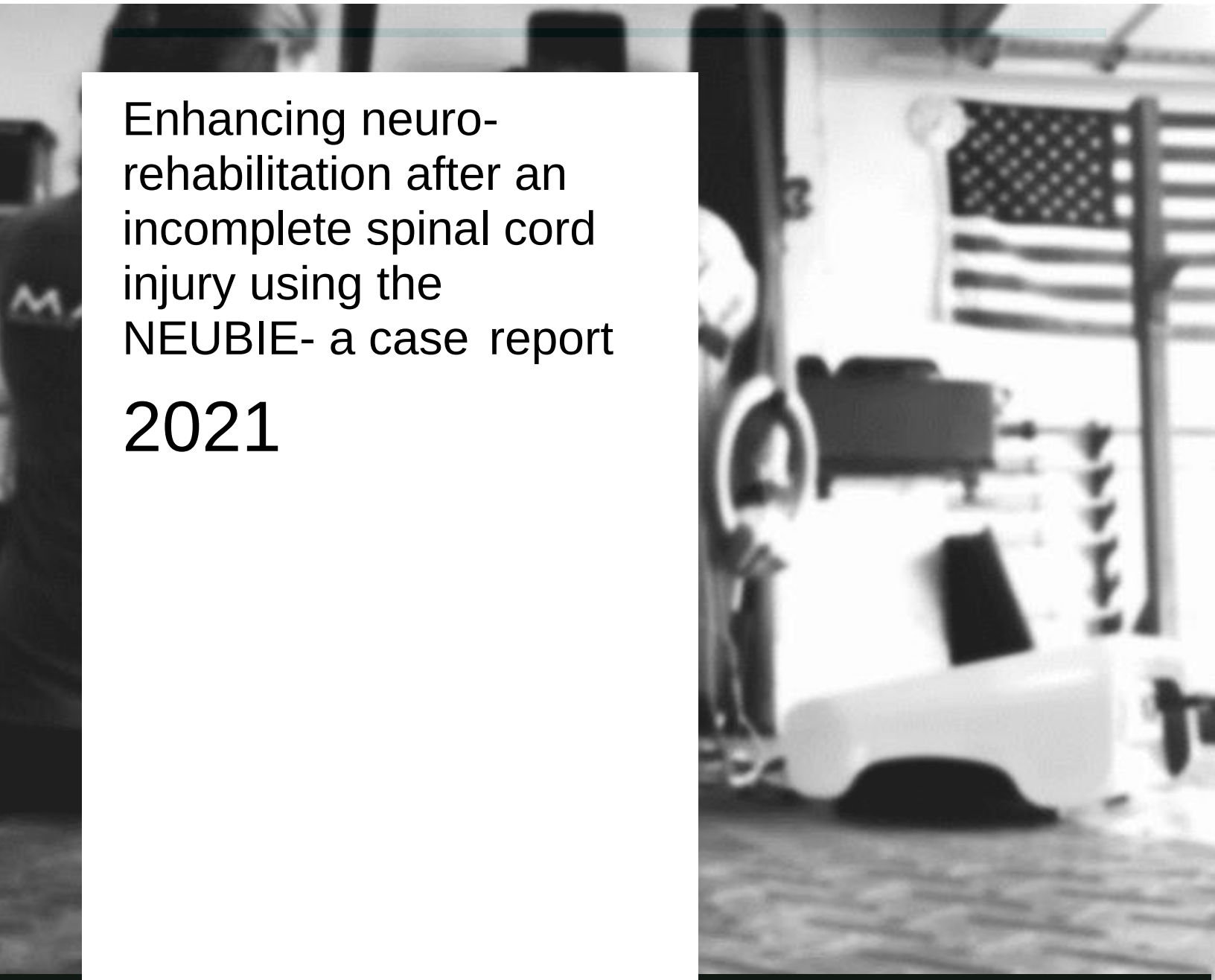

Enhancing neuro-rehabilitation after an incomplete spinal cord injury using the NEUBIE- a case report

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MATRX Health & Fitness
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Case Study Title: Enhancing Neuro-Rehabilitation After an Incomplete Spinal Cord Injury Using the NEUBIE- a case report

