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Effects of a 12-Week Telehealth Exercise Intervention on Gait Speed and Gait Deviations in Adults with Down Syndrome

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Abstract:

Background: Down syndrome (Ds) is associated with impairments affecting overall motor development including gait pattern and speed. Research on the effects of exercise on adults with Ds is lacking. The purpose of this study is to evaluate the effects of a 12-week telehealth exercise program on gait impairments in adults with Ds.

Methods: Twenty participants performed a 12-week telehealth exercise program based upon a diagnosis-specific procedure developed by Sarah Mann, PT, DPT. Gait deviations were assessed with the Ranchos Los Amigos Observational Gait Analysis. Comfortable gait speed was evaluated with the 4-meter walk test.

Results: Improvements in comfortable gait speed and reduced gait deviations were statistically significant. Other significant findings included fewer gait deviations during Single Leg Stance, Swing Limb Advancement, deviations at the hip, and at the ankle.

Conclusions*:* Gait velocity and observable gait impairments in adults with Ds significantly improved following a 12-week telehealth exercise program.

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Background

Down syndrome (Ds) is one of the most common genetic conditions which results in an additional full or partial copy of chromosome 21 (Trisomy 21) and is known to occur in 1 in 800 births.[1] Currently, more than 200,000 individuals with Ds live in the United States.[1] Due to improvements in childhood survival rates, individuals with Ds can now be expected to live well into their 5th and 6th decades of life.[2] Individuals with Ds present with specific cognitive, musculoskeletal, cardiovascular, and endocrine characteristics, which can influence their overall health and motor development.[3] Although the increase in life expectancy has improved, the prevalence of impairments secondary to Ds require further development of interventions, care plans, and lifestyle changes to maximize their health and motor development from childhood to older age. Of these impairments, musculoskeletal conditions related to Ds may be addressed through exercise interventions that focus on muscle strengthening and dynamic balance training.[4]

Children born with Ds typically present with skeletal muscle hypotonicity at birth that can cause delayed development of motor milestones, increased risk of musculoskeletal disorders, and generally results in a barrier to participate in physical activity.[5] Reduced physical activity and a sedentary lifestyle can contribute to low bone mass, obesity and inability to develop and maintain maximal muscle strength.[5] A prominent factor affecting the musculoskeletal system in individuals with Ds is an overproduction of Type VI collagen encoded by chromosome 21. This leads to global ligamentous laxity in over 90% of this population.[3,6] This ligamentous laxity can lead to hip instability, patellar dislocations, ligamentous injuries, digital deformity of the foot, and scoliosis which ultimately lead to postural and gait deviations.[5] A study examining gait in young adults with Ds demonstrated a decrease of step width, step length, and stride length by 20-25% in combination with a wider base of support when compared to adults without Ds.[7] In addition, adults with Ds often present with excessive anterior pelvic tilt, external rotation of the hip, decreased hip extension, tibial external rotation, limited knee flexion range of motion in walking, as well as pes planus foot posture during standing.[8,9] Gait deviations in individuals with Ds can also be attributed to developmental neurological abnormalities which includes reduced volume of the cerebellum,

delayed myelination, and proprioceptive and vestibular deficits that result in difficulties in planning, organization, and sequencing of movement patterns during gait.[9]

The current literature has shown decreased walking velocity by about 25% in adults with Ds, when compared to adults without Ds.[10] Slower walking velocities and longer stance phases have also been demonstrated throughout the gait cycle in comparison to typically developing individuals.[11] Slower gait velocities during activities of daily living combined with longer stance times have been shown to increase the risk of injury related to falls in older adults.[12] Taken together, these deviations and impairments may result in increased fall risk, decreased participation in community activities, decreased participation in physical activity, as well as an increased risk of injury.[14]

Most research on gait in individuals with Ds is centered on children. One study compared balance and gait in typically developing children and children with Ds of preschool and school age.[14] The outcomes measures utilized assessed both dynamic and static stability as well as spatiotemporal gait parameters, and the researchers found a significant difference in gait characteristics and postural deviations between the two groups of children. The study concluded that balance and gait improved with age and growth which remains limited in children with Ds, and therefore suggesting that children with Ds may benefit from therapeutic and exercise interventions to correcting gait and balance abnormalities in children with Ds.[14] Another study demonstrated the ability to change the gait pattern of pre-adolescent individuals with Ds with active training.[15] The study measured impulse (force applied during push-off) and stiffness (the ability of muscles to store and return elastic energy) during normal gait in adolescents with Ds compared to their typically developing peers. Participants received 4 days of active training with 12 repetitions of 60 seconds on the treadmill at their 75% overground gait speed. The authors found that individuals with Ds displayed increased impulse and stiffness compared to their typically developing peers. However, on post-testing the authors found that their impulse and stiffness lessened to become more like their typically developing peers. The authors concluded that with active practice individuals with Ds may have the ability to adapt qualities of their gait to demonstrate normalization of their gait pattern.[15] This provides

support that adults with Ds may be able to benefit from established interventions that allow for improvement of gait and general functional movements.

Despite a reasonable number of studies in children with Ds, the research in adults with Ds is minimal when it comes to examining the effects of exercise interventions on gait, specifically gait speed and incidence of gait deviations. There is a significant lack of studies specifically related to improving gait characteristics of adults with Ds through exercise. The purpose of this study was to evaluate the effects of a 12-week online exercise program on gait impairments in adults with Ds. This study was conducted using a remote-telehealth protocol due to stay-at-home orders and to protect the health of participants and researchers during the COVID-19 pandemic. The primary aim of this study was to determine the effects of a 12-week remote exercise program on gait deviations and speed in adults with Ds. We hypothesized that a 12-week exercise intervention will improve gait speed and reduce the number of gait deviations found in individuals with Ds.

