Effects of a Multi-Modal Gait Training Program in an Individual with Chronic Stroke: a Case Study

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Abstract

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ABSTRACT

Purpose: Multi-modal gait training (MMGT) may improve impairments and functional limitations in individuals' post-stroke. The purpose of this case study was to investigate effects of MMGT on gait and balance outcomes immediately post-intervention, 30-day short term (ST) and 1-year long term follow-up periods. **Method:** A 63-year-old patient, eight years post-stroke, participated in a MMGT program that included evidence-based gait interventions: unilateral treadmill training, inclined treadmill training at 8%, and over-ground fast walking. The eight sessions lasted 45-minutes each and consisted of the three interventions lasting 10-minutes each with rest breaks. **Results:** Self-selected (SS) and fastest comfortable gait speed revealed meaningful changes (post-intervention, however, only SS gait speed maintained improvements at ST measurements). The Activities Balance Confidence Scale (ABC) increased from 19% to 28% at 1-year. **Conclusions**: MMGT is soundly grounded in the contemporary principles of neuroplasticity. This case study confirmed that the combination of three task-specific and intense gait training interventions are safe and feasible for persons in the chronic phase of stroke. While ST results showed this MMGT improved all study outcomes from baseline to immediate post-intervention, substantial gains were retained only for SS gait speed and ABC scale at the 1-year follow-up.

Keywords: stroke, gait training, unilateral, incline, gait adaptability

INTRODUCTION

Stroke is the leading cause of disability in the United States, resulting in a variety of deficits in functional mobility and quality of life.[1-4] Common impairments in individuals' post-stroke are hemiparesis, impaired motor control, and decreased postural control. These impairments are shown to correlate with gait deficits, such as slower walking speed, asymmetrical spatial-temporal gait patterns, and increased energy expenditure.[1,2,5] Inability to walk is a critical factor contributing to physical disability status post-stroke.[6] Importantly, gait and balance deficits together contribute to long-term disability post-stroke.[7] Given that residual deficits in gait and balance are significant predictors of long-term disability in the post-stroke population, it is not surprising that several studies report the primary goal for rehabilitation is to improve walking.[8]

The majority of the existing evidence for walking recovery focuses on using singular approaches to improve gait and balance outcomes, with little evidence demonstrating the application of multiple modes that target multiple impairments and functional limitations post-stroke.[7, 9-13] For example, treadmill-based gait training is strongly supported in the literature as an approach to walking recovery post stroke, because it provides a permissive environment that allows intense repetitive task specific practice that can facilitate neuroplasticity.[14] Importantly, evidence supports unilateral training of the affected or less affected leg on the treadmill to improve walking outcomes using the principle of forced use of the lower extremity.[8,10,15]

Kam et al. demonstrated the effects of weightbearing acceptance on the involved limb improved both stepping threshold and stepping leg which may be advantageous to overcome dynamic balance impairments.[11] Emerging evidence also supports inclined treadmill walking to maximize functional strengthening of the lower extremities. Inclining the treadmill of at least 8 degrees has been found to result in increased power when compared to level walking.[12,16] Ahmed et al. found significant improvement in gait speed within a post-stroke sample following inclined treadmill training. Additionally, greater gains were noted when compared to a control group that trained on a treadmill without an incline.[13] Lastly, while treadmill training appears to be a beneficial mode to improve gait and balance outcomes, overground gait training is critical to translate and maximize gains from the treadmill to natural overground environments.[7]