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Key Words: spinal cord injury, quadriplegia, gait training, frequency specific microcurrents, muscle activation, neuromuscular re-education, functional training

Summary of Treatment and Outcome: The patient's right foot pain is nearly absent and his bilateral lower extremity sensation, gait kinematics, and right ankle/foot strength have improved significantly using various neuromuscular techniques combined with electrical stimulation. The patient's right wrist extension ROM and strength have increased using manual therapy, neuromuscular techniques, and frequency specific microcurrents (FSM) with the NEUBIE. He is making regular progress with single leg balance, gait, and stair management with ongoing sessions once a week.

Patient Information/Diagnosis: 78-year-old male who was involved in an automobile accident in July of 2016 resulting in Brown-Sequard syndrome at C5, quadriplegia ASIA D (American Spinal Injury Association). He also has a history of fungal meningitis in 2012. In July of 2018, the patient underwent C4-6 spinal fusion for treatment of radicular symptoms; his hospital course was complicated by a saddle pulmonary embolism, a LE DVT (deep vein thrombosis), and swallowing difficulties. He was evaluated and treated for a short period of time in late 2018 to early 2019. He was evaluated for physical therapy in January of 2019 and his primary complaints included: significant resting muscle tone throughout B UE/LE limiting ROM throughout, disruptions in gait causing instability, and some dizziness reaching toward the floor.

Clinical Findings:

Process: Early treatment was focused on vestibular rehab and testing included DGI (dynamic gait index), Manual Muscle Testing (MMT), MAS (modified Ashworth scale for tone assessment), mCTSIB (modified clinical test of sensory interaction and balance), VOR (vestibular ocular reflex), and balance. Full Neubie scan was performed throughout BUE to identify treatment areas for shoulders on eval. Scanning for lower body and trunk were performed during subsequent visits and additional testing was performed for sensation, AROM and PROM, and functional mobility.

Findings:

Weaknesses: Unilateral vestibular weakness with dysfunction in gaze stabilization and VOR. 17/24 on DGI with greatest deficits noted in vertical and horizontal head turns, lateral instability when turning to the R. Dizziness reported in conditions 2 and 4 with some increased sway on mCTSIB. ROM deficits throughout all joints, but most pronounced in cervical rotation and flex/ext, thoracic rotation, segmental spinal flex/ext throughout, B hip flexion and IR, B ankle DF and eversion affecting mobility. Pt has been unable to flex forward to don/doff his shoes 2/2 decreased ROM (standing forward flexion was measured c/ modified good morning: (-)2.5" from floor). LE strength was greater L than R (3 to 4/5 on R, 3+ to 4+ on L). Shoulder flexion was limited B (flex: 120° R, 130° L, abd: 118° R, 140° L). Pt has hypersensitivity to RUE, R trunk, and LLE due to Brown-Sequard with motor weakness greatest in trunk and UE (L hand > R) and in lower extremities (LLE>RLE).

Scan: revealed hot spots in UE: R delt sensitivity, R biceps, L wrist/digit extensors, and B rhomboids/middle traps; Trunk hypersensitivity along R side of trunk and ribs, hyper-reactive at spinal level T8-10 and ribs 9-10; LE: hyper-reactivity and pain at arch of R foot and L glut med. Patient had no sensation to stim in great toe, and of note, he was unable to feel stim in his feet during master reset.

Additional Findings: Patient reports significant pain with activations at tibialis posterior, gastrocnemius, and lateral sling. He also notes pain with activations to R flexor retinaculum.

Assessment: Patient presents with significant weakness throughout BUE, BLE, and trunk as well as limited functional ROM due to a combination of weakness and high resting muscle tone. He also presents with kinesthetic dysfunction in scapulothoracic rhythm. Compounding the patient's functional impairments is an underlying unilateral vestibular weakness leading to dizziness with select mobility, delayed balance reactions, and general instability with gait. Sensory impairments further impact balance and gait. Patient requires neuromuscular re-education to improve motor patterns, isolated muscle strengthening, and management of muscle tone for improvement in ROM. The treatment plan also included traditional vestibular training; vestibular re-training with the NEUBIE was not known to therapist during the initial phases of treatment. The NEUBIE scan revealed hot spots, indicating faulty signals and pathways that have been shut down due to the spinal cord injury. It also revealed areas of hyper-sensitivity that coincide with the patient's known deficits related to anatomy related to his specific SCI and the decussation and distribution of sensory pathways.

