BETTER GAIT QUALITY AND SPEED IN ADULTS WITH DOWN SYNDROME WHEN WEARING SUPPORTIVE SHOES COMPARED TO UNSUPPORTIVE SHOES AND BAREFOOT

By

Bailey Gosse

Kimberly Nguyen

Zoe Zelensky

A doctoral project submitted in partial fulfillment
of the requirements for the

Doctor of Physical Therapy

Department of Physical Therapy
School of Integrated Health Sciences
The Graduate College

University of Nevada, Las Vegas
May 2024

Doctoral Project Approval

The Graduate College
The University of Nevada, Las Vegas

May 9, 2024

This doctoral project prepared by

Bailey Gosse

Kimberly Nguyen

Zoe Zelensky

entitled

Better Gait Quality and Speed in Adults with Down Syndrome when Wearing Supportive Shoes Compared to Unsupportive Shoes and Barefoot

is approved in partial fulfillment of the requirements for the degree of

Doctor of Physical Therapy
Department of Physical Therapy

Daniel Young, Ph.D.
Examination Committee Chair

Thessa Hilgenkamp, Ph.D.
Research Project Advisor

Merrill Landers, Ph.D.
Chair, Department of Physical Therapy

Alyssa Crittenden, Ph.D.
Vice Provost for Graduate Education &
Dean of the Graduate College

Abstract

Background: Individuals with Down syndrome (DS), often experience a slower gait speed and decreased quality of gait. Different types of footwear have shown changes in gait in people without DS. The current study aimed to examine the differences between wearing commercially available supportive shoes, unsupportive shoes, and no footwear on gait quality and speed in people with DS.

Methods: In this repeated measures study, 20 adults with DS walked under three footwear conditions: supportive, unsupportive, and no footwear. Gait deviations were scored according to the Rancho Los Amigos Observational Gait Analysis (OGA) and gait speed was measured using the 10-Meter Walk Test.

Results: When gait was examined, the OGA results showed significant differences across all three conditions for overall major deviations (F=3.912, df=2, *p*=.029; *p*=0.026) and overall total deviations (F=3.896, df=2, *p*=.029; *p*=0.047) for left and right legs, respectively. Pairwise comparisons between conditions did not reach significance. There was a significant difference in gait speed (Greenhouse-Geisser adjusted F=8.974, *p*=0.004). Gait speed was significantly faster when participants wore supportive shoes compared to when they walked barefoot (8.9±2.0 vs. 10.0±2.3, *p*=0.002) and compared to when they wore unsupportive shoes (8.9±2.0 vs. 10.8±3.4, *p*=0.014)

Conclusion: Adults with Down syndrome who wore supportive shoes demonstrated better gait quality with fewer deviations compared to when they walked barefoot. Additionally, they had a faster gait speed when walking in supportive shoes compared to both walking in unsupportive shoes and barefoot.

Table of Contents

1 | Introduction |

According to the Centers for Disease Control, 1 in 700 babies are born with Down syndrome (DS) in the United States each year (Centers for Disease Control and Prevention, 2020). In people with DS, intellectual disability, morphological abnormalities, and metabolic diseases such as diabetes, are prevalent (Moreau et al., 2021). Individuals with DS are more likely to be overweight or obese compared to those without intellectual disability (Rimmer et al., 2010). The prevalence of obesity in the DS community could be compounded by the lack of participation in physical activities. It has been shown that people with DS have a reduced exercise capacity that may be partly due to ligamentous laxity and can affect their control of their body dynamics and balance (Moreau et al., 2021).

Musculoskeletal disorders most notably seen in adults with DS are pes planus, toe deformities, joint laxity, inflammatory arthritis, and scoliosis (Foley & Killeen, 2019; Mansour et al., 2017; Mik et al., 2008). Pes planus was both present in 58% of individuals with DS who had foot x-ray imaging and more prevalent in individuals with DS than without DS (Perotti et al., 2018; Mansour et al., 2017).

Musculoskeletal disorders may affect gait. Gait patterns in people with DS are described as “cautious and abnormal” (Cimolin et al., 2010). Common abnormal gait patterns include: forward tilted pelvis, increased hip flexion throughout the gait cycle, increased hip stiffness, knee flexion that is reduced in swing phase, but increased in stance phase, reduced ankle power, and reduced ankle joint stiffness (Cimolin et al., 2010; Galli et al., 2008). These abnormalities in gait patterns lead to a decreased stride length and gait speed (Galli et al., 2008). Gait speed (both comfortable and fast) can predict decline in ability to perform instrumental activities of daily living in the future for older adults with intellectual disability (Oppewal et al., 2015). It is important to characterize gait patterns and gait speed in adults with DS in order to observe function after intervention.

Generally, to improve gait and posture, both surgical and non-surgical interventions are used, depending on the cause of the gait deviations. One non-surgical intervention is the use of orthotics (Banwell et al., 2014). In people with DS, the use of foot orthoses such as insoles improve foot posture by decreasing heel eversion in standing (Selby-Silverstein et al., 2001). In addition, the use of custom foot orthoses may decrease the foot progression angle in adolescents with DS (Galafate et al., 2020).

A second non-surgical intervention that may affect gait is the selective use of specific types of footwear. The impact of commercially available shoes on gait patterns has been studied in populations without Down syndrome. Gait patterns in children and young adults show increased gait speed, step length, stride length, base of support, step time, and stride time in athletic shoes compared to barefoot (Lythgo et al., 2009). Additionally, variability in stride length, variability in toe clearance, and dynamic stability were improved in a minimalist shoe when compared to walking barefoot in adults (Petersen et al., 2020).

Research has identified that people with DS more commonly wear shoes that are inadequately sized (length and width) for their feet compared to people without DS (Calvo-Lobo et al., 2018). People with DS may benefit from footwear that accommodates the specific needs of their feet, such as pes planus and toe deformities. However, there is a lack of research determining the effect of different footwear on gait characteristics in adults with DS. The purpose of this study is to examine the differences between wearing commercially available supportive shoes, unsupportive shoes, and no footwear on gait quality and speed in people with DS. We hypothesized that participants would have fewer gait abnormalities and faster gait speed while walking in a supportive shoe, in comparison to unsupportive footwear and no footwear.

2 | METHODS |

2.1 | Design

We used a repeated measures study design to compare gait quality and speed in supportive footwear, unsupportive footwear, and no footwear in adults with DS.

2.2 | Participants

Participants were recruited from an outpatient physical therapy practice in Arvada, Colorado that specializes in treating patients with Down syndrome, and from community events and centers in the Las Vegas area. To be included in this study, participants had to be an adult aged 18-35 with DS, and ambulatory without the use of an assistive device. Participants were excluded if they had a recent musculoskeletal injury that could have inhibited their ability to participate in the study.

