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Effects of Transcranial Direct Current Stimulation on Gait and Balance Post-Stroke

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EFFECTS OF TRANSCRANIAL DIRECT CURRENT STIMULATION ON GAIT AND BALANCE POST-STROKE

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Abstract

Background: Non-invasive brain stimulation is effective in combination with traditional physical therapy to facilitate motor performance in patients who recently survived a stroke. Current literature has focused on transcranial direct current stimulation and transcranial magnetic stimulation efficacy for improving the completion of fine motor tasks in the upper extremities. However, there is a lack of current evidence regarding the efficacy of this therapy in the lower extremities.

Objective: To measure the effects of transcranial direct current stimulation on lower extremity clinical outcomes in patients who had a stroke including gait speed, functional reach, and balance.

Methods: Randomized control trial in adults (n=10) at least 6 months post-stroke recruited from the community. Anodal tDCS applied over the lesioned motor cortex using a 2mA current for a total of 20 minutes. Gait was assessed via 10M Walk Test and Berg Balance Scale. Balance was assessed utilizing the Bertec Balance Advantage System.

Results: We found significant differences between stimulation and sham treatment for Static start 10M Walk Test, forward reach distance, backward movement velocity, and backward endpoint excursion. There were no differences between groups for the other dependent variables that we tested.

Conclusion: Treatment resulted in increased speed to initiate walking, improved functional reach, and further backwards center of gravity excursion. We recommend incorporating non-invasive brain stimulation with rehabilitation training and neuroplasticity facilitation techniques to facilitate walking and improve balance in patients following stroke.

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Introduction

Stroke is a serious health problem in the United States that carries significant public health and economic ramifications. On average, a stroke occurs in the U.S. every 40 seconds, and approximately 795,000 people experience a new or recurrent stroke each year.[1] In 2015, approximately 1 out of every 19 deaths in America was due to stroke.[1] Although stroke mortality has decreased within certain populations over the past several decades, the long-term economic cost of stroke rehabilitation continues to increase as people are living longer with post-stroke disabilities.[1] Medicare beneficiaries average health care expenditures between $38,000 and $48,000 in the first four years following an initial event.[2] Some of the most common impairments that affect stroke survivors are associated with gait and balance, leading to decreased physical activity, psychological issues, and loss of independence.[3, 4] Half of stroke survivors report having some type of chronic physical disability or a long-term dependence on others to complete everyday tasks.[5]

To address common problems with gait and balance post-stroke, the focus of current treatment has been to address the underlying issues causing gait and balance impairments, including decreased endurance,[6] reduced walking speed,[7] disuse atrophy, and diminished muscle strength and power.[5,8] These motor impairments are caused by neurological imbalances that result from increased excitation on the contralesional hemisphere and decreased excitation on the ipsilesional hemisphere.[9] Neurorehabilitation to address these impairments include treadmill training, gait training, and strength training.[7, 10]

In addition to more traditional physical therapy, clinicians have applied various forms of transcranial direct current stimulation (tDCS) to the cerebral cortex of these patients. TDCS can be used to either increase cortical excitability with the use of anodal stimulation, or down-regulate and decrease cortical excitability using cathodal stimulation. The goal is to decrease the

imbalance between the patient's cerebral hemispheres.[11] The stimulation at the cortical level is delivered via low-intensity direct electrical currents through the motor region of the brain.[11] The current primes the nervous system for neurogenic change.[11] Physical therapy combined with tDCS has lasting functional effects up to 3 months post treatment,[11] and a single session has demonstrated significant changes in motor performance.[12] Specifically in regards to the lower extremity, tDCS has been reported to be effective in improving quadriceps strength and function in those who are non-neurologically impaired and improve lower limb motor function in patients with subacute stroke when paired with movement therapy.[4, 13] Recent literature reports greater functional motor improvements when training paradigms are combined with various stimulation protocols, compared to training alone.[14]

Most of the current studies related to the use of tDCS in patients post-stroke have examined function associated with the upper extremity.[15] Non-invasive brain stimulation (NIBS) approaches for upper limb recovery are generally accepted due to the large number of studies conducted in this area; however, there are insufficient published studies regarding NIBS targeting lower limb recovery.[12] Within the limited research on lower limb recovery with tDCS, research has primarily been focused on isolated movements. Several studies have implemented tDCS stimulation with unilateral foot movement during training, but walking and balance tasks are more complex movements that require interaction and coordination between both hemispheres and both lower limbs.[12] To date, the use of tDCS and functional training of balance and gait post-stroke has not been systematically examined.[12] Therefore with the current evidence, it cannot be concluded that stimulation of the cortex via anodal tDCS while paired with a unilateral lower extremity task will lead to improved gait parameters. Furthermore, balance training protocols within available research that are implemented in conjunction with tDCS are

often qualitative and do not quantify measures such as movement velocity, directional control, or reaction time.[4,16-18]

Despite recent research studies, evidence is still lacking on overall quantitative improvement of balance and gait after motor priming using anodal tDCS in patient's post-stroke. Our study is designed to quantifiably measure the effects of functional balance training with priming of the lesioned motor cortex using anodal tDCS to improve balance and gait in individuals with chronic post-stroke hemiparesis. We hypothesize that functional balance training combined with anodal tDCS over the lesioned motor cortex will improve patients' balance and gait functions post-stroke.

Aim

To investigate the effects of functional balance training with priming of the lesioned motor cortex using anodal tDCS to improve balance and gait in individuals with chronic post-stroke hemiparesis.

Hypothesis

Functional balance training combined with anodal tDCS over lesioned motor cortex will improve the post-stroke balance and gait function when assessed using the Berg Balance Scale, Functional Reach test, Bertec, and 10-m walk test.

Methods

Participants

Ten participants (58.2 +/- 9.55 years old (4 females and 6 males) who had sustained a cortical or subcortical stroke for at least 6 months and were able to walk independently without the use of an assistive device were included in the study. Participants were excluded if they had metallic implants, a previous injury to the central nervous system different from their stroke, or family history related to seizures.