Treatment: muscle activations to weak muscles in BLE, AROM B shoulders with NEUBIE stimulation to hot spots (middle trapezius and biceps), AROM for lumbar spine with NEUBIE stimulation to hot spots (spinal extensors T8-10 and lateral flank around ribs 9-10), and ankle DF strengthening with NEUBIE to hot spots (plantar arch and tibialis anterior).

Patient report after initial evaluation: Patient was able to demonstrate and report increased freedom of movement with repetition of shoulder ROM on the NEUBIE. On follow-up, patient reported that the gains in ROM carried over for 1.5 days. He was able to maintain great toe contact with the floor and notes improvement in foot hyper-sensitivity leading to increased "comfort" with his level of stability during gait.

Detailed Treatment, Timeline, and Outcome:

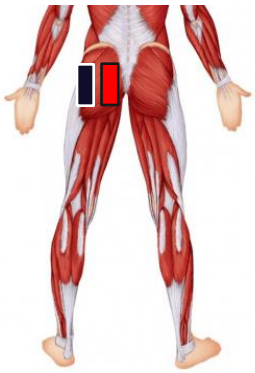
Frequency: Patient had received a short bout of treatment in late 2018 into early 2019 by writer for vestibular rehab. Treatment was interrupted during the COVID pandemic, and patient did not return for treatment until October of 2020. He has been consistent with treatment 1x/ week, except for two brief interruptions (1-2 weeks each). During the course of treatment, the patient also experienced a fall from a ladder with resulting rib and transverse process fractures. He is also attending traditional physical and occupational therapy 2x/week at an outside clinic.

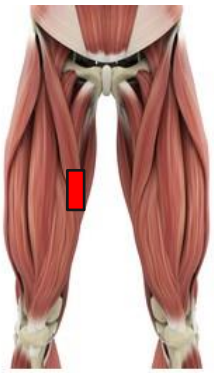
Techniques used in follow up sessions: Early sessions focused mostly on tissue elongation, functional ROM, joint mobilization, and pain management concurrent with the high frequency setting (500 Hz) at the mapped locations to control tone and improve segmental mobility. Traditional vestibular training was utilized during initial sessions to manage vestibular weaknesses. Later addition of the vestibular set up on the NEUBIE led to more significant carryover with stability and proprioceptive input during gait and single leg balance. Treatment focuses have shifted as the patient has progressed. Treatments for shoulder ROM and back pain were not particularly successful, and focus shifted to LE function, balance, and gait. After activations and master reset, strengthening was provided for targeted muscle groups. A regular sequence of manual therapy and activations (500 Hz) throughout the lower extremities, PAILS/RAILs (500 Hz on antagonist muscle groups with 55 Hz used on agonist muscle groups for hip internal and external rotation), and AROM with NEUBIE on hot spots (500 Hz) was repeated for 3 sessions. This progressed to isolated gluteal and tibialis anterior strengthening at 55 Hz and later (12 weeks) to varied frequencies for additional strengthening and endurance benefits (varied frequencies between 500, 250, 160, and 100 Hz continuously as well as 75 and 55 Hz pulsed at 5 sec on/10 sec off) followed by functional carryover during gait and balance activities. FSM was added using the NEUBIE to aid in right wrist mobility and strength followed by strengthening of the wrist extensors (55 and 250 Hz) concurrent with stretching/lengthening of the wrist flexors (500 Hz using the NEUBIE glove).

