High-Intensity Gait Training in an Individual With Neuromyelitis Optica and Research Recommendations for Individuals With Multiple Sclerosis

Rebecca Phelan, DPT, PT; and Kirsten Potter, DPT, PT, MS

From the Department of Physical Therapy, Spaulding Rehabilitation, Charlestown, MA; and the Program in Physical Therapy, Department of Rehabilitation Sciences, Tufts University, Boston, MA. *Correspondence:* Kirsten Potter, DPT, PT, MS, Program in Physical Therapy, Department of Rehabilitation Sciences, Tufts University, 136 Harrison Ave, Boston, MA 02111; *email:* kirsten.potter@tufts.edu.

Running head: High-Intensity Gait Training in NMO

doi:10.7224/1537-2073.2023-035

Practice Point

- Given the similarities between neuromyelitis optica and multiple sclerosis, this case study suggests that high-intensity gait training may be helpful for persons with multiple sclerosis.

Abstract

Background: Neuromyelitis optica (NMO), similar to multiple sclerosis (MS), is an autoimmune disorder affecting the central nervous system. In people with central nervous system diagnoses, high-intensity gait training (HIGT) can support neuroplasticity, improving functional mobility. While low- to moderate-intensity exercise is beneficial in improving outcomes in individuals with NMO and MS, the impact of HIGT has not been thoroughly explored. This case study explores the safety and efficacy of HIGT in an individual with NMO.

Methods: A 43-year-old man with NMO participated in a HIGT program utilizing the least amount of body weight support necessary to achieve a target heart rate of 60% to 80% of heart rate reserve or a Borg Rating of Perceived Exertion score of 15 to 17 during an in-patient rehabilitation stay. Interventions incorporated stair training, gait variances, and virtual reality.

Results: The patient successfully completed a 90-minute training session 4 to 7 times per week for 6 weeks following a HIGT regimen for 40% to 60% of each session. Meaningful gains in bed mobility, transfers, and gait allowed for a discharge to his home.

Conclusions: This case suggests that HIGT in patients with NMO can be safe and effective in improving functional mobility. Due to the similarities between NMO and MS, this case provides a framework to assist clinicians in developing a HIGT plan of care for individuals with MS. Additional research is needed to clarify HIGT parameters, including intensity and duration, to improve functional mobility in individuals with MS. *Int J MS Care.* 2023;XX:XXX-XXX.

Introduction

Neuromyelitis optica (NMO), also known as Devic disease, and multiple sclerosis (MS) are demyelinating autoimmune disorders of the central nervous system (CNS).[1] Due to the similarities in clinical presentation, including fatigue, muscle weakness, sensory changes, loss of balance, and vision disturbances, NMO was considered to be a variant of MS.[1,2] This assumption changed when the NMO-immunoglobulin G (IgG) autoantibody marker was identified, allowing for the differentiation between NMO and MS at the serological level.[3] Despite the pathological differences between MS and NMO, patients with these conditions demonstrate functional similarities, including difficulty with ambulation, transfers, bed mobility, and stair negotiation.

While the distinction between NMO and MS is critical when selecting pharmacological intervention,[3] whether the distinction extends to exercise parameters has not been thoroughly explored. One study of individuals with NMO suggests that moderate-intensity exercise, including strength training, aerobic exercise, balance interventions, ambulation, and transfer training, is safe and effective, and it helps to improve balance and the performance of activities of daily living.[4] The study documents mild adverse events (eg, pain, weakness, fatigue) in 2 of 36 participants. Exercise recommendations for individuals with MS suggest that low- to moderate-intensity exercise and balance training can reduce fatigue and improve endurance, muscle strength, and balance.[2]

There is a common belief that high-intensity exercise should be avoided in patients with demyelinating diseases.[5] Clinicians are often unfamiliar with NMO and assume that individuals with the disease should be treated with low-intensity interventions due to NMO's association with MS. Despite recommendations for low- to moderate-intensity exercise, the literature indicates that high-intensity exercise is safe for individuals with MS,[6,7] and includes positive results of higher intensity cycling and resistance interventions that improved patients' endurance and muscle strength.[7,8]

