THERAPEUTIC-YOGA AFTER STROKE: EFFECT ON WALKING RECOVERY

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Abstract

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Therapeutic-Yoga after Stroke: Effect on Walking Recovery

Introduction

Stroke is a sudden and devastating medical condition. People who experience a stroke tend to have long-term physical limitations including impaired walking as part of the ongoing consequences of stroke. While a variety of rehabilitation interventions have demonstrated efficacy for improving walking after stroke, none of the interventions have emerged as superior, and prior to this study, therapeutic-yoga had not been tested as an intervention to improve walking recovery after stroke.

Methods

This study was a secondary data analysis of group therapeutic-yoga on walking recovery measures including walking speed, walking distance, and spatiotemporal step parameter symmetry. The walking recovery measures were collected as secondary outcomes in a sub-sample (n=12) in a pilot randomized controlled study (n=47) designed to test the efficacy of 8-weeks of group therapeutic-yoga on balance and fear of falling. Participants in the current study completed 12-weeks of group therapeutic yoga with outcome assessments at baseline, 8-weeks, and 12-weeks. The main analysis was repeated measures ANOVA to assess the main effect of time with additional analyses including effect sizes, percent of participants achieving change greater than or equal to minimal detectable change (MDC), and mean change score comparisons between baseline and 8-weeks, 8-weeks and 12-weeks, and baseline and 12-weeks.

Results

Twelve people with chronic stroke enrolled in the study with 9 completing the intervention and all 3 assessments. No significant main effect of time was found on any of the variables of interest. Walking distance demonstrated a trend toward significant

change (p=0.064) and step length symmetry demonstrated significant change (p=0.05) between baseline and 12-weeks. Several spatiotemporal step parameter symmetry ratios demonstrated small to medium effect sizes with the majority (91%) being a negative effect.

## Conclusion

Twelve weeks of group therapeutic-yoga appears to be feasible in a population of people with chronic stroke. Walking distance and step parameter symmetry should be tested in a larger sample. An improved understanding of the impact, progression, and remediation of walking asymmetry is needed.

Arlene A. Schmid, PhD, OTR, Chair

Table of Contents

List of Tables

List of Figures

Chapter 1: The Problem

Introduction

Cerebral vascular accident (CVA), or stroke, is a sudden and devastating medical event. Stroke is the third leading cause of death in the United States[1,2] and a leading cause of long-term disability.[3-5] Many adults with stroke experience long-term physical and psychological impairments and related disability.[1,3] Moderate long-term disability is reported in 40% of adults who survive a stroke and severe long-term disability in 15%-30% of people with stroke.[6] Specifically, 40%-50% of adults who have had a stroke remain unable to walk at speeds consistent with age matched healthy controls and approximately 30% remain unable to walk without assistance at 6 months post-stroke.[2,7]

This walking impairment is likely associated with changes in spatiotemporal step parameters, including step length, stance time and swing time. Evidence on spatiotemporal step parameters after stroke suggest that there is significantly greater variability in steps with the paretic leg compared to the non-paretic leg.[8] Persistent walking impairments after stroke contribute to significant physical disability after stroke.[9-11] In addition to physical disability, walking impairment after stroke is associated with decreased function and participation.[1,3,12-14] Consequently, impaired walking is a significant rehabilitation problem and walking recovery is an important goal during recovery from stroke.[9,10,15,16]

During rehabilitation, walking recovery is assessed with a variety of clinical measures and facilitated with several rehabilitation interventions. Common clinical measures used to assess walking recovery include: walking speed;[17] walking distance;[17] and spatiotemporal step parameters (step length; swing time; stance time).[8] Walking recovery is facilitated through a variety of rehabilitation interventions such as: overground walking pratice;[18-22] treadmill training with or without body weight support

(BWS);[9,10,21,23,24] strengthening;[10,20,25-27] endurance training;[26] neuromuscular re-education including balance and postural control training;[22,25,27] and mental imagery.[18,28,29] Even though improvement in walking is facilitated through rehabilitative efforts, post-stroke rehabilitation is increasingly shorter in duration and rehabiliation is often completed prior to attaining maximal functional recovery.[30,31] Access to safe and effective exercise activity is needed for people in the chronic stage post-stroke and a complementary and alternative medicine (CAM) approach might be an effective option for engaging people with chronic stroke in exercise activity to promote ongoing recovery after discharge from rehabilitation.

Therapeutic-yoga is an aspect of CAM that can be adapted for people with chronic stroke and implemented in a community-based setting.[32] An 8-week therapeutic-yoga intervention has been successfully tested in a population of people with chronic stroke demonstrating improved balance scores and balance self-efficacy with additional preliminary findings of improved walking speed and distance.[32] In older adults, other researchers have found therapeutic-yoga affects multiple body systems and functions including: body alignment; agility; flexibility; strength; overall fitness; endurance; relaxation; and mental and emotional well being.[33-37] Therapeutic-yoga is not task specific for walking but it is a multisystem whole body approach which has been shown to affect complex tasks like balance and may also affect walking recovery after stroke. Therapeutic-yoga has been shown to affect walking speed in women with musculoskeletal problems,[38] but the effect of therapeutic-yoga on walking recovery after stroke has not, to my knowledge, been reported. This study used therapeutic-yoga as an intervention to facilitate walking recovery during chronic stroke by examining the effect of 12 weeks of group therapeutic-yoga on walking recovery.