The sample size was calculated using G*Power 3.1 (University Düsseldorf) (Faul et al., 2009). Based on the variables of gait speed and foot progression angle from Lythgo et al. 2009, and the variable of stance time from Zhang et al. 2013, and using an alpha level of 0.05 and a power of 0.95, the required sample size for a repeated measures design was n=17. Our target sample size was n=20 to account for any attrition.

2.3 | Procedure

The protocol was approved by the Biomedical Institutional Review Board of the University of Nevada, Las Vegas. The data collection process of this study took place at the same locations we recruited participants: a specialized physical therapy practice and community events and centers. We first obtained informed consent from the participants and/or their legal guardians. We then collected demographic information from each participant, including height, mass, age, sex, activity level, L/R handedness, and shoe size, in order to describe the baseline characteristics of the participants.

The three footwear conditions; barefoot, unsupportive shoes, and supportive shoes, were randomized for each participant. We used the Saucony Triumph (Lexington, MA, USA) as the supportive shoe. We selected this shoe because it is a supportive, lightweight (about 10 oz), flexible sneaker that has a neutral fit and a wide toe box, which accommodates hallux valgus while still providing medial arch and calcaneal support. The shoe is available in both standard and wide sizes. This is useful because it is common for people with Down syndrome to require a wide-fitting shoe. We used the Crocs Classic Clog (Broomfield, CO, USA) as our unsupportive comparison shoe. We selected this shoe because of its lack of foot support and because a clinician who specializes in this population observed its widespread use and popularity amongst individuals with DS. The pivoting heel strap of this shoe was positioned around the participant’s heel to avoid excessive motion of the shoe on the foot during gait.

Figure 1: Crocs Classic Clog (left; unsupportive shoe) and Saucony Triumph (right; supportive shoe)

A random number generator was used to randomize the order of the three footwear conditions for each participant prior to testing. Distances of 0, 2, 12, and 14 meters were marked with tape on a level surface. Immediately prior to recording each walking trial, participants walked for one practice trial with each specific shoe to make sure they were comfortable. Two video cameras (Apple iPhone 11 and iPad Air 4th generation, Cupertino, CA, USA) were set up to record the sagittal plane view and frontal plane view of participants while they completed the 10-Meter Walk Test (Sánchez-González et al., 2023). For this test, participants were instructed: "When you are ready, I want you to begin walking at a comfortable walking speed past that line. I will be timing you. Ready, Go!". Participants were instructed to walk from the 0 to the 14 meter mark. While the walking trial was recorded using the video camera, a handheld stopwatch was simultaneously used to time how long it took each participant to walk the 10 meter distance. They were only timed between the 2 and 12 meter marks to ensure our findings would not be affected by acceleration or deceleration. In each condition, participants were timed three times at their comfortable walking speed.

2.4 | Anthropometric Measures

To assess baseline foot posture deviations in a quantitative manner, we utilized the Foot Posture Index (FPI-6) prior to the intervention (Redmond et al., 2006). This index determined how pronated, normal, or supinated a participant's foot is by using a scoring scale with 6 different components (Redmond et al., 2006). The FPI-6 was used to determine if there was a correlation between the baseline foot posture and the gait characteristic results. To support the use of this index, we took pictures of the participant's feet from 3 different views: posterior, medial, and posteromedial. During data collection, we followed the standard FPI-6 protocol and palpated the head of the talus in order to determine if it was equally palpable on lateral and medial sides. The photos were later evaluated and scored for each of the remaining 5 components of the index (lateral malleoli curve, calcaneal position, talonavicular joint prominence, medial longitudinal arch, and forefoot abduction/adduction) using an integer number ranging from -2 to +2. Scores of the 6 factors were then totaled for each foot. Participants' scores were then compared to the reference values provided in the FPI-6 to determine if their foot posture was normal (0 to +5), pronated (+6 to +9), highly pronated (+10 to +12), supinated (-1 to -4), or highly supinated (-5 to -12) (Redmond et al., 2006). This measure has shown high inter-examiner reliability with novice examiners who had minimal experience with the FPI-6 (McLaughlin et al., 2016). The FPI-6 demonstrated concurrent validity in detecting variations in posture when compared to a skin mounted sensor (Redmond et al., 2006).

2.5 | Outcome Measures

The Rancho Los Amigos Observational Gait Analysis (OGA) form was used to assess the participant’s gait (Rancho Los Amigos National Rehabilitation Center, 2001). The form is used to score different qualitative characteristics of gait and the absence or presence of gait deviations categorized in different body regions (trunk, pelvis, hip, knee, ankle, and toes) and in different phases of gait (initial contact, loading response, midstance, terminal stance, pre-swing, initial swing, mid-swing, and terminal swing). These eight phases are then combined into three major phases: weight acceptance (initial contact, loading response), single limb support (midstance, terminal stance), and swing limb advancement (pre-swing, initial swing, mid-swing, and terminal swing).

Deviations are classified as 'minor deviation' or 'major deviation' following the Rancho OGA score sheet. Figure 2 shows the OGA scoresheet with all potential observable deviations. Each deviation observed is given a score of 1 and lack of deviation observed is scored 0. The number of deviations present is added to show total deviations, deviations within phases of gait, and deviations based on body region. Figure 3 shows how a document was formatted to add the number of deviations. Although the foot was only visible during the barefoot trial, the results were still included since a prior study found that wearing a shoe with heel toe drop increased the peak dorsiflexion moment and decreased extensor hallucis longus activation (Quan et al., 2023). This measure has shown moderate intra-rater reliability, and fair to moderate inter-rater reliability and concurrent validity (McConnell & Silverman, 2015).

Within the current study, three raters were trained to use the OGA form to score selected participants' barefoot trials. These OGA forms were then compared and all three raters and one clinician with experience using the form and observing gait in adults with DS discussed the forms' similarities and differences. This process was continued until raters had better consistency in scoring. The inter-rater reliability of the three independent raters was then calculated based on scoring of barefoot walking trials of left and right feet of five participants with a two-way mixed effects intraclass correlation coefficient (ICC) for average measures. The ICCs indicated moderate to good reliability, as the ICC for total deviations was 0.84, the ICC for major deviations was 0.84 and the ICC for minor deviations was 0.58. To further limit potential bias, when completing the OGA for all participants, all three conditions of the same participant were scored by different observers. The OGA form was completed for both right and left reference limbs in order to account for any unilateral gait deviations. Additionally, we compared left and right leg instead of dominant and non-dominant leg, as handedness in individuals with intellectual disabilities including DS is not conclusive (Oppewal et al., 2013).