Importantly, each of these singular modes of intervention (i.e., unilateral step training using the treadmill, incline treadmill training and overground training) are task-specific and can be delivered in an intense manner and additionally align with the current practice recommendations for gait improvement post-stroke. Current clinical practice guidelines promote the application of task-specific, intense, and repetitive gait training interventions to improve walking speed and endurance in chronic (> 6 months) non-progressive neurologic populations (CPG guidelines).[17] In summary, experimental evidence and practice recommendations supports the use of each of these singular task-specific approaches to improve gait and balance performance post-stroke. However, multi-modal gait training programs that combine these singular evidence-based approaches should be evaluated.
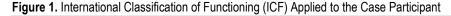
Combinatorial approaches to gait training are suggested to maximize neuroplasticity and emerging clinical paradigms suggest use of several therapies to maximally benefit functional outcomes.[18] Current clinical practice guidelines additionally emphasize application of task-specific, intense, and repetitive gait training interventions to improve walking speed and endurance in individuals with chronic stroke. Therefore, the aim of this study was to test the safety and feasibility of a multi-modal gait training (MMGT) program comprised of evidence-based task-specific interventions of unilateral lower extremity step training, inclined treadmill training, followed by the transfer to overground walking training involving multi-directional training to improve gait adaptability. The MMGT program appears to be a pragmatic approach to translate multiple intervention modes within a singular treatment session delivered within a typical episode of care. Since the purpose of this study was to develop the MMGT program, establish the safety and feasibility by evaluating the preliminary efficacy, we used a single case study approach to deliver the MMGT intervention on an individual with chronic post-stroke hemiparesis. Immediate, short term (ST), and long-term (LT) outcomes of gait and balance were recorded within this case study.

METHODS-
Participant

The participant selected for this case study met the following inclusion criteria: chronic stroke > 6 months, age 18-75 years old, and walking with a gait speed <.8 meters per second (m/s) suggesting presence of substantial impairments. In addition, the participant did not present with any co-morbidities that would exclude from participation in structured activity or exercise. The participant was 63-year-old female eight years post right (R) cerebral vascular accident (CVA) with resultant left (L) hemiparesis. She was a retired x-ray technician and lived alone while her husband who worked out of state would visit her as able. She could drive independently with modifications to her vehicle, dress independently, microwave food for herself, and bathe by herself. Occasionally, her niece helped with cleaning and laundry as needed. She enjoyed volunteering in the community and visiting with family. Prior to the study, her daily physical activity consisted mostly of walking short distances in her home.

At the time of the study, the participant demonstrated a step to gait pattern and walked with modified independence using a narrow-based quad cane for short distances. The participant also wore a functional electrical stimulation (Bioness) device on her L lower extremity and preferred the use of a scooter for long distance ambulation. The participant acquired the Bioness device > 5 years prior to the study and consistently wore the device while ambulating inside and outside the home to facilitate foot clearance during swing. She had not received structured physical therapy for gait and balance deficits in over two years and did not receive any additional physical therapy during the duration of study participation. Her medications consisted of Abilify (15mg), Avalide (300/15mg), Fetzima ER (120mg), Lipitor (10 mg), Toprol XL (100 mg), Vesicare (5 mg), Xanax XR (1 mg), and Zanaflex (4 mg). The participant reported no change in her medications during the duration of the study. Other significant medical history included history of depression, anxiety disorder, low back pain, reported fear of falling, and a history falls. The participant's functional abilities described using the International Classification of Functioning, Disability and Health (ICF) framework shown in Figure 1. The participant provided written informed consent approved by the Institutional Review Board of the University of St. Augustine for Health Sciences.

Figure 1. International Classification of Functioning (ICF) Applied to the Case Participant

Case Description: 63 yo Female with 8 yrs Chronicity of R CVA with L Hemiparesis

Body Structure/Function

Motor Recovery (*FMA)
Gait Speed/Symmetry
(*Instrumental Gait Analysis)

Activity Limitation

Endurance (*6MWT)
Dynamic Balance

Participation Restrictions

Fear of Falling (*ABC)
Limited Social Outings

Personal Factors

Functional ES L Ankle
Narrow Base Quad Cane
Depression
Fear of Falling

Environmental Factors

Lives Alone
2 Stairs to Enter Home
Supportive Family

Study Design and Outcome Measures
This case study consisted of repeated measures over the course of one year in an individual with chronic stroke. Outcome measures were assessed at the following time points; baseline (pre), immediately after completion of the eight sessions of the MMGT program (post), at a 30-day follow-up (ST), and at 1-year long-term follow-up (LT). Testing was performed indoors in a university building and lasted approximately one hour. Two licensed physical therapists with board certification in neurologic physical therapy and combined clinical practice of at least 17 years were present for all data collection time points and interventions. The same licensed physical therapist administered all the assessments (pre- and post-). Standard safety procedures such as vitals monitoring and guarding for safety were followed with the assistance of another licensed physical therapist. The participant walked with a narrow base quad cane during all assessment time points. The participants' fear of falling prevented her from walking without assistance and the participant walked with modified independence (Mod I) using a quad cane throughout the testing. Stand by assistance was provided initially and did not significantly change across testing time points. Rest breaks were offered to the participant, as needed, during the testing. The investigators selected four of the six core set of outcome measures recommended for adults with neurologic conditions across the ICF (Figure 1) for a comprehensive assessment of impairments, activity limitations and participation restrictions.[19]

