International Journal of Physiotherapy and Research,
Int J Physiother Res 2024, Vol 12(4):4748-67. ISSN 2321-1822
DOI: https://dx.doi.org/10.16965/ijpr.2024.121

Case Report

An Integrated Approach Using Physical Therapy and Therapeutic Lenses to Treat Post Encephalitis Syndrome and Lupus

Natasha Johnson *[1], Denise Gobert [2], William V. Padula [3].

[*1] PT, MSPT, Certified vestibular therapist, V2fit certified therapist, certified functional vision rehabilitation specialist.

[2] PT, MEd PhD, NCS, Texas State University 200 BobCat Way - Willow Hall #336, Round Rock, Texas 78665

[3] OD, SFNAP, FAAO, FNORA.

ABSTRACT

Background and Purpose: This case report documents the use of physical therapy, primitive reflex integration and neuro-optometric interventions for AM, a 38-year-old, left-handed female, with flu-like signs and symptoms with cognitive changes over a 5-month period. AM had a sudden onset of chorea, headache, blurred vision, light sensitivity, loss of smell, sensation, strength, and coordination. Diagnostic tests and imaging studies suggested the diagnoses of Post Encephalitis Syndrome, Lupus, and Autoimmune Encephalitis.

Case Description: With a noxious stimulus present, such as noise, AM exhibited dystonic movements, hyperkinetic gait, an extensor synergy in the left lower extremity and a flexor synergy in the right upper extremity. Symptoms resolved immediately with removal of noxious stimulus. AM's symptoms also suggested bilateral cerebellar involvement.

Methods: Primary impairments included sensorimotor deficits including decreased cervical muscle–and core strength, presence of primitive reflexes, balance dysfunction and incoordination. Therefore, the physical therapy plan of care incorporated Rhythmic Movement Training, primitive reflex integration exercises, cervical muscle and core strengthening as well as high-level balance, coordination and agility training. Following neuro-optometric testing, retinal neuromodulation and mapping techniques, AM received various therapeutic lenses that improved quality of movement when presented with noxious stimuli.

Results: Following therapy techniques and use of various therapeutic lenses, AM exhibited improved coordination and times on PT standardized tests, the absence of dystonic movement with noxious stimuli, improved recruitment of muscles during surface electromyography studies and improved coherence in the quantitative electroencephalogram measures.

Conclusion: This retrospective case study demonstrates an interdisciplinary approach to address sensorimotor processing impairments linked to Post Encephalitis Syndrome with autoimmune infirmities. It also highlights the importance of evaluation for the presence and integration of primitive reflexes following adult brain injury and the benefit of neuro-optometry to facilitate improved coordination and processing of visual, sensorimotor, and auditory information.

KEY WORDS: Vestibular, Retinal Neuromodulation, Post Encephalitis Syndrome, Lupus, Sensorineural Dysfunction, Neuro-Optometry, Physical Therapy, Primitive reflexes.

Address for correspondence: Dr. Denise Gobert, PT, MEd PhD, NCS; Texas State University 200 BobCat Way - Willow Hall #336, Round Rock, Texas 78665; E-Mail: dgobert@txstate.edu

Access this Article online	Journal Information
Quick Response code	**International Journal of Physiotherapy and Research** ISSN (E) 2321-1822 | ISSN (P) 2321-8975 **https://www.ijmhr.org/ijpr.html** **DOI-Prefix:** https://dx.doi.org/10.16965/ijpr
	Article Information
DOI: 10.16965/ijpr.2024.121	Received: 19 Jun 2024 Peer Review: 23 Jun 2024 Accepted: 10 Aug 2024 Published (O): 30 Aug 2024 Published (P): 30 Aug 2024

INTRODUCTION

Encephalitis includes inflammation of the brain matter [1] and has an incidence rate of 4.3 million worldwide [2]. There are various causes of encephalitis including viral, bacterial, fungal, and autoimmune infections and predominate in women and young patients [2,3].

Considered an acquired brain injury (ABI), encephalitis survivors present uniquely in each case, despite some similarities of signs and symptoms usually with long-term, persistent, neurological, and cognitive sequelae [4] and several common symptoms for this disorder [5]. (see Table 1: Post Encephalitis Symptoms)

Table 1: Post Encephalitis Symptoms [5].

Emotional lability	Anxiety
Dampening of emotional response	Depression
Light Sensitivity	Changes in self-awareness
Decreased coordination and apraxia	Impulsivity and disinhibition
Dysarthria and Dyspraxia	Fatigue/Sleep disturbances
Sensory & Auditory Sensitivities/Challenge	Headaches
Hormonal Imbalance	Increased Processing and Reaction Times

Systemic Lupus Erythematosus (SLE) is associated with multisystemic inflammation resulting from abnormal immunological function with the highest prevalence in women and persons between 20 and 40 years of age, with an incidence of 12.5–39.0 per 100,000 people [6]. Many autoantibodies identified in SLE are antinuclear antibodies

(ANAs). The detection of ANAs is essential to the diagnosis [1]. SLE is hallmarked for having bouts of inflammatory flares and periods of remission [7].

The following case study of encephalitis that later developed into concurrent SLE is being presented with unique treatment strategies over two years with combination of vestibular, neurologically based physical therapy and neuro-optometry. The case study illustrates some of the complex challenges when these disorders are seen together.

Patient History

AM was a left-handed female, working as a physician in Malawi, who at 38 years old experienced flu-like signs and symptoms likely from typhoid fever and cognitive changes over a 5-month period, followed by a sudden onset of chorea, headache, blurry vision, light sensitivity, loss of smell, loss of sensation, strength, coordination and sleep disturbances. AM was in the Intensive Care Unit for 10 days, and 3 weeks in the hospital prior to transfer from Malawi to Houston. Her past medical history included asthma, otherwise it was unremarkable. Blood analyses revealed positive Epstein Barr Virus antibodies and ANA titer (see Table 2). Although ANA testing has nearly 100% sensitivity for diagnosis of SLE, it is not specific for this diagnosis [1]. The presence of Cardiolipin Immunoglobin M may be primary or secondary in association with other autoimmune conditions such as SLE [8]. AM had negative Lyme titers and human immunodeficiency virus tests.

Table 2: Timeline of AM's Lab Results.

Date	Test	Result
24-10-2017	EBV VCA IgM	Positive
24-10-2017	EBNA IgG	Positive
25-10-2017	Leptospira IgM EIA	Positive
30-10-2017	ANA titer	Positive
01-11-2017	HSV Type 1 &2 IgM	Positive
01-11-2017	HSV Type 2 IgG	Positive
01-11-2017	Varicella Zoster IgG	Positive
03-11-2017	Cardiolipin IgM	Positive
18-04-2018	Lyme titer	Negative
17-07-2018	1:20 Titer MOG IgG	Positive
18-07-2018	RMSF IgG 1;64 titer	Positive
10-12-2019	MOG-IgG1	Negative
19-01-2019	Chromatin Antibody 1.4	High
01-08-2019	NMDA-R	Negative
01-08-2019	Paraneoplastic Markers	Negative
19-08-2019	Pulse	Bradycardia 30's bpm

Epstein-Bar Virus (EBV), Epstein-Bar Nuclear Antigen (EBNA), Antinuclear Antibodies (ANA), myelin oligodendrocyte glycoprotein (MOG), Rocky Mountain Spotted Fever (RMSF), Herpes Simplex Virus (HSV), N-methyl-D-aspartate receptor (NMDA-R)

AM received several medical diagnoses throughout her recovery, where her physicians theorized Autoimmune or Limbic Encephalitis, and SLE. They agreed on autoimmune encephalitis and SLE diagnoses. AM presented with unconventional sensory (including visual) processing and motor challenges requiring a multi-disciplinary approach to address symptoms.