The 10-Meter Walk Test was used to measure gait speed. The three times recorded for comfortable walking speed were averaged. The 10 meter distance was divided by the average time to calculate speed in meters per second. The 10-Meter Walk Test has shown good intra-rater and excellent inter-rater reliability when measured in children and adults with DS (Sanchez-Gonzalez et al., 2023).

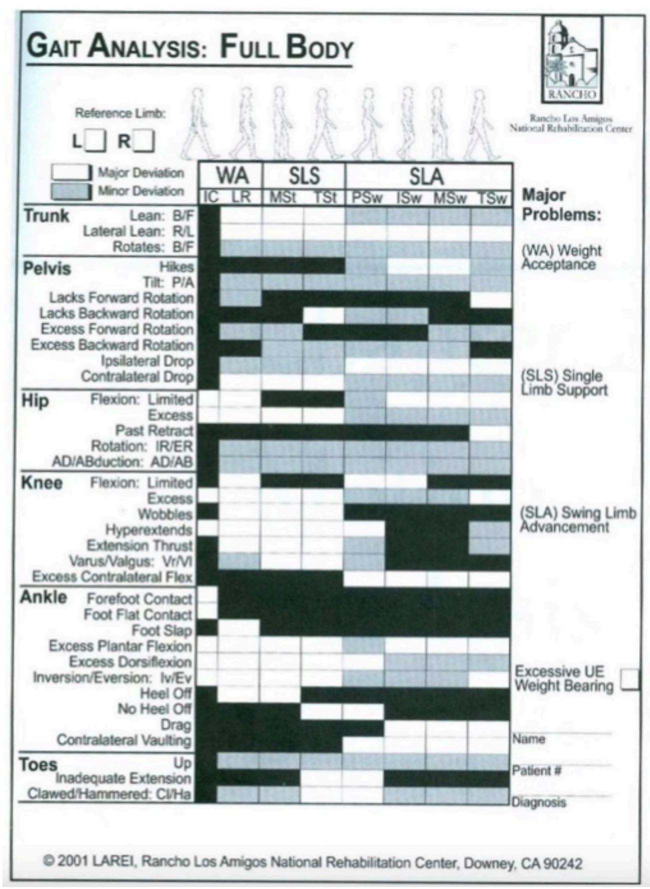

Figure 2: Rancho Los Amigos Observational Gait Analysis form

				IC	LR	MSt	TSt	PSw	Isw	MSw	TSw	Major Deviatio	Minor Deviatio	Total Deviations		
Trunk	Lean: B/F	Backward	Forward		0	0	0	0	0	0	0	0	0	0	Trunk Deviations	
	Lateral Lean: L/R	Left	Right		0	0	0	0	0	0	0	0	N/A	0	Major:	0
	Rotates: B/F	Backward	Forward		0	0	0	0	0	0	0	N/A	0	0	Minor:	0
Pelvis	Hikes							0	0	0	0	0	0	0	Total	0
	Tilt: PA	Posterior	Anterior		0	0	0	0	0	0	0	N /A	0	0	Pelvis Deviations	
	Lack forward Rotation				0						0	0	0	0	Major:	0
	Lacks Backward Rotation						0	0	0			0	0	0	Minor:	0
	Excess Forward Rotation				0	0				0	0	N/A	0	0	Total	0
	ExcessBackward Rotation				0	0	0	0	0	0		N/A	0	0		
	Ipsilateral Drop				0	0	0	0	0	0	0	0	0	0		
	Contralateral Drop				0	0	0	0	0	0	0	0	0	0		
Hip	Flexion: Limited			0	0			0	0	0	0	0	0	0	Hip Deviations	
	Flexion: Excess			0	0	0	0	0	0	0	0	0	0	0	Major:	0
	Past Retract										0	0	N/A	0	Minor:	0
	Rotation: IR/ER	IR	ER		0	0	0	0	0	0	0	N/A	0	0	Total:	0
	Ad/Abduction	Abduction	Adduction		0	0	0	0	0	0	0	N/A	0	0		
Knee	Flexion: Limited				0			0	0			0	N/A	0		
	Flexion: Excess			0	0	0	0	0	0	0	0	0	0	0	Knee Deviations	
	Wobbles				0	0	0					0	N/A	0	Major:	0
	Hyperextension			0	0	0	0	0			0	0	0	0	Minor:	0
	Extension Thrust				0	0	0	0			0	0	0	0	Total:	0
	Varus/Valgus:Vr/Vl	Varus	Valgus		0	0	0	0				0	0	0		
	Excessive contralateral Flexion							0	0	0	0	0	N/A	0		
Ankle	Forefoot Contact			0								0	N/A	0		
	Flat-Foot Contact			0								0	N/A	0		
	Foot Slap				0							0	N/A	0	Ankle Deviations	
	Excess Plantar Flexion			0	0	0	0	0	0	0	0	0	0	0	Major:	0
	Excess Dorsiflexion			0	0	0	0	0	0	0	0	0	0	0	Minor:	0
	Inversion/Eversion: Iv/Ev	Inversion	Eversion	0	0	0	0	0	0	0	0	0	0	0	Total:	0
	Heel Off				0	0						0	N/A	0		
	No Heel Off						0	0				0	N/A	0		
	Drag								0	0	0	0	N/A	0		
	Contralateral Vaulting							0	0	0	0	0	N/A	0	Foot Deviations	
Toes	Up				0	0	0	0	0	0	0	N/A	0	0	Major:	0
	Inadequate Extension						0	0				0	N/A	0	Minor:	0
	Clawed/Hammer Toes				0	0	0	0	0	0	0	0	0	0	Total:	0
	Major Deviations (Phases)			0	0	0	0	0	0	0	0	0				
	Minor Deviations (Phases)			N/A	0	0	0	0	0	0	0	0				
	Total Deviations (Phases)			0	0	0	0	0	0	0	0	0				
					Minor	Major										

Figure 3: Rancho Los Amigos Observational Gait Analysis form converted to document for adding the number of deviations

2.6 | Statistical Analysis

Baseline characteristics were presented using descriptive statistics. Outcome variables were checked for outliers with boxplots, and normality with the Shapiro-Wilk test. Bivariate correlations between the FPI and walking speed, total, major and minor gait deviations for left and right foot were calculated to determine whether the FPI needed to be included as a covariate in the repeated measures analyses. We conducted a repeated measures ANOVA with the ‘condition’ as the repeated independent variable (supportive footwear, unsupportive footwear and no footwear), the FPI-6 as a continuous covariate in case of any significant bivariate correlation coefficients with the outcomes measures, and the various outcome measures on the OGA as the dependent variable (Minor, major and total deviations overall, by gait cycle and by joint). Mauchly’s test was used to check the assumption of sphericity. In the case of violation of this assumption, the Greenhouse-Geisser estimate was used. Post hoc pairwise comparisons using the Bonferroni method were used to investigate which conditions were different from each other. For our statistical analysis we use $p < 0.05$ as the significance level.