ICF Body Structure/ Impairment Domain
Spatial-Temporal Parameters of Gait
Spatial-temporal parameters of gait included in study were gait speed (m/s) at self-selected (SS) and fastest comfortable (FC) speeds, percentage of swing and stance phase, and bilateral step lengths. Spatial -temporal parameters were measured using an instrumented walkway, the GAITRite® (Hanover, PA) electronic system. The GAITRite® is a 5.3-meter-long portable electronic walkway that detects footfalls via pressure-activated sensors embedded within the mat and has demonstrated excellent reliability and validity for measurement of spatial-temporal gait parameters.[20,21,22] Assessment of gait speed in particular has shown to provide an accurate assessment of gait ability post-stroke and gait speed as an outcome measure is shown to have excellent reliability and validity in the chronic stroke population. [23] Responsiveness of spatial-temporal parameters is not established but some responsiveness metrics to identify meaningful changes in gait speed after an intervention are established. The minimal detectable change (MDC) for the chronic stroke population is suggested to depend on the baseline gait speed, with a change of 0.1 m/s representing a likely meaningful change for those walking at speeds < 0.4 m/s.[24] The participant was instructed to complete the walking trials at the SS and FC speeds using the following instructions: "please walk at a comfortable, safe speed" and "please walk at a fast yet safe speed". The participant was allowed to complete the trials using her narrow base quad cane. The average speed of the two trials was used for data analysis. The 10 Meter Walk Test was used prior to each session to determine the intervention parameters.

The 10 Meter Walk Test
The *10 MWT* is an assessment tool that measures gait speed. Individuals walk a total of 10 meters, with the central 6 meters being timed for speed.[25] This assessment requires little equipment and space and can be performed at both comfortable and fast gait speeds. Flansbjer et al found excellent reliability for both comfortable (ICC=0.94) and fast (ICC=0.97) gait speed using the 10 MWT in individuals post stroke.[23] The 10MWT was only used during the intervention to establish the participant's gait speed to adjust the progression of the treadmill treatment modes.

The *Fugl-Meyer Assessment of Motor Recovery after Stroke (FMA)*
The FMA, a recovery-based outcome measure, was used to assess lower extremity motor control.[26] The FMA evaluates five domains including: motor function, sensory function, balance, joint range of motion, and joint pain using a 3-point ordinal scale with "0" being cannot perform and a "2" being performs fully. The FMA motor score has excellent test-retest reliability (ICC=0.97) in patients with hemiparesis.[27] The minimal clinically important difference for the lower-extremity FMA in the chronic stroke population is suggested to be 6 pts or more.[28] Since this case study was aimed to improve walking and balance only the lower extremity motor domain (lower extremity score = 34) was assessed with standardized procedures as published in earlier studies.[29]

ICF Activity Limitations Domain
Four Square Step Test (FSST)
The FSST is an assessment that evaluates stepping in multiple directions within four quadrants placed in a cross configuration.[30,31] The FSST has excellent interrater reliability (ICC=.99) and intrarater reliability (ICC= .82-.83) in the chronic stroke population and a mean time of 11 seconds was found to differentiate between subjects with chronic stroke and healthy subjects.[32] Minimal detectable change and minimal clinically important difference have not been established for the chronic stroke population. To begin the FSST, the participant was instructed to step from the first square to the fourth square in a clockwise manner and then immediately perform the sequence in a counterclockwise manner, as fast and as safe as possible.[31] The timing began with the first foot contacted the floor in the second square and ended when the last foot contacted the ground back in square one. The participant was instructed to stay forward facing throughout the sequence and to try not to step on the canes. The FSST was performed for two timed trials and was scored based on the fastest completed trial.[18,30]

