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The Acute Effects of Muscle Power Training on Short-Term Functional Mobility in Patients Post-Stroke: A Case Series

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Background and Purpose: Stroke is the leading cause of disability in the United States, but there is a lack of therapeutic exercise guidelines available for this patient population. Studies focusing on creating exercise protocols to improve lower extremity muscular power generation for these patients have demonstrated improvements in gait speed. Our purpose was to evaluate acute changes in gait speed and functional mobility following strength and power exercise protocols for patients post-stroke. **Measures:** The following outcome measures were conducted to track change in gait speed and functional mobility with strength and power training: 10 Meter Walk Test, Five Time Sit to Stand, Timed Up and Go Test, and ascending a flight of 18 stairs for all three patients and the Functional Gait Assessment for two patients. Minimal detectable change (MDC) was used to determine if a real change occurred in outcome measure scores following each stage of the exercise protocol. **Interventions:** Three patients post-stroke with decreased ambulatory abilities, including use of an assistive device and decreased ambulatory speed, completed a 4 week exercise protocol consisting of 2 weeks of muscular strength training and 2 weeks of muscular power training. **Outcomes:** A positive change was observed in all 14 variables evaluated following power training, with 11 of 14 variables exceeding the MDC. A positive change was observed in 6 of 14 variables following week 1 of strength training with 2 exceeding the MDC, and a positive change was observed in 5 of 14 variables following week 2 of strength training with 1 exceeding the MDC. **Conclusion:** Physical therapy rehabilitation programs with an emphasis on power training may cause greater acute improvements in gait speed and functional mobility when compared to strength training for the post-stroke patient population.

Key Words: *stroke, strength training, gait speed*

INTRODUCTION

There are 6 million people in the United States who have had a stroke and it is the leading cause of long term disability in our country.[1] Less than 50% of survivors regain the ability to complete community ambulation independently, with the majority that do still reporting limitations related to walking.[1] The most common complaint for ambulatory stroke survivors is decreased walking speed.[1] Following stroke, physiologic adaptations contribute to these functional deficits including the muscle increasing in the number of fast-twitch muscle fibers (Type IIA and Type IIX) and intramuscular fat content, while decreasing in the amount of slow twitch (Type I) muscle fibers.[2] This causes a reliance on easily fatigued anaerobic Type II muscle fibers, leading to oxidative injury and inflammation which causes glucose intolerance and a decrease in muscular strength and power in the affected extremity.[2] As a result of this, functional abilities are altered and made worse by the individual decreasing the amount of physical activity they participate in. Some of the largest risk factors for stroke and secondary stroke are hypertension, obesity and diabetes mellitus[2] which can be reduced with increased physical activity.[3] The American Heart Association and American Stroke Association (AHA/ASA) Guideline article, reports exercise will reduce blood pressure and insulin resistance, improve lipid metabolism, and may help with weight loss, and therefore, reduce the risk of stroke.[3] Overall, physical inactivity (<10 min any kind of physical activity) is present in 28.5% of males and 31.5% of females, which is heightened in those with stroke and increased age.[2] Engaging in physical activity can reduce risk of stroke and mortality by approximately 25-30%, with positive effects shown on hypertension, arterial function in the hemiparetic limb, and insulin response.[2] This leads to the importance of interventions provided by a physical therapist to optimize patient functional abilities following stroke and improve their quality of life by enabling them to participate in physical activity that will decrease risk for secondary stroke.[2] The AHA/ASA have developed secondary prevention guidelines for stroke that consist of aerobic exercise 3-4 times per week with moderate to vigorous intensity for 40 minutes.[2] While these guidelines may decrease the general risk for secondary stroke, we need research to determine how to appropriately implement other exercise types, such as strength and power training, to the post-stroke population to promote optimal physiological adaptations and maximize function.

To determine how physical therapy can prescribe exercise to optimize recovery for patients post-stroke, we must understand what causes the change in the ability to perform functional movements. Power and strength loss are not created equally in stroke survivors. Following a stroke, power generation is reduced more than muscle strength which is problematic because muscle power impairments limit function to a greater extent than muscle strength.[1,4,5,6] Therefore, it has been proposed decreased power leads to decreased walking speed which is justified by looking at the definition of power. Power is the amount of work that occurs in a given amount of time, or the amount of force that is moved with a certain velocity.[4] Strength is the ability to exert force[4]. When looking at activities of daily living, power generation is needed to complete activities such as sit to stands, negotiating stairs, and walking at increased speeds.