Table 1. Characteristics of participants

Participant	Age (years)	Sex (F/M)	Paretic Side (L/R)	Time Since Stroke Onset (years)	Lower Extremity Fugl-Meyer Motor Function Score (n/34)
Participant 1	49	M	L	7	18/34
Participant 2	63	F	L	19	21/34
Participant 3	49	M	R	2	19/34
Participant 4	51	M	R	4	21/34
Participant 5	64	M	R	3	32/34
Participant 6	43	F	R	2	24/34
Participant 7	70	M	R	3	26/34
Participant 8	70	F	L	10	30/34
Participant 9	64	F	R	6	32/34
Participant 10	59	M	L	5	29/34

Abbreviations: F = Female, M = Male, L = Left, R = Right, n = number

Procedures

All participants were read a TMS/tDCS standard screening questionnaire and gave their written informed consent for the study, which was approved by the Institutional Review Board at University of Nevada-Las Vegas (UNLV) This was a double-blind, sham-controlled, crossover study. Each participant attended two sessions separated by a minimum of 14-days to ensure

washout. For each session, the participants received either anodal tDCS or sham tDCS stimulation over the lesioned motor cortex. For each session, prior to and immediately after the tDCS application, gait and balance function was assessed for each participant using Bertec's adaptation assessment and motor control assessment. The type of stimulation was pseudorandomized in session one using a coin toss. After randomizing the stimulation type for the first participant, each participant thereafter received the opposite stimulation of the participant before them. In session two, following the washout period, each participant received the second stimulation that was not administered in the first session.

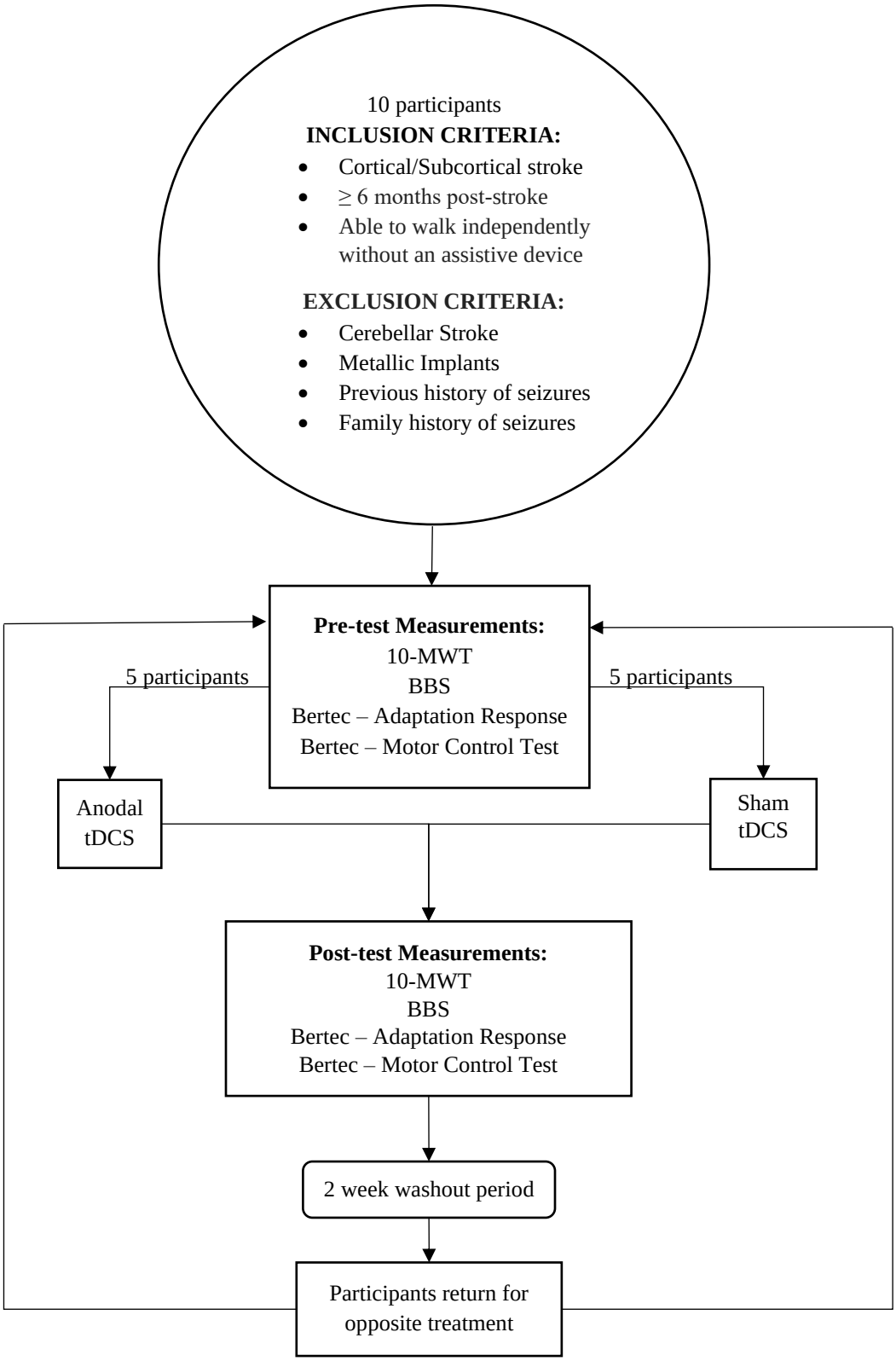

Figure 1. Experimental Method

tDCS Stimulation protocol

Using the 10:20 EEG system, the anode was placed 1cm anterior to the cranial vertex and the cathode was placed over the opposite supraorbital area. This arrangement has been shown to increase cortical excitability to lower extremities.[19, 20] Sterile saline was applied to the 5cm x 5cm electrodes and a head strap kept the electrodes in place. Anodal tDCS was applied over the lesioned motor cortex using a 2mA current with a ramp-up period of 30 seconds, stimulation period at 2mA for 19 minutes, and ramp-down period to 0 mA in the final 30 seconds for a duration total of 20 minutes. Sham tDCS followed a similar protocol and arrangement, but stimulation at 2mA for 30 seconds, after which the current was ramped-down and turned off for the rest of the treatment. This procedure blinded participants to the type of stimulation they received while preventing any changes in cortical excitability.[21, 22]

Functional Balance Training

During the 20 minutes of tDCS application, the participant simultaneously underwent limits of stability training using a computerized dynamic posturography device. This training involved the patient controlling their center of mass by weight shifting. The patient was represented by a cross on a screen in front of them and was asked to reach specified targets by altering their center of pressure and moving their center of mass without losing balance. Participants were asked if they needed a rest break at the halfway mark to prevent fatigue. As per their response, patients were allotted 1 minute to sit down.