Conceptual Framework

Recovery after stroke is complex and multi-faceted. Stroke can affect a wide range of brain functions resulting in a variety of associated problems.[39] The International Classification of Functioning, Disability, and Health (ICF) provides a useful framework to assess stroke rehabilitation.[39,40] The ICF is a conceptual framework developed to classify health which includes domains of body structure and function, activities, and participation as well as both personal and societal factors as influences on the domains.[40,41] Specifically, the domains are defined as follows: body functions are physiological functions of body systems; body structures are anatomical parts of the body; activity is the execution of a mobility task or action by an individual; and participation is the involvement in a life situation.[42] The relationships between the domains of the ICF are represented by bi-directional arrows (Figure 1) meaning influence is reciprocal between each of the domains. This study explored the bi-directional arrow between body functions and activity in people with stroke. Group therapeutic-yoga was used as an intervention to facilitate changes in body functions (spatiotemporal step parameters) and activity (walking speed and walking distance).[40] I expected to find an improvement in walking speed, walking distance, and spatiotemporal step parameter symmetry as a result of participation in 12 weeks of group therapeutic-yoga in adults with chronic stroke. The knowledge gained will increase understanding of walking recovery after stroke and help inform future studies designed to develop and test therapeutic interventions aimed at improving walking recovery in people with chronic stroke.

Figure1: ICF Model



**"Health Condition"**
(disorder or disease)

Body Functions and Structures ↔ Activities ↔ Participation

Personal Factors    Environmental Factors
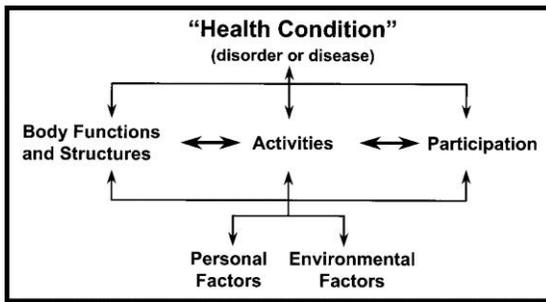
## Statement of Problem

Stroke is a life changing medical event that leads to motor impairment and loss of motor skills including the ability to walk. Walking recovery promotes improved function and life participation. Thus, interventions to promote walking recovery are integral to rehabilitation after stroke. Rehabilitation strategies to facilitate walking recovery are varied and tend to focus on specific impairments or repetitive task practice. Although both strategies facilitate improvement, many people with stroke experience long-term walking impairment. Persistence of long-term walking impairment after stroke suggests that best practice for maximizing walking recovery after stroke has not been established. Therefore, development and testing of alternate strategies, such as therapeutic-yoga, to promote walking recovery is needed for people with stroke.

## Purpose

The purpose of this study was to test the effect of group therapeutic-yoga delivered in 2 dosing protocols (8 weeks and 12 weeks) on walking recovery after stroke. Walking recovery was assessed with standardized walking outcome measures at baseline, 8 weeks, and 12 weeks in a sample of people with chronic stroke participating in 12 weeks of group therapeutic-yoga. The long-term objective of this research is to improve understanding of walking recovery after stroke.

Research Question(s)

The research question for this study was: Do people with chronic stroke demonstrate a main effect of time with improvements in walking speed, walking distance, and spatiotemporal step parameter symmetry after group therapeutic-yoga, delivered in two dosing protocols, 8 weeks and 12 weeks?

Hypotheses

The central hypothesis for this project was that people with chronic stroke will demonstrate a main effect of time with improvements in walking speed, walking distance, and spatiotemporal step parameter symmetry, assessed with repeated measures at baseline and after 8 and 12 weeks of group therapeutic-yoga. The specific research hypotheses were as follows:

1. People with chronic stroke will demonstrate a significant main effect of time on fast walking speed measured at baseline and after 8 and 12 weeks of group therapeutic-yoga.

2. People with chronic stroke will demonstrate a significant main effect of time on walking distance measured at baseline and after 8 and 12 weeks of group therapeutic-yoga.

3. People with chronic stroke will demonstrate a significant main effect of time on spatiotemporal step parameter symmetry for: swing time; stance time; swing time/stance time ratio; and step length measured at baseline and after 8 and 12 weeks of group therapeutic-yoga.

4. People with chronic stroke will demonstrate significant improvement between baseline and 8 weeks, baseline and 12 weeks, and 8 weeks and 12 weeks on walking speed, walking distance, and spatiotemporal step parameter symmetry.