Pad Placement for PAILs and RAILs:

For increased hip internal rotation:
Channel 1: 500 Hz
(Red) Medial gluteus maximus
(Black) Lateral gluteus maximus
Channel 2: 55 Hz
(Red) Adductors
(Black) TFL

For increased hip external rotation:
Channel 1: 55 Hz
(Red) Medial gluteus maximus
(Black) Lateral gluteus maximus
Channel 2: 500 Hz
(Red) Adductors
(Black) TFL





Pad Placement for FSM:

Channel 1: (Red) proximal flexor tendons
(Black) dorsal surface of hand
Channel 2: (Red) proximal extensor tendons
(Black) palm of hand

Pad Placement for Wrist Strengthening:

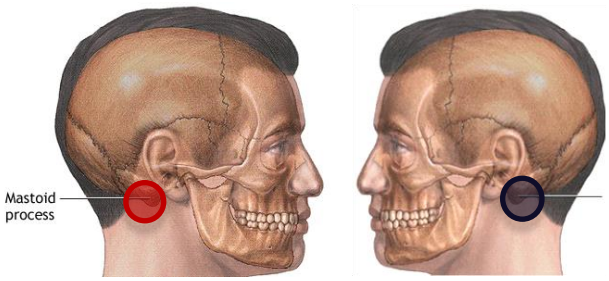
Channel 1: 500 Hz continuous for elongation
(Red) proximal flexor tendons
(Black) NEBUIE glove
Channel 2: 55 Hz pulsed at 5 on/10 off
(Red) proximal extensor tendons
(Black) palm of hand

Pad Placement for Ankle Strengthening:

Channel 1: 500 Hz continuous for elongation
(Red) proximal gastrocnemius
(Black) distal gastrocnemius
Channel 2: 55 Hz pulsed at 5 on/10 off
(Red) proximal tibialis anterior
(Black) distal tibialis anterior

Vestibular/Balance Training:

Channel 1: (Red) left mastoid process
(Black) right mastoid process
Frequency: 500 Hz



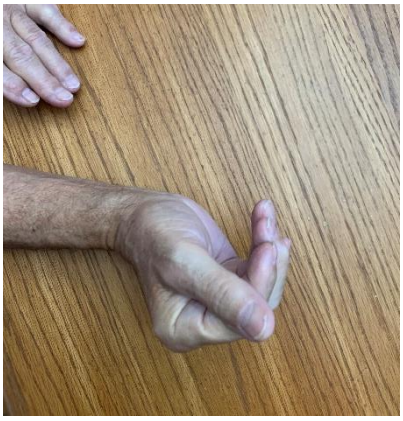
Results: Treatment is ongoing. Measurable Improvements noted:

- Improvement in hamstrings length and functional forward reach (pt was able to reach to the floor to his 1st MCP joint).
- Ankle ROM would improve within a session and result in improvement in gait kinematics (decrease in early heel off, increased balance in weight shift during stance, and decrease in weight shift onto lateral aspect of R foot), but this result never seemed to carryover from session to session.
- Increased sensation in B feet and lower legs during treatment, but again, this result does not seem to hold more than 2-3 days.
- Increased strength on RLE on PN 3/5/2020: Tib Ant to 4-/5 (3/5 on eval), Tib Post 4-/5 (3/5 on eval), GT Ext 4+/5 (3+/5 on eval).
- Improvements noted in gait kinematics (likely in part due to improved sensation and in part due to improvement in strength noted above):
    - pt demonstrates increased heel contact (reduction in foot slap at initial contact)
    - increased tibial control during early stance through heel off
    - increased GT contact with the floor (previous experienced sustained digit extension s/ contact) during mid-stance
    - decreased lateral weight shift during stance. He experiences much fewer instances of lateral instability when walking
    - Also note better tracking of the knee over the second metatarsal during sit<>stand practice (likely in part due to increased ankle ROM). Previously, pt was unable to maintain hip adduction and demonstrated significant ankle eversion.
- Within a single session on 10/29/2020 following vestibular treatment c/ the Neubie, SLS time increased from 3 s to 7.67 s on R c/ noted increased ankle strategies. He was able to assume the SLS position s/ UE support (which he required previously).