Assessment of gait and balance function

Each participant was evaluated using the following assessments prior to and immediately following the tDCS stimulation:

Bertec

The Bertec Balance Advantage System (Bertec Corporation; Columbus, OH) measures balance and postural stability using the participant's center of gravity (COG), calculating an equilibrium score from 0 to 100 that is based on postural deviance and COG sway path.[23] Participants underwent two different Bertec assessments which included the adaptation test and motor control test. The adaptation test measured the sway energy, or the force magnitude required to overcome a postural instability when the platform under the participant tilts up or down. The motor control test measured the amplitude scaling, or the magnitude of the active force response the participant exerts to impede the angular momentum observed when the platform under the participant shifts forward or backward. While undergoing tDCS treatment, participants simultaneously followed a functional training protocol with Bertec's limits of stability assessment. A final post-test evaluation was taken for the two aforementioned assessments in the same order they were evaluated during the pre-test procedure.

Berg Balance Scale

The BBS is a 14-item scale utilized in clinical settings to assess the fall risk of patients.[24] This test has demonstrated excellent test-retest reliability as well as interrater and intrarater reliability in patients with both an acute or chronic stroke.[25] Berg et al. has also demonstrated adequate construct validity of this scale and correlation with self-reported balance rating ($r=0.39$ to 0.41) as well as Timed-Up and Go scores ($r=-0.48$).[26] In this test participants are instructed to perform 14 varying, functional tasks such as sit-to-stands, forward reaching, and balancing on one foot, with each task being graded from 0 to 4 based on quality of movement and time to complete each task.[23] The highest possible score for the assessment is 56 points, with an 6.3-point difference between assessments being the minimal detectable change for patients who are independent ambulators.[27] Along with the total score at the end of the test, the forward reach

scores were also examined independently and run through statistical analysis to examine any changes before and after stimulation. Tools required for the assessment included a ruler, a standard chair with armrests, a standard chair with armrests, a footstool, a stopwatch, and a 15ft walkway.[23]

10-m Walk Test (10MW)

In the 10MW, participants were instructed to walk in a straight line for 10m, while the evaluator recorded time of completion with a stopwatch. The test was performed in two conditions: a dynamic start condition and a static start condition as described by others.[28] In the dynamic start condition, participants walked for 4-m before the instructor started timing them for the next 10-m. The static start condition had the participant immediately start the 10m walk in a static standing position. A one-min break was provided between each condition, as per protocols followed in similar studies.[28]

Statistical Analysis

A 2 (conditions: anodal stimulation, sham stimulation) x 2 (time: pre, post) repeated measures ANOVA was conducted on each dependent variable. Where there was a significant interaction effect, we further examined simple main effects using a repeated measures ANOVA with Bonferroni correction. Paired samples T-tests were conducted on each variable tested within the limits of stability assessment. Significant main effects were reported if there were no significant interactions. P values less than or equal to 0.05 were considered statistically significant.

Results

The mean age of the 10 participants included in the analysis was 58.5 years with 6 of the participants being male and 4 female. The mean time between the date of stroke and the time of data collection for the 10 participants is 6 years.

Table 2. Comparison of clinical assessment measures (mean±SD) pre and post anodal and sham tDCS stimulation.

		Anodal	Sham
Berg Balance Score (n/56)	Pre	52.70 ± 4.16	52.30 ± 4.99
	Post	53.70 ± 3.53	53.20 ± 4.39
Forward Reach (in)	Pre	8.62 ± 2.82	9.02 ± 2.52
	Post	9.74 ± 2.58	8.86 ± 2.48
10m walk with dynamic start (m/s)	Pre	0.91 ± 0.37	0.88 ± 0.38
	Post	0.97 ± 0.40	0.89 ± 0.35
10m walk with static start (m/s)	Pre	0.83 ± 0.31	0.81 ± 0.32
	Post	0.87 ± 0.31	0.81 ± 0.32

Abbreviations: n= number, in = inches, m/s = meters per second

Static Start 10MW

For the static 10MW, there was a statistically significant interaction between tDCS stimulation and time ($F(1,9)=6.115$, $p=0.035$). Simple main effects revealed that participants walked faster after receiving anodal tDCS (pre= 0.83±0.31m/s; post=0.87±0.31 m/s) ($p<0.05$) but not following sham tDCS (pre=0.81±0.32m/s; post=0.81±0.32m/s) ($p>0.05$).

Dynamic Start 10MW

For the dynamic 10MW, there was no significant interaction between tDCS stimulation and time ($F(1,9)=0.642$, $p=0.444$). There was a statistically significant main effect of time

(F(1,9)=7.879, p=0.02). In post-hoc analysis we observed no statistically significant difference between anodal and cathodal stimulation (p=0.151).

BBS

For the BBS, using two-way ANOVA we observed no significant interaction between tDCS and time (p=0.823). Furthermore, no significant differences were found for the main effects of tDCS (p=0.562) and time (p= 0.088).

BBS – Forward Reach

For the forward reaching, there was a statistically significant interaction between tDCS stimulation and time (F(1,9)=11.348, p=0.008). In simple main effects analysis we observed that the average magnitude of reaching distance was greater after receiving anodal tDCS (pre= 8.6200±2.82294; post= 9.7400±2.57680) ($p<0.05$) but not after sham tDCS (pre= 9.0200±2.52127; post= 8.8550±2.47526) ($p>0.05$).

Table 3. Comparison of dynamic posturography assessments (mean±SD) pre- and post- anodal and sham tDCS stimulation.

	Perturbation			Anodal	Sham	Averaged across stimulations
Adaptation test	Toes up	Sway energy (mm/s)	Pre	80.94 ± 13.98	80.14 ± 20.53	80.54 ± 17.10
			Post	67.26 ± 11.34	64.42 ± 12.04	*65.84 ± 11.48*‡
	Toes Down	Sway energy (mm/s)	Pre	78.48 ± 10.87	72.18 ± 12.72	75.33 ± 11.96
			Post	68.48 ± 10.01	65.94 ± 9.48	*67.21 ± 9.58*‡
Motor control test	Forward translation	Latency (ms)	Pre	139.60 ± 9.40	135.70 ± 13.50	137.65 ± 11.49
			Post	138.00 ± 8.76	134.40 ± 15.02	136.20 ± 12.11
	Backward translation	Latency (ms)	Pre	139.60 ± 9.40	135.70 ± 13.50	137.65 ± 11.49
			Post	138.00 ± 8.76	134.70 ± 14.86	136.35 ± 11.99

‡ indicates statistically significant difference from Pre-test ($p \leq 0.05$) when averaged across stimulation types.

Bertec Adaptation Assessment – Toes Up

There was no significant interaction between tDCS stimulation and time ($F(1,9)=0.314$, $p=0.589$). There was a statistically significant main effect of time ($F(1,9)=30.55$, $p<0.001$). In post-hoc analysis we observed no statistically significant difference between anodal and cathodal stimulation ($p=0.61$).