3 | RESULTS |

A total of 20 subjects participated in this study. This consisted of 10 females and 10 males (mean age 23 yrs ± 4.09 , mean height 64 inches± 20.16, mean mass 175 lbs ±45.28). 75% of participants reported that they perform at least 150 minutes of moderate to vigorous activity per week. 14 participants were right handed, 2 left, 3 ambidextrous, and 1 declined to report handedness. Average Saucony size was 6.60±1.18 and average Crocs size was 5.89±1.29. The average FPI-6 scores were +7.7 for left and +7.6 for right, which demonstrated pronation. The FPI scores were not significantly correlated to walking speed (correlation coefficients r ranging from -0.160 to 0.278, p>0.05), overall minor, major or total gait deviations for either the left or the right foot (r ranging from -0.297 to 0.281, p>0.05).

When gait was examined for the left leg, the OGA results showed significant differences between all three conditions for overall major deviations (p=.029, F=3.912, df=2) and overall total deviations (p=.029, F=3.896, df=2) when scores within subjects were compared (Table 1). Pairwise comparisons between conditions did not reach significance.

When specific phases of gait were considered for the left leg, the OGA results showed a significant difference in major and total gait deviations for the weight acceptance phase, and the pairwise comparisons revealed a significantly higher average number of gait deviations when participants walked barefoot compared to when they wore supportive shoes for both major and total deviations (major deviations for barefoot vs. supportive shoes: 3.2±1.8 vs. 1.0±1.5, p=0.017; total deviations for barefoot vs. supportive shoes: 4.7±2.5 vs. 3.0±2.1, p=0.042). Similar significant differences were seen during the swing limb advancement phase, the average number of minor deviations and total deviations was significantly higher when participants walked barefoot compared to when they wore supportive shoes (minor deviations for barefoot vs. supportive shoes: 7.6±4.9 vs. 4.1±3.8, p=0.02; total deviations for barefoot vs. supportive shoes: 10.3±6.2 vs. 5.9±4.5, p=0.037) (Table 1). No significant differences were found during the single limb stance phase.

When specific body regions were considered, the average total number of gait deviations at the pelvis and the ankle differed across conditions, with pairwise comparisons only demonstrating a significantly higher number of deviations at the ankle when participants walked barefoot compared to when they wore shoes (both unsupportive and supportive shoes) (pelvis: p=0.046; ankle barefoot vs unsupportive: 8.6±4.5 vs. 5.1±3.7, p=0.025; ankle barefoot vs supportive: 8.6±4.5 vs. 4.2±4.0, p=0.025, respectively) (Table 1).

Table 1: Statistical analysis for left reference limb.

		Mean (SD)			Repeated measures ANOVA	Pairwise Compari-sons		
Outcome	Type of gait deviation	1. Barefoot	2. Crocs	3. Saucony	p-value	Between 1-2 p-value	Between 1-3 p-value	Between 2-3 p-value
Overall	Major	10.1 (5.9)	7.1 (3.0)	6.2 (4.5)	0.029*	0.096	0.089	1.000
	Minor	10.6 (7.0)	9.1 (7.0)	6.9 (6.1)	0.097	1.000	0.140	0.371
	Total	20.7 (11.4)	16.2 (8.6)	13.1 (9.3)	0.029*	0.396	0.058	0.604
WA	Major	3.2 (1.8)	2.4 (1.4)	1.0 (1.5)	0.014*	0.171	0.017*	0.171
	Minor	1.6 (1.3)	1.4 (1.2)	1.2 (1.1)	0.443 [a]	1.000	0.835	0.785
	Total	4.7 (2.5)	3.7 (1.4)	3.0 (2.1)	0.015*	0.333	0.042*	0.330
SLS	Major	4.1 (2.7)	3.2 (2.2)	3.6 (2.5)	0.173	0.912	0.285	1.000
	Minor	1.5 (1.6)	2.0 (1.5)	1.5 (1.6)	0.406	0.911	1.000	0.405
	Total	5.6 (3.7)	5.1 (3.2)	4.2 (3.7)	0.377	1.000	0.677	0.615
SLA	Major	2.8 (2.4)	1.5 (1.6)	1.7 (1.8)	0.102	0.108	0.391	1.000
	Minor	7.6 (4.9)	5.75 (4.9)	4.1 (3.8)	0.015*	0.381	0.020*	0.481
	Total	10.3 (6.2)	7.2 (5.6)	5.9 (4.5)	0.021*	0.184	0.037*	1.000
Trunk	Total	0.7 (1.8)	.15 (.5)	0.5 (1.7)	0.524	0.589	1.000	1.000
Pelvis	Total	2.3 (3.5)	4.6 (5.1)	2.8 (4.0)	0.046*	0.133	1.000	0.191
Hip	Total	3.5 (3.8)	4.6 (4.7)	3.9 (3.0)	0.585	1.000	1.000	1.000
Knee	Total	2.6 (2.9)	1.7 (1.6)	1.8 (1.8)	0.276 [a]	0.535	0.903	1.000
Ankle	Total	8.6 (4.5)	5.1 (3.7)	4.2 (4.0)	0.007*	0.025*	0.021*	1.000
Foot	Total	3.1 (1.3)	0 (0)	0 (0)	0.001*	0.001*	0.001*	N/A

WA: weight acceptance (initial contact, loading response) SLS:single limb support (mid-stance, terminal stance) SLA:swing limb advancement (pre-swing, initial swing, mid-swing, terminal swing)

** p < 0.05*

[a] Greenhouse-Geisser estimate used due to violation of assumption of sphericity

For the right leg, a similar significant difference was found between the conditions with regards to major deviations and total deviations (*p*=0.026 and *p*=0.047, respectively), but none of the pairwise comparisons reached significance.