Methods

Design and Participants

The study followed a repeated-measures design. The participants were recruited for this research study by distributing flyers among local organizations involved in furthering research and supporting Ds awareness, events for individuals with Ds, and through social media sharing. Inclusion criteria for participation in this study included age 18-35 years, generally healthy, sedentary lifestyle, functioning thyroid, and a diagnosis of Ds. Exclusion criteria for this study included a history of cardiovascular disease, currently smoking, presence of asthma, congenital heart conditions, as well as current pregnancy. The sample size of 20 for this study, using G*Power version 3.1, was based on a previous study conducted by Rimmer et al.[16] We used a power of 0.8 and alpha level set at 0.05, and assumed correlation between pre and post of 0.7, the effect size is 0.71 and the most conservative required sample size to detect a difference in a repeated design is 18.[16] This was based on differences in peak VO2 in participants, as our study in gait deviations was a part of a larger study concerning the effects of exercise in individuals with Ds.

Procedure

For each participant, comfortable gait speed and observational gait analysis was obtained before and after a 12-week remote exercise intervention program. Given the circumstances surrounding the COVID-19 pandemic in the United States, and to maintain the health and safety of our participant population, this study was conducted via Zoom Video Communications (Zoom Inc. 2020 San Jose, CA) software due to the health risks and safety of the participant population. Utilizing Zoom with a HIPAA compliant license, the research team organized 3 trained researchers to remotely instruct the participants each of the tests and measures conducted.

During the testing session, a facilitating researcher would provide instructions while a secondary researcher would collect data and measurements. The secondary researcher would have audio and video inactive to ensure comfort of the participant. The participants had a caretaker or assistant present at the test time and the assistant would aid with collecting times, setting up equipment, or providing safety supervision for some tasks. Furthermore, the researchers met with both the participant and assistant prior to the initial visit as an introductory meeting to familiarize the participant with the researchers as well as resolve any technological or setup issues. The participants attended one testing session prior to intervention as well as one testing session after the intervention concluded.

Participants were given supplies needed for accurate and reliable testing measurements. Supplies provided to the participants included: a 4-meter length of string, tripod mount, wide-view lens camera that can be attached to a smartphone or tablet, a stopwatch, and painter's tape. Additionally, written instructions and supplemental demonstration videos were provided to both the assistant and participant to familiarize them with the expectations of the testing session and to reduce possible confusion or anxiety related to testing procedures.

Outcome measures

Data collection before and after the remote exercise intervention contained two outcome measures, the first being comfortable walking speed (CGS) measured with the 4-meter Walk Test (4mWT), and the second as the observational gait analysis obtained from Ranchos Los Amigos Observational Gait Analysis (OGA).

Comfortable gait speed (CGS): The 4mWT was chosen to measure CGS due to previous research showing the efficacy of using this test to analyze an individual's functional mobility level. Fritz and Lusardi reported that gait speed is a reliable, sensitive, and specific measure which provides valuable insights on two important factors of overall health such as individual's functional capacity and balance confidence. Age related cut off scores for gait speed can be used as predictive measures for health status,

functional decline, risk of future falls, fear of falling, and quality of life across all ages and health conditions.[17] Therefore, gait speed can be used to reliably track progression of speed during exercise interventions and can be compared to specific reliable cut offs. Due to safety concerns of the COVID-19 pandemic, outcome measures used must be feasible in the home environment.[17] Fritz and Lusardi also produced evidence that a 10-foot walking test can be considered both reliable and valid. Therefore, the 4mWT was used as a short walking test.[17,18] Goldberg and Schepens found that assessment of gait speed over shorter distances has high reproducibility across trials, further supporting the 4mWT as a reliable measurement tool.[19]

Participants and their assistants used the pre-measured 4-meter string to mark the beginning and end of the 4 Meter Walk Test (4mWT) on a hard, level surface. Each end of the string was demarcated with blue tape to cue the participant as well as provide a clear point for the research team to reference when analyzing video. The participant and their assistant were provided detailed instructions for setting up camera angles to allow for an anterior and posterior view of the participant walking at a CGS. Participants occasionally required cueing and pre-trial attempts to walk at a CGS. The facilitating researcher would, at times, prompt the participant's assistant to determine if the gait quality appeared typical for their function. The camera and tripod were elevated to view the entire walkway and whole body of the participant. Time of 4mWT was recorded by the assistant with a stopwatch that had an audio function to ensure accurate timing. When the participant was ready, they began walking at their comfortable speed across the 4 meters and the stopwatch was stopped once participants crossed the tape and the time was recorded. Both the research team and participant assistant recorded times for each trial. CGS was calculated with a period of acceleration at the initiation of gait and the participants were instructed to walk through the blue tape without decelerating. Breaks were allowed in between trials if needed but did not exceed 1 minute. This was then performed 2 more times for a total of 3 trials, and the average time was calculated for each participant to be used in the final analysis.

Observational Gait Analysis (OGA)

The Rancho Los Amigos OGA was selected to observe biomechanical changes in gait over time, its reproducibility, and its easy application in video analysis. A previous study indicated that the OGA conducted through video observation had both a high intra-observer and inter-observer reliability while assessing the gait mechanics of the push-off phase of the foot in individuals post-stroke.[20] The OGA has also demonstrated a moderate to substantial intra-rater reliability and a fair-to-moderate inter-rater reliability and concurrent validity at the ankle, knee, and hip in the sagittal plane when analyzing gait of people with spastic cerebral palsy.[21]

The OGA is separated into distinct functional tasks periods of gait during gait, including Weight Acceptance (WA), Single Limb Support (SLS), and Single Leg Advancement (SLA).[22] See appendix 2 for a visualization of this information. Each functional task period is further divided into specific phases of gait in which deviations can be observed and clinically evaluated. WA includes the phases of initial contact (IC) and loading response (LR) in which the reference limb is outstretched and contacts the ground and weight is loaded onto the limb. SLS includes Mid-stance (MSt) and Terminal-Stance (TSt), in which the weight is transferred to one leg to metatarsal heads and heel raises from the ground. SLA includes Pre-swing (PSw), Initial Swing (ISw), Mid-Swing (MSw), and Terminal Swing (TMs) in which the reference limb leaves the ground behind the body and swings to the front of the body.[23] The OGA consists of descriptive data points to determine if specific gait deviations were present or not present in different body regions (Trunk, Hip, Knee, Ankle and Foot) during different parts of the gait cycle. The possible gait deviations that can be observed at the hip are listed in the appendix section.