Bertec Adaptation Assessment – Toes Down

There was no significant interaction between tDCS stimulation and time ($F(1,9)=1.826$, $p=0.210$). There was a statistically significant main effect of time ($F(1,9)=8.271$, $p=0.018$). In post-hoc analysis we observed no statistically significant difference between anodal and cathodal stimulation ($p=0.19$).

Bertec Motor Control Assessment – Forward Translation Medium & Large

There was no significant interaction between tDCS stimulation and time for either medium or large translation ($F(1,9)=0.096$, $p=0.764$ and $F(1,9)=0.076$, $p=0.790$ respectively). No significant differences were found for the main effects of tDCS ($p=0.105$) and time ($p=0.462$) during medium translations. No significant differences were found for the main effects of tDCS ($p=1.000$) and time ($p=1.000$) during large translations.

Bertec Motor Control Assessment – Backward Translation Medium & Large

There was no significant interaction between tDCS stimulation and time for either medium or large translation ($F(1,9)=3.214$, $p=0.107$ and $F(1,9)<0.001$, $p=1.000$ respectively). No significant differences were found for the main effects of tDCS ($p=0.735$) and time ($p=0.382$) during medium translations. No significant differences were found for the main effects of tDCS ($p=0.280$) and time ($p=0.607$) during large translations.

Limits of Stability (LOS)

We found a statistically significant difference in the anodal tDCS group compared to the sham tDCS group for backwards movement velocity ($p=0.025$), defined as the average speed at which one's COG shifts. A statistical difference was also observed in the anodal tDCS group compared to the sham tDCS group for backwards endpoint excursion ($p=0.025$), defined as the distance willingly covered by the participant on their very first attempt. No significant differences were found for any other variables (reaction time, movement velocity forward, endpoint excursions forward, maximum excursions, and directional control).

Discussion

Significant differences between the two types of stimulation (anodal tDCS and sham) were found for some of the dependent variables including; Static start 10MW times, forward reach distance, backward movement velocity, and backward endpoint excursion. All of the other dependent variables that we tested were not different between stimulation and sham treatment. Additionally, there were several statistically significant findings using time as a factor. Specifically, dynamic start 10MW times, Bertec adaptation assessment- toes up scores, and Bertec adaptation assessment- toes down scores all improved for patients following training. However, since there was no significant main effect for stimulation type, these findings suggest that the improvements in energy exerted to combat postural instability were caused by training and not neural modulation.

The first outcome measure utilized in this research was the 10MW test which is a test of speed and functional ability. Patients who score faster times on this measure are safer community ambulators.[29] Starting from a static position and transitioning into walking requires strength and the ability to send the appropriate signals to the correct muscles in an appropriate amount of time, with coordination.[30] Our results support the conclusion that anodal tDCS may be able to help stimulate the initiation of walking. It also suggests that by having a patient walk and gain practice with ambulation the patient will be able to improve overall ambulation time. This finding is consistent with the current literature and with the principle of specificity of training.[31-34]

In addition to utilizing ambulation-based outcome measures, balance-based measures were also examined. Although a traditional functional reach test was not performed, the forward reach test utilized in the BBS is very similar to this outcome measure, which is typically used to

predict falls in the elderly.[35] Kim et al. observed significant improvements in functional reach scores after participants underwent therapeutic exercises aimed at improving activation of the quadriceps, hamstrings, and soleus muscles in patients post-stroke.[36] Our results revealed significant improvements in forward reach scores in the anodal tDCS group, but not the sham tDCS group which suggests that neural modulation and not training led to the observed improvement in scores. We can conclude that neural modulation of the cortical representation of these lower extremity muscles with anodal tDCS may contribute to a significant increase in patients' balance. Other aspects of balance tested using the BBS did not have significant differences between groups. This lack in significant outcomes may be attributed to the patients' high functional mobility levels prior to their participation in the study, which can be seen with their pre-intervention scores. Only one participant BBS fell below the threshold for being a fall risk, 45 points.[37] Additionally, all but three patients were within two points of a perfect score initially, leaving little room for improvement.

The Bertec Balance Advantage System is another research-based tool used to measure patient outcome variables related to balance. The specific program, Limits of Stability, is used to quantifiably measure reaction time, movement velocity, endpoint and maximum excursion, and directional control of each participant. Studies have shown that patients suffering from stroke have demonstrated improvements in both motor function and functional independence by using force platform biofeedback.[38] We found that anodal tDCS could be a catalyst for recovery of functional balance, since after receiving anodal stimulation our participants were able to shift their COG backwards faster, over a greater distance. These results are comparable to other studies that used platform biofeedback in functional outcome measures.[38, 39] Our results suggest that anodal tDCS may facilitate balance training using force platform biofeedback.

It is important to consider the principles of motor learning within this study. Our ten participants went through two days of testing where they were rated a total of four times on each outcome measure. It has been found that task-specific training will improve performance in isolation from any other intervention.[34] This principle was likely observed in our study, and must be considered across all results when interpreting our findings, including differences in stimulation type.

There were several limitations to our study. First, our study was limited by region, as the ten participants included in this study were all recruited from the Las Vegas metropolitan area. Second, our study was limited by pre functional mobility level. All participants had high initial BBS scores, and most received a full score by their second attempt. Additionally, we were limited by our inability to account for motor learning due to training. Finally, the qualitative outputs generated on these patients during training were all recorded by the Bertec Advantage Balance System. While reliability testing is lacking on this system, the Bertec Advantage Balance System is a widely used tool for quantifying balance in current and previous literature.[23, 40]

All of the data collected in this study were based on quantitative values for the assessments and outcome measures, with no quantitative assessment on the neurophysiological changes in the participants. We only tested the effects of a single session of tDCS on balance and gait. Future studies should include Transcranial Magnetic Stimulation to determine the changes to motor evoked potentials before and after training. Future research should also examine the effects of tDCS over multiple treatment sessions, since some recent studies have shown it to have a cumulative effect on participants.[41]

Conclusion

Functional balance training combined with anodal tDCS over the lesioned motor cortex improved patients' balance and gait following stroke, as demonstrated by increased speed in initiating walking, improved functional reach, and improved backwards excursion as recorded using the Bertec Balance Advantage System. Ultimately, our research was novel because no other studies have looked at the effects of tDCS on functional balance and gait. Based on our findings, we recommend tDCS as a powerful tool that can be utilized in conjunction with balance training to help patients who have suffered a stroke to regain functional balance.