When specific phases of gait were considered for the right leg, the average number of major deviations when participants walked barefoot were significantly higher than when they wore supportive shoes (3.3±1.7 vs. 2.1±1.6, p=0.029), during the weight acceptance phase. The total deviations during the weight acceptance phase were significantly different as well, although none of the pairwise comparisons reached significance. During swing limb advancement, the average number of total deviations when participants walked barefoot was significantly higher compared to when they wore supportive shoes (10.5±6.2 vs 6.1±4.5, p=0.048) (Table 2). Additionally, during this swing limb advancement phase, there was a significant difference across all conditions for major deviations (ANOVA F: 3.669, p=0.035), however, pairwise comparisons did not reach significance (pairwise comparisons between no footwear-unsupportive footwear, no footwear-supportive footwear, unsupportive-supportive, respectively: p=0.065, p=0.139, p=1).

When specific body regions were considered, the average total number of deviations at the ankle was significantly higher when participants walked barefoot than when they wore either the unsupportive or the supportive shoes (barefoot vs. unsupportive: 8.6±4.3 vs. 5.1±3.8, p=0.035; barefoot vs. supportive: 8.6±4.3 vs. 4.7±4.2, p=0.047, respectively) (Table 2).

Table 2: Statistical analysis for right reference limb

		Mean (SD)			Repeated measures ANOVA	Pairwise Comparisons		
Outcome	Type of gait deviation	1. Barefoot	2. Crocs	3. Saucony	p-value	Between 1-2 p-value	Between 1-3 p-value	Between 2-3 p-value
Overall	Major	10.4 (5.5)	7.2 (3.3)	6.6 (4.4)	0.026*	0.078	0.076	1.000
	Minor	10.5 (7.2)	9.1 (6.8)	7.2 (6.2)	0.168	1.000	0.260	0.564
	Total	20.9 (11.4)	16.2 (8.7)	13.7 (9.6)	0.047*	0.403	0.085	0.946
WA	Major	3.3 (1.7)	2.4 (1.4)	2.1 (1.6)	0.016*	0.082	0.029*	1.000
	Minor	1.6 (1.3)	1.5 (1.2)	1.2 (1.1)	0.320 [a]	1.000	0.590	0.412
	Total	4.9 (2.6)	3.8 (1.5)	3.2 (2.3)	0.022*	0.262	0.051	0.825
SLS	Major	4.2 (2.7)	3.3 (2.1)	2.9 (2.5)	0.274	0.919	0.472	1.000
	Minor	1.5 (1.6)	2.1 (1.6)	1.6 (1.7)	0.352	0.733	1.000	0.405
	Total	5.6 (3.6)	5.3 (3.1)	4.5 (3.8)	0.509	1.000	0.931	0.914
SLA	Major	2.9 (2.1)	1.5 (1.7)	1.6 (1.6)	0.035*	0.065	0.139	1.000
	Minor	7.5 (5.1)	5.6 (4.7)	4.5 (4.0)	0.053	0.408	0.091	0.990
	Total	10.5 (6.2)	7.0 (5.4)	6.1 (4.5)	0.024*	0.162	0.048*	1.000
Trunk	Total	0.7 (1.8)	0.2 (.5)	0.6 (1.7)	0.445	0.613	1.000	0.754
Pelvis	Total	2.4 (3.5)	4.6 (5.1)	2.8 (3.9)	0.052	0.161	1.000	0.186
Hip	Total	3.6 (3.8)	4.5 (4.7)	4.1 (3.1)	0.699	1.000	1.000	1.000
Knee	Total	2.7 (2.9)	1.9 (1.6)	1.6 (1.8)	0.164 [a]	0.499	0.437	1.000
Ankle	Total	8.6 (4.3)	5.1 (3.8)	4.7 (4.2)	0.017*	0.035*	0.047*	1.000
Foot	Total	33.0 (1.6)	0.0 (0.0)	0.0 (0.0)	<0.001*	<0.001*	<0.001*	N/A

WA:weight acceptance (initial contact, loading response) SLS:single limb support (mid-stance, terminal stance) SLA:swing limb advancement (pre-swing, initial swing, mid-swing, terminal swing)

** $p<0.05$*

[a] Greenhouse-Geisser estimate used due to violation of assumption of sphericity

There was a significant difference in gait speed (Greenhouse-Geisser adjusted F=8.974, *p*=0.004). Gait speed was significantly faster when participants wore supportive shoes compared to when they walked barefoot (8.9±2.0 vs. 10.0±2.3, *p*=0.002) and compared to when they wore unsupportive shoes (8.9±2.0 vs. 10.8±3.4, *p*=0.014) (Table 3).

Table 3: Statistical analysis for 10-Meter Walk Test Time

	Mean (SD)			Repeated measures ANOVA	Pairwise Compari-sons		
Outcome	1. Barefoot	2. Crocs	3. Saucony	p-value	Between 1-2 p-value	Between 1-3 p-value	Between 2-3 p-value
Walking Time (s)	10.0 (2.3)	10.8 (3.4)	8.9 (2.0)	0.004* [a]	0.304	0.002*	0.014*

* *p<0.05*

[a] *Greenhouse-Geisser estimate used due to violation of assumption of sphericity*

4 | DISCUSSION |

Our findings demonstrated that there were significant differences in gait deviations when walking barefoot, with unsupportive shoes or with supportive shoes. For gait deviations, when both left and right sides were considered, the number of major gait deviations during the weight acceptance phase and total deviations in the swing limb advancement phase were significantly higher when participants walked barefoot compared to when they wore supportive shoes. Additionally, when considering only the left lower extremity as the reference limb, the number of total gait deviations during the weight acceptance phase and the number of minor deviations during the swing limb advancement phase were significantly higher when participants walked barefoot compared to when they walked with supportive shoes. These differences showed that when specific phases of gait were considered separately, adults with DS who walked barefoot demonstrated more deviations than when they walked in supportive shoes. However, when considering overall gait deviations and using pairwise comparisons, there was no statistically significant difference in the number of gait deviations when walking in supportive vs unsupportive shoes or barefoot vs unsupportive shoes. These results lead us to accept our hypothesis that supportive shoes improve gait compared to walking barefoot. However, they only partially confirm our hypothesis that the supportive shoes would lead to improvements compared to unsupportive shoes.

Our findings further demonstrated that there were significant differences in the number of gait deviations within specific body regions when different footwear conditions were used. The two body regions that showed differences in the number of gait deviations were the pelvis (only left leg) and the ankle (both legs). The change in number of gait deviations at the pelvis with the right leg as the reference limb was close to reaching significance (p=0.052), but did not reach the significance threshold. The ankle was the only body region that showed an improvement from barefoot to both types of footwear.