Participants and their assistants were given detailed instructions for proper camera set up on the provided tripod to observe the whole body of the participant in an anterior, posterior, and lateral views as well as proper attire. Due to the nature of flat-foot prevalence in this population, this study requested that participants wear their most comfortable and supportive shoes as this would be consistent with community ambulation conditions. The camera captured the participants walking at least one complete gait cycle on each limb in the anterior, posterior, and lateral views. Participants first performed the first 3

trials at their typical walking speed while recorded in an anterior/posterior view, which was recorded as the participant walked away from the camera and towards the camera. This provided the research team with 3 video samples of the anterior aspect of the participant and 3 video samples of the posterior aspect of the participant. The second 3 trials were performed in a lateral view, in which the participant walked at least one gait cycle past the camera with the camera positioned on the right or left side of the participant. This provided the research team with 3 video samples of the right lateral side of the participant and 3 video samples of the left lateral side of the participant. When the camera was unable to capture the participant's entire body throughout the gait cycle a wide-angle lens was attached to camera to expand the frame of the recorded video.

Intervention

The intervention used for this study was an online, 12-week integrative exercise program developed and provided by a PT with extensive experience working with adults with Ds (Dr. Sarah Mann, PT, DPT, MBA, NSCA-CPT in Arvada, Colorado). Participants attended 3 virtual exercise sessions per week for a total of 12 weeks. The exercise sessions were approximately 1 hour in duration. Within a session, 20 minutes were allotted to cardiovascular exercise, 15 minutes to foundational strengthening, 10 minutes to hip strengthening,10 minutes to balance activities, and 5 minutes for cool down. The cardiovascular exercises included a dancing warm up, repeated anterior/posterior and medial/lateral jumping with a wide and narrow base of support. The foundational strengthening exercises in this program consist of multi-joint movements that target abdominal activation, gluteal activation, and neuromuscular sequencing. Examples of foundational exercises include squats, squats with the assistance of exercise balls, planks, modified planks, push-ups, and gluteal bridges. The hip strengthening exercises target gluteal muscles and lateral hip musculature to improve hip strength and stability, such as hip abduction, standing marches, quadruped exercises, seated marches, and tall-kneeling tasks. The balance activities focused on weight shifts progressing to single leg balance, righting reactions, lateral tilts, rotational ball passes (horizontal and diagonal), anterior/posterior tilts of the pelvis, over-under passes. Each session of the exercise

intervention included a warm-up, and the session was concluded with a cool-down period of stretching the lower extremities and upper extremities. Participants and assistants of participants were provided time to ask questions, share their experiences, and receive additional information if needed.

Data processing

To extract quantitative data from the Ranchos Los Amigos Observational Gait Analysis (OGA) form, typically a qualitative clinical measure, student researchers produced a binary coding system to numerically characterize qualitative characteristics of gait. A digitized adaptation of the original OGA used in this study can be found in appendix 3. The OGA consists of descriptive data points to determine if specific gait deviations were present or not present; within, there were deviations that were classified as 'minor deviations' and 'major deviations'. If a particular gait deviation was observed at least once throughout the sample videos of participant gait, a '1' was attributed to that deviation. For deviations not observed, the deviation would be attributed a '0'. Data was summarized by major deviations, minor deviations, and total deviations of body regions (trunk, pelvis, hip, knee, and ankle), and phases of gait (initial contact, loading response, midstance, terminal stance, pre-swing, initial swing, mid-swing, and terminal swing). The OGA examined changes in trunk and pelvic deviations, but these findings were omitted due to the variability in participant clothing. This study also omitted toe deviations present in the original OGA as they were not observable with shoes. Therefore, we only used the total number of deviations of the body regions (hip, knee, and ankle), total gait cycle, and functional tasks of gait (WA, SLS, and SLA) for statistical analysis. The student researchers who performed the observations and data collection using OGA were trained and educated from previously on gait analysis and had prior experience utilizing the OGA analysis form. To combat possible bias in OGA data collection, pre-intervention data was collected and processed by the research team prior to collection and subsequent processing of post-intervention OGA data.

Statistical analysis

Baseline characteristics of the group were calculated with descriptive statistics. Normality of the 4mWT was checked with the Shapiro-Wilk test. Paired t-tests were then performed to compare the 4mWT at a comfortable gait speed (CGS) before and after the remote exercise intervention for each participant. Gait deviation data from the Rancho Los Amigos from before and after the intervention was compared with Wilcoxon sign rank test to detect significant difference among non-normal distributions. With Bonferroni correction for multiple testing effect 7 comparisons, the null hypothesis was rejected when the probability was below alpha = 0.0071. For all analyses, IBM SPSS Statistics for Windows version 26.0 by Armonk NY: IBM Corp was used.

Results

Eighteen participants completed both pre-and post-intervention data collection sessions, their descriptive characteristics are described in Table 1. Of the original 20 participants, one was lost due to dropout for reasons unrelated to the program. The other participant was omitted from these results due to an injury that occurred outside of the exercise intervention and ultimately prevented OGA analysis in post-testing. CGS improved significantly (Pre=0.83±0.2 m/s, Post=0.98± 0.2 m/s, p=0.04). There was also a statistically significant reduction in total deviations of the gait cycle after intervention (Table 2). While there was no change in WA phase after intervention, significantly fewer deviations were found in the SLS phase and SLA phase (Table 2). When examining the deviations of the body parts, significant fewer deviations were found after intervention in the hip and ankle (Table 2). Using the Bonferroni correction, no statistically significant change was found in knee deviations post-intervention (Table 2).

Table 1. Participant Characteristics

	Mean ± Std. Deviation	Range
Age (years)	25.4 ± 4.8	19-34
Height (meters)	1.6 ± 0.1	1.3-1.6
Weight (kg)	72.5 ± 14.6	51.3 – 101
Sex male (n)	13	

Circumferential Measurements (cm)	Mean ± Std. Deviation Pre-intervention
Waist (cm)	92.8 ± 12.4
Hip (cm)	106 ± 11.8
Calf (L cm), (R cm)	(37.7 ± 4.4), (37.8 ± 4.6)

Table 2. Comparisons of the numbers of gait deviations and comfortable gait speed before and after intervention.