The *Functional Gait Assessment for Postural Stability (FGA)*
The FGA was used to determine postural stability during walking tasks. The FGA consists of 10-items scored on an ordinal scale 0-3, with "0" being severe impairment and "3" being normal ambulation, totalling a 30/30 as the highest score. The FGA demonstrates excellent test-retest reliability (ICC=0.95), excellent interrater reliability (ICC=0.94), and excellent intrarater reliability (ICC=0.97) in individuals with stroke.[33,34] For individuals post stroke, the minimal detectable change (MDC) for FGA is 4.2 points.[33] Additionally, the FGA has been shown to have a lower ceiling effect when compared to other outcome measures for the post-stroke population.[33] The participant was instructed to perform to 10-items as written in the FGA document.

The *6-minute Walk Test (6MWT)*
The 6MWT measures the distance walked over 6 minutes, without physical assistance, and may include assistive devices. The 6MWT includes a 42-meter distance path marked with cones at walk around at each end.[35] Excellent test-retest reliability exists for

distance covered in meters (ICC= 0.99) in the post-stroke population.[23,35] For the 6MWT, the increase of 36.6 m or a 13% change meets MDC and 34.4 m meets the MCID for individuals with stroke.[23,36] The participant was instructed to "walk as far as possible" using her small-based quad cane over a straight path of 42 meters distance designated by cones to walk around at each end for six minutes.

ICF Participation Restriction Domain
The Activities-Specific Balance Confidence scale (ABC)
The ABC is a 16-item questionnaire that can be administered through self-report, by telephone, or by face-to-face interview. The ABC assesses an individual's confidence to maintain balance without falling while performing specific activities that requires some position change or walking in progressively more difficult situations ranging from walking inside the home to walking on icy sidewalks. Participants rate their balance confidence using a numerical scale from 0% (no confidence) to 100% (complete confidence) in performing each activity without losing balance or becoming unsteady. The ABC is reported to have excellent test-retest reliability (ICC=0.85) in individuals with stroke.[37] The minimal detectable change for individuals with a chronic stroke is reported to be 5 pts or above.[38] The participant in this study completed the ABC assessment through face -to-face interview.

Intervention
Designed to represent a traditional 30-day plan of care for physical therapy, the participant received the intervention two times a week for a total of eight sessions. Each gait training mode lasted 10 minutes, interspersed with rest periods resulting in each session totalling 45 minutes. The MMGT program consisted of three gait training modes supported by evidence to enhance walking recovery post-stroke. The participant wore the Bioness on the L LE during both interventions modes of treadmill training and overground. Two licensed physical therapists provided all the training to the study participant while consistently providing verbal and tactile cueing as needed during the training sessions. Blood pressure (measured using a blood pressure cuff) and heart rate (measured using the radial pulse point) were monitored at the beginning of each session and following each Intervention (every 10 minutes). Throughout the MMGT program, the participant rated her perceived exertion using the 20-point Borg rate of perceived exertion (RPE) scale every 5 minutes.[39] The intensity was adjusted if the heart rate or Borg RPE ratings exceeded the recommended prescribed range of 40-80% heart rate reserve or RPE rating (11-16).[40]

To customize the speed parameter for the unilateral step training and incline training on the treadmill, the 10MWT was performed prior to each session to determine the SS gait speed. The three modes of the MMGT program were administered in a predetermined order beginning with task-specific unilateral stepping of the non-paretic limb on the treadmill, followed by bilateral inclined walking, and ending with over-ground training with variable contexts for real-world transfer of walking skills. During initial assessments, gait asymmetries were noted in the percentage of stance and swing phases of the gait cycle in all conditions (Table 1).

The participant began each MMGT session with unilateral treadmill training for 10 minutes. After noting decreased stance percentage on the left lower extremity (LLE) and decreased swing percentage on the right lower extremity (RLE), the decision was made to promote LLE weight bearing by targeting LLE stance phase during RLE swing phase within the unilateral treadmill step training. During unilateral treadmill training, the participant received external tactile cues to the more affected limb provided by a licensed physical therapist to promote stability and encourage forced weight bearing during stance. Verbal cues were also provided to encourage the participant to increase the step length of the RLE thus creating a longer swing percentage. Additionally, to promote proper weight shifting during unilateral treadmill training, assistance was provided at the pelvis by another licensed physical therapist.

