Case report

Atypical autonomic dysreflexia during robotic-assisted body weight supported treadmill training in an individual with motor incomplete spinal cord injury

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Context/objective: A 41-year-old man with a history of C6 American Spinal Injury Association (ASIA) Impairment Scale (AIS) C spinal cord injury (SCI), enrolled in an Institutional Review Board (IRB)-approved, robotic-assisted body weight-supported treadmill training (BWSTT), and aquatic exercise research protocol developed asymptomatic autonomic dysreflexia (AD) during training. Little information is available regarding the relationship of robotic-assisted BWSTT and AD.

Findings: After successfully completing 36 sessions of aquatic exercise, he reported exertional fatigue during his 10th Lokomat intervention and exhibited asymptomatic or silent AD during this and the three subsequent BWSTT sessions. Standard facilitators of AD were assessed and no obvious irritant identified other than the actual physical exertion and positioning required during robotic-assisted BWSTT.

Conclusions/clinical relevance: Increased awareness of potential silent AD presenting during robotic assisted BWSTT training for individuals with motor incomplete SCI is required as in this case AD clinical signs were not concurrent with occurrence. Frequent vital sign assessment before, during, and at conclusion of each BWSTT session is strongly recommended.

Keywords: Autonomic dysreflexia, Body weight support treadmill training, Motor incomplete spinal cord injuries, Robotic-assisted exercise, Lokomat, Tetraplegia

Introduction

Autonomic dysreflexia (AD) occurs frequently in individuals with spinal cord injury (SCI) at level T6 or above, including both greater than 20–30 mmHg blood pressure (BP) change, and relative bradycardia (slow heart rate).^{1,2} AD with elevated BP is a known risk factor for intracerebral hemorrhage, and therefore, is treated as a medical emergency.^{3–5} AD can be precipitated by various afferent irritants from below the level of the injury particularly novel stimuli such as electrical stimulation and body weight supported exercise.⁶ Alan *et al.*⁶ reported that injury-induced vasculature changes may contribute to AD occurrence via circulatory changes and the altered ability to tolerate novel sensory input.

The syndrome is commonly associated with headache and diaphoresis, but sometimes can be asymptomatic. There are reports of silent AD during voiding,⁷ bowel programs,⁸ sperm retrieval,⁹ and possibly acupuncture.¹⁰ It is unclear what long-term impact these large systolic blood pressure (SBP) changes cause, or what mechanism(s) stimulate these SBP fluctuations.¹¹ Upright walking-like exercise is also reported to increase BP via exaggerated spinal reflexes in individuals with SCI at T6 or above.¹²

The Consortium for Spinal Cord Medicine Clinical Practice Guidelines for the acute management of AD emphasize the need to be aware of AD symptoms, while noting that AD clinical signs are not always present.⁴ Currently, it is unclear exactly how robotic-assisted BWSTT impacts potential AD. During BWSTT, autonomic regulation of BP is reported to

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improve, with a positive impact upon blood flow in the femoral and carotid arteries is reported.¹³ Krassioukov and Harkema¹⁴ reported the need to carefully assess cardiovascular responses in individuals with upper thoracic and cervical SCI while in the BWSTT harness system, finding significant increase in arterial pressure while sitting in the harness. This pressure abrogated, however, when standing without gait training. This case report details the potential relationship between robotic-assisted BWSTT and AD in an individual with C6 AIS C chronic SCI.

Case report

A 41-year-old African-American man with C6 ASIA Impairment Scale (AIS) C Impairment Scale tetraplegia secondary to a sports injury 23 years ago participated in a body weight-supported robotic treadmill training (BWSTT) and aquatic exercise research protocol. The participant enrolled in an ongoing randomized clinical trial, approved by the University of Maryland Baltimore and Department of Defense Institutional Review Boards, to evaluate the cardiovascular and mobility effects of 3 months of robotic-assisted BWSTT exercise versus 3 months of aquatic-based exercise in people with chronic (>1 year) cervical and thoracic motor incomplete SCI. Therapist-directed exercise interventions under each arm of the protocol occurred three times per week, every other day, for 40 minutes in an outpatient rehabilitation setting.

This patient uses a power wheelchair for mobility and is actively employed as a computer programmer specialist. His spasticity, primarily of the lower extremities, is well managed with oral baclofen at 10 mg three times per day. He manages his bladder with external condom catheter drainage and his bowel routine includes every other day bisacodyl suppositories. His remote history includes renal stones and headache in the context of bladder distension and the passage of renal calculi. Serial imaging studies of his collecting system during the last few years, however, demonstrated no hydronephrosis or renal stones, and serial blood tests document normal renal function.

Randomized to start in the aquatic therapy intervention, J.W. completed 36 aquatic therapy sessions over 12 weeks with no known AD occurrence. Vital signs were assessed at the beginning and end of each aquatic therapy session with no significant changes noted. BP readings were also unchanged during peak VO₂ arm ergometry testing, a study outcome measure, and during his pre-study standing frame assessment.

The robotic-assisted BWSTT (Lokomat[®]) intervention consisted of the standard partial weight support

using the appropriate straps, harness system, and limb lengths based on prior measurements. Weight support was initiated at 80–100% with treadmill speed initiated at 1.5 mph (0.42 m/second) to 1.8 mph (0.5 m/second) km/hour and adjusted to the predetermined optimal treadmill speed (3.2 mph as a target) measured during the acclimation training session. Treadmill speed was modified, as tolerated, to provide an additional aerobic challenge during the peak assessment. J.W. viewed his effort via the real-time visual feedback of lower extremity force on a screen display. A Polar[®] monitor recorded continuous heart rate.