Summary

Stroke is a devastating and debilitating medical event. Adults who have had a stroke often experience long-term physical disability including impaired walking.[1-3,6,7] Walking recovery is facilitated through a variety of rehabilitation interventions focusing on impairment reduction or task practice and is assessed through a variety of measures including: walking speed;[17] walking distance;[17] and spatiotemporal step parameters.[8] Even though walking recovery is a focus during rehabilitation, long-term walking limitations are a significant problem during chronic stroke even after the completion of all rehabilitation.[9] These ongoing walking limitations provide a strong rationale for developing effective community-based programs to promote walking recovery for people with stroke who have completed structured traditional rehabilitation. Therapeutic-yoga might be an appropriate option as a post-rehabilitation program. Therapeutic-yoga is a form of CAM which focuses on mind-body-spirit connections to promote health and healing.[43-45] In addition to the health and healing effects, therapeutic-yoga facilitates improvement in impairments associated with walking ability after stroke.[32,46-48] Therefore this study tested the effect of 8 and 12 weeks of group therapeutic-yoga on walking recovery after stroke. These data will be used as part of a long range research program to better understand walking recovery after stroke. Better understanding of walking recovery will help guide rehabilitation therapists in providing high quality evidence-based care to maximize walking recovery after stroke. Finally, maximization of walking recovery after stroke through evidence-based practice will advance rehabilitation science as both a research and clinical discipline.

Chapter 2: Literature Review

Relevant Literature

Stroke Impact

Stroke is a serious and disabling global health problem.[49] Stroke is the leading cause of permanent disability in Europe and the United States (US).[50] In the US, approximately 795,000 people experience a stroke each year with over 6 million people living with the consequences of stroke.[2] At 6 months post stroke; 50% experience hemiparesis, 30% are unable to walk without assistance, 26% are dependent in activities of daily living (ADL), 19% have aphasia, and 35% are depressed.[2] Stroke is a leading cause of motor disability[51] with a substantial number of people who have had a stroke experiencing moderate to severe motor disability.[50] Americans living with motor limitations report a negative impact on their daily lives including functional limitation.[52] Even though 50%-70% of people regain functional independence,[2] stroke leads to long-term limitations in activity[39] and participation.[4] Incomplete re-acquisition of motor skills is a frequent contributor to these long-term limitations.[50] Therefore recovery of motor skills such as walking is important during post-stroke rehabilitation. Interestingly, walking recovery is considered to be among the most important goals for people with stroke.[10,16,23,53,54]

Walking Recovery after Stroke

Walking is a complex motor task involving coordination of multiple body structures and functions including: muscle and joint activity in all extremities; postural alignment and control; endurance; dynamic balance; sensory awareness; and motor control. Walking is typically described using the gait cycle (Figure 2) which includes both spatial (distance) and temporal (time) parameters.[55] One gait cycle is defined as 1 stride which is 2 steps, right and left.[55] The gait cycle is described in 2 phases, swing (not in contact with support surface) and stance (in contact with support surface) as well as 2

7

periods of double support (both feet in contact with the support surface).[55] While both

swing and stance can be assessed as temporal parameters (swing time and stance

time), swing can also be assessed as a spatial parameter (step length).[55] Normal

walking produces gait cycles with symmetrical spatiotemporal step parameters between

left and right and 60% of time in stance with 40% in swing.

Figure 2: Gait Cycle
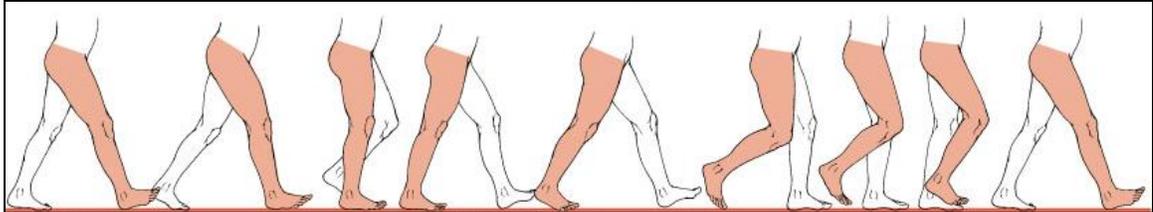


After stroke, impaired walking is common due to pathology in central structures

responsible for programmed controlled movements as well as secondary impairments

from altered movement control.[56,57] Several aspects of walking can be affected after

stroke including: walking speed;[9,12,15,17,21,23,26,27,54,58-64] walking endurance

(distance);[5,7,9,17,23,26,27,64-66] gait symmetry;[8,9,54,58-60,67,68] energy expenditure;[5,9,26,58]

appearance or movement quality of walking;[64] and walking independence.[12,21,64,69]

Although functional independence with walking is attained by many people with stroke,

community walking skills continue to be a problem long-term after stroke.[18,26,61,70,71]

Specific aspects of walking which may contribute to long-term community walking

impairments include speed, distance, and symmetry.

