhythmic, repetitive and coordinated way, emphasizing its specificity to walking-related activities.

Despite the beneficial effects of the present protocol on the walking capacity (speed and distance), there was also observed an increase in HRwalking post-intervention, resulting in a lack of improvement in the energy cost of walking (PCI). Similarly, du Plessis [51] who assessed a 12-week hippotherapy program in adolescents with diplegia, noted an increase in gait speed but no difference in PCI. It's noteworthy that, although hippotherapy may not explicitly target cardiac parameters, its theoretical foundations propose that enhancing motor parameters, balance, and coordination could potentially reduce energy costs during gait. However, the current data doesn't fully substantiate this hypothesis, and more research is needed on the topic.

On the other hand, there was a reduction in the self-perceived fatigue of our participant, which was improved by 11 points, exceeding the 4 points that constitute a clinically significant difference for the MFIS. This improvement supports the assumption that hippotherapy can improve perceived fatigue in people with MS [9]. From the analysis of the results of Frevel [6], where hippotherapy was found to be superior to a home e-training program in improving perceived fatigue and quality of life, it is understood that the horse itself and the whole context in which the hippotherapy takes place contribute to the improvement of the psychological and social domain. The subjective sense of fatigue is one of the most common symptoms of patients with SPMS which together with performance fatigability can influence many aspects of daily functioning and compromise the quality of life [52]. The improvement in both manifestations of fatigue (objective and subjective) together with the improvement of walking capacity justifies the proposal to investigate even more the effect of hippotherapy on patients with MS.

To facilitate a comprehensive understanding of the mechanisms underlying the observed alterations outlined in this study, it is imperative to consider the following details regarding hippotherapy. The previously noted similarity in pelvic movements between horses and human, coupled with continuous reactions of the neuromuscular system to repeated postural provocations and perturbations, fosters an ideal environment for motor learning. This dynamic interaction not only challenges the rider's abilities but also ensures a safe yet continuously stimulating experience, embodying the essence of effective motor skill development [53]. Moreover, the rider's nervous system is continually challenged to process and adapt to various sensory stimuli, including visual, vestibular, and somatosensory inputs [8,27]. This constant stimulation aligns with the principles of dynamic systems theory, enriching the empirical understanding of therapists utilizing hippotherapy and underscoring the interconnectedness of the human body's systems, elucidating how each component interacts to produce positive therapeutic outcomes [54]. It should be mentioned that although our program included some movements on the ground, these accounted only for 10 mins of the whole program, so the main improvements seen are majorly attributed to the part of the program with the greatest volume, which involved interaction with the horse for 30 mins. Additionally, the use of hippotherapy not only impacts on physical but also on psychosocial parameters, which were not targeted in the present program on the ground. Previous research that used an equine-facilitated learning program has documented a reduction in cortisol levels (the predominant stress hormone), and this finding underlines the physiological benefits and the positive effects of interaction with horses [55]. Also, qualitative as well as quantitative study both report human participants developing a relationship with the horse [56,57] and according to Bachi [58] attachment theory explains that this link is comparable to that of a mother and child. Hence, the amelioration in perceived fatigue, as measured by MFIS, could be twofold: attributed to improvements in physical parameters (such as balance, walking distance, and speed), and the interaction between International Classification of Functioning, Disability, and Health (ICF) domains (Body Functions and Structures, Activities and Participation, Environmental Factors and Personal Factors) where each influences the other [59,60], as well as to the potential psychosocial benefits of utilizing horses in therapeutic praxis [61,62].

5. Limitations

Recognizing the place of a case study on the pyramid of evidence hierarchy the results should be interpreted with appropriate care. The type of MS as well as the patient's level of functioning as defined by the EDSS (3.5) are key factors in the difficulty of generalizing the results. The use of a bigger sample, the presence of controls, the inclusion of measurement methods other than clinical ones, and the existence of follow-up are additions that would enhance the strength of the results. Lastly, external factors such as environmental changes or unforeseen events could have influenced the outcomes, which were beyond the control of the researchers. Despite these limitations, efforts were made to mitigate biases and ensure the rigor and integrity of the study's findings.

6. Conclusions

Hippotherapy was shown to have particularly positive effects on dynamic balance at rest and at fatigue, thus improving performance fatigability which is an objective measurement of fatigue in people with MS. Improvements in walking capacity and in subjective perception of fatigue were also noteworthy, but no difference was found in the energy cost of walking after the intervention. These results are the first step in investigating the effect of hippotherapy on performance fatigability in people with MS opening up research questions to be addressed. Additionally, these findings have significant implications beyond scientific advancement, particularly in terms of economic benefits. By potentially reducing the impact of fatigue and improving mobility in individuals with MS, hippotherapy could lead to decreased reliance on costly medical interventions, such as prolonged hospital stays or intensive rehabilitation programs. Moreover, enhancing functional abilities through non-invasive interventions like hippotherapy may alleviate the economic burden on healthcare systems and improve the overall quality of life for patients and their families.

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