All of the data collected in this study were based on quantitative values for the assessments and outcome measures, with no quantitative assessment on the neurophysiological changes in the participants. Also, our research only showed the effects of one single session of tDCS on balance and gait. Further investigation of the neurophysiological effects and adaptations of tDCS after training should be examined with Transcranial Magnetic Stimulation to determine the changes to motor evoked potentials before and after training. Future research should also examine the effects of tDCS over multiple treatment sessions.

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29. An, S., et al., *Gait velocity and walking distance to predict community walking after stroke.* Nurs Health Sci, 2015. **17**(4): p. 533-8.
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41. Fan, J., et al., *Transcranial direct current stimulation over multiple days enhances motor performance of a grip task.* Ann Phys Rehabil Med, 2017. **60**(5): p. 329-333.

Curriculum Vitae

Peyton Hobson
Email: peytonlhobson@gmail.com

Education

DPT	University of Nevada, Las Vegas – Las Vegas, Nevada	2017-2020	Physical Therapy
BS	Towson University – Towson, MD	2012-2016	Athletic Training

Clinical Experience

2020 (Spring)	Student Physical Therapist, Johns Hopkins Hospital Baltimore, MD
2019 (Fall)	Student Physical Therapist, Sunrise Hospital and Medical Center Las Vegas, NV
2019 (Summer)	Student Physical Therapist, Synergy Physical Therapy Henderson, NV
2018 (Summer)	Student Physical Therapist, ATI Physical Therapy Parkesburg, PA

Work Experience

2016-2019	**PRN Athletic Trainer** – Select Medical
2018-2019	**PRN Athletic Trainer** – Gameday Sports
2016-2019	**Cocktail waitress** – Downtown Grand Hotel and Casino

Research Interest and Experience

My research interest and experiences include: Application of neuromodulation as a treatment approach in patients post-stroke and its effects on balance and gait.

- 2018-present Co-investigator: "*Effects of transcranial direct current investigation on gait and balance post-stroke"* Ubalde L, Jacklin J, Hobson P, Wright-Avila S, Liang J.

Licensure

LAT- Licensed Athletic Trainer (2016-Present)

Certifications

ATC- Certified Athletic Trainer (2016)
CITI Training Certified (March 2018)
CPR Certified (April 2018)
Certified Hawkgrips Practitioner Level 1 (September 2018)
HIPPA Training Certified (September 2017)
Blood Borne Pathogens training certified (September 2017)

Skills

Computer skills:	Word Processing: Microsoft Word
	Data Presentation: Microsoft PowerPoint

Data Entry and Analysis: Excel

Neurosoftware: Bertec Balance Advantage System

Honors and Awards

2018	UNLVPT Scholarship, $2,500
2018	UNLVPT Student Opportunity Research Grant, $1,785
2017-2020	University of Nevada, Las Vegas Dean's Honor List
2012-2016	Towson University, Towson MD Dean's List
2016	Magna Cum Lade – Towson University

Leadership and Service

05/10/2019	Attendee of NV SB355 Hearing (Committee on Commerce and Labor)
04/17/2019	Volunteer - Dignity Health WomensCare/Outreach Center (Tai Chi)
02/01/2019	Volunteer – 2019 Student Interview Day
11/09/2018	Volunteer – Lambda Kappa Delta pre-PT mock interviewer
10/2018-12/2018	Volunteer for Rock Steady Boxing
01/19/2018	Volunteer – 2018 Student Interview Day
01/26/2018	Volunteer – 2018 Student Interview Day
2018	Synergy Grand Opening flyer creation
11/2017	Volunteer - Lambda Kappa Delta pre-PT mock interviewer
11/2017	On boarding faculty surveys

Professional Growth and Continuing Education

- Johns Hopkins Hospital – Baltimore, MD, March 9, 2020 – 1 hour
    - In-service on Patients Post-stroke with Cognitive Impairments
- Johns Hopkins Hospital – Baltimore, MD, February 12, 2020 – 1 hour
    - "Hemiplegia: Applications to Clinical Care" – Casey Houlihan, PT, DPT, Neurologic Resident
- Gatorade Sports Science Institute Online Courses for Continuing Education – September, 28, 2019
    - Heat Acclimatization to Improve Athletic Performance in Warm-Hot Environments
    - Hydration and Thermal Strain in Youth Sports: Responses and Recommendations to Minimize Clinical Risk and Optimize Performance in the Heat
    - Protein and Exercise in Weight Loss: Considerations for Athletes
    - Dietary Protein to Support Active Aging
    - Sweat Testing Methodology in the Field: Challenges and Best Practices
    - Branched-chain Amino Acid Supplementation to Support Muscle Anabolism Following Exercise
- Gatorade Sports Science Institute Online Courses for Continuing Education – September, 27, 2019
    - Nutritional Strategies to Improve Skeletal Muscle Mitochondrial Content and Function
    - The Female Athlete: Energy and Nutrition Issues

    - Healthy and Sustainable Youth Sports- The Future of Youth Athlete Development
    - Weight Management for Athletes and Active Individuals
- Baseline Concussion Testing- Select Physical Therapy, May, 2018
    - Logix testing
    - Bess & Vision
- American Physical Therapy Association Combined Sections Meeting, New Orleans, Louisiana, February 22-24, 2018- 18 hours
    - Thursday, February 22, 2018: " Sports Medicine Secrets: Motor Control Impairments in the Overhead Athlete"
    - Thursday, February 22, 2018: Neurology Platforms – "Academy of Neurologic Physical Therapy Section Platform Session 1 – Parkinson's Disease and Balance Disorders"
    - Friday, February 23, 2018: "Low- Cost Neuromodulatory Priming Techniques for Post-stroke Motor Rehabilitation"
    - Friday, February 23, 2018: "The effects of transcranial direct current stimulation (tDCS) on cortical excitability and motor behaviors of the lower extremity: a systematic review."
    - Friday, February 23,2018: "Neuromuscular Training After ACLR to Decrease ACL Reinjuries and Risk in Young Female Athletes."
    - Saturday, February 24, 2018: "Cardiovascular and Pulmonary Section Platform Presentation 2: Prevention to Innervation for Patients with Pulmonary Disease"
    - Saturday, February 24, 2018: Neurology Platforms -"Academy of Neurologic Physical Therapy Section Platform Session III- Stroke and Traumatic Brain Injury"

Membership in Professional Organizations

- Member of the National Society of Collegiate Scholars
- Member of Omicron Delta Kappa, the national leadership Honor society (2015-present)
- Member of the American Physical Therapy Association (APTA) (2017-present)
- Member Nevada Physical Therapy Association (2017-present)