Walking Speed

Walking speed is an important aspect of walking recovery. Walking speed can be

used to predict level of disability in people with stroke based on categories of walking

ability defined as follows: 1) household walking ability at speeds less than 0.4

meters/second (m/s); 2) limited community walking ability at speeds between 0.4 m/s

and 0.8 m/s; and 3) full community walking ability at speeds greater than 0.8 m/s.[10,72]

Walking speed has been recognized as an important variable for measuring recovery after stroke,[73] and is commonly used to assess walking ability after stroke.[12] As walking speed increases, people with stroke experience better function and quality of life.[15] Consequently, many clinicians and researchers recommend walking speed as an outcome measure after stroke.[74]

Walking speed measured with short distance (5-10 meters) timed walking tests are frequently used to measure walking ability in people with stroke.[12,75,76] These tests are simple to complete,[77] and have been shown to be reliable and responsive measures of walking ability in people with stroke.[12,17,73,77-79] Specifically, high test re-test reliability has been demonstrated for both Comfortable Walking Speed (CGS) and Fast Walking Speed (FGS) in acute[12,73] and chronic[17,74] stroke. Meaningfulness of change can also be assessed with walking speed measures with the minimal detectable change (MDC) or the minimal clinically important difference (MCID). The MDC is the amount of change needed to assess true change (greater than random error) while the MCID is the amount of change required to reflect clinically important change in an anchor-based analysis.[62] The MCID has been reported in people with acute[62] and subacute[15] stroke, and the MDC has been reported in people with acute and subacute stroke[12,62,73,80,81] as well as chronic stroke.[17] Based on the importance of walking speed in assessment of walking ability after stroke and availability of reliable easy to use walking speed measures, walking speed is an important measure to include when assessing effectiveness of interventions to improve walking ability.

Walking Distance

Another key aspect of walking to consider is walking distance. Walking distance is an essential factor in achieving functional community ambulation.[7,17,66,71] Walking distance has been identified as important by people with stroke.[64,82] Participants in one study identified walking distance as the second most important aspect of walking behind

walking independence,[64] while in another study, the majority of participants indicated that walking distance was more important than walking speed.[82] In people with stroke, walking distance has been associated with walking speed,[83] balance,[7,83,84] and lower extremity motor function.[7,83,84] Finally, walking distance measured in people with stroke has been reported to be 10% (acute patients), 40% (subacute patients), and 50% (chronic patients) less than in healthy older adults.[7]

Walking distance is commonly measured in people with stroke using the 6 minute walk test (6MWT).[7,17,66,71,85] This test is easy to administer and has demonstrated good test re-test reliability as well an established MDC in both acute[66] and chronic stroke.[17,86] Therefore, in addition to walking speed, walking distance is a feasible and important measure to include when evaluating walking capacity in people with stroke.

Spatiotemporal Step Parameters

Spatiotemporal step parameters can be measured in distance (spatial) or time (temporal) and include specific step characteristics such as step length, stance time, and swing time (Table 1).[8,59,87-92] The normal walking pattern in both spatial and temporal step parameters in healthy adults is relatively symmetrical (<6% variability).[8,54,93,94] However, due to hemiparetic distribution of motor deficits after stroke, step parameters in people with stroke are not typically symmetrical.[8,54,60,61,67,68] Step parameter asymmetry in people with stroke is believed to contribute to compensatory motor action during walking and to be indicative of underlying impairments.[8,54,59,60,67,68] Therefore, measurement of step parameter symmetry is an important factor to include in a comprehensive walking assessment in people with stroke.

Table 1: Step Parameter Definitions

| Step Parameter | Definition |
|---|---|
| Swing time | The time in seconds during the swing phase of gait (no contact with the support surface). The time between toe off and heel strike of same foot |
| Stance time | The time in seconds during the stance phase of gait (contact with the support surface). The time between heel strike and toe off of the same foot |
| Swing time/Stance time ratio | The percentage of time spent in swing compared to stance expressed as a ratio. |
| Step length | The distance covered in centimeters between toe off and subsequent heel strike of the same foot |

Step parameter symmetry can be collected and assessed with a variety of technology applications including video and walking mats with sensors. Raw data collected on step parameters can be calculated into symmetry measures using 1 of 4 different calculations (spV=step parameter variable): 1) symmetry ratio=spV paretic/spV non-paretic; 2) symmetry index=l(spV paretic-spV nonparetic)/0.5(spV paretic+spV non-paretic)l x 100%; 3) gait asymmetry=l100x[ln(spV paretic/spV non-paretic]l; and 4) symmetry angle=[$45^0$-arctan(spV paretic/spV non-paretic)x100%]/90.[67] All 4 equations demonstrated similar discriminative ability in 161 people with chronic stroke, but the symmetry ratio seemed to be the easiest to interpret.[67] Therefore collection of step parameters for calculation into a symmetry ratio for analyses is an important walking measure to assess recovery after stroke.