Within this study, it was commonly observed that wearing supportive shoes improved excessive ankle plantarflexion, eversion, early heel lift, flatfoot/forefoot contact, excessive hip flexion, excessive knee flexion, and knee valgus/varus. Supportive footwear tended to allow participants to have sufficient dorsiflexion needed to have heel strike at initial contact. Consistent with our findings, research has shown that footwear affects the ankle during gait. Footwear affected gait in those with chronic ankle instability and those with flat feet by increasing the ankle dorsiflexion angle (Moisan et al., 2020; Chen et al., 2010), which subsequently can have beneficial effects such as reduced mechanical load applied to the knee and improved extensibility of the gastro-soleus muscle complex (Aali et al., 2021).The heel toe drop effects of shoes may help decrease flat foot/forefoot contact, decrease early heel off, and improve heel-first strike. Aali's research reported that people with stiffness in the gastroc-soleus and decreased ankle dorsiflexion, compensate with more knee flexion and consequently compensatory hip flexion when compared to healthy people. This heel-first strike showed a decrease in compensatory knee flexion at initial contact and stance phase (Aali et al., 2021). Furthermore, it was observed in this study that wearing shoes decreased participants' ankle eversion and promoted a more neutral foot posture. By providing medial support for the arch of foot, supportive shoes can allow proper gait kinematics of the ankle and foot from pronation to supination and decrease risk of musculoskeletal injury (Nagano & Begg 2018). Future studies would be needed to determine if these changes in gait caused by footwear have any effect on functional abilities, fitness level, or ability to participate in activities of daily living in adults with DS.

Another commonly observed gait deviation when walking barefoot during the weight acceptance and swing limb advancement stages was great toe extension. We hypothesize that the excessive great toe extension and use of the extensor hallucis longus as the primary dorsiflexor for foot clearance during swing limb advancement phase was due to an insufficient use of the tibialis anterior. However, the toes up deviation may not have an influence on walking speed since research suggests forward propulsion in adults without DS may be more heavily impacted by ankle plantarflexors, especially in participants with early heel off gait (Dockery, 2019).

Our findings also demonstrated that participants walked faster when wearing supportive shoes in comparison to unsupportive shoes and barefoot. Interestingly, the slowest gait speed was observed when participants walked in unsupportive shoes. Our results of faster gait speed with supportive shoes compared to barefoot aligned with that same finding in adults without DS (Zhang et al., 2013). Our findings indicate that it may be necessary to choose footwear carefully or document footwear type when performing prognostic tests because gait speed is a predictor of decline in mobility and ability to perform activities of daily living in adults with intellectual disability (Oppewal et al., 2014). Further research would be needed to determine if wearing supportive shoes, which results in faster gait speed, can contribute to a higher physical fitness level and prevent limitations in daily functioning.

The average gait speed for no footwear, unsupportive footwear, and supportive footwear was 1.00m/s, 0.93m/s, and 1.12m/s, respectively. The increase in gait speed from wearing unsupportive to supportive shoes met the minimal detectable change value of 0.188m/s previously reported in people with DS (Sánchez-González et al., 2023). When compared to barefoot, when participants walked in supportive shoes, their gait speed was statistically significantly faster, but did not exceed the MDC. Our initial hypothesis that participants would have faster gait speed when they walked in supportive shoes compared to unsupportive shoes and barefoot was supported.

4.2| Strengths and Limitations

Strengths of this study include the thorough training protocol that observers underwent for the gait analyses, standardization of testing procedures, standardizing footwear conditions for participants, and the adequately powered sample size.

Our study also had some potential limitations. One potential limitation could be the potential effects of motivation or fatigue on gait. We attempted to minimize the effects of motivation as we used consistent verbal cueing for every participant. We also attempted to minimize the effects of fatigue on our gait speed analysis by randomizing the order of footwear conditions for each participant. Another potential limitation was the use of only one type of supportive and unsupportive shoe. Future research may benefit from further investigation into the ideal type of supportive shoe for adults with DS. Another potential limitation is the OGA statistical analysis only showed the number of deviations rather than which specific deviations were affected. A second possible limitation of using the full OGA form was that the participant's toes were not visible while wearing shoes, however the results were still included in this paper since wearing shoes can affect gait deviations of the foot. Finally, our unsupportive shoe was less secured to the foot compared to our supportive shoe. Along with lacking sufficient medial arch and calcaneal support, this shoe also had the potential to move more in relation to the participant's foot during ambulation. We did try to minimize this effect by utilizing the shoe's heel strap around the posterior ankle.

4.3| Implications for research and practice

As our study only examined participants over three 10 meter walks, we suggest that further research examine differences in kinematics of participants' lower extremity and trunk over a prolonged period of time to see if there are further changes in gait with supportive shoes.

5 | CONCLUSION |

Adults with Down syndrome who wore supportive shoes demonstrated better gait quality with fewer deviations compared to when they walked barefoot. Additionally, they had a faster gait speed when walking in supportive shoes compared to both walking in unsupportive shoes and barefoot. These results should be considered by any researchers studying gait or walking interventions in adults with DS. Furthermore, clinicians who work with adults with DS may be able to immediately apply this information in their clinical practice by recommending the use of supportive footwear, the avoidance of unsupportive footwear, and the use of supportive footwear at times when barefoot walking is common, such as within the home.

References

Aali, S., Rezazadeh, F., Badicu, G., & Grosz, W. R. (2021). Effect of heel-first strike gait on knee and ankle mechanics. *Medicina (Kaunas, Lithuania), 57*(7), 657. doi:10.3390/medicina57070657.

Banwell, H. A., Mackintosh, S., Thewlis, D., & Landorf, K. B. (2014). Consensus-based recommendations of australian podiatrists for the prescription of foot orthoses for symptomatic flexible pes planus in adults. *Journal of Foot and Ankle Research, 7*(1), 49-n/a. doi:10.1186/s13047-014-0049-2.

Calvo-Lobo, C., Ramos García, A., Losa Iglesias, M. E., López-López, D., Rodríguez-Sanz, D., Romero-Morales, C., & Becerro-de-Bengoa-Vallejo, R. (2018). The relationship between shoe fitting and foot health of persons with Down syndrome: A case control study. *International Journal of Environmental Research and Public Health, 15*(5), 983. doi: 10.3390/ijerph15050983.

Centers for Disease Control and Prevention. (2020). Data and statistics on Down syndrome. Accessed October 20, 2021. Retrieved from https://www.cdc.gov/ncbddd/birthdefects/downsyndrome/data.html.

Chen, Y., Lou, S., Huang, C., & Su, F. (2010). Effects of foot orthoses on gait patterns of flat feet patients. *Clinical Biomechanics (Bristol, Avon), 25*(3), 265-270. doi:10.1016/j.clinbiomech.2009.11.007.