Total Deviations of	Pre-Intervention mean ± SD	Post-Intervention mean ± SD	p-Value
Gait Cycle	79.9±25	58.2±27.1	0.003*
Weight Acceptance Phase (WA)	11.8±4.9	9.7±5.7	0.088
Single Limb Support Phase (SLS)	22.6±6.4	16.2±6.7	0.004
Single Leg Advancement Phase (SLA)	45.4±15.7	32.3±15.9	0.006
Hip	18.5±5.3	12.8±7.9	0.005*
Ankle	13.9±5.58	8.5±6.6	0.000*
Knee	10.4±4.1	6.9 ±4.4	0.009
Comfortable Gait Speed (m/s)	0.82 ±0.21	0.98 ± 0.22	0.004*

SD= standard deviation, *= significant P-Value <0.0071

Discussion

The purpose of this study was to determine the effectiveness of a 12-week remote combined exercise intervention on the qualities of gait in adults with Ds. Overall, statistically significant improvements in gait were seen in comfortable gait speed and a reduction of total deviations in the gait cycle; specifically, a reduction in deviations in in single leg stance and single leg advancement, and deviations previously seen at the hip and ankle. Our findings agree with the hypothesis that a 12-week exercise intervention can increase gait speed and reduce the number of gait deviations seen in adults with Ds.

The importance of gait speed has been thoroughly investigated with regards to the impact on mortality and incidence of cardiovascular disease.[24] Gait speed has also been described in the literature as the sixth vital sign as it related to an individual's functional mobility.[25] Bohannon and Wang demonstrated the mean gait speed of adults aged 18-85 was 1.12(+/- 0.23) meters per second.[18] A systematic review by Bohannon and Glenny analyzed the gait velocity in older adults with multiple sclerosis, hip fracture, and stroke with the 4mWT and found that changes in gait speed from 0.10 to 0.20m/s may be significant across different patient populations.[26] Similarly, Goldberg and Schepens have previously used the 4mWT to assess gait speed in older adults, and reported that significant change in gait speed must exceed 0.108m/s to account for any measurement errors.[19] The results of our study demonstrated a statistically significant improvement in CGS after a 12-week exercise intervention of 0.16m/s, which complements the findings of Bohannon and Wang and exceeds the previously stated significant changes in gait velocity in the studies of gait speed. Zago et al. explains that a reduced gait velocity and quality of postural reactions in Ds leads to compensatory movement patterns in the gait cycle which can highlight that improving gait velocity may reduce the number overall compensation in gait patterns.[27] The 12-week exercise intervention during this study focused on core, hip and lower extremity strengthening which allows the muscles frequently used during gait to create joint and trunk stability to facilitate a more efficient gait pattern.

Instrument-assisted gait analysis is the gold standard for identifying and evaluation gait deviations; however, due to the COVID-19 pandemic the social distancing requirements and stay at home orders were considered when determining appropriate methods to evaluate gait characteristic in individuals with Ds. Our work highlighted the importance of using OGA to identify improvements in different tasks and body parts during gait. Several studies have stated that there is decreased stability in individuals with Ds and this stems from neuromuscular abnormalities that involve hypotonia, ligamentous laxity, and muscular weakness.[8,28] However, joint stiffness, which was measured by the flexion-extension moment and angle during gait cycle, was noted specifically in the hip and ankle joint level with gait pattern. Cimolin et al. suggest that the increased joint stiffness at the hip and ankle seen within their study may possibly be due to muscle weakness in individuals with Ds. This is due to the fact that individuals with Ds, who generally have decreased muscle strength as compared to typically developing individuals, and as a result, have increased hip and ankle stiffness as a compensatory mechanism to counteract stability issues that were observed with ankle and hip balance strategies.[9] In the same study, they did not analyze stiffness in the knee joint level due to not having any kinematic and kinetic linear relationship. With improvements in muscle strength from the exercise intervention, this may have improved the stability of the participants and optimizing their overall reactive strategies from the ankle and hip, thereby leading to fewer gait deviations. This may contribute toward a significant decrease of major/minor deviations that were observed within the study.

Adults with Ds have decreased stability and increased body kinematic deviations with their gait pattern compared to typically developing individuals.[28] The primary body deviations observed were increased anteroposterior and mediolateral oscillations during gait and increased step width as well as reduced step length, and subsequently reduced gait velocity related to decreased stability.[27] During the gait cycle, there is less stability from single limb support during the SLS and SLA phases as compared to WA, which consists of double limb support through its phase of gait. After completion of the 12-week exercise intervention, the significant improvements seen within our participants in SLS and SLA may have been

due to the improved stability and decreased number of body deviations that were observed using the OGA. Exercises that focus on strengthening the lower extremities and improving dynamic balance, this may have contributed to improvements with individuals' SLS that were observed. According to a previous study, there were significant improvements in muscle strength within the lower extremities and balance after utilizing a 12-week exercise intervention that may have contributed toward better overall gait stabilization with stance phase.[4] Additionally, in the OGA, there are significantly fewer major and minor deviations that can be analyzed in WA phase compared to SLA and SLS (Figure 1). As a result, this finding could be attributed to increased variability observed through more possible deviations within the SLA and SLS phases. The variability in body deviations seen within adults with Ds during their gait cycle is primarily due to different compensatory patterns utilized for correcting decreased stability. Zago suggests that intensive gait training may produce long term improvements within this population.[27]

Although most gait parameters showed a significant improvement, there were two areas in which no significant change occurred. The p-value for knee deviations is below 0.05, however it is not considered statistically significant due to the multiple testing correction. This is likely due to an insufficient power of this sample to detect all differences. Although a power analysis was performed for this study, this was not based on individual sub scores of the OGA and may therefore not be able to detect all the differences. The other area of data collection that showed no significant improvement is the WA period. This is likely due to the WA period consisting of a lower number of possible gait deviations compared to the other phases, resulting in smaller variations in the data. The WA period therefore likely had insignificant changes due to the small data set being analyzed under the same power as the larger data sets of the other two gait periods.

Further studies may be conducted to fully determine the impact of these improvements on a participant's overall quality of life. Another question to be answered in future studies is whether these musculoskeletal improvements can be maintained after the exercise program was completed. Lastly, this 12-week exercise

program may be performed again, in-person, after the COVID-19 pandemic has ended to observe gait improvements with more sophisticated measures to measure and analyze gait impairments and gait speed.