Rehabilitation Interventions for Walking after Stroke

Interventions to promote walking recovery after stroke are integral to post-stroke rehabilitation programming. Interventions tend to focus on impairments (body structure & function) or task-practice (activity). Walking recovery interventions after stroke have recently focused on task-practice due to better understanding of motor learning and activity-dependent neuroplasticity.[95,96] However, evidence has shown that well designed

and appropriately dosed impairment-based interventions are also effective in facilitating walking recovery after stroke,[10,96] and equally important to develop and test for people after stroke. The ICF provides a framework for considering salient concepts from both approaches. Body structures and functions include impairments while activity includes the importance of functional task practice.[40,42] Due to the reciprocal relationships represented by the bi-directional arrows between body structures and functions and activity, effective rehabilitation interventions focusing on both impairments (body structures and functions) and task-practice (activity) are needed for people with stroke.

Impairment-Based Interventions

Impairment-based interventions for walking recovery typically target lower extremity strength, balance, or endurance.[69] These interventions target specific impairments related to walking. Examples of impairment-based interventions include: 1) exercise prescriptions designed to work on strength, flexibility, and endurance; and 2) patient handling interventions to inhibit abnormal muscle tone and movement patterns and to facilitate postural control and normal movement patterns.

A few studies have reported on the impact of interventions designed to alter nervous system functioning and promote postural control and normal movement on walking in people with stroke. Specifically, Stock and Mork assessed the efficacy of an intervention designed to increase weight bearing control and hemiparetic leg activation on walking speed.[25] At the conclusion of daily intense therapy for 2 weeks in 12 patients with acute stroke, researchers reported a significant improvement in FGS (1.06 m/s - 1.33 m/s p=0.002).[25] In another study with 26 people with subacute stroke, participants received treatment designed to address neurological impairments to optimize postural and movement strategies.[22] Participants also received task practice opportunities and were compared to participants who received task practice only.[22] Both groups demonstrated significant improvement in walking distance, but there was no significant

difference between the groups.[22] When looking at walking speed, the group receiving treatment to address neurological impairments demonstrated significantly greater improvement than the group not receiving treatment for neurological impairments (26.6 m/min vs. 9.9 m/min, p=0.01).[22]

Several studies have reported on the effectiveness of exercise in improving walking capacity in people with stroke. Some studies report on efficacy of exercise on improving walking measures after stroke without comparison to a control group. For example, a study with 18 people with subacute to chronic stroke used an exercise program consisting of low-intensity progressive exercises targeting lower extremity strength delivered 2 times/week over 14 weeks.[97] Researchers reported a significant increase in walking speed (0.54 m/s to 0.75 m/s, p<0.001).[97] Olney et al.[98] tested a strengthening and conditioning program in 72 people with chronic stroke. Participants were assigned to 2 groups (supervised or unsupervised exercise) performing the same exercise program.[98] Significant increases in walking speed measured with the 6MWT were reported for both the supervised and unsupervised groups at 10 weeks and 1 year follow-up (p-values 0.01 to 0.001).[98] Leroux tested an 8 week group exercise program in a population (n=20) of people with chronic stroke.[99] Although balance and timed-up-and-go tests both demonstrated significant improvement (p<0.008), walking distance measured with the 6MWT only demonstrated a trend towards improvement but not significant improvement (170.7 m vs. 188.8 m, p=0.012).[99] These studies suggest potential improvement in walking outcome measures after participation in exercise targeting fitness and lower extremity strength, but do not provide evidence of comparative effectiveness.

Other researchers have tested exercise programs targeting walking impairments in comparative trials with control groups. One such trial included 100 people with chronic stroke randomized to one of two groups, intervention (n=50) or usual care (n=50), the

intervention group participated in at home supervised exercises designed to improve

strength and endurance for 36 sessions over 12 weeks, while the usual care group

received no ongoing therapy visits outside of any incidental therapy prescribed by their

physician.[30] Subjects in the intervention group demonstrated significantly greater

improvements in both walking speed and walking distance than the usual care group at

p<0.05 (speed 0.18 m/s vs. 0.11 m/s; distance 61.61 m vs. 33.59 m).[30] In another trial,

Pang et al. randomized 63 people with chronic stroke living in the community into 2

groups, intervention (n=32) and control (n=31).[100] The intervention group participated in

a fitness and mobility exercise group to improve cardiorespiratory fitness, mobility, leg

strength, balance, and hip bone mineral density while the control group participated in a

group upper extremity exercise program.[100] Significantly greater improvements were

reported for cardiorespiratory measures and leg strength in the intervention group.[100]

Specifically, the 6MWT difference between the intervention and control group was 64.5

m vs. 38.4 m (p=0.02).[100] Finally, Lee and colleagues randomized 52 people with chronic

stroke to 1 of 4 groups; 1) aerobic cycling and progressive resistive strengthening