Cimolin, V., Galli, M., Grugni, G., Vismara, L., Albertini, G., Rigoldi, C., & Capodaglio, P. (2010). Gait patterns in prader-willi and Down syndrome patients. *Journal of Neuroengineering and Rehabilitation, 7*(1), 28. doi:10.1186/1743-0003-7-28.

Dockery, L. J. (2019). Analysis of gait propulsion during the ankle and forefoot rocker sub-phases (Publication No. 22587404) [Doctoral dissertation, University of Central Arkansas]. ProQuest.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149-1160.

Foley, C., & Killeen, O. G. (2019). Musculoskeletal anomalies in children with Down syndrome: An observational study. *Archives of Disease in Childhood, 104*(5), 482-487. doi:10.1136/archdischild-2018-315751.

Galafate D, Pournajaf S, Condoluci C, et al. Bilateral foot orthoses elicit changes in gait kinematics of adolescents with Down syndrome with flatfoot. *International Journal of Environmental Research and Public Health.* 2020;17(14):4994. Published 2020 Jul 11. doi:10.3390/ijerph17144994.

Galli, M., Rigoldi, C., Brunner, R., Virji-Babul, N., & Giorgio, A. (2008). Joint stiffness and gait pattern evaluation in children with Down syndrome. *Gait & Posture, 28*(3), 502-506. doi:10.1016/j.gaitpost.2008.03.001.

Lythgo, N., Wilson, C., & Galea, M. (2009). Basic gait and symmetry measures for primary school-aged children and young adults whilst walking barefoot and with shoes. *Gait & Posture, 30*(4), 502-506. doi:10.1016/j.gaitpost.2009.07.119

Mansour E, Yaacoub JJ, Bakouny Z, Assi A, Ghanem I. (2017). A podoscopic and descriptive study of foot deformities in patients with Down syndrome. *Orthopaedics & Traumatology: Surgery & Research*,*103*(1):123-127. doi:10.1016/j.otsr.2016.10.001.

McConnell, J., & Silverman, B. (2015). Comparing usability and variance of low- and high technology approaches to gait analysis in health adults [Doctoral project, University of Nevada, Las Vegas].

McLaughlin, P., Vaughan, B., Shanahan, J., Martin, J., & Linger, G. (2016). Inexperienced examiners and the foot posture index: A reliability study. *Manual Therapy, 26*, 238-240. doi:10.1016/j.math.2016.06.009.

Mik, G., Gholve, P. A., Scher, D. M., Widmann, R. F., & Green, D. W. (2008). Down syndrome: Orthopedic issues. *Current Opinion in Pediatrics, 20*(1), 30-36. doi:10.1097/MOP.0b013e3282f35f19.

Moisan G., Descarreaux M., Cantin V. (2020). The influence of footwear on walking biomechanics in individuals with chronic ankle instability. *PLOS ONE 15*(9): e0239621. doi:10.1371/journal.pone.0239621.

Moreau M, Benhaddou S, Dard R, et al. (2021). Metabolic diseases and Down Syndrome: How are they linked together?. *Biomedicines, 9*(2):221. Published 2021 Feb 22. doi:10.3390/biomedicines9020221.

Nagano H, Begg RK. Shoe-insole technology for injury prevention in walking. *Sensors*. (2018); 18(5):1468. doi:10.3390/s18051468.

Oppewal A, Hilgenkamp TIM, van Wijck R, Schoufour JD, Evenhuis HM. (2014). Physical fitness is predictive for a decline in daily functioning in older adults with intellectual disabilities: Results of the HA-ID study. *Research in Developmental Disabilities*, *35*(10):2299-2315. doi:10.1016/j.ridd.2014.05.027.

Oppewal A, Hilgenkamp TIM, van Wijck R, Schoufour JD, Evenhuis HM. (2015). Physical fitness is predictive for a decline in the ability to perform instrumental activities of daily living in older adults with intellectual disabilities: Results of the HA-ID study. *Research in Developmental Disabilities,* 41-42:76-85.

Oppewal A, Hilgenkamp TI, van Wijck R, Evenhuis HM. (2013). The effect of handedness on grip strength in older adults with intellectual disabilities. *Research in Developmental Disabilities,* 34(5):1623-1629. doi:10.1016/j.ridd.2013.02.013.

Perotti, L. R., Abousamra, O., Del Pilar Duque Orozco, M, Rogers, K. J., Sees, J. P., & Miller, F. (2018). Foot and ankle deformities in children with Down syndrome. *Journal of Children's Orthopaedics, 12*(3), 218-226. doi:10.1302/1863-2548.12.170197.

Petersen, E., Zech, A. & Hamacher, D. (2020). Walking barefoot vs. with minimalist footwear – influence on gait in younger and older adults. *BMC Geriatrics 20*, 88. doi:10.1186/s12877-020-1486-3.

Quan, W., Gao, L., Xu, D., Zhou, H., Korim, T., Shao, S., . . . Gu, Y. (2023). Simulation of lower limb muscle activation using running shoes with different heel-to-toe drops using opensim. *Healthcare (Basel), 11*(9), 1243. doi:10.3390/healthcare11091243.

Rancho Los Amigos National Rehabilitation Center (2001). *Observational gait analysis.* Los Amigos Research and Education Institute.

Redmond, A. C., Crosbie, J., & Ouvrier, R. A. (2006). Development and validation of a novel rating system for scoring standing foot posture: The foot posture index. *Clinical Biomechanics, 21*(1), 89-98. doi:10.1016/j.clinbiomech.2005.08.002.

Rimmer, J. H., Yamaki, K., Lowry, B. M. D., Wang, E., & Vogel, L. C. (2010). Obesity and obesity-related secondary conditions in adolescents with intellectual/developmental disabilities. *Journal of Intellectual Disability Research, 54*(9), 787-794. doi:/10.1111/j.1365-2788.2010.01305.x.

Sánchez-González JL, Llamas-Ramos I, Llamas-Ramos R, Molina-Rueda F, Carratalá-Tejada M, Cuesta-Gómez A. (2023). Reliability and validity of the 10-meter walk test (10MWT) in adolescents and young adults with Down syndrome. *Children (Basel)*. 10(4):655. doi: 10.3390/children10040655.

Selby-Silverstein, L., Hillstrom, H. J., & Palisano, R. J. (2001). The effect of foot orthoses on standing foot posture and gait of young children with Down syndrome. *NeuroRehabilitation (Reading, Mass.), 16*(3), 183-193. doi:10.3233/NRE-2001-16307.

Zhang, X., Paquette, M. R., & Zhang, S. (2013). A comparison of gait biomechanics of flip-flops, sandals, barefoot and shoes. *Journal of Foot and Ankle Research, 6*(1), 45-45. doi:10.1186/1757-1146-6-45.