	(1/28/2021)		(6/3/2021)	
AROM	**Prev R.**	**Prev L.**	**Right**	**Left**
Ankle DF	100	120	112	120
Ankle DF in standing	0	120	6 (4/1/21)120	
Seated hip IR	2	20	8	30
Seated hip ER	16	35	20	40
Wrist Ext (c/lumbrical flex)	10	40	40	NT
Wrist Ext c/ full digit ext:	-10	40	6	52
Seated Hip ER in Figure 4			64	58

	(11/12/2020)		(6/3/2021)	
PROM	**Prev R.**	**Prev L.**	**Right**	**Left**
Ankle DF (gastroc)	100	116	112	120
Ankle DF (soleus)	112	120	120	120

	Prior (11/12/2020)		(1/28/2021)		(4/1/2021)		(6/3/2021)	
MMT			**Prev R.**	**Prev L.**	**Right**	**Left**	**Right**	**Left**
Wrist Ext			4	5	20.6#	34.5	26.6#	33.8
Wrist Flex			3	4+	23.9	32.8	27.3	31.9
Digit Ext			3+	4+	11	12.7	8.0	16.9
Ankle Inv/Ev			4-	4+	15/21.7	NT	21.6/26.5	42.1/55.0
Ankle DF	3	5	3-	4-	39.9	NT	43.5	60.8
Hip ER/IR	4/3-	4/4	4	4	47.9/32.1	29.4/26.2	28.5/23.0	25.0/34.5
Great Toe Ext	3+	5	4-	4+				
Hip Adduction			4	4				
Hip Flexion	4-	4+						
Hip Ext		3	3+					
Hip Abduction	3-	4-						
Tib post		3	4+					
Fibularis Longus		4+	4+					



4/22/2021
Left: R wrist ext AROM with flexed digits. Middle: R wrist ext AROM with digit extension. Right: Active wrist and digit extension conccurent with NEUBIE strengthening stimulation as per above.

Discussion: Patient's recent course of treatment began several years after his spinal cord injury. Prior to starting with our clinic, he received regular neurologic physical therapy (4x/week, then down to 3x/week) since his hospital discharge in 2016. He had been treated by his current physical therapist in the past, including outpatient in 2016-2017 specifically for assistance addressing LE and trunk strengthening and ROM, gait, balance, and functional mobility. During that time, progress had plateaued. The patient was walking without a device, but with B custom shoe inserts and with significant gait deviations. Since working with the NEUBIE, the patient's vestibular symptoms have resolved. He has begun making improvements in ROM, strength in new available range, LE sensation, and resulting strides with balance and gait kinematics. Similarly, FSM and manual therapy have helped to unlock wrist ROM. Within months of focused treatment to the right ankle, the patient was able to achieve an active ROM within functional limits and strength against resistance throughout the R foot and ankle. Stretching and strengthening with the NEUBIE have aided in carryover with R wrist function between sessions. The patient's previous therapy experience provides a good comparison to demonstrate to power of the NEUBIE to unlock potential that traditional therapy has been unable to tap with neurologic deficits. The treatment methods used had been applied to this patient in the past, but the addition of the NEUBIE allowed for new and rapid progress in function.

Patient Perspective: The patient continues to express shock at the progress made within a single session. He reports that progress made during previous therapy has been "short lived" and "fades within a few hours". When using the NEUBIE, he regularly reports carryover for several days to a week. After a prolonged absence from NEUBIE treatments due to the COVID epidemic, patient clearly regressed with regard to gait mechanics and balance. However, he notes, "I'm actually surprised at how much sensation I still have in my feet." Even though he is unable to fully understand how the technology works, he notes, "it's obviously been the difference-maker".

Additional videos available:
https://drive.google.com/drive/folders/1g9uFsobLoTfKvk0W0tY4AXrD_9SGgfvA?usp=sharing

Pre-gait stepping with NEUBIE and ankle mobility wedges performed after activations and gastroc lengthening + tib anterior strengthening in sitting. (Titled: "Pre-gait ankle mobs with stim on 3.18.21")

First day patient was able to achieve gravity resisted ankle DF in standing (carryover after treatment) (Titled: "Larry standing ankle DF 4.22.21")

Progressions of wrist extension including a video without stim after the first session of the above mentioned protocol, performance on stim 2.11.21 and 3.4.11 to show progress and part of the set up.