Currently, the literature does not adequately note the importance of neuro-optometric interventions, particularly retinal stimulation via therapeutic lenses, as part of the interdisciplinary approach to facilitate one's recovery of function. Therapeutic lenses influenced AM's performance during standardized physical therapy (PT) measures, movement quality, processing of environmental visual and auditory information and muscle recruitment with surface electromyography (sEMG) and improvements on Quantitative Electroencephalogram (QEEG) coherence measurements. The purpose of this case report is a retrospective view to feature the combination of physical therapy and neuro-optometric techniques (specifically retinal neuro-modulation) used to address AM's unique visual, sensorineural, cognitive, and physical difficulties following an ABI (and improve AM's functional independence). More specifically, the use of retinal neuromodulation, which enhanced PT techniques used to improve AM's functional independence. Also, to emphasize the value of physical therapists to assess and treat retained primitive reflexes in adults after an ABI.

Clinical Presentation

AM presented to the clinic in June 2018, via referral from another clinician, where she reported poor and interrupted sleep patterns, incoordination, headaches, disorientation, noise, light and motion sensitivities as well as decreased activity tolerance. AM scored 25 out of 28 on the Insomnia Severity Index, indicative of severe insomnia [9]. She had bouts of bradycardia, hypotension, and poor thermal regulation. She displayed forward head posture, right head tilt, rounding and elevation of shoulders with an adopted wide standing base of support at ~16 cm (typically 5-10 cm) [10]. AM presented with hyperkinetic gait, or "stamping" gait patterns, upon encountering exposure to a noxious stimulus, such as noise and fluorescent light. AM had difficulty coordinating her left (dominant) hand for functional activities, where compensated by predominant use of right hand. She also demonstrated an extensor synergy in the left lower extremity (LE), which consisted of knee extension, plantarflexion, supination and inversion of foot [11]. AM exhibited flexor synergy to the right upper extremity (UE) with internal rotation, shoulder flexion, abduction of shoulder with elbow, wrist, and finger flexion [12].

In addition, she had light sensitivity and reported tinnitus with noise sensitivity. During noxious noise stimuli, AM struggled with speech production via stuttering with rapid repeating sounds. Additionally, she could not drink and ambulate concurrently or initiate upright movement during lingual movements.

METHODS

Physical Therapy Assessment

Portions of the PT evaluation assessed coordination, proprioceptive awareness, dynamic balance, visual motion sensitivity and vestibular function. Cerebellar function tests (CFTs) revealed more difficulty with coordinating her left side and challenges with initiating movement more pronounced on the left [13,14]. On the Tandem gait test (with eyes open), AM performed 3 consecutive steps prior to loss of balance (typical: >10 consecutive steps) [15]. She exhibited poor proprioceptive awareness-unable to detect during testing where limb was positioned in space on left, diminished vibratory sense to left malleolus, a positive Romberg response, and absent vestibulospinal reflex (VSR) on left [16]. During visual motion sensitivity testing [17], AM experienced disorientation, loss of balance, and headache. AM had a negative Hoover's sign [18].

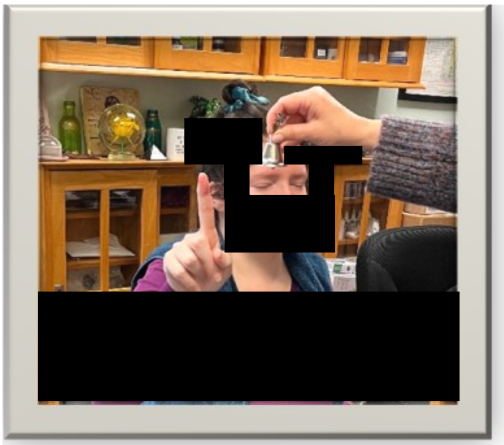
The PT evaluation also explored an oculomotor screen, UE/LE and cervical strength as well as cervical proprioceptive and kinesthetic awareness tests. AM demonstrated difficulty tracking across midline and inability to track highly coordinated eye movements (appeared saccadic or jerky). Her gross UE and LE strength measured right at 4+/5 and left at 4-/5, excluding glutei medii at 3/5. Deep cervical flexor (DCF) endurance test resulted in the inability for AM to attain the test position (typical measure: >29.4 seconds for females) [19]. The Joint Position Error (JPE) Test measures midline awareness of the cervical spine [20]. The clinician placed a target 90 cm from the patient, at the patient's midline position. AM wore a laser light headband. With eyes closed, the head was turned to ~45 degrees (right and left), by the clinician, and she returned her head to her perception of midline, which measured greater than 6 degrees of error (typical range: 0-4.5 degrees of error) [20].

Optometrist Assessment and Specialized Testing

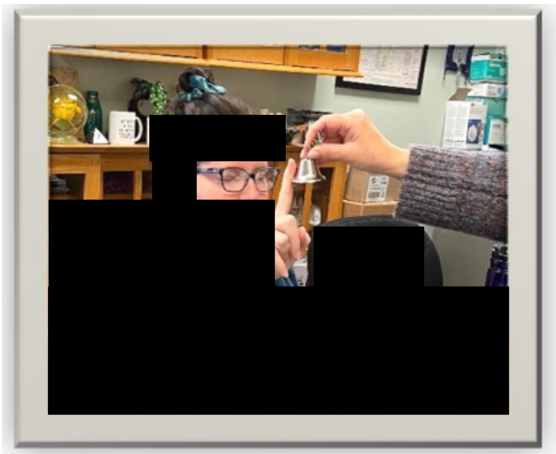
AM reported vision as "off" with light sensitivity, challenges with reading, excessive fatigue, headaches and disorientation especially in open, visually stimulating environments. From the unusual oculomotor dysfunction in the PT exam, AM was referred to an optometrist. AM repeatedly measured 20/20 on near and far acuities with traditional optometric examinations and demonstrated unremarkable structural ocular health. AM was prescribed tinted (rose colored; Fluorescent-41) lenses to address these symptoms with limited response. She still had challenges with the same symptoms including dystonia, headaches, tinnitus and dysarthria. Consequently, AM was referred to a specialized neuro-optometrist.