Jordon Jacklin
Email: jordon.jacklin@gmail.com

Education

DPT	University of Nevada, Las Vegas – Las Vegas, Nevada	2017-2020	Physical Therapy
BS	Brigham Young University – Provo, Utah	2010-2017	Public Health

Clinical

January 2020 — March 2020	**Student** — Sunrise Hospital and Medical Center Las Vegas, NV
September 2019 — December 2019	**Student** — University of Utah Hospital Salt Lake City, UT
July 2019 — September 2019	**Student** — Peak Physical Therapy Spanish Fork, UT
June 2018 — August 2018	**Student —** Select Physical Therapy Seven Hills Clinic Henderson, NV

Certifications

- Collaborative Institutional Training Initiative Biomedical IRB Course (March 2018)
- HIPPA Training Certified (September 2017)
- Blood-borne Pathogens Training Certified (September 2017)

Employment

May 2010 – September 2013 **Physical Therapy Technician** – Orrock and Mendenhall Physical Therapy and Sports Medicine

- Assisted 5-8 patients with exercises, ultra sound, soft tissue message, and electrical stimulation a day.

Research Activity

- Liang J., Ubalde, L., **Jacklin, J.,** Hobson P., and Wright-Avila S. Modulation of Cortical Excitability to Improve Gait and Balance Post Stroke.
- Liang J.**,** Schomig J., Lyon S., Ubalde L., **Jacklin J.,** and Ferraro A. Modulation of the Spinal Circuit Using Transcranial Direct Current Stimulation in Individuals Post-Stroke.
- Liang J., Ho K., Cummins A., Ferraro A., **Jacklin J.,** and Krist D. Characterization of the Spinal Reflex Circuit Function and Achilles Tendon Micromorphology in Individuals with Chronic Post-Stroke Hemiparesis.
- Liang J., Ho K., Ferraro A.**,** Ubalde L., Charalambous C., **Jacklin J.,** and Hung V. Exploring Biomarkers and Changing Spinal Inhibition to Improve Walking in People Post-Stroke.

Membership in Professional Organizations

- Member American Physical Therapy Association (2017 to Present)
- Member Nevada Physical Therapy Association (2017 to Present)

Service

- Utah State Hospital
    - Physical Therapy Aid (January 2016 – August 2016)
- Elevate Physical Therapy
    - Physical Therapy Aid (April 2016 — August 2016)
- Now I Can Foundation
    - Physical Therapy Aid and Volunteer (April 2016 — August 2016)

Honors and Awards

- 2019 UNLV Physical Therapy Scholarship Recipient
- 2018 UNLV Physical Therapy Scholarship Recipient
- 2016 Brigham Young Scholarship
- 2015 College of Life Science Dean's List

Continuing Education Attended

- Annual Nevada PT/OT Conference June 2, 2018
    - "Early Progressive Mobility" Craig Jamison and Karen Czaja
    - "Interprofessional Evidence-Based Fall Prevention Dissemination: Building PT/OT Teams of Leaders" Shannon Martin, Mindy Renfro, and Jennifer Nash
    - "Dementia Cognitive and Functional Assessment and Care Management Strategies" Kathryn Conroy and Trevor Mahoney
    - "Cannabis 101: What all Rehabilitation Practitioners Should Know" Michael S. Laymont
- University of Nevada-Las Vegas Brown Bag Series
    - April 26, 2019 "The Role and Benefits of Cancer Rehabilitation from Diagnosis to Survivorship" Dr. Leslie J. Waltke Cancer Rehabilitation Specialist
    - March 28, 2019 "An Example of Evidence-Basis for Electrotherapy: Muscle Strengthening" Dr. David M. Selkowitz, PT, PhD, DPT, OCS, DAAPM
    - February 13, 2019 "Multiple Sclerosis in Disadvantaged Populations" Dr. Dominique Kinnett-Hopkins PhD
    - October 4, 2018: "Development of a Strength Training Program in Duchenne Muscular Dystrophy" Dr. Donovan Lott, PT, PhD, CSCS
    - August 27, 2018: "#ForTheLoveOfScience: A clinician-Scientist's Journey" Dr. Sandra A. Billinger, PT, PhD, FAHA
    - June 8, 2018: "Bench to Bedside: Exercise-induced Brain changes in Parkinson's Disease" Dr. B.E. Fischer PhD, PT, FAPTA
    - April 19, 2018: Pei-Jung Wang
    - March 5, 2018: "Runner's (Leg) Dystonia: The Mystery Movement Disorder" Nancy Byl, PT, PhD
    - November 30, 2017: "Behavioral Evidence and Neural Correlates of Relearning of Writing Skills in Patients with Parkinson's Disease" Sanna Broeder, PT

    - November 16, 2017: “Incorporating Wellness Services into PT Practice” Mitch Smith, PT, DPT
    - September 21, 2017: “Pain Medicine” Mehesh Kuthuru, MD
    - June 16, 2017: “Canine Therapy”
- University of Nevada-Las Vegas Distinguished Lecture
    - October 27, 2017: “Disruption and Opportunity in Health Delivery: Go Hard or Go Home” Sharon Dunn, PT, PhD, OCS
    - October 26, 2017: “APTA: Pursuing our Transformative Vision” Sharon Dunn, PT, PhD, OCS
- NVPT Chapter Meeting
    - February 12, 2019: “Pulsed Electromagnetic Field the Physical Therapist Guide” Michael Laymont, PT, Dsc.
    - April 10, 2018: “Nutrition and Physical Therapy: A Multidisciplinary Approach to Healing”
    - January 9, 2018: District Meeting
    - November 14, 2017: “Freezing of Gait in Parkinson’s disease” Jason Longhurst, PT, DPT, NCS
    - September 12, 2017: “Traumatic Brain Injury” Julie Dendy, PT
- Sports Didactic Meeting
    - September 24, 2018: “Principles of Soft Tissue Message” David Homes DC

Leonard Ubalde
Email: leonardubalde@gmail.com

Education

DPT	University of Nevada, Las Vegas – Las Vegas, Nevada	2017-2020	Physical Therapy
BS	University of Nevada, Las Vegas – Las Vegas, Nevada	2013-2016	Kinesiology

Clinical Experience

2020 (Spring)	Student Physical Therapist, Sunrise Hospital and Medical Center Las Vegas, NV
2019 (Fall)	Student Physical Therapist, VA Southern Nevada Healthcare System North Las Vegas, NV
2019 (Summer)	Student Physical Therapist, Spring Valley Hospital Medical Center Las Vegas, NV
2018 (Summer)	Student Physical Therapist, Edwin Suarez Physical Therapy Las Vegas, NV