(n=13), 2) progressive resistive strengthening and sham aerobic cycling (n=13), 3)

aerobic cycling and sham progressive resistive strengthening (n=14), and 4) sham

progressive resistive strengthening and sham aerobic cycling (n=12).[26] Even though

strength and stair climbing ability both demonstrated significant improvement with

strengthening and aerobic exercise, none of the groups demonstrated significant

improvements in walking speed or distance.[26] However, the aerobic cycling and

progressive exercise group demonstrated a trend towards improved walking distance,

but did not achieve statistical significance (p=0.06).[26] These data suggest that

impairment-based interventions have potential to positively impact walking capacity in

people with stroke. However, the data do not support exercise targeting lower extremity

strength and endurance as an absolute best-evidence treatment for walking recovery after stroke.

Task-Practice Interventions

Task-practice interventions for walking recovery after stroke involve structured walking practice in a controlled environment typically emphasizing specific parameters such as repetition and intensity. The use of body weight supported (BWS) walking practice with or without a treadmill has gained much interest in both clinical and research practice over the last 15 years in post-stroke rehabilitation.[10] Several studies have reported benefits from BWS walking practice creating momentum for fast adoption of BWS walking practice into clinical care during post-stroke rehabilitation.[10]

Some of the evidence supporting BWS treadmill training comes from case reports and small pilot studies. In a case report, Combs and Miller reported significant improvement in both walking speed and walking endurance after BWS treadmill training 5 days/week for 2 weeks and at 3-month follow-up.[23] Significance was demonstrated by greater than 3 standard deviations above baseline measurements on the 6MWT and CGS.[23] In another single subject design study, an individual 30 months post-stroke participated in BWS treadmill training 3 times per week for 4 weeks.[101] The participant demonstrated significantly improved balance measures between baseline and immediately following the intervention (Berg Balance Scale, p=0.001; right lateral reach, p=0.008; left lateral reach, p=0.030) but no significant difference in walking speed (p=0.134).[101] A small pilot study demonstrated significant increase in single limb support (p=0.012)  and significant decrease double support time (p=0.0001) in 8 people with chronic stroke after 6-8 weeks of BWS treadmill training.[102]

Other researchers have tested the impact of different walking speeds using a treadmill.[53] Sullivan and colleagues randomized 24 people with chronic stroke to 1 of 3 groups including; slow (0.5 mph), fast (2.0 mph), and variable (0.5, 1.0, 1.5, 2.0 mph).[53]

Results were significantly improved CGS in all 3 groups immediately following completion of the intervention (4 weeks) p<0.001 which held at the 1-month follow-up (p<0.01).[53] However, at 3-month follow-up, gains were still noted but not at a statistically significant level (p=0.77).[53]

Several studies have compared effectiveness between walking training with and without BWS. One study compared walking training with BWS and without BWS by randomizing 100 people with chronic stroke to over ground walking with 40% BWS (n=50) or over ground walking without BWS (n=50) 4 times per week for 6 weeks.[103] Results indicated significantly greater improvement in both walking speed (0.34 m/s vs. 0.25 m/s, p=0.029) and walking endurance (147 m vs. 105 m, p=0.018) in the BWS group when compared to the no BWS group.[103] Researchers also reported significantly greater improvement in balance (p=0.001) and motor recovery (p=0.001) in the BWS group as well as continued greater improvement in walking speed (p=0.006) and motor recovery (p=0.039) at 3-month follow-up.[103] Trueblood reported walking speed and swing and stance symmetry in 10 people with chronic stroke ambulating in 3 conditions: 1) over ground without BWS; 2) over ground with BWS; and 3) treadmill with BWS.[102] Participants demonstrated better swing symmetry ratio when walking over ground with BWS compared to walking over ground without BWS (0.22 vs. 0.72) as well as better stance ratio (0.11 vs. 0.84).[102] Sousa and colleagues assessed walking speed and spatiotemporal step parameters in a population (n=13) of people with chronic stroke to determine differences in walking characteristics between over ground walking without the BWS harness or with the BWS harness but no unweighting or with the BWS harness and 30% unweighting.[104] The researchers reported significant positive differences in walking speed and stride length with 30% unweighting in the BWS harness when compared to no harness.[104]