The neuro-optometrist conducted specialized testing that included The Z-Bell Test® to facilitate the creation and prescription of therapeutic lenses. In the Z-bell® test, a patient sits in a chair with their eyes closed (at times, with feet symmetrical or one foot crossed over the other); the clinician rings a pitched bell in an area on each side of the patient asking the patient to reach out and touch the bell. A small amount of light striking the retina through a closed eyelid is enough to alter auditory localization [21]. The patient is fitted with various prescription lenses and the bell ringing is repeated.[a] (Elliott endnote) Per Dr. Zelinsky, the creator of the test, the perceived visual space and perceived auditory localization in space should be the same. If the prescription lenses are effective in correcting non-image-forming retinal processing problems, the patient's ability to reach and touch the bell improves.[a]

The lenses were graded to the sensorimotor responses. The lenses had varying positions and shapes of Bangerter foils. Bangerter foils block light and their occlusion ranges from .1 to 1.0 where lower numbers, appear more opaque. Application of a partial occlusion foil blocks entering light signals from striking a hypersensitive area of the retina can alleviate symptoms by lessening the effect of incoming stimuli [22]. "A" and "B" therapeutic lenses contained plus lenses which are convex in shape and—converge light where the accommodative system must relax in order to keep an image clear [23]. "C" and "D" spectacles contained minus lenses. A minus lens which is concave in shape, diverges light and the accommodative system must stimulate in order to keep an image clear [24].



Imbalanced visual and auditory perception



Balanced visual and auditory perception

Table 3: Z Bell test®

Lenses Label	Description of the lenses
"A"	
"A"	Occlusion (low opacity) on the inferior nasal quadrant of the lens. OD: +1.00 sphere, OS: +0.62 -.25x180
"B"	
"B"	Occlusion (higher opacity) on the superior nasal and temporal quadrants of each lens. Slight yellow tint. Shift light more to the right eye. OD: +0.75 sphere, OS: +0.37 sphere
"C"	
"C"	Occlusion (higher opacity) on the superior temporal quadrants (one filter in the upper right portion of the lens at an angle outlined in red to facilitate the location). OD Plano -0.25x 090, OS -0.25 -0.25x090
"D"	
"D"	Occlusion (higher opacity) on the superior nasal and temporal quadrants of the lens. OD Plano -0.25 x 090, OS Plano -0.25 x090

Table 4: Label and Description of Therapeutic Lenses

(Note: the higher the lens power, the more influence on accommodative function; these conditions occur with those without presbyopia-a physiological condition wherein there is a progressive functional decline in the accommodative capacity of the crystalline lens) [25]. Minus lenses constrict the usable volume of space, which results in a three-dimensional compression of information [24]. A minus lens emphasizes figure versus the background [21]. AM was prescribed lenses "A", "B", "C and "D".

RESULTS

Integration of Therapeutic Lenses and Physical Therapy

Therapeutic lenses were integrated in the therapy sessions based on how AM presented during the treatment session. Functional motor responses varied according to the following:

Timed Up and Go Test

The Timed Up and Go (TUG) test measured the functional activity of standing, walking a distance, turning and sitting again. Elevated times associated with fall risk (>7 seconds, with BI and age considerations) [26]. The standardized TUG test was conducted with and without Rhythmic Movement Training (RMTi) (discussed in next section). In particular, the movement stimulated cerebellar input, which improved motor coordination, balance and timed measures of the TUG Test, even during brainstem activation and drinking. The TUG test, with right hand improved from 12.18 seconds with "A" to 8.86 seconds with "B". When performing hypoglossal nerve activation, AM exhibited dystonic movement, synergistic posturing of Right UE and left LE and had difficulty initiating movement with "A" lenses, resulting in elevated times for TUG tests. The greatest increase to times due to dystonia was with tongue position to the left, superiorly and to right (positions off midline). The clinician administered TUG test with "C" and "D" lenses while AM performed oral motor stimulation without a delay to initiate movement, stand and walk. Tongue to left with "A" and "B" lenses had times at 23.78 seconds and 8.23 seconds; 5.23 seconds and 6.97 seconds with "C" and "D" lenses, respectively. Drinking with her left hand, AM had times of 23.81 seconds and 18.45 seconds with "C" and "D" lenses, respectively. (see table 5) Following cerebellar RMTi (30 repetitions), times reduced by more than half with "C" and "D" lenses, (see table with bar graph of RMTi influence) respectively. The tongue positioned inferiorly, times measured with "C" lenses at 8.59 seconds and "D" lenses at 7.11 seconds

Table 5: Timed Up and Go Test Times with and without Therapeutic Lenses

TUG Condition	A(sec)	B(sec)	C(sec)	D(sec)	Without lenses (sec)
Tongue - Up	11.06”	7.97”	8.70”	7.83”	16.51”
Tongue- Down	9.25”	13.81”	8.59”	7.11”	8.63”
Tongue- Left	23.78”	8.23”	5.23”	6.97”	15.41”
Tongue-Right	9.91”	7.87”	6.15”	6.81”	14.40”
Drinking Water	12.18”	8.86”	8.19”	6.98”	-

Table 6: Percentage Difference on TUG With and Without Therapeutic Lenses

TUG Condition	A	B	C	D
Tongue -Up	39.54%	69.77%	61.93%	71.32%
Tongue -Down	-3.47%	-46.17%	0.46%	19.32%
Tongue - Left	-42.71%	60.74%	98.64%	75%
Tongue - Right	36.94%	58.76%	80.29%	71.60%

The difference of measures of TUG at baseline (without therapeutic lenses) compared to measures with therapeutic lenses A-D divided by the average of the measures. A negative percentage indicates a faster time without therapeutic lenses.

compared to 9.25 seconds and 13.81 seconds with “A” and “B” lenses, respectively. (Minimal Detectable Change (MDC)=2.9 seconds)

When comparing percentage differences with use of therapeutic lenses to without lenses, “C” and “D” had the highest differences overall. (see Table 6/percentage differences) With “C” lenses, AM had more ballistic, uncontrolled movement, although a few times measured faster. The percent average differences between lenses and without during the TUG tests incorporating oral motor were greatest with tongue positioned superiorly at 39.54%, 69.77%, 61.93% and 71.32% for “A”, “B”, “C” and “D”, respectively.

10-Meter Walk Test

The 10-Meter Walk Test [27] was conducted to measure gait velocity in response to use of different lenses and simultaneous oral motor function. The standardized preferred gait speed of her age and gender ranges from: 1.34-1.43 m/sec for decreased fall risk [27]. A slower speed correlates with increased fall risk. “A” lenses, tongue in neutral, the gait speed measured 2.11 m/sec, with “B” lenses, tongue in neutral, the speed measured 2.41 m/sec. Drinking with right hand had speeds of .28 m/sec “A” lenses, “B” .39 m/sec, “C” .92 m/sec, and “D” 1.54 m/sec. Use of left (dominant) hand usually increased dystonia. Drinking with left hand with “D” lenses had the highest gait speeds from .54 m/sec with “D” lenses to 1.03 m/sec with “D” lenses in combination with RMTi (closer to the preferred gait speed) (MDC =.05 m/sec).