The literature lacks guidelines on how to best structure interventions to maximize functional benefits for patients post-stroke. Many exercise programs currently prescribed focus on improving strength in muscles that demonstrate weakness following stroke. While there are deficits in strength, it may be beneficial to determine if exercise prescription by physical therapists should include more focus on improving power and if this will result in improved function and quality of life for stroke survivors. The study by Hunnicutt, et al., focusing on power therapeutic exercise consisting of leg press, calf raises, jump training, sit to stands, step ups, and 10 meter walking trials for both old and young post-stroke survivors, demonstrated improvement in self-selected walking speed (SSWS) for patients post-stroke <40 years old and improvement in lower extremity muscle power generation for those <40 years old and >60 years old.[6] Of note in this study is the younger group had a longer mean time since stroke compared to the older group but still had better improvements in the SSWS.[6] This suggests chronicity of stroke may not be as strong of a limiting factor in functional improvements if we focus on the appropriate training. Another study by Morgan et al, focused on fast walking trials and an exercise program consisting of leg press, calf raises, and shuttle jump training. The results of this study showed improvement in lower extremity strength and power, SSWS, and fastest walking speed following completion of this exercise protocol.[1] Based off these studies and the physiological changes that occur post-stroke, we hypothesized that an exercise program consisting of calf raises, squats, lunges, and stair negotiation, with an emphasis on performing the concentric phase of the activity with maximum speed, or velocity, to emphasize power would result in more acute improvements in walking speed and functional abilities when compared to classic strength training with the movement being performed at a more consistent velocity. Functional improvement would be followed using the TUG, 5xSTS, 10 MWT, and time to ascend 18 steps. The purpose of this case series is to describe the effects of therapeutic exercise, with an emphasis on power training, on walking speed and the ability to perform functional activities for ambulatory patients post-stroke.

CASE DESCRIPTION

Participants: Patient recruitment was based upon a convenience sample of patients referred to and attending physical therapy at a post-acute inpatient and outpatient neurological physical therapy clinic. Three patients, 2 males and 1 female ranging from 3 to 4 months post-stroke, were chosen to participate in the case series based upon their status of being ambulatory with an assistive device despite decreased self-selected walking speed, and having the ability to physically handle vigorous interventions provided by a physical therapist sessions. All patients utilized a single point cane to ambulate while initially requiring contact guard assist to minimal assist for anticipatory and reactive balance assistance. Further demographics of our patient sample, including relevant history, type of CVA, and physical deficits, are listed in Table 1.

Examination and Evaluation: Each patient completed an initial evaluation and examination that included testing of strength, range of motion, coordination, tone, endurance, sitting and standing balance, outcome measures, bed mobility, transfers, and gait to determine the severity of the patient's neurological deficits. Outcome measures completed included the 10 Meter Walk Test (MWT), 6 Minute Walk Test, and 5 Times Sit to Stand (STS) Test. Time restraints and initial physical status of the patients limited the number of initial outcome measures completed. However, through the testing completed, it was evident all patients required extensive gait and functional mobility training to optimize independence with activities of daily living and decrease the assistance needed for safe ambulation. Deficits in gait were evaluated and identified through observation by the physical therapist while the patient ambulated during the initial session. The major physical deficits and limitations of each patient can be seen in Table 1.

Table 1. Characteristics of participants.

Sex	Age	Stroke Diagnosis	Relevant Medical History	Physical Deficits
P1 Female	55	Acute infarct to right midline pons; 3 months post-stroke	Type II Diabetes, Diabetic neuropathy, and hypertension	Left sided hemiparesis, Left lower extremity (LLE) foot drop, Left knee hyperextension during stance phase requiring Mod A, Step to gait pattern with stance phase on LLE, and poor dynamic balance.
P2 Male	38	Left MCA CVA with left basal ganglia petechial hemorrhage; 3 months post-stroke	Low testosterone	Right sided hemiparesis, R plantarflexor tone 2+, R hip abductors/adductors tone 1+, L3-S2 dermatomes diminished, poor dynamic balance, R foot plantarflexed throughout gait cycle, RLE circumduction, CGA with ambulation on level surfaces, and R knee hyperextension during stance phase.
P3 Male	35	Subarachnoid hemorrhage; 4 months post-stroke	Type II Diabetes and hypertension	Left sided hemiparesis, L1-S1 dermatomes diminished on LLE, decreased L foot clearance during swing phase of gait, decreased LLE stance phase, and increased L knee flexion during stance phase, and Min A for LLE foot clearance and placement during gait.