Limitations

Overall, this study provides support for the benefits of exercise interventions for improving gait velocity and gait impairments in adults with DS; however, there are some limitations within this study due to barriers and challenges resulting from observational gait analysis in a telehealth protocol via Zoom. First, the data analysis was observed through different recording devices by participants, which created variability with the quality of some images. However, participants were all given the same set of instructions for recording which included using a cell phone, tablet, or laptop with video camera, recording in an indoor space with sufficient space and lighting, and ensuring that the camera was positioned to include the entirety of the participant's body in the frame. These requirements were ensured in-session by a virtual observer and the administrator of the tests. To ensure video recordings captured all aspects of each participant's gait and deviations present, we utilized multiple frames of the participant's gait cycle from an anterior, posterior and both lateral views to observe any deviations not seen in the different frames and had satisfactory results. Video analysis was limited at times by frame rates and resolution related to the variability in participant device and internet connectivity, resulting in reduced clarity of images. Second, this study lacked the standardization typically seen in experimental studies which were seen in variability in each participants clothing, surface compliance each participant ambulated on, and background distractions that are unique to each of the of the participant's home environment. Participants were consistently asked to wear comfortable shoes, and to wear shorts and t-shirts of differing colors for ease of analysis. These variables may have affected reproducibility of our tests and measures. An additional limitation is that this study was unable to use a control group. There was no other group to compare our results to help validate our clinical findings.

Conclusion

Gait speed and observable gait deviations improved significantly after a 12-week remote combined exercise program for adults with Ds. The results of this study support clinicians using remote combined exercise interventions addressing foundational movement, hip strengthening, visual-vestibular training, and cardiovascular endurance, to improve gait speed and reduce gait deviations in individuals with Ds. The success of the telehealth protocols used in this study furthermore provides evidence that telehealth may continue to be a valid intervention and data collection method in future research. Overall, this study demonstrates that exercise interventions are effective to address mobility impairments in adults with Ds as evidenced by the increase in gait speed and by the reduction of overall gait deviations.

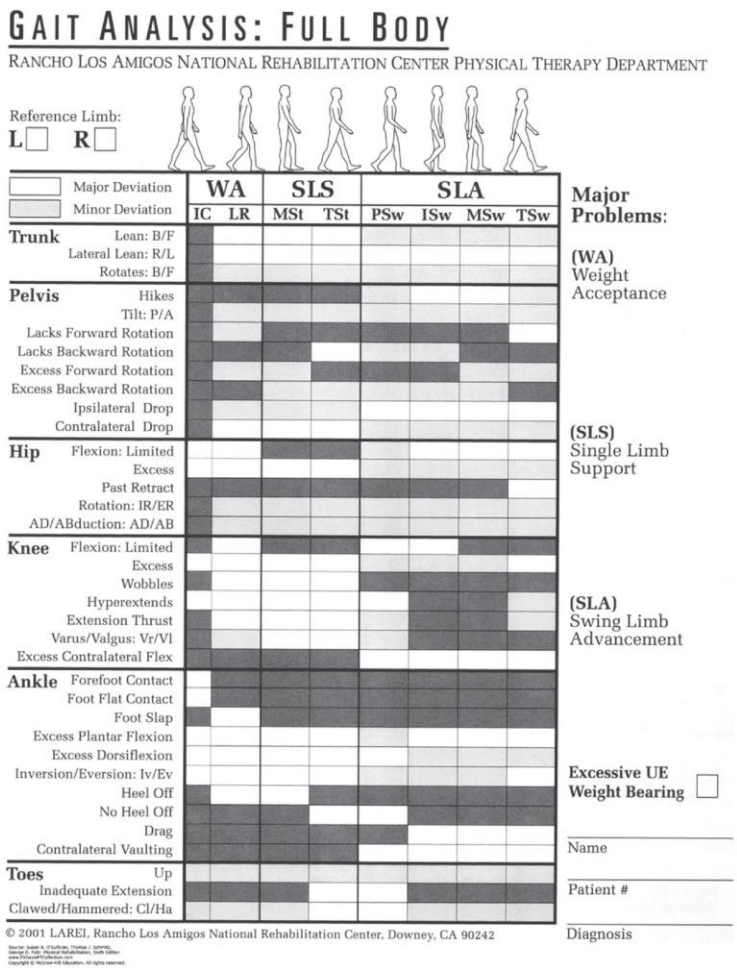
Appendix

Appendix A: Complete OGA Data Collection

Paired Samples Statistics						Paired Samples T-Test							Wilcoxon Signed Rank Test
	Deviations by Totals	**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**	**Mean diff**	**SD**	**SE Mean**	**95%CI Lower**	**95%CI Upper**	**t**	**df**	**Sig. (2-tailed)**	**Sig. (2-tailed)**
Pair 3	**Gait Cycle Total Deviations Pre-Intervention**	79.94	18	25.16	5.93	21.78	24.92	5.87	9.38	34.17	3.707	17	0.002*	0.003
	Gait Cycle Total Deviations Post-Intervention	58.17	18	27.10	6.39									
	Deviations by Ranchos Los Amigos Generalized Gait Phase	**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**	**Mean diff**	**SD**	**SE Mean**	**95%CI Lower**	**95%CI Upper**	**t**	**df**	**Sig. (2-tailed)**	**Sig. (2-tailed)**
Pair 4	**Weight Acceptance Total Deviations Pre-Intervention**	11.83	18	4.88	1.15	2.11	4.95	1.17	-0.35	4.57	1.811	17	0.088	0.148
	Weight Acceptance Total Deviations Post-Intervention	9.72	18	5.68	1.34									
Pair 5	**Single Leg Stance Total Deviations Pre-Intervention**	22.61	18	6.44	1.52	6.39	7.91	1.86	2.45	10.32	3.426	17	0.003*	0.004
	Single Leg Stance Total Deviations Post-Intervention	16.22	18	6.66	1.57									
Pair 6	**Swing Limb Advancement Total Deviations Pre-Intervention**	45.39	18	15.72	3.70	13.11	14.93	3.52	5.69	20.53	3.727	17	0.002*	0.006
	Swing Limb Advancement Total Deviations Post-Intervention	32.28	18	15.94	3.76									
	Deviations by Body Region	**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**	**Mean diff**	**SD**	**SE Mean**	**95%CI Lower**	**95%CI Upper**	**t**	**df**	**Sig. (2-tailed)**	**Sig. (2-tailed)**
Pair 17	**Total Hip Deviations Pre-Intervention**	18.50	18	5.31	1.25	5.72	7.27	1.71	2.11	9.34	3.341	17	0.004*	0.005
	Total Hip Deviations Post-Intervention	12.78	18	7.92	1.87									
Pair 18	**Total Knee Deviations Pre-Intervention**	10.39	18	4.12	0.97	3.44	4.88	1.15	1.02	5.87	2.996	17	0.008*	0.009
	Total Knee Deviations Post-Intervention	6.94	18	4.41	1.04									
Pair 19	**Total Ankle Deviations Pre-Interventions**	13.94	18	5.58	1.31	5.44	5.16	1.22	2.88	8.01	4.477	17	0.000*	0.000
	Total Ankle Deviations Post-Interventions	8.50	18	6.64	1.56									