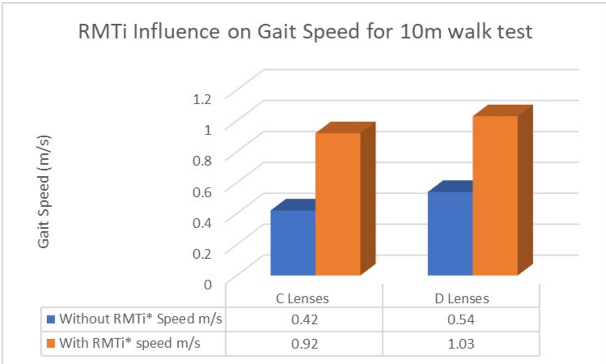


Table 7:

High Mobility Assessment Tool

AM performed the High Mobility Assessment Tool (HiMAT) [28], a functional test, that includes stepping over obstacles, skipping, running, walking backward, and ascending/descending stairs with various lenses. Without lenses, due to increased dystonia and safety concerns upon attempt, AM was unable to complete the HiMAT, and had a score of 11/54. AM had scores of 30/54 with “A” lenses and 45/54 with “B” lenses, “C” lenses 34/54 and “D” lenses 43/54 on the HiMAT. AM had faster times overall recorded on the HiMAT, on the most challenging portions, with “D” lenses compared to” A”, “B”, and “C” lenses. (see Table 8). Namely, hopping on the left leg improved from 46.38 seconds without lenses to 5.89 seconds with “D” lenses. The HiMAT category of descending stairs improved to 9.23

Table 8: Portion of HiMAT Times, Scores and Percent Differences Without Lenses and Lenses “A”-”D”

Test	No lenses	A	B	C	D
HiMAT	11/54 (20.4%)	30/54 (55.5%)	45/54 (83.3%)	34/54 (63%)	43/54 (80%)
Run		2.70”	2.23”	2.98”	2.48”
Skip HIMAT	6.65”	7.80”	4.06”	3.38”	2.79”
% Difference Skip		-17.29%	38.95%	49.17%	58%
Hop Left HiMAT	46.38”	8.71”	7.18”	7.33”	5.89”
% Difference Hop		81.22%	85.52%	84.20%	87.12%
Backward Walk		8.71”	7.18”	7.33”	5.97”
Stairs Ascend/Descend		9.88”/11.01”	7.49”/10.91”	8.67”/10.26”	8.25”/9.23”

seconds, with “D” lenses, without the need to look at stairs to ensure lower leg position (as AM exhibited with other lenses) due to augmented proprioceptive and kinesthetic awareness.

Joint Position Error Test (JPE)

With the JPE [20] assessments of the cervical spine position, with “B” lenses, JPE improved to ~4.5 degrees of error. The addition of active assisted Left UE Proprioceptive Neuromuscular Facilitation (PNF) [29] pattern movement, this further improved JPE result to 1-3 degrees from >6 degrees (without lenses) [20].

Cerebellar Function Tests

CFT for upper and lower extremities coordination were repeatedly assessed as a gross measure of quality and accuracy of movement [13,14]. “A” lenses produced slowed movements with challenges in initiating movement. With “B” lenses, AM had better initiation of movement and overall coordination of movement compared to “A” lenses. Therapeutic lenses, “C” and “D” were introduced approximately in 2019. (See Table 3) AM exhibited more ballistic, poor grading of movement, and decreased accuracy of localizing fingertip to nose with “C” lenses. Upon wearing “D” lenses, AM exhibited better kinesthetic awareness of upper and lower extremities and exhibited improved cervical and truncal alignment during testing.

Deep Cervical Flexor Endurance Test

With the DCF endurance test [19] wearing lenses “A”-”C” and without lenses, AM exhibited challenges with initiating the contraction to adopt the test position or the inability to perform the test. With “D” lenses, AM could lift her head against gravity and sustain the position for 2.31 seconds.

Therapeutic Lenses’ Impact on Surface Electromyography

Surface electromyography (sEMG) via the Brucker Biofeedback Method® determined an estimate on recruitment of muscles for against gravity and functional movement [30]. (see Table 9) Movement against gravity (muscle grade 3-/5) occurs at 14% of a potential maximum voluntary force (90 out of 640 microvolts) [31]. Through use of visual or auditory feedback that instantaneously reflects electrical activity of targeted muscles, patients can be trained (via operant conditioning) to inhibit unwanted spastic motor activity and facilitate improved strength, range of motion and control of paretic muscle [30].

AM exhibited improved initiation and percentage of muscle recruitment on sEMG with “B” lenses, in comparison to “A” lenses. There was an emphasis of sEMG measurements, during the course of therapy sessions, on the left due to decreased strength and challenges to activate muscles on left side. ”B” lenses facilitated better percentages of muscle recruitment for the left side of the rectus abdominus, upper trapezius and gluteus medius, at 22% (i.e. 140 microvolts/ 640 microvolts), 39%, and 28%, respectively amongst lenses “A”-”D”. A 9-29% improvement in muscle recruitment was discovered with “B” lenses compared to “A” lenses. Interestingly, randomizing (and repeating) measures between “A” lenses and “B” lenses,

Table 9: Influence of Therapeutic Lenses on sEMG Percentage Muscle Recruitment

Biofeedback Muscle Assessment	"A" lenses	"B" lenses	"C" lenses	"D" lenses
Rectus Abdominis	Left 13%	Left 22%	Left 16%	Left 14%
Upper Trapezius	Left 10%	Left 39%	Left 16%	Left 12%
Iliopsoas	Left 13%	Left 31%	Left 19%	Left 50%
Hamstrings	Left 50%	Left 60%	Left 60%	Left 40%
Gluteus Medius	Left 10*	Left 28%	Left 12%	Left 14%
Rhomboids	Left 18*	Left 39%	Left 31%	Left 43%

*Slow (>20 seconds) to initiate movement

the recruitment signal consistently decreased with "A" lenses and increased wearing "B" lenses. With "D" lenses, AM had the highest recruitment of the iliopsoas and rhomboids muscles in comparison to other lenses.

Impact of the Therapeutic Lenses

QEEG Studies

Quantitative Electroencephalography (QEEG) consists of modern Electroencephalography (EEG) analysis and involves the recording of digital EEG signals that are processed, transformed, and analyzed using complex mathematical algorithms [32,33].

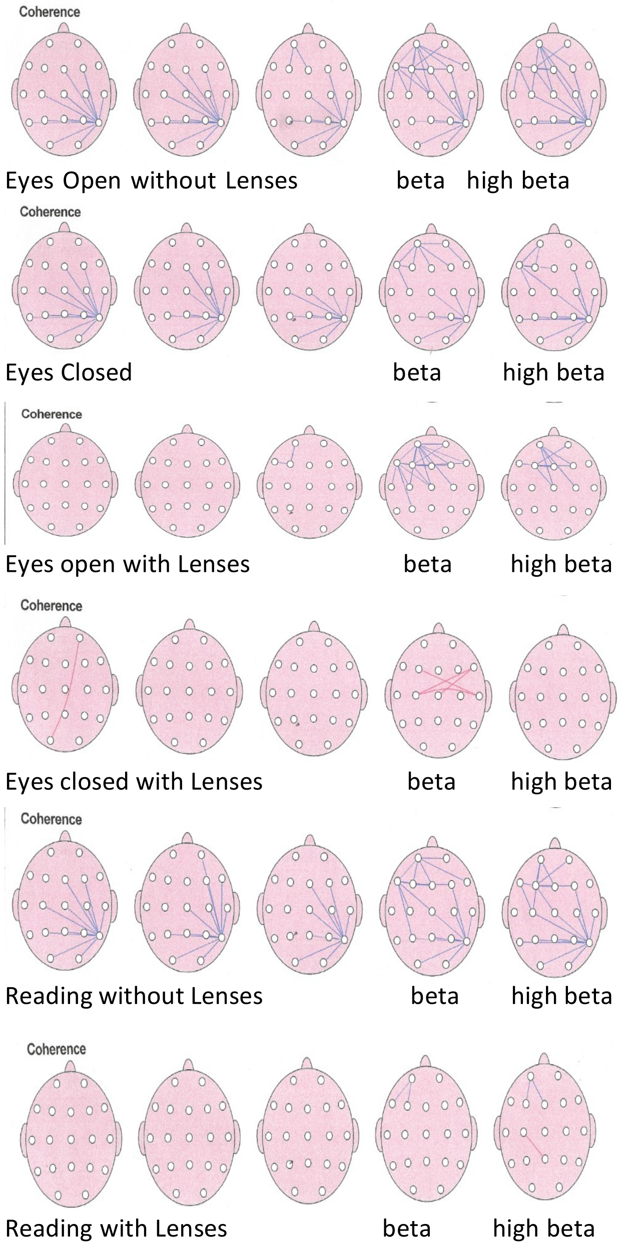
Subsequently, QEEG can be used in more productive ways than non-QEEG to predict the outcome of therapeutic intervention [33].