Outcome Measures: Throughout the study, the 10 MWT, 5x STS, Timed Up and Go (TUG) Test, and time to ascend 18 stairs were utilized to analyze functional improvements demonstrated by the patients. Lower extremity power was measured with the 5x STS Test which measures how quickly you can go from a sitting to standing and back to sitting position five consecutive times. The test is used to evaluate a patient's lower extremity strength and functional performance. The intra-rater ICC was .93[7]-.97[8], the interrater ICC was .999[8], and the test-retest reliability was 0.93[7]-0.98[8] for this test when used for chronic stroke patients. The calculated SEM is 1.98 seconds and MDC is 5.5 seconds. It has also been determined a time of 12 seconds discriminates between healthy elderly patients and chronic stroke with a sensitivity of 83% and specificity of 75%.[8] The cutoff score of 15 seconds also predicts falls in the elderly.[9] Guideline values to determine if elderly patients are above or below average have been determined for ages 60-69 years old at 11.4 seconds, 70-79 years old at 12.6 seconds, and 80-89 years old at 14.8 seconds.[10]

The TUG Test is used to evaluate functional mobility in patients post-stroke. It was included in this study due to it predicting how well patients post-stroke can participate in daily activities. The test-retest ICC for patients post-stroke is reported between 0.94 to 0.99[11] and 0.95-0.96.[12,13] The SEM is 1.14 seconds and the MDC is 2.9 seconds.[12] No cutoff score has been officially established[14] but a study by Shumway-Cook, et al. determined a time of 13.5 seconds predicted falls in community dwelling elderly patients[15], though this has never been verified[14], and average healthy adults ages 60-80 having average times of ≤10 seconds ±1 for males and ≤11 seconds ±3 seconds for females.[16] General guidelines regarding functional abilities for all patients is a score of <10 seconds predicting complete independence with or without assistive devices, <20 seconds predicting independence with functional mobility regarding the tub, shower, climbing stairs, and going outside, and >30 seconds predicting dependence required with most activities.[14]

The 10 Meter Walk Test is used to evaluate the short distance walking speed of a patient. We utilized it in this study to determine the change in fast gait speed of the patients. The test-retest ICC for stroke patients with fast walking speeds is reported to be 0.97.[12] The inter-rater ICC has been reported as 0.998 with the intra-rater reliability reported at 0.87-0.88 for patients post-stroke and this test.[17, 18] The SEM is 0.04 m/s[19] and the MDC_{90} is 0.3 m/s for subjects with stroke[20] and 0.18 m/s for post-stroke subjects utilizing assistive devices.[21] The MCID for patients ambulating at a comfortable gait speed is 0.14[19]-0.16 m/s.[19, 21] For the relationship between the times recorded and patient function, no guidelines have been established due to variations in distance used and lack of consistency in reporting if SSWS or faced paced walking, static or dynamic start, or encouragement were used.[22]

The Functional Gait Assessment (FGA) was utilized to assess ability to perform dynamic tasks while ambulating. For patients post-stroke, the test retest ICC is 0.95, the inter-rater ICC is 0.94, and intra-rater ICC is 0.97 which demonstrates a high reliability throughout statistical testing.[24,25] The SEM is 1.52 and the MDC is 4.2, which is considered 5 clinically.[23] There are not established guidelines with scores on this test and function in the stroke population, however, scores of 22/30 effectively predict unexplained falls in community-dwelling older adults.[26]

Patients were asked to ascend 18 stairs at maximal speed throughout the study. Patients used a handrail on the stairs with a reciprocal gait pattern and stand-by assist or CGA by the therapist for safety. In the study by Weiss et al., patients ascended a flight of 8 stairs with good reliability based off an ICC of 0.756.[7] In this study we had patients ascend a flight of 18 stairs to evaluate improvement in the ability to perform functional, everyday tasks. To determine the significance of any changes with stair ascension, we utilized the information from the study by Weiss et al. to calculate an SEM of 0.48 seconds and MDC of 1.32 seconds. There are no cutoff scores or values established to predict function from the ability to ascend stairs, but it is used in other tests evaluating functional abilities such as the Functional Independence Measure (FIM).[17]