*= Significant p-value < 0.0071

Appendix B: Ranchos Los Amigos Observational Gait Analysis Form



GAIT ANALYSIS: FULL BODY

RANCHO LOS AMIGOS NATIONAL REHABILITATION CENTER PHYSICAL THERAPY DEPARTMENT

Reference Limb:
L☐ R☐

Major Deviation
Minor Deviation

		WA		SLS		SLA			
		IC	LR	MSt	TSt	PSw	ISw	MSw	TSw
Trunk	Lean: B/F								
	Lateral Lean: R/L								
	Rotates: B/F								
Pelvis	Hikes								
	Tilt: P/A								
	Lacks Forward Rotation								
	Lacks Backward Rotation								
	Excess Forward Rotation								
	Excess Backward Rotation								
	Ipsilateral Drop								
	Contralateral Drop								
Hip	Flexion: Limited								
	Excess								
	Past Retract								
	Rotation: IR/ER								
	AD/ABduction: AD/AB								
Knee	Flexion: Limited								
	Excess								
	Wobbles								
	Hyperextends								
	Extension Thrust								
	Varus/Valgus: Vr/Vl								
	Excess Contralateral Flex								
Ankle	Forefoot Contact								
	Foot Flat Contact								
	Foot Slap								
	Excess Plantar Flexion								
	Excess Dorsiflexion								
	Inversion/Eversion: Iv/Ev								
	Heel Off								
	No Heel Off								
	Drag								
	Contralateral Vaulting								
Toes	Up								
	Inadequate Extension								
	Clawed/Hammered: Cl/Ha								

Major Problems:

(WA) Weight Acceptance

(SLS) Single Limb Support

(SLA) Swing Limb Advancement

Excessive UE Weight Bearing ☐

Name

Patient #

Diagnosis

Appendix C: Observational Gait Analysis Score Sheet (Google Sheets, 2021)

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

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Curriculum Vitae

Robert Lum
Los Angeles, California
robertlum@yahoo.com

Education

University of Nevada, Las Vegas – Las Vegas, Nevada 2019-2022

- Doctorate Physical Therapy

University of California, San Diego – San Diego 2013-2017

- Bachelor of Science in Public Health

Licensure

Nevada Physical Therapy Board - License Pending Graduation May 2022

Certifications

American Heart Association, BLS for Healthcare Providers May 28, 2020

Collaborative Institutional Training Initiative March 19, 2020

HIPAA Training Certified June 17,2019

Employment / Clinical Experience

Student Physical Therapist – Boulder City Hospital January 2022 – April 2022

- Developed plan of care for a variety of orthopedic conditions and geriatric population
- Utilized communication skills to develop rapport with patient and family members

Student Physical Therapist –Valley Hospital Medical Center Sept 2021 – December 2021

- Developed plan of care for patients post-operative
- Managed and rehabilitated patients using wound care and therapeutic exercises

Student Physical Therapist – Advanced Health Care of Henderson July. 2021 – September 2021

- Utilized therapeutic exercise and patient education for long term patient care
- Collaborated with other healthcare providers to discuss patient progress and goals

Student Physical Therapist – Tru Physical Therapy Dec 2020 – January 2021

- Developed plan of care and engaged in patient education with patients
- Utilized therapeutic exercises and manual therapy to rehabilitate patients

Student Physical Therapist – Select Physical Therapy, Blue Diamond July 2020 – August 2020

- Developed plan of care and engaged in patient education with patients
- Utilized manual therapy and exercise intervention to rehabilitate patients

Current Research Activity

Graduate Research – University of Nevada Las Vegas – Physical Therapy Department March 2020 - Present

- Hilgenkamp T, Ho K, Lum R, Roys C, Stopka D, Souza T. Examining the effects of a 12-week exercise program on gait in adults with Down syndrome

Continuing Education

Supplemental Lectures

- Stephen Hunter, PT, DPT, OCS, FAPTA, Director of Internal Process Control, Rehabilitation Services, Intermountain Healthcare, Salt Lake City, Utah, "Standardized care processes, patient outcomes, and clinical decision making" Dec 2020

Christopher Roys
c.royspersonal@gmail.com| Las Vegas, NV

Education

Doctor of Physical Therapy (DPT) — Anticipated Graduation May 2022

University of Nevada, Las Vegas

Kinesiology, B.S. — Graduated May 2019
Business Administration & Management, Minor
University of Nevada, Las Vegas

Licensure

Doctor of Physical Therapy License — Anticipated May 2022

Employment:

Teaching Assistant | ***University of Nevada, Las Vegas — Physical Therapy Dept.*** — August 2020 – June 2021

- Utilize communication skills to educate students and work with faculty.
- Led supplemental instruction for foundational orthopedic courses
- Collaborated with other teaching assistants to educate first-year students

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PT Technician, Inventory Manager | ***Synergy Physical Therapy— Las Vegas, NV*** — December 2015 – September 2021