Connectivity analyses of the brain are performed to map out the communication networks needed for the brain to function [34].

A Neuro Biofeedback team performed QEEG measures for AM via the low-resolution electromagnetic tomography (LORETA) analysis, which provided information on effective connectivity from 10 networks (exploring the influence of "A" lenses to without lenses to brain waves).

Effective connectivity uses the functional connectivity information that provides areas that have similar frequency, phase and/or amplitude of correlated activity, and goes one step further and determines the direct or indirect influence that one neural system may have over another, more specifically the direction of the dynamic information flow in the brain [35]. Coherence is a linear math method in the frequency domain for calculating neuronal networks [36].

Table 10: QEEG Coherence Diagrams



Coherence is the most common measure used to determine if different areas of the brain are generating signals that are significantly correlated (coherent) or not significantly correlated (not coherent) [36].

The QEEG revealed improved coherence with neural signal (effective) connectivity with "A" lenses as compared to without lenses. The changes in coherence would improve immediately with the wearing of "A" lenses to without lenses. The improvement and decline in coherence changed repeatedly with and without the "A" lenses, respectively. Although coherence improved, absolute power with beta and high beta waves showed hyperactivity in the posterior temporal pole on the right (see Table 10 QEEG images for coherence) with eyes open and eyes closed. Sleep improved on the Insomnia Severity Index Scale from 25 (severe) to 9 (mild).

Specialized Physical Therapy Strategies and Outcomes

AM reported the inability to drink and simultaneously ambulate during a therapy session approximately 4 months into undergoing physical therapy. The clinician assessed movement quality with the attempt to perform oral motor activities, where the patient exhibited challenges with simultaneous oral motor, limb and head movement. The clinician explored any potential influence of retained primitive reflexes due to the question of why AM had difficulty performing these tasks.

It has long been recognized that primitive reflexes are present in newborn infants, integrate during normal development, and may reappear in disease states [37]. Experts suggest that these responses are suppressed and not lost during maturation [37]. After Brain Injury (BI), the frontal lobe is unable to inhibit their activity and they are released [38,39]. Poor integration of early infant reflex movements can be the basis of problems such as "poor ocular movement, binocularity, accommodation, and visual performance."[b] The neurodevelopmental movements are also important for remediation of visual skills [40].

Developed by collaborative works of Dr. Blomberg, Kerstin Linde and Moira Dempsey, Rhythmic Movement Training (RMTi) replicate movements in utero stimulate neural connections to the brainstem and organize central nervous system-including the Basal Ganglia, Thalamus, Limbic System, Cerebellum, and Neocortex [41]. These movements are used at any age to create effects like those seen in infancy [41].

The clinician assessed AM's ability to visually track across midline and perform cross body movements, where AM had difficulty. AM had an exaggerated startle response to tapping the mat near ears while lying down, unexpected touch to upper or lower extremities and/or ambient movement (especially on the left) and sound. In quadruped, pitch and yaw plane head movements, elicited instability of the arm at the elbows. Pitch plane head movement with the eyes open or closed in standing elicited loss of balance. These responses indicated the presence of primitive reflexes (amongst others, but featuring these as they were emphasized consistently during therapy sessions): Moro, Symmetrical Tonic Neck Reflex-(STNR), Asymmetrical Tonic Neck Reflex (ATNR) and Tonic Labyrinthine Reflex (TLR).

With this discovery, the clinician introduced cerebellar RMTi (performed at mid-range, rapidly) (Figure 1a and 1b), as well as active techniques to integrate Moro, ATNR, STNR, and TLR, beginning with Moro primitive reflex. The cerebellar RMTi promotes the release of Gamma-aminobutyric acid (GABA) [41] to facilitate regulation of the cerebellum, hence improved motor performance. GABA is inhibitory to modulate motor output. AM reported increased tinnitus and had dystonia with performing ATNR (see Figures 2a and 2b), STNR (see Figures 3a and 3b) techniques with "B" lenses, where "A" lenses decreased the intensity of tinnitus. AM then performed the cerebellar RMTi, ATNR or STNR techniques followed by only left sided Moro technique (modified by clinician). This was used to determine whether it facilitated improved left lower extremity movement while in clinic during exposure to noise/vibratory noise input. Noise and vibration would typically cause dysmetric movements of the left lower extremity. The clinician found the intervention successful, as it normalized the left leg movement pattern in these conditions. (see Figures 4a and 4b) Following, AM ambulated, performed balance patterns and tandem gait without dystonia. At times, the session would start and end with reflex integration techniques of Moro and/or Cerebellar RMTi with the goal of minimizing the brain's sympathetic nervous response, with use of "A" lenses, in order to facilitate typical movement, if overstimulated. When AM performed cerebellar RMTi following superior, inferior, or left lingual movements, AM did not exhibit dystonia as seen previously. Also, following cerebellar RMTi, AM could ambulate past air condition units, with its motor noise, without dystonia.

The clinician incorporated PNF Diagonal 1 LE pattern and modified TLR techniques (see figures 5a and 5b) where AM reported improved proprioception without an increase in tinnitus. To increase abdominal and hip flexor demand on the left side, clinician implemented left knee towards the chest patterns (see Figure 6). Afterwards, AM demonstrated improved awareness of core during dynamic balance. Vitals and symptoms, such as significant decreases or spikes in resting pulse (30-40 or >100 beats per minute) or blood pressure, reduced oxygen saturation rate, headaches and increased tinnitus (measured on a modified visual analog scale) were monitored to determine intolerance to RMTi. The combination of lenses "C" and "D" with TLR techniques, AM performed cross body (excluding crossing left LE posteriorly) and multi-directional movement without dystonia or migraines. With repetition, AM successfully performed patterns in "B", "C" and "D" lenses without dystonia-attaining the goal of exhibiting fluidity of movement independent of lenses worn

Figure 1a: Adopted Cerebellar RMTi beginning position [41].

Figure 1b: Adopted Cerebellar RMTi ending position [41].

Figure 2a: Asymmetrical Tonic Neck Reflex (ATNR) technique beginning position [41].

Figure 2b: Asymmetrical Tonic Neck Reflex (ATNR) ending position [41].

Figure 3a: Symmetrical Tonic Neck Reflex STNR beginning position [41].

Figure 3b: Symmetrical Neck Reflex (STNR) ending position [41].