In people with acute onset CNS injuries (eg, stroke, spinal cord injury), the implementation of task-specific gait and step training at higher cardiovascular intensities has been established as a best practice to improve ambulation and balance.[9,10] High-intensity gait training (HIGT) can be defined as ambulation or stair training (1) performed at an intensity of 60% to 80% of heart rate reserve (HRR) as measured continuously or (2) performed to a score of 14 to 17 on the Borg Rating of Perceived Exertion Scale.[10] With ambulation being such a salient task, participants tend to be invested in gait training. It increases their engagement and volitional activity, which in turn increases the neuromuscular and cardiovascular demands to achieve higher intensities of this task-specific practice.[10] Salience, intensity, and specificity are also key principles of neuroplasticity.[11] The underlying mechanisms of neuroplasticity are not fully understood, but, given improvements seen in locomotor function after high-intensity walking training,[10] they may be similar among adults with different neurologic conditions such as chronic traumatic brain injury, incomplete spinal cord injury, and stroke. If HIGT positively influences neuroplasticity and mobility in adults with chronic CNS conditions, it is possible that individuals with chronic, degenerative CNS diagnoses may benefit from HIGT in similar ways.

The effects of HIGT for individuals with NMO and MS have not been explored. Due to the success of HIGT in other neurologic conditions and its possible benefits for patients with

NMO, this case study aimed to assess the safety and efficacy of HIGT for an individual with NMO and extends its findings to individuals with MS due to the similarities of the conditions.

Methods

Participant

The individual was a male, aged 43 years, who presented to the emergency department with acute progressive diffuse sensory impairments and lower extremity (LE) weakness. Prior to admission, he was independent in all forms of mobility and worked full time in retail. MRI findings were consistent with NMO with involvement in the cervical and thoracic spine; lumbar puncture was positive for NMO antibodies. Following 1 week in acute care, he was transferred to inpatient rehabilitation where he presented as dependent in all functional mobility. His predicted discharge location was to a subacute facility due to his home environment (ie, 4 flights of stairs). Long-term goals included transferring and ambulating with minimal assistance and an assistive device. The individual signed a consent form indicating his agreement with the plan of care and dissemination of the case study.

Tests and Measures

Tests conducted at admission and discharge, as seen in Table 2, included the manual muscle test (MMT), coordination tests, and light touch sensation test. Per the Academy of Neurologic Physical Therapy's recommended core set of outcome measures for individuals with neurologic conditions, the following performance-based assessments were used to measure balance, transfers, gait speed and endurance, and dynamic gait, respectively: Berg Balance Scale (BBS), Five Times Sit to Stand (5xSTS), 10-Meter Walk Test (10mWT), 6-Minute Walk Test (6MWT), and the Functional Gait Assessment (FGA).[12] Mobility was also assessed using Centers for Medicare and Medicaid Services Quality Indicators (QI).[13]

Procedure

The individual with NMO participated in a HIGT program 4 to 6 times a week for 40% to 60% of a 90-minute treatment session, as recommended by Hornby et al.[10] The goals were to perform at 60% to 80% of HRR with a score of 15 to 17 on the Borg Rating of Perceived Exertion Scale.[14] Heart rate was continuously monitored using a Polar heart rate monitor on the patient's chest. Blood pressure and oxygen saturation were intermittently monitored, typically during rest breaks. The individual also received daily occupational therapy and endurance training on a NuStep recumbent cross trainer 2 to 3 times per week for up to 30 minutes, consistent with his target heart rate.

Table 1 provides the progression of the plan of care as the individual's mobility improved during his rehabilitation. Interventions prioritized gait variances, including overground, complaint surface, and treadmill (with virtual reality) ambulation; varying gait speeds; resistance; increasing treadmill incline; multidirectional stepping; and stair training. Body weight support was weaned to provide the least amount of support necessary to allow for a step-through gait pattern with adequate foot clearance and upright posture.

Results

Admission and discharge assessment results are presented in Table 1 and **Table 2**. At admission, the patient showed impairments of bilateral lower extremity (LE) strength, upper extremity (UE) and left LE coordination, and UE and LE light touch sensation. He was unable to complete any of the performance-based core set measures and QI ratings showed he was dependent for all functional mobility skills.

The individual safely and successfully completed a HIGT regimen during his inpatient stay without any adverse events. From admission to discharge, his bilateral LE strength and left LE coordination improved. Sensation and UE coordination did not show measurable improvements. Gains were made in balance and all mobility skills (Table 1 and Table 2), improving from dependent at admission to supervision-independent at week 5. His long-term goals of transferring and ambulating with an assistive device and minimal assistance were exceeded, and he was able to perform both independently with a rolling walker.