Intervention:

Subjects completed two exercise protocols, one with an emphasis on strength training and another on improving muscular power. The exercises included in the strength protocol were squats, split squats, seated/standing calf raises, and ascending 18 steps at a self-selected speed. These exercises were performed twice weekly for weeks 1 and 4 of the study during the daily 1 hour physical therapy session. Sets and reps were prescribed at a level that led to patients reporting muscular fatigue along with deviation from what is considered normal biomechanics for each exercise which would confirm fatigue. During this portion of the study, patients were instructed to perform the exercises listed above with isotonic movements at a "controlled, normal pace", to perform the exercises similar to how strength and hypertrophy exercises are often completed.

During weeks 2 and 3 of the study, the exercise protocol consisted of squats, lunges, seated/standing calf raises, and ascending 18 stairs with the emphasis placed on improving muscular power. This was done by instructing the patients to eccentrically control the movement during the lowering phase and to move with maximum velocity, or "explode up to the starting position", and to ascend the flight of stairs at their maximum speed. Once again, these exercises were performed twice weekly during the daily 1 hour physical therapy session with sets and reps being prescribed for each individual at a level that led to the patients reporting muscular fatigue with decreased kinematics. We hypothesized these 2 weeks of the protocol would have greater effects on functional improvements in the patients due to power showing greater effects on functional mobility than strength.

Throughout the strength and power protocols, 2-3 sets with repetitions ranging from 10-25 were completed for the squats and lunges/split squats, 1 set ranging from 30-40 repetitions for the seated/standing calf raises, and the stairs were ascended 1-10 times. These sets, reps, and rest breaks were determined based off patient reports of fatigue and a need for rest with a concurrent decrease in the ideal biomechanical performance of the movement. All exercises were performed with body-weight only and no external load placed on the patients.

The 1-2-1 model used in this study, regarding the weeks that strength or power exercises were performed, was created by the authors to best determine if power training had true effects on post-stroke patient functional performance during such a short period of time. We hypothesized if both treatments were performed in 2 week periodization block protocols it would be difficult to determine if change was truly caused by the intervention. Since we wanted to evaluate if power training was more beneficial for these patients, we grouped this into the middle two weeks with the strength training placed before and after. If improvements were caused by general health improvements due to longer time since the stroke, we determined there should be a similar trend of improvement seen following the end of the week 3 power training protocol and the week 4 strength training protocol. If there was no difference between training effects, we believed there would be no meaningful differences shown between the strength and power training throughout the 4 weeks. However, if power exercise does play a role in acutely improving post-stroke patient functional mobility, differences would be shown between the weeks the strength and power protocols were completed. The interventions and completion of outcome measures were implemented by the same therapist for each patient throughout the course of the 4 week exercise protocol to optimize the consistency and maximize the validity for each of the exercise protocols administered.

Table 2: Results of outcome measures

Patient	Week	10 MWT (sec)	FGA	Stairs (sec)	TUG (sec)	5x STS (sec)
P1	Initial Results	35.03	16	84.91	32.28	11.75
	Post- Strength Week 1	46.34	13	34.08	34.09	14.97
	Post-Power Weeks 2&3	26.25	16	31.00	22.47	8.55
	Post Strength Week 4	25.38	15	29.46	26.27	10.07
P2	Initial Results	11.00	18	18.09	12.66	11.84
	Post- Strength Week 1	11.10	16	16.60	12.84	11.2
	Post-Power Weeks 2&3	8.28	22	12.98	9.49	8.84
	Post Strength Week 4	10.01	21	11.72	9.16	8.97
P3	Initial Results	16.78		17.63	18.59	11.75
	Post- Strength Week 1	14.50		14.25	14.69	11.75
	Post-Power Weeks 2&3	11.96		11.72	11.71	10.53
	Post Strength Week 4	13.30		13.43	15.18	9.52