Figure 4a: Modified Moro emphasizing left side beginning position [41].

Figure 4b: Modified Moro emphasizing left side ending position [41].

Figure 5a: Modified Tonic Labyrinthine Reflex (TLR) technique beginning position [41].

Figure 5b: Modified Trailing Limb Reciprocal (TLR) technique ending position [41].

Figure 6: Modified Tonic Labyrinthine Reflex (TLR) technique with increased abdominals and hip flexors activation left [41].

Table 11: Proprioceptive Neuromuscular Facilitation and Rhythmic Movement Training Exercise Parameters.

Technique	Number of Repetitions	Times per day
PNF LE D1 flexion/extension	10	3
Cerebellar RMTi	30	4-5
Modified Moro	3-5	1-2
ATNR	3-5	1
STNR	3-5	1
Modified TLR	3-5	1-2
Modified TLR with increased abdominals and hip flexors	1-3	1-2

Neuro-Optometry Specialized Strategies

Retinal stimulation can influence signaling in both autonomic and central nervous systems. An emerging subset of optometrists is now prescribing customized eyeglasses with their tools to modify the direction, intensity, amount of entering light (influence the autonomic and central nervous systems) alter biochemical and neurological activity (via retinal stimulation) [42].

Retinal stimulation activates three types of receptors - cones for central eyesight (to focus on a target), rods for peripheral eyesight (to aim at the background) and intrinsically photosensitive retinal ganglion cells (ipRGCs) for processing of ambient light [43]. The seven different cell types in the retina include: Rods, Cones, Retinal Ganglion cells, Bipolar cells, Horizontal cells, Amacrine cells and the most recent Campana cells [44,45]. More expansive studies are needed on the newly discovered Campana cells, but latest research suggests that they may play a role in temporal memory due to its persistent firing [45]. Axons of the ipRGCs project directly, to the Suprachiasmatic nucleus (SCN) along the retinohypothalamic tract (RHT) via the optic nerve, optic chiasm, which is involved with circadian patterns and sleep [46].

An appreciation of what comprises the retina and how vision is processed is necessary. External information that enters the brain via retina sensors is composed cortically of bimodal processing [47]. Peripheral eyesight leads to spatial and postural awareness as well as anticipatory judgements [48], where central eyesight generates the identification of a target [49].

The focal mode is almost exclusively visual, while the ambient mode acts in concert with the vestibular, somatosensory, and auditory senses to subserve spatial orientation, posture, locomotion and gaze stability [50]. Peripheral vision is intimately related to the brainstem areas that control vital functions such as blood pressure, heart rate, respiration, etc. [44]. The tectospinal tract is involved in orienting the eyes and the head towards sounds as part of the auditory and visual reflex [51].

After prolonged stress, shock, injury, or disease, behavior, perception, and responses to environmental changes are frequently affected, often creating abnormal neuro modulation [21]. AM repeatedly measured 20/20 on near and far acuities testing. With traditional optometric examinations, demonstrated unremarkable structural ocular health results without potential explanations for AM's signs/symptoms. AM reported vision as "off" with light sensitivity, challenges with reading, excessive fatigue, headaches and disorientation especially in open, visually stimulating environments. AM had an exaggerated Startle reflex with motion detected in peripheral vision, particularly on the left. One common compensatory mechanism to sensory overload is to ignore outside external stimuli [21]. Various tests, such as the Yoked Prism Walk Test, Super Fixation Disparity Test©, the Padula Visual Midline Shift Test [52], the Van Orden Star Test and Z-Bell® Test are simple ways to assess sensory linkages [53]. Neuro-optometric testing revealed the imbalance between visual, auditory/sensory systems.

Visuospatial information is matched with information gathered from the kinesthetic, proprioceptive, tactile and vestibular systems; this sensorimotor feedback loop also occurs in the midbrain [54]. Focal and ambient vision can be dissociated by brain damage [55]. Ambient dysfunction can cause disorientation and/or motion sickness [55].

This concept of the visual cortex being not only part of a feedforward system of visual signals from the retina, but also being used during feedback circuitry in higher level processes is relatively new [56].

There are also many subcortical pathways (non-imaging forming) visual pathways, whose signals are generated by retinal stimulation from external sources as well as internal activation via feedback loops other sensory signaling [57,58,59]. Studies have discovered the cerebellar connections with visual areas V1-V5, the Superior Colliculus, Middle Temporal (MT), Medial Superior Temporal (MST) and its role in processing motion and ambient visual information [60,61,62].

From a functional viewpoint, visual signaling is split into fast reflex including body orienting movements against gravity, subconscious anticipatory processing and spatial awareness, and slower conscious processing of what is being looked at and what intended action is taken.

”A” and “B” therapeutic lenses contained plus lenses which are convex in shape and converge light where the accommodative system must relax in order to keep an image clear [23]. “C” and “D” lenses contained minus lenses. A minus lens which is concave in shape, diverges light and the accommodative system must stimulate in order to keep an image clear [24]. (Note: the higher the lens power, the more influence on accommodative function; these conditions occur with those without presbyopia-a physiological condition wherein there is a progressive functional decline in the accommodative capacity of the crystalline lens) [50]. Minus lenses constrict the usable volume of space, as a result, there is a three-dimensional compression of information [24]. A minus lens emphasizes figure versus background [21]. (see Table 4)

Application of a partial occlusion foil blocks entering light signals from striking a hypersensitive area of the retina and can alleviate symptoms by lessening the effect of incoming stimuli [22]. A brief and very simplified overview of the visual pathway will facilitate comprehension of the effect of Bangerter foils used on AM’s various lenses had on visual processing. For example, light signals entering the eye from the inferior visual field (superior retina) travel through the optic nerve, optic chiasm, lateral geniculate nucleus (LGN) and optic radiations and generally interact with parietal lobes; light signals from the superior visual field (inferior retina) generally interact with temporal lobes [63]. The temporal visual field, processed by the medial retina, courses to the opposing cerebral hemisphere at the optic chiasm and LGN [64]. (The tract then splits to optic radiations in the parietal region and temporal region (Meyer’s loop) [64]. Hence, the left temporal visual field is processed by the medial retina which traverses to the right cerebral hemisphere. The nasal visual field of each eye is processed by the temporal retina, that travels to the ipsilateral cerebral hemisphere [63]. Ultimately, they course to the visual cortex for additional processing.

With each pair of lenses, the clinician had AM perform PNF Diagonal 1 LE pattern to assess patient’s ability to initiate movement, coordinate a complex movement (requiring whole extremity movement) [29] and cross midline at specific parameters. (see Table 11) At baseline, AM had a delay and inability to initiate the movement without clinician assistance as well as difficulty visually tracking the left lower extremity movement. PNF uses a multi-sensory approach incorporating the auditory, visual and tactile systems [65]. PNF facilitates normalizing movement through motor planning and sequencing the coordination of agonist and antagonist muscles to produce volitional, whole body movement patterns [65]. Based on the performance of the PNF pattern, cerebellar function tests (CFT), and physical therapy tests, the clinician collaborated with the neuro-optometrist on lenses’ impact on movement quality and coordination where modifications occurred to prescribe future therapeutic lenses.