Sullivan and colleagues took a different approach comparing 4 groups with different combinations of task-practice and exercise interventions.[105] Eighty people from 4 months to 5 years post-stroke were randomized to 1 of 4 groups including: 1) BWS treadmill training and upper extremity ergometry; 2) limb-loaded resistive leg cycling and upper extremity ergometry; 3) BWS treadmill training and limb-loaded resistive leg cycling; and 4) BWS treadmill training and lower extremity progressive resistive exercise.[105] Participants participated in intervention activities 4 times per week for 6 weeks alternating between the two assigned activities.[105] Comparisons between group 1 and group 2 demonstrated significantly greater improvements in both CGS and FGS for group 1 (CGS 0.13 m/s vs. 0.01 m/s, p<0.004; FGS 0.10 m/s vs. 0.01 m/s, p<0.03).[105] Groups 1, 3, and 4 (BWS treadmill training part of intervention) all demonstrated significantly greater CGS and FGS when comparing within group pre and post-test measures (CGS p=0.001, 0.004, and <0.0001; FGS p=0.008, 0.032, and 0.0002).[105] A significant difference was not noted on walking distance between groups 1 and 2 (p=0.50), but a significant difference was found for all groups when comparing pre- and post-test measures within each group (group 1, p=0.011; group 2, p=0.049; group 3, p=0.011; and group 4, p<0.0001).[105] The researchers concluded that task-practice with BWS treadmill training was more effective at improving walking speed than resisted leg cycling.[105]

Although data from these trials are encouraging, none of them test effectiveness of task-practice compared to other established interventions for walking recovery. In 2011, Duncan and colleagues reported results from a large randomized control trial comparing BWS treadmill training with an established exercise protocol for walking and balance after stroke.[10] Participants were assigned to 1 of 3 groups; 1) early locomotor training with treadmill and BWS, 2) late locomotor training with treadmill and BWS, and 3) progressive exercise program.[10] Results from this randomized controlled trial

demonstrated significant improvements that were clinically meaningful in all 3 groups for both walking speed and walking distance.[10] However, there were no significant differences between groups making it impossible to determine superiority of one intervention strategy over another.[10] In a follow-up article, Duncan and Dobkin suggest that more research on impairment-based interventions designed to facilitate walking recovery after stroke might be needed.[96] Although much work has already been done on exercise programs designed to address specific impairments, development and testing of complementary and alternative approaches such as yoga to facilitate walking recovery after stroke has not yet been reported.

Yoga

Yoga is an ancient wellness practice which directs students to discover the human experience as a yoked existence encompassing the body, mind, and spirit.[43,45,106] Although yoga is considered a form of CAM, it has similar guiding principles as the holistic (biopsychosocial) approaches used in modern healthcare.[43] The adoption of holistic approaches in routine clinical practice has been slow, leading many patients with chronic conditions to seek CAM options on their own.[44,107-109] Yoga has been reported to be the most visible CAM approach with over 20 million people in the US participating.[43]

Yoga comes from the Sanskrit root for the word yoke.[43,45] The implied meaning is a harnessing or 'yoking' to a way of life.[45] In modern day healthcare this idea of 'yoked' refers to creating health or wholeness in the human experience of the mind, body, and spirit.[43] Yoga is a 5000 year old practice which is believed to have evolved from Hindu, Jaina, and Buddhist religions.[43] Even though yoga developed out of several religious traditions, it makes no expectation of students for particular religious beliefs.[43] Yoga is considered an Indian philosophy and life practice.[43,45] In its comprehensive and classic approach, Raja yoga encompasses 8 paths to personal development and well-rounded

health (Table 2).[43] However, Hatha yoga which is more of a fitness-based practice is

representative of most yoga practice in western cultures.[43,45,106]

Table 2: Eight Paths of Raja Yoga

| Path | Description |
|------|-------------|
| Yamas | Moral precepts: non-harming, truthfulness, nonstealing, chastity, greedlessness |
| Niyamas | Qualities to nourish: purity, contentment, austerity (exercise), self-study, devotion to a higher power |
| Asana | Postures/movements: a calm, firm, steady stance in relation to life |
| Pranayama | Breathing exercises: the ability to channel and direct breath and life energy |
| Pratyahara | Decreased reactivity to sensation: focusing senses inward; non-reactive to stimuli |
| Dharna | Concentration: unwavering attention, commitment |
| Dhyana | Meditation: mindfulness, being attuned to the present moment |
| Samadhi | Ecstatic union: flow, "in the zone," spiritual support/connection |

Hatha yoga consists of 3 basic components including Asana (postures),

Pranayama (breath), and Dhyana (meditation).[43,106] Postures used in Hatha yoga focus

on stretching and strengthening muscles as well as relaxation and tension release to

improve energy level.[45,106] Breathing practices used in Hatha yoga are taught to facilitate

lengthening, expansion, and stretching of the thorax to promote diaphragmatic breathing

and decrease accessory muscle breathing to promote self-awareness and decrease

sympathetic nervous system control.[45] Meditation practice is designed to bring focus to

the current moment to note the state of the body and promote decreased anxiety and

depression and increased body awareness.[106] Yoga has been adopted as an alternative

intervention for managing several medical problems influenced by stress such as

anxiety, depression, high blood pressure, and chronic pain.[110] However, equally

important to physical rehabilitation is the efficacy of yoga in managing physical

impairments and activity limitations.