OUTCOME

Of the 36 variables evaluated from the outcome measures (TUG, 5x STS, 10 MWT, and stairs) used with all 3 patients (P1, P2, and P3) and evaluated at 3 different times (Strength training week 1 (ST1), 2 weeks of power raining (PT), and strength training week 2 (ST2)), positive change was found in 23/36 variables. These positive changes occurred for all 12 of PT variables, 6/12 following ST1, and 5/12 for ST2. For the 6 variables evaluated from the FGA for 2 of the patients (P1 and P2) during the training protocol, positive changes in FGA scores occurred in both patients following PT with no improvement in FGA scores following ST1 or ST2. Line graphs depicting the weekly change of each outcome measure can be found in Figures 1-5 in the Appendix. Each patient had a large amount of variability for initial outcome measure times based upon their level of physical disability post-stroke. Table 2 provides the results of the variables for the patients following each portion of the training protocol completed.

The 5 Time Sit to Stand Test had a calculated MDC of 5.5 seconds.[8] Based upon this value, meaningful positive changes likely occurred only for P1 following PT. No meaningful changes likely occurred for P2 throughout testing. Negative change occurred for P1 following ST1 and ST2 and no meaningful differences likely occurred for P3 throughout testing for the 5x STS.

The TUG test has a MDC of 2.9 seconds to evaluate functional mobility for patients post-stroke. Based upon this value, positive change occurred that was likely meaningful for each patient following PT with P3 also showing positive change for ST1. P1 and P2 had negative changes following ST2.

The 10 MWT had a MCIC of 0.14-0.16 m/s for the patient post-stoke gait speed assessment. Based upon this value, meaningful positive changes likely occurred in all patients following PT, in P1 following ST2, and in P3 following ST1. Negative changes occurred for P1 after ST1, and P2 and P3 after ST2.

The FGA was utilized on P1 and P2 to evaluate their ability to ambulate while performing dynamic tasks. The MDC for this assessment is 4.2, so a positive change that was likely meaningful occurred only for P2 following PT. No other meaningful change occurred. P3 did not undergo testing utilizing the FGA due to not demonstrating a high enough level of ambulatory abilities to perform the test at the start of the case series, and to continue balance evaluation using the Berg Balance Scale (BBS), which had been utilized with this patient prior to the study.

Stair ascension was used to evaluate the improved ability of patients to perform functional tasks with a MDC of 1.32 seconds calculated from the paper by Wiess et al.[7] Positive change exceeding the MDC occurred for all patients for both ST1 and PT with P1 also having positive results for ST2. Negative change occurred only in P3 following ST2.