DISCUSSION

The authors aimed to present a very complex patient case which included a variety of treatment strategies and theoretical concepts. Note: In general, standard PT interventions were performed in accordance with evidence-based practice and treatment recommendations from the Academy of Neurological Physical Therapy (ANPT). AM attended therapy sessions twice a week for approximately 60-minute sessions each. However, she exhibited a unique sensorimotor presentation following encephalitis, such as dystonia, incoordination, muscle imbalance triggered by exposure to noise, variations of light and oral motor function. Standardized assessments and tests provided objective outcomes to communicate with other clinicians such as the neuro-optometrist about response to treatment. For example, the effect of the lenses on quality of movement and coordination as well as progression towards established goals.

Treatment Progression

Treatment progression was detailed in this review including multidiscipline testing and shared consultations. Specifically, AM underwent specialized neuro-optometric testing every 3 to 6 months, with modifications to or prescription of additional therapeutic lenses as needed. The Z-bell® test facilitated therapeutic lenses prescription and helped gauge improvements in visual and auditory localization (or localization of auditory cues). The therapeutic lenses, which altered light on the retina, had a positive impact on muscle recruitment, coordination, and alleviating signs and symptoms during the presence of noxious stimuli or periods of overstimulation, and during episodes of intolerance to primitive reflex integration exercises (RMTi). Standardized tests helped to determine significant improvements in coordination, quality of movement, balance, and UE/LE functions.

Sensorimotor coordination responses could be explained by Dr. Zelinsky who described how the limbic system contributes to shutdowns in motor systems and an overload in sensory systems [21]. Therapeutic lenses, “A”-”D”, (see Table 4) may have provided a graded prescribed stimulation and activation of the superior colliculus with targeted connection to subcortical visual pathways [57].

Dose Responses

There lies uncertainty about all the exact regions of the brain that received input with the lenses. Further research is warranted. The use of occlusion on the therapeutic lenses, minimized input on portions of visual processing pathways (cortical and subcortical) and hence increased input to other pathways that had an impact on AM’s function. As an example, AM tended to have significant sensitivity to minimal changes to placement of the Bangerter occlusion foils, a millimeter of movement or slight change in the opacity of the occlusion (in cases that the filter fell off and had to be replaced), AM exhibited challenges in coordination and movement until the filter was replaced or adjusted to exact previous settings. Dr. Zelinsky and her team also found similar responses during lenses prescription with placement of filters in their clinic.

Primitive Reflex Integration, Motor Activation, Proprioception, Coordination, Standardized Tests and QEEG Results

With therapeutic lenses and sector occlusion, specialized exercises for integration of primitive reflexes and cerebellar function, AM improved notably with the performance on standardized tests, cervical postural awareness, muscle recruitment and processing of auditory input. Muscle activation via sEMG had the highest recruitment of core stabilizers for balance with “B” lenses which reflected in the marked improvement in speed, balance and agility skills, such as bounding, skipping, and running, necessary for a higher, hence better score with the HiMAT. AM had the highest score, with “B” lenses due to more efficient, better-quality movement. (Refer to table 8) “D” lenses had the fastest times (and subsequent lower fall risk) overall with oral motor activation during TUG test even including the functional task of drinking compared to “A”-”C” lenses. (refer to line graph 5) The TUG Test with oral motor stimulation, the percent difference averages reflected a marked improvement with therapeutic lenses “B”, “C” and “D” (see Table 6) over times without lenses. Cervical midline awareness, via the JPE test, improved with use of UE PNF patterns and while wearing “B” lenses to typical ranges. “B” and “D” lenses also improved AM’s ability to process high decibel noise or deep vibration without dystonia. One must consider whether these lenses, which contained partial occlusion, facilitated bypassing areas of injury in the brain to allow processing in other, perhaps, intact areas.

When rhythmic movement techniques, particularly the cerebellar RMTi were implemented, all times, including those without lenses, improved. For instance, the 10 m Walk Test, drinking with the left (dominant) hand, “C” and “D” lenses with RMTi improved times by almost half of those with only lenses (refer to Table 7). Following the RMTi cerebellar movements, the gait speed on 10 m Walk Test doubled from speeds with lenses alone with

"C" and "D" lenses (closer to standardized speeds and decreased fall risk). The use of "D" lenses in combination with cerebellar RMTi facilitated AM to use her dominant left hand to drink water and ambulate simultaneously. Prior to this, AM was unable to perform or had inefficient movement or coordination resulting in elevated times for the activity. Based on the improvements demonstrated with "B" and "D" lenses, AM wore those lenses for coordination, agility and balance training during therapy sessions. When AM experienced overstimulation while in noisy or visually stimulating environments or intolerance to RMTi (evidenced via undesirable measures in vitals), the "A" lenses were incorporated. The "A" lenses had a dampening effect, especially for reducing the intensity level of tinnitus, and facilitated relaxation.

During sEMG studies, "B" lenses had the highest percentage of muscle recruitment of gluteus medius, rectus abdominus and upper trapezius of all lenses. AM had the highest recruitment of rhomboids and iliopsoas with "D" lenses. "A" had the lowest measures of all lenses (refer to table 9 sEMG measures). Without the lenses, AM had challenges recruiting muscles for movement, especially to rhomboids and upper trapezius. sEMG revealed that AM had decreased strength to upper trapezius below typical measures without lenses that likely contributed to spasms, headaches and complaints of tightness, due to decreased strength. Based on this information, upper trapezius and core strengthening exercises were incorporated with "B" lenses due to its improved upper trapezius, gluteal, and rectus abdominus recruitment.

The QEEG studies also supported the calming effect via demonstration in regulation of atypical (hyperactivity in the posterior temporal pole on the right) connectivity in high beta coherence measures while wearing "A" lenses as compared to without therapeutic lenses. The QEEG revealed improved coherence with neural signal (effective) connectivity with "A" lenses compared to without lenses-the changes in coherence would improve immediately with the donning of "A" lenses. Although coherence improved, absolute power with beta (15-22 Hz) and high beta (22-38 Hz) [36] waves/areas showed hyperactivity in the posterior temporal pole on the right (see Table 10 QEEG coherence). With the discovery of improved coherence with "A" lenses, further exploration is warranted on how "B", "C" or "D" lenses would influence QEEG measurements. Noteworthily, QEEG coherence measured similarly during eyes open, and eyes closed with conditions of comparison between no lenses and "A" lenses, suggesting retinal stimulation and visual processing occurs with eyes open and closed. AM tended to sleep in "A" lenses for improved sleep quality which reflected on the Insomnia Severity Index scores, from 25 (severe) to 9 (mild).

Foundation for Novel Treatment Strategies

Quality of movement and times changed on standardized tests, reflecting improvements and regressions in performance times/ measures dependent on lenses worn. AM had reproducible results of improving and decreased function with use of the intended design of therapeutic lenses-elevated times/ slower performance (relaxation) in lenses "A" and faster times and generally better movement performance in lenses "B"-"D" especially with its comparison to AM's performance without lenses. The novel treatment of retinal neuromodulation and use of the Z-bell test® are not mainstream practices of neuro-optometry. This unorthodox approach warrants further use with larger patient populations to support its effectiveness. AM's outcomes and improvements in objective measures represent data points that serve to advocate more research and development of the use of that specialty of neuro-optometry.