As stated previously, the individual's discharge disposition at admission was predicted to be a subacute facility, as it was deemed unlikely that he would be able to ambulate on stairs by the time he was discharged. However, during week 3 of his stay, he was able to initiate stair training with minimal assistance and by week 4, he improved to contact guard assistance (Table 1). This improvement indicated that extending his length of stay and continuing therapy might enable him to return home rather than being discharged to a skilled nursing facility for further care. So his length of stay was extended to 6 weeks with the goal of discharge home. In his final weeks of rehabilitation, he continued to progress and, at discharge, he was independent with regard to bed mobility, transfers, and ambulation with a rolling walker, and he was able to negotiate stairs with supervision.

Discussion

This case report explored the effects of HIGT on an individual with NMO during an in-patient rehabilitation stay. Although current research supports use of HIGT to improve overall functional mobility and gait in individuals with stroke, traumatic brain injury, and spinal cord injury,[10] it may also benefit individuals with other neurologic conditions.

This particular individual exhibited substantial improvements in all measures of balance and function. Although he was unable to perform any of the items on the BBS at admission (with a score of 0 out of 56), his score of 46 out of 56 at discharge indicated substantial improvements in static and anticipatory balance. While scores on the dynamic balance assessment (ie, FGA) improved less than the BBS (from 0 out of 30 at admission to 15 out of 30 at discharge), this may be explained by the higher complexity of tasks on the FGA as compared with the BBS.

By discharge, gait speed and distance also improved greatly, classifying him as a limited community ambulator when ambulating at self-selected speeds. His fast gait speed also met the minimum for community ambulation.[15] His scores on the 6MWT indicated the ability to walk in some community settings (eg, small businesses).[16] It is also notable that his LE strength and coordination improved despite a lack of treatment geared specifically toward these impairments. It is likely that the intensity of HIGT created a sufficient challenge that improved measures of impairment, as has been seen in the literature.[10] Similarly, his bed mobility and transfers (ie, 5xSTS) also improved, supporting the idea that HIGT can improve functional mobility other than gait.[17] It is important to recognize that spontaneous neurologic recovery, other interventions during his rehabilitation stay (eg, occupational therapy), and a longer length of stay in in-patient rehabilitation may have contributed to these changes.

This case report describes the use of HIGT for a single patient with NMO; thus, caution should be used when interpreting the results of the intervention and generalizing the information to other patients, due to the less rigorous nature of case studies. However, given the functional similarities between individuals with NMO and MS, we find it probable that individuals with MS would benefit from HIGT. Clinicians may be hesitant to use HIGT in this population due to fatigue-related concerns, particularly since HIGT paradigms use continuous exercise, but a systematic review that included 7 studies involving individuals with MS indicated that high-intensity interval training using cycle and arm ergometers was well tolerated; only 4 of 55 participants in 1 study experienced adverse events (ie, lower extremity pain). Therefore, this study suggests that individuals with MS may tolerate HIGT.[6] Clinicians who have concerns about the continuous nature of HIGT may want to begin with intermittent gait training. Karpatkin et al[18] studied individuals with MS using intermittent gait training versus continuous walking; participants in the intermittent gait cohort increased their walking distance with significantly lower subjective fatigue. Another study by Karpatkin et al[19] found that intermittent walking led to significantly longer walking duration and distances when compared with continuous walking, yet subjective fatigue scores were not significantly different between the 2 groups. An intermittent walking paradigm (eg, using short bursts of high-intensity walking while applying additional challenges such as varied surfaces, speed, resistance, or virtual reality) could be applied within HIGT and the use of HIGT alone may reduce the need to engage patients in other energy-taxing exercise (eg, strength training), as seen in this case.

To date, HIGT hasn't been studied in individuals with MS, possibly due to hesitation about higher intensity interventions, but we call for future studies to examine its use in this population. While the individual in this report did not describe any adverse events related to fatigue, future studies should consider formally assessing fatigue given its prevalence as a symptom of MS. A limitation of this case report is this individual's 6-week stay in in-patient rehabilitation, which may not always be feasible. The effectiveness of HIGT protocols that last for a shorter term also should be studied.

In conclusion, this case study showed that HIGT was well tolerated in an individual with NMO and resulted in improvements in impairment and function. It is possible that HIGT may be effective for individuals with MS as well. Future studies are needed.