Curriculum Vitae

Bailey Gosse
Baileygosse1@gmail.com

Education

Doctor of Physical Therapy
University of Nevada, Las Vegas
May 2024

Bachelor of Science major in Community Health Science- Kinesiology
Minor in Gerontology, Certificate in Gerontology
University of Nevada, Reno
May 2019

Associated Experience

- January 2024- March 2024 Spring Valley Inpatient Acute Care Clinical Experience
- September 2023-November 2023 Mountain View Hospital Inpatient Rehab Clinical Experience
- July 2023- September 2023 Anders and Associates Physical Therapy Clinical Experience
- June 2022- July 2022 Barton Outpatient Rehabilitation Clinical Experience

Related Service

- October 2022/2023 Las Vegas Down Syndrome Conference 2022/2023
    - Gait analysis for proper shoe fitting for people with DS.
- May 2022 Special Olympics Health and Wellness Fair
    - Performed initial physical assessment of athletes with down syndrome

Membership in Professional Organizations

- 2021- present Member American Physical Therapy Association
- 2022-present Member Academy of Geriatrics of American Physical Therapy Association
- AED National Health Preprofessional Honor Society
- Sigma Phi Omega Gerontology Honor Society

Kimberly Nguyen
kimberlynguyenn22@gmail.com

Education

DPT University of Nevada, Las Vegas 2021-2024 Physical Therapy
B.S. California State University, Long Beach 2016-2020 Kinesiology – Exercise Science

Associated Experiences

January 2024 - March 2024 – **CA Rehabilitation and Sports Therapy**
- Outpatient Orthopedics Physical Therapy Clinical Experience

September 2023 – December 2023 – **Sunrise System – Mountain View Hospital, Rehab**
- Inpatient Rehab Physical Therapy Clinical Experience

July 2023 – September 2023 – **Spring Valley Health System – Acute Care**
- Acute Care Physical Therapy Clinical Experience

June 2022 – July 2022 – **Tru Physical Therapy – Heritage Park**
- Outpatient Orthopedics Physical Therapy Clinical Experience

Volunteer Work

October 7, 2023 - **2nd Annual Las Vegas Down Syndrome Conference**
- Assessed gait with supportive and unsupportive footwear, and barefoot in adults with Down syndrome

March 25, 2023 - **GiGiFIT Acceptance Challenge Walk**
- Assisted with setup, checking in participants, and support for the participants in the walk/event

October 22, 2022 - **1st Annual Las Vegas Down Syndrome Conference**
- Monitored and provided tech support for break out sessions and interacted with people with Down syndrome and their families

September 20, 2022 – **Memory and Balance Screening – Sun City Summerlin**
- I assessed the balance and memory of older adults in the Sun City Summerlin community during Fall Prevention Awareness Week. Along with my colleagues, I performed cognitive tests, STEADI assessments, and discussed the results with the participants.

May 19, 2022 – **Special Olympics Health Fair**
- I performed FUNfitness screenings, evaluation of flexibility, strength, balance and aerobic condition, for the youth with intellectual disabilities in the Las Vegas community.

Professional Memberships/Organizations
- 2021-present - **Member American Physical Therapy Association**

- 2021-present - **Member Nevada Physical Therapy Association**
- 2022-present - **Member Academy of Geriatrics of the American Physical Therapy Association**

Zoe Zelensky
zoezelensky@gmail.com

<u>Education</u>

University of Nevada, Las Vegas - Doctorate of Physical Therapy

- June 2021 - May 2024

University of Nevada, Las Vegas- Bachelor of Science, Kinesiology

- August 2016 - May 2020

<u>Graduate Research Projects</u>

Better Gait Quality and Speed in Adults with Down Syndrome When Wearing Supportive Shoes Compared to Unsupportive Shoes and Barefoot

- Co-investigator. Presented May 2024

<u>Associated Experience</u>

Valley Health Specialty Hospital, physical therapy clinical rotation

- January 2024 - March 2024 (10 weeks)
- Managed full caseload in inpatient rehab setting
- Treated patients with stroke, MS, fracture, joint replacement, amputation, encephalopathy, and debility

University Medical Center, physical therapy clinical rotation

- September 2023 - December 2023 (10 weeks)
- Managed 75% of caseload in acute care setting of a level 1 trauma center
- 5 weeks experience in cardiac ICU, 5 weeks in various med-surg, intermediate care, psych, burns, peds

Leavitt Physical Therapy, physical therapy clinical rotation

- July 2023- September 2023 (10 weeks)
- Managed 75% of caseload in outpatient orthopedic setting
- Assessed and treated patients with acute and chronic, non-op and post-surgical orthopedic conditions

Rapid Rehab, physical therapy clinical rotation

- June 2022 - July 2022 (5 weeks)
- Outpatient orthopedic clinical experience

<u>Associated Employment Experience</u>

Self-employed, Pilates instructor

- March 2019 - present

- Instruct individualized one-on-one and small group Pilates classes

Family and Sports Physical Therapy, physical therapy aide
- September 2018 - April 2021
- Assisted patients with exercises and assisted team in outpatient orthopedic clinic operations

Community Service

Las Vegas Down Syndrome Conference, Down Syndrome Connections Las Vegas
- October 2022
- Supported conference in a volunteer capacity

Rock Steady Boxing
- October 2022
- Assisted group boxing class for individuals with Parkinson's disease

UNLVPT Balance and Memory Screening Event
- September 2022
- Screened seniors for dementia (using Mini Cog) and fall risk (using CDC's STEADI outcome measures)

Certificates

The Otago exercise program: falls prevention training certification
- September 2022
- Evidence-based falls prevention exercise intervention for older adults

STEADI: CDC's Stopping Elderly Accidents, Deaths, and Injuries certification
- September 2022
- Training for evidence-based evaluation of fall risk

Pilates Teacher Training Certification
- March 2019
- Assessment based certificate for a 450 hour contemporary Pilates training program in mat, reformer, cadillac, and chair

Continuing Education

APTA Combined Sections Meeting
- February 2023, San Diego
- February 2022, San Antonio

Honors, Awards, and Memberships

APTA member, 2021 - present

American Council of Academic Physical Therapy Honor Society, 2024

UNLV PT Sports Medicine Club member, 2021 - 2024

UNLV PT Recognition of Achievement Award, 2024

UNLV Physical Therapy Department Award, 2022

Undergraduate honors and awards:

- Pre-physical Therapy Honor Society member and chair of public relations; Dean's Honor List for academic merit-based recognition for seven semesters; Millennium Scholarship for academic merit-based scholarship