DISCUSSION

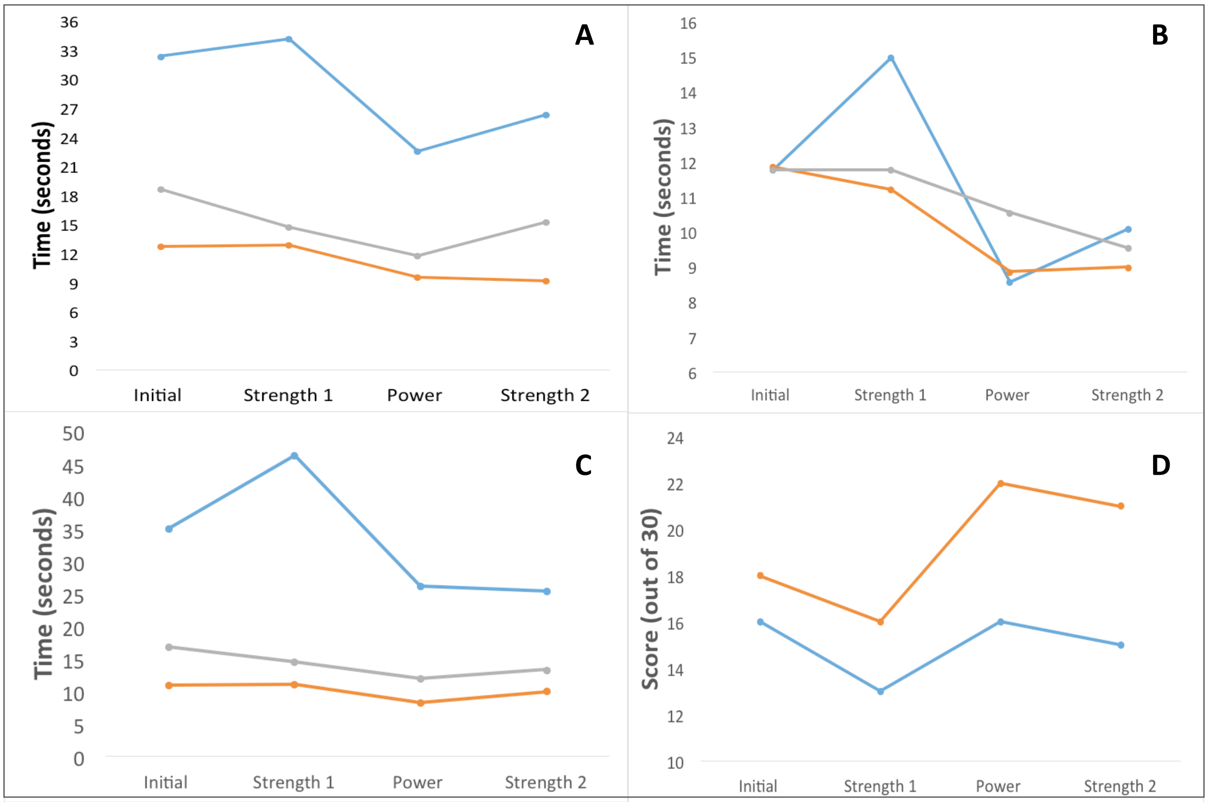
An improvement in outcome measure scores was seen in all 14 variables evaluated following the PT weeks for the patients included in the study. Of these 14 variables, 12 exceeded the MDC and MCID values and are likely to be due to real change. This suggests performing exercise with an emphasis on power may have a greater positive acute impact on function and ambulation during the initial phases of recovery. The article by Morgan et al., reported similar findings with patients post-stroke having improved lower extremity muscle strength and power, self-selected walking speed, and fastest walking speed following a power training program.[1] The study by Hunnicutt et al. also had similar positive findings for patients post-stroke with improved lower extremity muscle power generation for both young and elderly patients and improved locomotor function for patients <40 years old.[6] This evidence supports interventions provided by a physical therapist using exercise prescription to specifically target decreased power generation for patients post-stroke.

This case series was completed with limitations, the first being the equipment available. In the studies previously mentioned by Morgan and Hunnicutt, equipment was available that allowed exercises to be completed in a way better following the general ACSM guidelines to maximally improve power. These guidelines are to complete 1-12 reps while using lighter loads of 0-60% of the 1 rep max (1 RM) for lower extremity exercises and a fast muscular contraction.[27] Rest between sets is 3-5 minutes for 3-5 sets.[27] The shuttle was utilized in both studies to allow patients to complete the jumping motion in a gravity minimized position to limit compensations and allow for more optimal kinematics. During this case series, patients completed 2-3 sets with reps up to 25 which does not strictly follow the guidelines for power training. Therefore, having weighted vests in the physical therapy clinic for this patient population may be beneficial to allow increased weight on the patient similar to when using a barbell. The small sample size of patients and variability in type of stroke obtained are other limitations. While it would be difficult, future research would benefit from gathering data from a large pool of patients with similar stroke types to better determine which physical therapy treatments lead to the best functional improvements. Another limitation is patients developing more skill performing the outcome measures used the more it was completed. Due to never having performed these outcome measures before, the times for the initial data collection may have been worse, improved for the power training weeks, and then stabilized into a ceiling effect by the final week of the protocol. The final limitation is the protocol length. Due to limitations in time, only 4 weeks were available for data collection which are not optimal to analyze the physiological effects that take place with resistance and power training. Improvements could be made by performing a study with a larger sample size completing an extensive power and strength training protocol that would track patient ambulatory speed and functional mobility for an extended period. This would allow long term outcomes of physical therapy exercise protocols for patients post-stroke to be evaluated because there are no current guidelines for this population from the American College of Sports Medicine.[28]

To determine the physical therapy protocols to most efficiently improve functional abilities of the post-stroke patient population, studies need to evaluate the effects of strength and conditioning principles for healthy adults. Periodization is utilized when training athletes to optimize their physical abilities through variation in exercise programing including training methods, frequency, volume, and intensity. This allows the individual to peak at an optimal time and avoid injury, a plateau in physical improvements, and overtraining.[29] If it works well for athletes, it could be adapted for patients post-stroke when they reach a higher level of function. Some considerations would be altering the plan to not over-fatigue the involved musculature and ensure proper input is being provided to the nervous system to promote correct biomechanics and motor control.