Acknowledgments: We wish to thank the individual who allowed us to use his case report. Also, thanks go to Faye Bronstein, who provided mentorship during the individual's high-intensity gait training and encouraged us to present this case at the American Physical Therapy Association, Combined Sections Meeting.

Prior presentation: This material was presented as a poster at the American Physical Therapy Association's Combined Sections Meeting; February 5, 2022; San Antonio, Texas.

References

1. Zhang L, Tian J-Y, Li B. Current immunotherapies for multiple sclerosis and neuromyelitis optica spectrum disorders: the similarities and differences. *Neuroimmunol Neuroinflamm*. 2019;6:8. doi:10.20517/2347-8659.2019.06

2. Halabchi F, Alizadeh Z, Sahraian MA, Abolhasani M. Exercise prescription for patients with multiple sclerosis; potential benefits and practical recommendations. *BMC Neurol*. 2017;17(1):185. doi:10.1186/s12883-017-0960-9

3. Lennon VA, Wingerchuk DM, Kryzer TJ, et al. A serum autoantibody marker of neuromyelitis optica: distinction from multiple sclerosis. *Lancet*. 2004;364(9451):2106-2112. doi:10.1016/S0140-6736(04)17551-X

4. Li Q, Wang B, Cheng B, et al. Efficacy and safety of rehabilitation exercise in neuromyelitis optica spectrum disorder during the acute phase: a prospective cohort study. *Mult Scler Relat Disord*. 2022;61:103726. doi:10.1016/j.msard.2022.103726

5. Petajan JH, White AT. Recommendations for physical activity in patients with multiple sclerosis. *Sports Med*. 1999;27(3):179-191. doi:10.2165/00007256-199927030-00004

6. Campbell E, Coulter EH, Paul L. High intensity interval training for people with multiple sclerosis: a systematic review. *Mult Scler Relat Disord*. 2018;24:55-63. doi:10.1016/j.msard.2018.06.005

7. Wens I, Dalgas U, Vandenabeele F, et al. High intensity exercise in multiple sclerosis: effects on muscle contractile characteristics and exercise capacity, a randomised controlled trial. *PLoS One*. 2015;10(9):e0133697. doi:10.1371/journal.pone.0133697

8. Collett J, Dawes H, Meaney A, et al. Exercise for multiple sclerosis: a single-blind randomized trial comparing three exercise intensities. *Mult Scler*. 2011;17(5):594-603. doi:10.1177/1352458510391836

9. Moore JL, Nordvik JE, Erichsen A, et al. Implementation of high-intensity stepping training during inpatient stroke rehabilitation improves functional outcomes. *Stroke*. 2020;51(2):563-570. doi:10.1161/STROKEAHA.119.027450

10. Hornby TG, Reisman DS, Ward IG, et al. Clinical practice guideline to improve locomotor function following chronic stroke, incomplete spinal cord injury, and brain injury. *J Neurol Phys Ther*. 2020;44(1):49-100. doi:10.1097/npt.0000000000000303

11. Kleim JA, Jones TA. Principles of experience-dependent neural plasticity: implications for rehabilitation after brain damage. *J Speech Lang Hear Res*. 2008;51(1):S225-S239. doi:10.1044/1092-4388(2008/018)

12. Moore JL, Potter K, Blankshain K, Kaplan SL, O'Dwyer LC, Sullivan JE. A core set of outcome measures for adults with neurologic conditions undergoing rehabilitation: a clinical practice guideline. *J Neurol Phys Ther*. 2018;42(3):174-220. doi:10.1097/NPT.0000000000000229

13. Quality Measures. Centers for Medicare and Medicaid Services. Accessed March 21, 2023. https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/QualityMeasures

14. Williams N. The Borg Rating of Perceived Exertion (RPE) Scale. *Occupational Medicine*. 2017;67(5):404-405. doi:10.1093/occmed/kqx063

15. Fritz S, Lusardi M. Walking speed: the sixth vital sign. *J Geriatr Phys Ther*. 2009;32(2):2-5.

16. Andrews AW, Chinworth SA, Bourassa M, Garvin M, Benton D, Tanner S. Update on distance and velocity requirements for community ambulation. *J Geriatr Phys Ther*. 2010;33(3):128-134.