The second gait training mode was bilateral LE inclined treadmill training to maximize intensity and promote LE strengthening. To improve strength, this study utilized an incline of eight degrees. Verbal cues of encouragement were provided as needed but no tactile cues of manual assistance were provided. Treadmill training speed remained the same or was increased by 25% of the resulting 10 MWT SS gait speed per the participant's tolerance to ensure sufficient intensity of practice.[15] The participant was allowed to use the handrails for safety if needed but encouraged to independently step when possible.

Finally, to enhance transference and generalization of walking skills, over-ground adaptability training included walking at fastest comfortable speed forwards, sideways, and backward, walking over various surfaces, around obstacles, and traversing curbs with and without narrow base quad cane. For safety during over-ground training, the participant wore a gait belt and was provided with handheld assistance in place of her assistive device as needed.

The 6-20 point Borg Rate of Perceived Exertion (RPE) Scale was used to assess perceived intensity throughout the entire MMGT program, with the goal of maintaining an RPE within the range of 13-14 (somewhat hard to hard) throughout the training for sufficient intensity of practice. The intervention was progressed based on the SS gait speed and increased as tolerated by 25% while consistently maintaining sufficient intensity of practice as measured by the RPE of 13-14 (somewhat hard to hard).[15,18]

Table 1: Spatial-temporal parameters of gait using the GAITRite

	Measure	Pre	Post	30-day	1-year
Self-selected	Stance % L	72.9	71.2	70.2	70.0
	Stance % R	77.9	75.6	76.6	78.0
	Swing % L	27.1	28.8	29.5	30.0
	Swing % R	22.1	24.4	23.4	22.0
	SL (cm) L	43.7	55.7	53.3	59.4
	SL (cm) R	43.5	55.5	53.3	59.2
	Speed (m/s)	0.26	0.32	0.32	0.29
Fastest Comfortable	Stance % L	71.6	70.7	71.4	70.0
	Stance % R	76.5	74.8	75.1	76.0
	Swing % L	28.4	29.3	28.6	30.0
	Swing % R	23.5	25.2	25.0	24.0
	SL (cm) L	48.5	59.5	55.4	52.5
	SL (cm) R	48.4	59.2	55.1	52.4
	Speed (m/s)	0.38	0.45	0.41	0.38

Pre - Mean of pre-intervention; Post – Mean of post-intervention, 30-day – Mean of 30-day follow-up, 1-year – Mean of 1-year follow-up, L – left, R – right, SL – Stride length

RESULTS
The participant completed the 4-week MMGT program by attending all eight sessions delivered at a frequency of two times per week over a 30-day period. The participant successfully performed all three modes of gait training each session without any adverse symptoms or events. For the unilateral treadmill training, the participant began the first session with an average training speed of 0.6 mph which she perceived as 13 on the Borg RPE. Over the course of the program, speed increased to 2.0 mph while maintaining an RPE of 13 on the BORG at this faster speed. Incline treadmill training began at 0.7 mph with an 8% incline at a Borg RPE score of 13, increasing slightly to 14 while training at 1.2 mph at a 10% incline upon completion of the program. Finally, the participant maintained a Borg RPE score of 13-15 throughout all sessions of the over-ground varied gait training. The spatial temporal and clinical examination outcomes at the different time points through the MMGT program are summarized in Tables 1 and 2.

The self-selected (SS) gait speed increased slightly from pre-test (0.26 m/s) to post-test (0.32 m/s) and was maintained at the 30-day (ST) follow-up (0.32 m/s). Similarly, FC gait speed increased slightly pre-test (0.38 m/s) to post- test (0.45 m/s) but decreased at the 30-day (ST) follow-up (0.41 m/s) and returned to baseline at the 1-year (LT) follow-up (0.38 m/s). Following the MMGT, bilateral step lengths increased immediately post intervention, with improvements ranging from 22% up to 28% while walking at SS and FC speeds (Table 1). Notably, SS step length for both right and left lower extremities increased by 36% at the 1-year follow- up when compared to baseline measures. There were no other notable changes in spatiotemporal gait parameters in either SS or FC walking speeds from the pre-test to post-test or at the follow-up time points (Table 1).