A periodization protocol could be followed that trains strength, power, and speed.[30] To improve strength in healthy adults the guideline is to perform exercises at ≥80% of the 1 rep max with high load and less reps.[30] While this is not feasible in the majority of the post-stroke population, we still need to consider increasing external load to promote the peak force output of the muscle to increase maximum strength capabilities.[30] Strength training will improve muscular power by increasing force producing capabilities, but will not train the ability to increase the velocity of movements. For this, we can implement speed and power portions in a periodization plan. Based on the results of this case series, the velocity component of exercises for patients post-stroke may have an acute positive effect on functional mobility, and if discontinued, may have an acute detrimental effect on this improved mobility. If we can reproduce the efficiency that is present in strength and conditioning exercise prescription of athletic populations in the post-stroke population it may enhance their ability to physically function in a similar way to their prior levels.

Figure 1. Clinical outcomes for patients. Patient 1 in blue, Patient 2 in orange and Patient 3 in gray. A: Timed up and go, B. 5 Sit to stand, C. 10m Walk test, D. Functional gait assessment.



Future research can also investigate the effects power cluster training has on the post-stroke patient population. Cluster training optimizes power output by having subjects perform exercise repetitions until there is a certain change in velocity of the movement. They then take a rest mid-set and finish the remaining repetitions at the same velocity. The study by Pareja-Blanco et al. had subjects perform a squat protocol where inter-set rest occurred after 20% decrease in velocity for one group and 40% decrease in another.[31] The study found the 20% group had greater vertical jump height improvements and similar squat strength gains compared to the 40% group despite this group performing 40% more reps and total work.[31] Another study by Oliver et al, found similar benefits in muscle hypertrophy and strength in subjects performing power cluster training with additional benefits including lower levels of perceived exertion when compared to those performing resistance training while also improving power output.[32] This perception of the amount of work performed can be used in interventions provided by a physical therapist to keep patients mentally engaged with lower levels of fatigue while still maximizing their therapy.

These different ways of prescribing exercise may enhance power generation sooner and therefore expedite the process of a patient performing functional activities. To optimize a patient post-stroke's prognosis, correct input needs to be provided to the nervous system immediately to best enable the individual to reach their prior level of physical function. Prior research has shown that strength training most consistently provides improvements for patients post-stroke including improved strength, walking distance, fast walking, and balance but no specifics are mentioned on exactly how the patients are instructed to perform the exercises.[33] Placing a focus on completing repetitive task specific practice at a high intensity and maximal speeds during strength training may improve muscle power generation the most, which correlates to higher walking speeds.[34] However, this case series shows the improvements in neural function in patients post-stroke may also decline quickly if not continuously performed during the initial phases of their physical therapy treatment. Further research should look at how rapidly power can be improved or decline based on exercise prescription in patients post-stroke.

There are many potential factors and reasons why patients in this case series may have shown larger improvements during the power training weeks. First, is the generalized neural improvements made with initial training in all patients that primarily occurs after two weeks of training.[35] This is likely a major reason why large improvements were seen in performance of the outcome measures after two weeks of training, so future research should evaluation the differences in physical therapy protocols over a much larger period of time. Secondly, the specificity of training for the power group may have provided a more optimal input to the nervous system to complete functional movements requiring increased muscular power by improving neuromuscular function via primary motor cortex excitability and efficiency, increased muscle fiber recruitment, and coordination of muscles recruited to complete the functional movement.[36] Another possibility is providing the cue to perform exercises with maximum velocity rather than a self-selected speed caused patients to perform the movement with a more forceful and maximal muscular contraction. This may promote a more powerful neural signal to be sent to the muscles causing increased motor unit firing and muscle activation rates. The result is functional movements being completed with increased ease.

In conclusion, interventions provided by a physical therapist for patients post-stroke need to focus on addressing the physiological changes that occur by utilizing exercise prescription to directly combat these changes. Power is proven to be limited more while having a greater impact on functional mobility and gait speed. Therefore, power training may need to be emphasized at all levels of the physical therapy continuum of care for patients post-stroke to maximize their functional abilities and quality of life.

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