Work Experience

2019 (Spring)	**Graduate Assistant** – Department of Physical Therapy, School of Allied Health Sciences, Division of Health Sciences, University of Nevada, Las Vegas
2018 (Summer-Fall)	**Research Assistant** – Department of Physical Therapy, School of Allied Health Sciences, Division of Health Sciences, University of Nevada, Las Vegas

Research Interest and Experience

Use of neuromodulation for neurodevelopmental disorders to improve functional mobility and functional outcomes in the pediatric population

Improving handling and therapeutic interventions in the Neonatal Intensive Care Unit to promote growth of neurotrophic factors and examination of neurodevelopmental outcomes

2019-present	Co-investigator: "*Does the location of muscle output affect the characterization of soleus corticospinal response?*" Charalombous C, Ubalde, L, Liang J Research dissemination phase
2018-present	Co-investigator: "*Effects of transcranial direct current investigation on gait and balance post-stroke"* Ubalde L, Jacklin J, Hobson P, Wright-Avila S, Liang J. Research dissemination phase
2017-2019	Co-investigator: "*Modulation of the spinal circuit using transcranial direct current stimulation in individuals post-stroke"* Lyons S, Schomig J, Henry K, Drobitch N, Liang J. Research dissemination phase concluded

Skills

Computer skills:	Word Processing: Microsoft Word Data Presentation: Microsoft PowerPoint

	Reference Management: Endnote
	Statistical Packages: SPSS
	Imaging software: Photoshop, Cinema4D, Adobe After Effects
	Assemblage, set-up, and maintenance of PC's
Neurosoftware:	TMS: Signal, Spike, PEST
	tDCS: Neurocomm
	Bertec Balance Advantage System
	Protokinetics: Zeno Walkway

Honors and Awards

2020	UNLVPT Scholarship, $2,550
2018	UNLVPT Student Opportunity Research Grant, $1,785
2016	Magna Cum Lade – University of Nevada, Las Vegas
2013-2016	University of Nevada, Las Vegas Dean's Honor List
2013-2016	University of Nevada, Las Vegas Valedictorian Scholarship

Leadership and Service

01/25/2020	Volunteer – 2020 Student Interview Day
01/24/2020	Volunteer – 2020 Student Interview Day
09/21/2019	Twitch Charity Event for Special Needs Resource Library
06/02/2019	UNLVPT Class of 2022 Technology Presentation
05/10/2019	Attendee of NV SB355 Hearing by the Committee on Commerce and Labor
04/20/2019	Volunteer – Rock Steady Boxing & Parkinson's Screening
03/28/2019	Volunteer – LKD mock interviewer
11/09/2018	Volunteer – LKD mock interviewer
02/01/2019	Volunteer – 2019 Student Interview Day
02/08/2019	Volunteer – 2019 Student Interview Day
01/19/2018	Volunteer – 2018 Student Interview Day
01/26/2018	Volunteer – 2018 Student Interview Day
12/04/2018	Student-led Interview – Dr. Randall Keyser, PhD, FACSM
08/26/2018	Student-led Interview – Dr. Sandra Billinger, PT, PhD
04/23/2018	Kinesiology Simulation Lab
04/03/2018	Student-led Interview – Dr. Boris Decourt, PhD
03/19/2018	Student-led Interview – Dr. Thorsten Rudroff
03/06/2018	Student-led Interview – Dr. Fidias E. Leon-Sarmiento, MD, MSc, PhD
12/15/2017	Nevada Health Link Holiday Health Fair
09/12/2017	Attended NVPTA Annual Membership Business Meeting – featured speaker Julie Dendy & Stacy Maratello

Professional Growth and Continuing Education

10/15/2019	Mindful Integrated Neuroscience Discussions (MIND) Symposium

05/04/2019 UNLVPT Stroke Support Group: Organized and led group discussion for stroke survivors at Desert Springs Hospital on physical therapy research and student interest in pursuing a career in physical therapy

UNLVPT Brown Bags

4/11/2019 Qing Chang, PT, DPT, NCS, "Neurological Physical Therapy Residency: a UNLVPT Graduate's Journey"

3/14/2019 Brown Bag Movie Night – 46th Mary McMillan Lecture 2015 by Lynn Snyder-Mackler, PT, ScD, ATC, SCS, FAPTA, "Not Eureka"

2/21/2019 Brown Bag Movie Night – 47th Mary McMillan Lecture 2016 by Carole B. Lewis, PT, DPT, PhD, MSG, GCS, FAPTA, "Our Future Selves: Unprecedented Opportunities"

10/18/2018 Brown Bag Movie Night – 48th Mary McMillan Lecture by Richard K. Shields, PT, PhD, FAPTA, "Turning Over the Hourglass"

6/8/2018 Dr. B.E. Fisher, PT, PhD, FAPTA, "Exercise-Induced Brain Changes in Parkinson's Disease"

11/6/2017 Dr. Adam Cope, PT, DPT, "PRN"

10/3/2017 Dr. Michael Tabo, PT, DPT, "Federal Physical Therapy"

American Physical Therapy Association Combined Sections Meeting

Denver, CO, February 13-15, 2020 – 18 hours, 1.8 CEUs

2/15/2020 "Strategies for Treatment of Bladder and Bowel Dysfunctions in Children With and Without Behavioral Challenges"

2/15/2020 Academy of Orthopaedic Physical Therapy Platform 6

2/15/2020 "The Intersections of Transgender Identities and Physical Therapy"

2/14/2020 "Finding Your Path: Developing and Implementing a Research Agenda"

2/14/2020 "Neuromodulation in Combination with Task-Specific Training to Improve Outcomes After Spinal Cord Injury (SCI)"

2/14/2020 "No Child Left in Pain: Multidisciplinary Chronic Pain Management for Typically and Nontypically Developing Pediatric Populations"

2/13/2020 "Combat Sports: Different Types, Rehabilitation, Performance Enhancement, and How Self Defense May Save Your Life"

2/13/2020 "Interpretation of Unusual Patterns of Nystagmus: Atypical Benign Paroxysmal Positional Vertigo"

2/13/2020 "Selective Motor Control of Infants and Children with Cerebral Palsy: Innovations in Assessment and Intervention"

New Orleans, LA, February 22-24, 2017 – 18 hours, 1.8 CEUs

2/22/2018 "Aquatics for Children on the Autism Spectrum"

2/22/2018 "Adaptive Behavior and Mastery Motivation in Children with Cerebral Palsy"

2/22/2018 "The Value of Post-professional Residency, Fellowship, and PhD Training"

2/23/2018 "Taking the Gloves Off: Evidence-Informed Manual Therapy for UE Conditions, Part 2"