Areas for Further Clinical Research and Considerations

Which exact areas of the visual pathways did the lenses via retinal neuromodulation either stimulate or inhibit to affect movement quality and performance? Which areas were affected by "A" lenses which elevated time measures and dampened motor processing? Why did cerebellar RMTi improve movement quality and minimize or abolish dystonia upon exposure to noxious stimuli and oral motor activities independent of lenses worn? Did the technique briefly stimulate the cerebellum to improve motor planning, ambient visual processing, and/or inhibit possible cortical and/or subcortical pathways' dysfunction? The lenses also had an influence over the lymphatic flow, but due to the number of topics covered, it was unable to be discuss in detail.

The assessment for appearance of primitive reflexes provided valuable information to possible contributors to atypical movement and processing of sensory and vestibular information. In retrospect, RMTi, due to their favorable influences on AM's movement, coordination, VSR, even during noxious stimuli, should have been introduced sooner, as well as performing more detailed primitive reflex testing. With the performance of ATNR and STNR RMTi, AM initially had increased level of tinnitus and exhibited synergistic patterns during ambulation and higher-level activities. Did this occur initially because Moro did not completely integrate and once integrated, the higher level ATNR and STNR could be introduced without dystonia or adverse symptoms? The TLR (clinician modified version) exercise improved proprioceptive awareness of AM's left side of the trunk, sustaining midline orientation with ability to perform cross body activities without dystonic movements also independent of lenses worn.

Anticipated Treatment Directions

AM will undergo future Functional Magnetic Resonance Imaging (fMRI) studies with specific protocols of activities for AM's brain and presentation. Further studies may_determine which areas function wearing therapeutic lenses with fMRI. AM will also receive Intravenous Immunoglobulin (IVIG) treatments. IVIG is a blood product prepared from the serum of between 1,000 and 15,000 donors per batch. It is the treatment of choice for patients with antibody deficiencies [66].

AM's team of physicians anticipate that IVIG treatments will reduce inflammation, hence episodes and intensity of SLE flares, and sensitivity to sensory and auditory processing.

CONCLUSION

This retrospective glance at AM's journey revealed the remarkable benefits of an interdisciplinary approach to patient care involving a complex presentation of multiple sensorimotor dysfunctions. Neuro-optometry, with its use of lenses, occlusion, prisms, and other optometric tools can facilitate improvement in body position, alignment and coordination, hence enhancing movement, balance and performance. Having the neuro-optometrist facilitate sensorineural processing via neuro-optometric tools, in combination with exercises to integrate retained primitive reflexes and more traditional PT interventions following AM's ABI, have been key to improve AM's function and quality of life. AM is now able to hike on uneven terrain, walk outside while cars pass, walk past air conditioner units, walk while drinking using the dominant hand, and goes to open environments (such as stores) with intermittent use of ear plugs without dystonia. AM also performs highly coordinated movements such as skipping and running without loss of balance, has increased activity tolerance, and experiences improved sleep quality.

The neuro-optometrist should be an integral part of the interdisciplinary team to contribute their expertise in visual links for promoting sensorineural and motor processing improvements. The physical therapist's evaluation and treatment of retained primitive reflexes in the adult BI population, whether traumatic or acquired, serves as an invaluable tool to facilitate typical movement, especially in combination with the neuro-optometric interventions.

Through this experience, a paradigm shift has occurred or more of an appreciation of incorporating these PT strategies used for AM. The clinician now assesses for and treats the presence of retained primitive reflexes in adult patients with similar systemic inflammatory conditions such as long COVID [67] (which the clinician has successfully implemented RMTi during clients' therapy sessions). This patient population also deserves attention for combination of neuro-optometric treatment and PT.

More expansive studies are needed to explore retinal neuromodulation/therapeutic lenses combined with PT interventions in Post Encephalitis Syndrome and SLE populations to determine widespread efficacy in addressing unique sensory processing challenges in these populations.

Informed Consent Statement:

This retrospective case report highlights the use of physical therapy and neuro-optometric techniques. AM agreed to the skilled interventions performed in regulation to HIPAA guidelines at the therapy clinic where physical therapy interventions took place. The case study also follows the guidelines stated in the Declaration of Helsinki. AM gave consent to use information regarding her care for this case study.

LIST OF ABBREVIATIONS

ABI- Acquired Brain Injury
SLE- Systemic Lupus Erythematosus
ANA- Antinuclear antibodies
PT- Physical therapy
sEMG- Surface Electromyography
QEEG- Quantitative Electroencephalogram
LE- Lower extremity
UE- Upper extremity
CFT- Cerebellar Function Tests
VSR- Vestibular Spinal Reflex
DCF- Deep cervical flexor
JPE- Joint Position Error
TUG- Timed Up and Go
RMTi- Rhythmic Movement Training
MDC- Minimal Detectable Change
HiMAT- High Mobility Assessment Tool
PNF- Proprioceptive Neuromuscular Facilitation
EEG- Electroencephalography
LORETA- Low resolution electromagnetic tomography
BI- Brain Injury
STNR- Symmetrical Tonic Neck Reflex
ATNR- Asymmetrical Tonic Neck Reflex
TLR- Tonic Labyrinthine Reflex
GABA- Gamma-aminobutyric acid
ipRGC- Intrinsically photosensitive retinal ganglion cells
SCN- Suprachiasmatic nucleus
RHT- Retinohypothalamic tract
MT- Middle Temporal
MST- Medial Superior Temporal
LGN- Lateral geniculate nucleus
ANPT- Academy of Neurological Physical Therapy
fMRI- Functional Magnetic Resonance Imaging
IVIG- Intravenous Immunoglobulin

END NOTES

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AUTHOR(S) CONTRIBUTION

Natasha Johnson performed assessments, prescribed and modified primary exercises, referred for sEMG Biofeedback studies, communicated with the neuro-optometrist team results of therapeutic lenses on tests and opinions on movement quality on varying lenses, researched journals and books, and formulated concepts to discuss in article. Dr. Denise Gobert provided guidance for organization, structure of the content for the case report, facilitated streamlining and professional critique of content, especially for physical therapy sections, was instrumental to the editing process, and provided invaluable encouragement and motivating support throughout this process. Dr. William Padula provided guidance and recommendations for Neuro-optometry content, professional critique of neuro-optometry information, facilitated creation of outlines and structure of the case study.

ACKNOWLEDGEMENTS

AM, AM's family, Robert Lee, MD and AM's medical team, Deborah Zelinsky, OD and the Mind-Eye Connection Team, Christina Hankins, PT, Erika Aguilar, PT, Bob Rambusek, PT, Amy Silver PT, Tequila Harris, PhD, Denise Gobert, PT, PhD, NCS, Texas State University Department of PT, Wid Bleything, OD, PhD, William Padula, OD, SFNAP, FAAO, FNORA, Neuro-Optometric Rehabilitation Association, Austin Biofeedback & EEG Neurotherapy Center, Nikki Boone, Adia Boone, Marques Fair, Tumarrow Romain.

Conflicts of interest: None

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How to cite this article: Natasha Johnson, Denise Gobert, William V. Padula. An Integrated Approach Using Physical Therapy and Therapeutic Lenses to Treat Post Encephalitis Syndrome and Lupus . Int J Physiother Res 2024;12(4):4748-4767. **DOI:** 10.16965/ijpr.2024.121