- Over 3,000 hours of patient interaction experience including administering modalities, instruction of exercises, and relaying information to supervising PT
- Managed inventory logistics across 4 clinical locations, communication and problem-solving

Clinical Experiences:

Student Physical Therapist | ***Dignity Health Physical Therapy — Las Vegas, NV*** — January 2022-April 2022

- Outpatient orthopedics clinic with FCE, worker's compensation, and direct access
- Presented in-service presentation on "Therapy Considerations for Veterans"
- Wide variety of patient populations in collaboration with OT

Student Physical Therapist | ***Encompass Health Rehabilitation — Las Vegas, NV*** — September 2021 – December 2021

- Interdisciplinary collaboration with nursing, OT, SLP, and dieticians
- Presented in-service presentation on "Therapy Considerations for Chronic Stroke"
- Extensive experience with post-stroke diagnoses and deconditioned individuals

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Student Physical Therapist | ***Reno VA Medical Center, VHAREN— Reno, NV*** — July 2021 – September 2021

- Cardiovascular, neurological, post-surgical Veteran's population
- Presented in-service presentation on "Bedside Tests in Acute Care"
- Experience with wound care, SLP, observed 3 orthopedic surgeries

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Student Physical Therapist | ***Wright Physical Therapy – Twin Falls, ID*** — July 2020 – August 2020

- Rural facility with high Medicare and Medicaid caseload
- Presented in-service presentation on "Functional Movement Disorders"
- Performed community education with PT staff to reduce risk of sports-related injury and participated in aquatic therapy sessions

Leadership:

Class President | ***University of Nevada, Las Vegas – DPT Class of 2022*** August 2019 – Present

- Worked closely with faculty, staff, and other students to make decisions under shared governance model
- Communicated class concerns to faculty and worked to resolve disagreement
- Worked with other class officers to organize volunteer events and other resources

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Student Body President | ***University of Nevada, Las Vegas- "CSUN"***

- Designed and executed budgetary priorities for the student body, $1.2-$1.5M USD — June 2017– May 2019
- Advocate for students at a statewide level with the Nevada Board of Regents
- Elected to 2 terms in office, achieved improved safety mechanisms and tuition guarantees

Research Experience

Participate/Create:

Student Investigator | ***University of Nevada, Las Vegas*** December 2019 – May 2022

"Effects of a telehealth 12-week exercise intervention on gait speed and gait deviations in adults with Down syndrome"
Thessa Hilgenkamp, Ph.D., Kai-Yu Ho PT, MSPT, Ph.D.

- All-virtual format for data collection and administering interventions
- Served as one of three "testers" in which I facilitated data collection with the participant and their caretaker while ensuring participant comfort
- Poster presentation at APTA CSM 2022 in San Antonio, Texas

Consume/Share:

UNLV DPT "Brown Bag" Lectures | **University of Nevada, Las Vegas** Spring 2020

- *Dr. Efosa Guobadia – Global and Community Health*
- *Dr. Ashley Reagor – "Starting a private practice"*
- *Dr. Natalie Weeks-O'Neil – "Native American Health & Cultural Competency*
- *Dr. Lisa Van Hoose – "Grief and Loss Felt By All During Social Crisis"*

UNLV DPT Distinguished Lecture Series | **University of Nevada, Las Vegas** 2019-2020

- *Dr. Catherine Lang – "Attempting to improve stroke rehabilitation across translation pathway"*
- *Dr. Catherine Lang – "Wearable sensors are changing how we think about movement and rehabilitation"*
- *Dr. Anthony Delitto – "A Randomized Clinical Trial of Treatment for Lumbar Spinal Stenosis"*
- *Dr. Anthony Delitto – "Exploratory Study of Different Doses of Endurance Exercise in People with Parkinson's Disease"*

Professional Development

APTA Combined Sections Meeting | **San Antonio, Texas** February 2022

- Presented poster *"Effects of a telehealth 12-week exercise intervention on gait speed and gait deviations in adults with Down syndrome"* and attended 10+ sessions

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APTA Wellness in Physical Therapy | **Online Seminar** September 2021

APTA Combined Sections Meeting | **Virtual** February 2021

OTAGO Fall Prevention Training| **Virtual** February 2021

American Association of Sports Physical Therapy, TCC Conference 2020 | **Virtual** December 2020

UNLV DPT Virtual Student Panel | **University of Nevada, Las Vegas** September 2020

- Served as a DPT student panelist to discuss the challenges, growth opportunities, and benefits of entering the physical therapy program to prospective students

APTA Combined Sections Meeting | **Denver, Colorado** February 2020

- Attended 10+ sessions with a focus on neurological, sports, orthopedics and healthcare policy

Service

Sandies for Shelby (SCI Survivor Fundraising Event) | **Las Vegas, NV** November 2020

UNLV PT Homecoming Event | **Las Vegas, NV** November 2019

PT Day of Service -- Clean the World LV | **Las Vegas, NV** October 2019

Membership in Professional Organizations

Member | **American Physical Therapy Association** August 2019 – Present
Section membership: *Health Policy, Neurological, Orthopedics, Research, Sports*

Taylor Souza, SPT
Las Vegas, NV | taysouza3@yahoo.com

Education

University of Nevada, Las Vegas **Estimated Graduation**
May 2022
Doctor of Physical Therapy (DPT)

University of Nevada, Reno **Aug 2014 –**
May 2018
Bachelor of Science (BS) in Kinesiology, Cum Laude

Licensure

Nevada State Board of Physical Therapy Examination **Estimated**
April 2022

Work Experience

Renown Rehabilitation Hospital | *Rehabilitation Technician* **Jul 2018 – Mar 2019**

Inpatient Rehabilitation

- Supported therapists and patients during therapy sessions to ensure safe patient centered care
- Individualized care while considerating the emotional and mental impact of various injuries
- Monitored patients with dysphagia during meals to ensure proper strategies
- Collaborated with Physiatrist, Physical, Occupational, and Speech Therapists to care for complex patients
- Utilized Epic charting system to review patient diagnoses.