2/23/2018 "Clinical Reasoning: Video Games and Virtual Reality in Pediatric PT Practice"

2/23/2018: "Research Poster Presentations"

2/24/2018 "Neonatal Lectureship – Trauma – Informed Care: A New Paradigm for the NICU"

2/24/2018 "Orthopedic Section Platform Presentation 7"

2/24/2018: "Private Practice 101: Defining Your Private Practice Vision"

Membership in Professional Organizations

2017-Present	Member American Physical Therapy Association
2017-Present	Member Nevada Physical Therapy Association

Sara Elizabeth Wright-Avila
Email: savila2@alumni.nd.edu

Education

DPT	University of Nevada, Las Vegas – Las Vegas, Nevada	2017-2020	Physical Therapy
MS	New York Medical College – Valhalla, New York	2010-2014	Basic Medical Science
BS	University of Notre Dame – Notre Dame, Indiana	2006-2010	Science-Business

Clinical Experience

2020 (Spring)	Student Physical Therapist, Encompass Health Rehabilitation Hospital Las Vegas, NV
2019 (Fall)	Student Physical Therapist, Boulder City Hospital Boulder City, NV
2019 (Summer)	Student Physical Therapist, MountainView Hospital Las Vegas, NV
2018 (Summer)	Student Physical Therapist, Rapid Rehab Las Vegas, NV

Work Experience

2018-2019	**Graduate Assistant** – Department of Physical Therapy, School of Allied Health Sciences, Division of Health Sciences, University of Nevada, Las Vegas
2018-present	**Indoor Cycling Instructor** – EoS Fitness

Research Interest and Experience

Clinical application of neuromodulation in post-stroke populations to improve functional mobility, balance, and gait

2018-present Co-investigator: "*Effects of transcranial direct current investigation on gait and balance post-stroke"* Ubalde L, Jacklin J, Hobson P, Wright-Avila S, Liang J.

Skills

Computer skills:	Word Processing: Microsoft Word Data Presentation: Microsoft PowerPoint Data Entry and Analysis: Excel
Neurosoftware:	Bertec Balance Advantage System

Honors and Awards

2018 UNLVPT Student Opportunity Research Grant, $1,785

Leadership and Service

10/13/2019 Volunteer – Tri State Physical Therapy Conference

05/10/2019 Attendee of NV SB355 Hearing (Committee on Commerce and Labor)
03/30/2019 Volunteer – Las Vegas AMBUCS Spring Bike Bonanza
02/01/2019 Volunteer – 2019 Student Interview Day
02/08/2019 Volunteer – 2019 Student Interview Day
10/20/2019 Volunteer – Parkinson's Moving Day
04/23/2018 Kinesiology Simulation Lab
01/19/2018 Volunteer – 2018 Student Interview Day
01/26/2018 Volunteer – 2018 Student Interview Day

Professional Growth and Continuing Education

American Physical Therapy Association Tri State Physical Therapy Conference
Las Vegas, NV, October 11-13, 2019 - 6 hours
10/13/2019 A Pain Neuroscience Approach to Manual Therapy
10/12/2019 Medical Marijuana and Pain Management
10/12/2019 Functional Rehabilitation for the Performer/Artist
9/15/2018 Orthotic & Prosthetic Activities Foundation: Gait Training and Exercises for Amputees workshop – 6 hours
9/8/2018 HawkGrips Level I: IASTM Fundamentals – 8 hours
UNLVPT Brown Bags
11/29/2018 Brown Bag Movie Night – 46th Mary McMillan Lecture 2015 by Laurie Hack, PT, DPT, PhD, MBA, FAPTA, "Wisdom and Courage: Doing the Right Thing"
11/15/2018 Dr. Irene Davis, PhD, PT, FACSM, FAPTA, FASB, "Footwear Matters: Let's Think Differently about the Foot"
11/16/2018 Dr. Irene Davis, PhD, PT, FACSM, FAPTA, FASB, "Well Aligned, Soft Landings: A Cure for Running Injuries?"
11/1/2018 Brown Bag Movie Night – 48th Mary McMillan Lecture by Richard K. Shields, PT, PhD, FAPTA, "Turning Over the Hourglass"
3/12/2018 Dr. Nancy N. Byl, PT, MPH, PhD, FAPTA, Professor Emeritus, University of California, San Francisco, "Runner's (Leg) Dystonia: The Mystery Movement Disorder"
2/12/2018 Donna Costa, DHS, OTR/L, FAOTA, Founding Program Director, Occupational Therapy Program, UNLV, "Managing Stress in College Students with the Koru Mindfulness Programs"
American Physical Therapy Association Combined Sections Meeting
Washington, D.C., January 23-26, 2018 – 18 hours, 1.8 CEUs
1/25/2019 "Academy of Acute Care Physical Therapy Platform 3"
1/24/2019 " Intentionally Breaking the Skin: A Dry Needling Approach to the Lymphatic System"
1/24/2019 "Neurocognitive and Motor Control Strategies in ACL Rehab"
1/24/2019 "Physical Therapy Considerations in Gender-Affirming Genital Surgery"
1/23/2019 "Blood Flow Restriction and Ischemic Preconditioning"
1/23/2019 "Pelvic Floor Training for the Older Adult"
1/23/2019 "The Pesky Patellofemoral Joint: An Ongoing Orthopedics Enigma"
New Orleans, LA, February 22-24, 2017 – 18 hours, 1.8 CEUs
2/24/2018 "Tommy John Surgery: Surgical Intervention, Rehab, and Return to Throwing"
2/23/2018 "Femoroacetabular Impingement: A Framework to Guide Clinical Practice"

2/23/2018	"Low-cost Neuromodulatory Priming Techniques for Post Stroke Motor Rehabilitation"
2/23/2018	"High Intensity Aerobic Exercise Enhances Function in Parkinson's Disease"
2/22/2018	"The Silver Tsunami: Meeting the Growing Rehab Challenges of Older Adults"
2/22/2018:	"Outpatient Cardiac Rehabilitation: Increasing Awareness, Referral, and Participation"
2/22/2018	"Science Meets Practice – Form Before Footwear Effectiveness vs. Efficacy in Running"

Membership in Professional Organizations

2017-present	Member American Physical Therapy Association
2017-present	Member Nevada Physical Therapy Association
2018-present	Member Academy of Acute Care Physical Therapy Section of the American Physical Therapy Association
2018-present	Cardiovascular and Pulmonary Section of the American Physical Therapy Association
2018-present	Member Orthopaedic Physical Therapy Section of the American Physical Therapy Association