The lower-extremity Fugl-Meyer assessment increased 3 points from pre-test to post-test but this increase was not sustained at ST or LT follow-up time points. Reactive balance scores (as assessed by FSST) did not reveal improvements across the time points and the participant remained at a fall risk (Table 2) with continued balance deficits during walking variability as assessed by FGA.

Gait endurance, as assessed by the 6MWT, improved with an increase in distance walked of 30.4 meters from pre-test to post-test representing a 30% change. However, this increase was not maintained at ST follow-up and the LT follow-up the 6-minute walk distance was lower than the pre-test (Table 2). Finally, the participant's perceived balance confidence increased as measured by the ABC score, increasing by 10 pts from pre-test to post-test and remained elevated at the 1-year follow-up assessment.

Table 2: Clinical Examination

Measurement	Pre	Post (%change)	30-day (%change)	1-year (%change)
Gait speed: (GAITRite)				
Self-selected (m/s)	0.26	0.32 (23%)	0.32 (23%)	0.29 (12%)
Fastest comfortable (m/s)	0.38	0.45 (18%)	0.41 (8%)	0.38 (0%)
Functional Walking Capacity: 6-minute walk test (m)	102.2	132.4 (30%)	106.9 (5%)	92.9 (-10%)
Fugl-Meyer for LE control	24/34	27/34 (9%)	25/34 (3%)	26/34 (6%)
Four Square Step test	41.2s	28.2s (32%)	39.5s (4%)	45.8s (-11%)
Functional Gait Assessment for Postural Stability	13/30	12/30 (3%)	15/30 (6%)	15/30 (6%)
Activities-specific Balance Confidence (%)	19	29 (53%)	26 (27%)	38 (47%)

Pre - Mean of pre-intervention, Post – Mean of post-intervention, 30-day – Mean of 30-day follow-up, 1-year – Mean of 1-year follow-up

Discussion

The purpose of this case study was to investigate the immediate, ST, and LT outcomes on gait and balance performance in a person with chronic stroke after participating in a MMGT program aimed at promoting positive neuroplastic changes through repetitive, intense, and task specific gait training interventions. The results from this study demonstrate the feasibility and safety of combining three intervention modes: unilateral treadmill training, incline treadmill training, and over-ground training into an eight-session multi-modal intervention program specifically for an individual in the chronic stage of stroke. The participant tolerated the combined interventions, completing the entire MMGT program with no adverse events. The results showed that following the eight sessions of the MMGT program, the 63-year-old participant with eight years of stroke chronicity demonstrated improvements at many levels of the ICF, albeit these improvements were small. While the short-term improvements were not sustained for most outcome measures at the 1-year follow-up, the results of the participant's perceived balance confidence improved substantially after the MMGT program with the improvements maintained at the 1-year follow-up.

Participating in the MMGT was associated with immediate improvements in gait speed, which increased slightly from pre-test to post-test, however, these changes were below the minimal detectable change of 0.1 m/s. Lewek and Sykes (2019) proposed that MDC criteria for gait speed be based on the baseline gait speed, with those walking at 0.4 m/s or slower requiring a change of 0.1m/s for a clinically significant change.[24] Postural stability during gait was assessed using the FGA. The two-point increase at 30-days ST follow-up was below the five point change shown to be clinically meaningful for the chronic stroke population.[33] The 6MWT revealed a substantial improvement in endurance from a baseline measurement of 102.2 m to the immediate post-intervention measurement of 132.4m, although this increase did not meet the established MCID of 34.4m shown in the chronic stroke population.[36]

The participant experienced immediate improvements in her balance as noted in the FSST with a 13 second improvement at post-test assessment. The improvements in the FSST may have resulted from the task-specific training of unilateral weight acceptance achieved by the unilateral treadmill training and over-ground side stepping. Unfortunately, the MCID for FSST is not established, therefore it is unclear if the 13 second change from pre-test to post-test is clinically meaningful. While the quantitative measure of improvement may be minimal, the perceived balance confidence assessed by the ABC not only improved from pre-test to post-test by 10 points, but the improvement was also maintained at the 1-year follow-up having only decreased by 1 point, maintaining a change of 9 points from baseline to 1-year follow-up. Importantly, the improved perceived balance confidence reached clinical significance (MCID=5 pts) and while all outcome measures trended back towards baseline values at the 30-day ST follow-up, the improvements in the ABC score was maintained at the 1-year follow-up.[38]