Clinical Experience

Fyzical Therapy and Balance Centers | *Student Physical Therapist* **Jan 2022 – Present**

Outpatient Orthopedics

- Utilized core outcome measures to assess fall risk and functional capacity in the geriatric population
- Delivered skilled therapy services through manual therapy and therapeutic exercises for patients with orthopedic injuries and neurological impairments
- Progressed patients safely within their post-operative protocols to promote optimal recovery
- Evaluated and treated patients with Benign paroxysmal positional vertigo and vestibular hypofunctions
- Educated patients with vertigo about our balance systems and the role of habituation training

Summerlin Hospital & Medical Center | *Student Physical Therapist* **Sept 2021 - Dec 2021**

ICU/Medical Surgical Inpatient Acute

- Educated patients on surgical precautions to ensure safety with functional mobility
- Participated in wound care evaluations and application of dressings to promote tissue healing
- Provided continuity of care through accurate documentation and development of patient care plans

- Identified appropriate discharge recommendation to promote safe return to prior level of function
- Skillfully reviewed ICU medical records to determine contraindications to therapy services and mobility
- Communicated with Physicians, Nursing Staff, and Case Managers about patient's functional mobility to advocate the need for skilled therapy services
- Presented an in-service on standardized outcome measures to assess balance, fall risk, and functional capacity

Reno Sport and Spine Institute | *Student Physical Therapist* **Jul 2021 – Sept 2021**

Orthopedic Outpatient

- Evaluated musculoskeletal injuries with evidence based special testing to determine a clinical diagnosis
- Provided skilled services to reduce pain, promote mobility, and optimize capacity in patients with injuries
- Utilized targeted interventions to facilitate improve muscular strengthen and endurance for activities of daily living, work-relates tasks, and recreational activities
- Educated patients on examination findings and plan of care to facilitate return to prior level of function
- Directed Physical Therapy Aides in therapeutic exercise procedures to ensure proper techniques and cues
- Presented an in-service on improving patient compliance through theoretical models and optimal prescription of therapeutic interventions.

Great Basin Physical Therapy | *Student Physical Therapist* **Jul 2020 - Aug 2020**

Outpatient Orthopedics

- Developed individualized resistance, balance, and aerobic therapeutic exercises
- Engaged educational material for Osteopathic approach to evaluate and treat the spine
- Communicated with PTs, PTAs Technicians to seamlessly transition patient care
- Improved documentation efficacy of initial evaluations, progress, and daily notes
- Presented an educational in-service on use and effectiveness of PRP Injections for Knee Osteoarthritis

Research Experience

University of Nevada, Las Vegas – Department of Physical Therapy **Jan 2020-May 2022**

- Research focused on analyzing changes in gait characteristics in adults with Down syndrome after implementing the Mann Method Exercise Program

Presentations

American Physical Therapy Association
Feb 2022

- Souza, T. & Roys, C. Effects of a telehealth 12-week exercise intervention on gait speed and gait deviations in adults with Down syndrome. Poster presented at the 2022 American Physical Therapy Association Combined Sections Meeting; February 3rd 2022; San Antonio, Texas.

Professional Memberships and Activities

American Physical Therapy Association | *Member* **Aug 2019-Present**

- Advocated for physical therapist and physical therapy students
- Exposure to Fedral and State Laws and Regulations related to Physical Therapy
- Understanding clinical practice guidelines for evidence based care for patients

Annual UNLV Fall Screening Prevention
Sept 2020

- Utilized the CDC's STEADI toolkit to assess community members for fall risk
- Conducted 4 Stage Balance Test with participants via Zoom
- Educated participants on level of fall risk and preventative strategies

Certifications

- BLS - American Heart Association **Jun 2020-Jun 2022**
- HIPAA Training Certified **Jun 2019**
- Blood-Borne Pathogens Training Certified **Jun 2019**

Daniel Stopka
dstopka@icloud.com

Education

DPT University of Nevada, Las Vegas (Las Vegas, NV) 2019-2022
Physical Therapy

BS University of Nevada, Reno (Reno, NV) 2015-2019
Kinesiology

Licensure

- Washington State Board of Physical Therapy - License pending graduation May 13, 2022

Certifications

- American Heart Association, BLS for Healthcare Providers (June 2020- June 2022)
- HIPPA training certified (June 2019)
- Collaborative Institutional Training Initiative (March 2020-March 2025)

Clinical Experience

- **Select Physical Therapy**
  4980 W Sahara Ave Suite 260, Las Vegas, NV 89146 July 2020-August 2020
  - Performed patient care under CI supervision
  - Learned time management skills in a busy outpatient clinic
  - Created plans of care for a wide variety of diagnoses and populations
  - Became proficient with online documentation system

- **Renown Regional Medical Center**
  115 Mill St, Reno, NV 89502 July 2021-September 2021
  - Performed acute physical therapy services to an underserved population
  - Extensive experience working with Covid-19 patient population
  - Worked often with OT and SLP teams to deliver team care as needed
  - Gained experiences on other floors including cardiac/ cardiac ICU, pediatrics, trauma/ TICU, neurology/ NICU, and SICU
  - Responsible for recommending appropriate discharge locations
  - Worked independently by the end of the experience

- **LCCA Las Vegas**
  6151 Vegas Drive, Las Vegas, NV 89108 September 2021-December 2021
  - Performed sub-acute physical therapy services in a SNF environment
  - Experience working with a wide range of patient populations

- Worked with OT and SLP teams frequently
- Exposure to wound care and paraplegic rehabilitation
- Worked independently for most of the experience

- **Therapeutic Associates West Valley**
  210 S 72nd Ave #130, Yakima, WA 98908 January 2022-April 2022
  - Performed outpatient physical therapy services with a rural population
  - Independently created and executed successful plans of care for a wide variety of diagnoses
  - Experience with both pediatric and geriatric populations
  - Frequently performed a range of manual techniques supplemented by modalities
  - Exposure to IASTM, kinesiotaping, and blood flow restriction techniques for various conditions
  - Proficient at documentation with the Athena medical system

Professional Organizations

- Student Member of the American Physical Therapy Association (September 2019-Current)

Research

- Lum R., Roys C., Stopka D., Souza T, Hilenkamp T., Ho K. “Effects of a 12-week telehealth exercise intervention on gait speed and gait deviations in adults with Down syndrome”