17. Scheets PL, Hornby TG, Perry SB, et al. Moving forward. *J Neurol Phys Ther*. 2021;45(1):46-49. doi:10.1097/NPT.0000000000000337

18. Karpatkin H, Cohen ET, Rzetelny A, et al. Effects of intermittent versus continuous walking on distance walked and fatigue in persons with multiple sclerosis: a randomized crossover trial. *J Neurol Phys Ther*. 2015;39(3):172-178. doi:10.1097/NPT.0000000000000091

19. Karpatkin H, Rachwani J, Rhodes R, et al. The effect of intermittent vs. continuous walking on distance to fatigue in persons with multiple sclerosis. *Disabil Rehabil*. 2022;44(26):8429-8435. doi:10.1080/09638288.2021.2018055

Table 1. Functional Improvement and Progression of HIGT From Admission to Discharge

	Bed mobility	Transfers	Ambulation	Stairs	Intervention
Admission	Dependent	Dependent	Dependent	Unable	• BWS treadmill and overground training with bilateral UE support, assistance at pelvis and trunk for weight shifting and upright posture, manual advancement of bilateral LEs
Week 1	Moderate assistance	Moderate assistance	Dependent	Unable	• Decreased percentage of BWS during gait training on treadmill and overground • Weaned manual assistance at pelvis/trunk and bilateral LEs • Maintained bilateral UE support
Week 2	Contact guard	Minimal assistance	Minimal assistance	Unable	• BWS for safety only • Further weaning of manual assistance at trunk and bilateral LEs; assisted only when patient was unable to correct self after 3 or more steps • Vary between bilateral and unilateral UE support
Week 3	Contact guard	Contact guard	Contact guard	Minimal assistance	• No BWS, manual assistance of therapist at pelvis/trunk or bilateral lower extremities • Verbal cuing for increased step length and upright posture • Challenged step length and upright posture via weighted vest, ankle weights, manual resistance at bilateral LEs with TheraBand, resisted walking with weighted rolling walker or manual resisting advancement of rolling walker anteriorly • Multidirectional walking • Initiated stair training with bodyweight support harness for safety

Week 4	Supervision	Supervision	Supervision	Contact guard	• Continued to challenge ambulation via resisted walking without UE support • Resisted walking with weight vest and ankle weights • Challenged walking via obstacle course, unstable and narrow surfaces, narrow surfaces, dual task ambulation, multidirectional walking over ground and on treadmill • Increased treadmill speed and incline, added obstacles to belt • Initiated virtual reality • Progressed stair training by varying UE support and removing BWS
Week 5	Independent	Supervision	Supervision	Supervision	• Ambulation as above in week 4 • Progressed stair training by adding ankle weights or weighted vest
Discharge	Independent	Independent	Independent	Supervision	

BWS, body weight support; HIGT, high-intensity gait training; LE, lower extremity; UE, upper extremity.

Table 2. Test and Measure Results at Admission and Discharge

Test/measure	Admission	Discharge
Impairment tests		
LE MMT for major muscle groups	L = 1/5 R = 3+/5	L = 3/5 except hip flexion 3-/5 R = 4/5
Coordination	FTN: Bilateral UE undershooting. HTS: R LE normal; L LE unable to assess due to weakness. Alternating pronation/supination: Dysdiadochokinesia bilaterally; single movements difficult to distinguish and increased time to complete motion. Intention tremor: When reaching, presented with an amplitude greater than 5 cm in bilateral UEs.	FTN: No change. HTS: R LE normal; L LE slightly abnormal while maintaining shin contact. Alternating pronation/supination: Somewhat irregular bilaterally with increased time to complete motion. Intention tremor: No change.
Light touch sensation	Diminished throughout bilateral UEs at the forearms and bilateral LEs distal to knees.	Diminished, but improved per patient report.
Functional measures		
BBS	0/56	46/56
5xSTS	0	29 seconds
6MWT	0	168 meters
10mWT	Self-selected speed: 0 m/s Fast speed: 0 m/s	Self-selected speed: 0.59 m/s Fast speed: 0.83 m/s
FGA	0/30	15/30

5xSTS, Five Times Sit to Stand; 6MWT, 6-Minute Walk Test; 10mWT, 10-Meter Walk Test; B, bilateral; BBS, Berg Balance Scale; FGA, Functional Gait Assessment; FTN, finger to nose;

HTS, heel to shin ; L, left; LE, lower extremity; m/s, meters per second; MMT, Manual Muscle Test; R, right; UE, upper extremity.