The results of this study are not surprising as the MMGT program was task-specific with feasible gait interventions in an older adult with an 8-year chronicity of stroke. The participant demonstrated substantial deficits in her gait and balance as noted in slow walking speed, poor walking endurance, severe motor deficits, dense balance deficits indicating a high fall risk and poor balance confidence. The participant was also limited in her community mobility as evidenced in her gait speed less than 0.4 m/s and in her report of use of a motorized scooter for community mobility.[6] While this participant was at a lower level of functioning, she was also living in the community independently with chronic deficits demonstrating the need for structured physical therapy to not only

improve her deficits, but to prevent further decline and sustain her level of independence. Few stroke research trials exist focusing on identifying effective approaches for individuals with a stroke of substantial chronicity (such as > 5 years). For the participant with chronic stroke of eight years, the MMGT program developed in this study was feasible in terms of participant time and aligned with standard patient care structure of frequency and duration and can be completed with the assistance of a physical therapist assistant. Future research is needed to establish safety and accessibility of the MMGT outside of a directly supervised environment, such as with a caregiver. Specialized equipment aside from a harness for safety while on the treadmill, or space, was not required for the delivery of the intervention. The MMGT program could be easily translated into the clinical setting. The intervention appeared safe while maintaining a somewhat hard to hard intensity throughout the intervention program, as measured by the participant's reported RPE. This study presents a feasible complex multi-modal gait training program targeted at recovery that takes less than 60 minutes to complete over a total of eight sessions. This protocol may have the potential to be applied as an intermittent program to promote episodic improvement overtime in a chronic post-stroke population.

Limitations

As with any study, limitations may include confounding variables, such as changes in health status during the year-long follow-up time frame thus potentially affecting the results from the long-term follow-up assessment. Though the current study adds to evidence that supports the use of a structured evidence-based MMGT program, due to the case study design we cannot confirm improvements are a direct result of the interventions. Thus, the authors caution applying the customized MMGT program from this case-based approach. Future research requires further case series or quasi-experimental design with larger sample sizes to study the differences within individuals receiving the MMGT and between individuals receiving the MMGT program compared to those receiving singular mode gait training programs. Secondly, implications reveal that the MMGT was beneficial immediately following intervention, however the maintenance of the gains should be further addressed. Future research should explore how to best continue gains after completion of the MMGT program. For example, this study did not include a home exercise program, nor did it promote a continuation of activity after completing the intervention protocol. Therefore, the development of a home exercise program to use when not under direct care of a physical therapist may serve as a continuation to maintain gains attained from physical therapy. A unique outcome of this case-study was the 10% improvement in perceived balance confidence as measured by the ABC immediately post intervention with retention over the one-year follow up, only decreasing by one percentage point. Although performance-based measures were regressing, balance confidence persisted. This result would benefit from future studies to explore perceived benefits over time with and without continued episodic or long-term multimodal programming. Finally, another limitation of this case study is that we did not consider treatment progression in terms of regression from the assistive device or discontinuation of the BIONESS. From a recovery-based paradigm, these aspects would warrant closer consideration that future studies should incorporate.

CONCLUSION

This case study presented a pragmatic approach to combine evidence based, recovery-based interventions into a multi-modal gait training (MMGT) program for a person with functional limitations from chronic stroke. The results from this study demonstrated improvements in gait and balance in an individual living with chronic stroke. This case study also promotes the feasibility and preliminary efficacy of the MMGT program promoting neuromotor and functional recovery supported by current evidence. We confirmed that the combination of three distinct task-specific and intense gait training interventions is safe and feasible for persons in the chronic phase of stroke. Further study of combining customized recovery-based interventions would be beneficial when considering a more extensive application to the chronic stroke population across all settings of physical therapy clinical practice.

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