J.W.'s initial nine Lokomat sessions were significant only for some minor knee pain, which resolved spontaneously, and discomfort from the harness, which was resolved with repositioning. On the 10th session, pre-exercise BP was 104/52. Twenty minutes into the session, JW complained of exertional fatigue. The Lokomat was stopped. BP at that time was 220/80 mmHg and rose to 260/110 mm/Hg on a repeat measure with no symptoms other than exertional fatigue. Upon removal from the BWSTT device, his BP quickly fell to 98/50 mmHg. No skin changes were noted as possible friction points. The Lokomat straps were not obstructing urine flow from his external collecting system. No other alternate cause for the BP change could be found. The subsequent three sessions followed a similar course with regard to BP and the lack of any AD clinical symptoms; exertional fatigue only occurred during 10th session (Table 1). A pre-exercise post-void residual obtained before the 12th session was unremarkable. Seated BPs in the harness before and after suspension were normal prior to robotic activation and without volitional movement. BP rose sharply only after commencing the 10th robotic-assisted BWSTT exercise session. The participant's BP returned to normal immediately following the termination of each session. J.W.'s participation in the research study was terminated due to concern about these repeated episodes of symptomatic elevation in BP during robotic-assisted BWSTT.

Discussion

This individual with long-standing motor incomplete tetraplegia experienced atypical AD during the active component of robotic-assisted BWSTT training using the Lokomat device. This finding was replicated across four different sessions on four different days. He experienced no recent similar episodes but has a past history of AD-associated headache during voiding. This was associated with renal stone disease with 1–2 episodes of symptomatic dysreflexia in 23 years, and none in the past 10

Table 1 BWSTT BP and heart rate response data

Session	Pre-exercise		Average exercise BP (two readings)		Post-exercise	
	Seated BP	Seated HR	Standing supported BP	Standing supported HR	Seated BP	Seated HR
10	104/52	67	240/95	84	98/50	NA
11	102/62	69	184/97	77	77/53	101
12	108/50	77	175/90	82	80/58	NA
13	94/60	NA	210/98	NA	90/60	NA

BP, blood pressure (mmHg); HR, heart rate (bpm); Session refers to BWSTT training sessions within the protocol.

years. He described headache and flushing as symptoms of his prior symptomatic dysreflexia. Being strapped into the BWSTT harness with body weight unloaded did not appear to be directly causal to the elevation of BP, because it was only during the aerobic exercise facilitated by the robot exoskeleton that the BP sharply increased. In addition, J.W.'s vital signs taken during screening in the standing frame did not display signs of dysreflexia during the 30-minute time span (Table 2). The clinical decision was made to stop further robotic-assisted BWSTT because of this asymptomatic AD and the concern that this activity might be harmful.

Prior to BWSTT, this individual tolerated rather strenuous aerobic exercise in an upright position in an aquatic environment without observed adverse BP changes. However, midpoint BP readings were only completed through the first eight aquatic sessions with no abnormal BPs obtained. Additionally, during aggressive arm cycle ergometry BP was assessed at several midpoints with no abnormal elevation. The combination of the harness system and the aerobic stimulus (rate perceived exertion 10/10) in this individual seemed to be a crucial AD precipitating factor. With harness suspension and aerobic exercise, the modulation of vascular and sensory feedback may be diminished secondary to the SCI.^{12,14} A larger clinical matter, is the health cost-benefit analysis of exercise on cardiovascular health and the potential AD which may occur during robotic-assisted BWSTT for individuals with level of SCI at or above T6.^{11,13,14–16}

The presence of atypical AD in this case report provides evidence that one individual with incomplete SCI

experienced sharply increased BP during robotic-assisted BWSTT activities with exertional fatigue reported in only the 10th session manifesting as the only AD clinical symptom. Identification of AD may be confounded as symptoms such as perspiration and flushing occur with aerobic exercise. Both aerobic exercise exertion and AD may be new occurrences; therefore, it may be difficult for the individual with SCI as well as the practitioner to identify the precise cause. More research is indicated to investigate how SCI affects cardiovascular function across the lifespan. The stimuli of these BP fluctuations are unknown, but silent AD may have serious, even fatal consequences, and should thereby be monitored and avoided as part of best practice.¹⁶

Conclusion/clinical relevance

This experience with robotic-assisted BWSTT provides data indicating the development of AD during Lokomat training for one individual with motor incomplete tetraplegia or paraplegia above the T6 level. Increased awareness of AD occurring during BWSTT for individuals with motor incomplete SCI is recommended for all clinicians conducting robotic-assisted BWSTT interventions. Frequent vital sign assessment before, during, and at the conclusion of each BWSTT training session is recommended to prevent possible complications from silent AD.

With the advent of increased access to aquatic exercise and BWSTT, it is equally important to assess midpoint BP on all individuals with SCI exercising at moderate to high intensity. Currently, we use a wrist cuff to provide easier midpoint BP and heart rate data during both aquatic and Lokomat sessions. These devices require a short interruption of exercise for 30 seconds. Investigation is ongoing of a system capable of providing BP data during Lokomat sessions.

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Table 2 Screening standing frame heart rate and BP data

Time (minutes)	Blood pressure (mmHg)	Heart rate (bpm)
0	106/66	75
5	102/60	82
10	84/60	80
15	98/58	80
20	102/65	94
25	104/62	79
30	92/60	88

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