Yoga in Physical Rehabilitation

Hatha yoga practice as a holistic approach to health and well-being might be an effective rehabilitation strategy for people with chronic physical limitations. In older adults yoga has been used to improve balance,[111,112] floor transfers,[111,112] and walking.[113] Tatum and colleagues demonstrated improvement in older adults' balance scores (48.98 vs. 54.11, p<0.001) and floor transfer skills (5.16 vs. 8.24, p<0.001) after 13 weeks of 90 minute weekly yoga sessions.[111] DiBenedetto et al. recruited 23 older adults to participate in an 8 week yoga program designed to improve lower extremity strength and flexibility.[113] The researchers reported significant improvements in peak hip extension (p<0.001) and stride length (p=0.03).[113] In another study assessing the impact of yoga on walking, 27 women with musculoskeletal problems demonstrated increased walking speed (0.80 m/s vs. 1.06 m/s, p<0.05) and decreased step irregularity (0.48 cm vs. 0.27 cm, p<0.05).[38] Participants attended 8 sessions of yoga treatment consisting of postures and breathing.[38] Although these data suggest that yoga may be able to impact physical functioning, subjects in these studies did not have neurological pathology limiting generalization to people with neurological pathology.

Yoga and Other Neurological Pathologies

Yoga practice has been documented in people with a variety of neurological pathologies including multiple sclerosis,[108,114] post-polio syndrome,[115] and Parkinson disease.[116] Specifically, Zwick and Dunn reported improved standing in a single subject with multiple sclerosis after participating in yoga postures in supine and sitting to prepare lower extremities for standing.[108] In another study with 69 people with multiple sclerosis randomly assigned to 1 of 3 groups (exercise n=21, yoga n=26, wait-list n=22), researchers reported significantly improved score (less general fatigue) on the Multi-dimensional Fatigue Inventory (p<0.01) and significantly improved vitality on the SF-36 (p<0.001) with both the exercise and yoga intervention.[114] The intervention was 90 minutes once per week for 6 months.[114] A population (n=23) of people with post-polio

syndrome demonstrated significant improvement in pain (p=0.009), fatigue severity

(p=0.004), fatigue impact (p=0.001) and fatigue self-efficacy (p=0.001) after participation

in 5 days of Hatha yoga followed by 12 weeks of home practice.[115] After participation in

yoga class 60 minutes once per week for 8 weeks, a single subject with Parkinson

disease demonstrated improved balance and timed-up-and go but not to a clinically

significant level.[116] Although these data suggest that people with neurological pathology

can participate in yoga, they do not provide evidence of feasibility or efficacy of yoga

practice in people with stroke.

Yoga and Stroke

A few studies have reported on yoga in people with stroke.[32,46-48] Garrett and

colleagues reported on the personal experiences and perceived outcomes in a

qualitative study with 9 people with chronic stroke.[47] Analysis of the data revealed 3

themes including: 1) greater sensation; 2) feeling calmer; and 3) becoming connected.[47]

Secondary themes were also reported including physical improvements (strength, range

of motion, walking ability) and possibility to reconnect and accept a different body.[47] In

another small pilot study, Lynton et al. reported improved fine motor skill and improved

aphasia that did not reach significance.[46] Three subjects with chronic stroke were

enrolled in the study and participated in 90 minute yoga sessions twice per week for 12

weeks.[46] Bastille and Gill-Body enrolled 4 people with chronic stroke in a preliminary

investigation to assess the effects of 8 weeks (16 sessions) of yoga-based exercise on

balance measured with the Berg Balance Assessment, the Timed Movement Battery,

and the Stroke Impact Scale.[48] Using the 2 standard-deviation-band method for

significance, the researchers reported significant improvement in 3 of the subjects on the

Timed Movement Battery and in 2 of the subjects on the Berg Balance Assessment.[48]

Finally, in a randomized pilot study with 47 people with chronic stroke, Schmid et al.

reported significant improvement in balance and balance self-efficacy.[32] Participants

were randomized to yoga (n=37) or waitlist control (n=10) and participated in 8 weeks of group yoga twice per week for a total of 16 sessions.[32] Within the yoga group, significant improvement between base-line and 8 week measures were demonstrated for balance scores (p<0.001), level of independence measured with the Modified Rankin Scale (p<0.001), and fear of falling (p<0.001).[32] These data suggest that people with chronic stroke can participate in yoga as well as benefit with improved physical functioning and perception of disability.

<div align="center">Gap in Literature</div>

The scientific literature on stroke clearly indicates that people with stroke experience long-term limitations in walking. These limitations are an important focus during recovery from stroke. Even though multiple intervention strategies have been tested demonstrating different levels of effectiveness, the evidence does not support one intervention strategy over another and people with stroke continue to experience long-term walking limitations. Finally, yoga appears to be feasible in people with chronic stroke with potential to promote improved physical functioning. However, yoga has not been tested in people with chronic stroke to promote walking recovery. Therefore this study tested the effect of group therapeutic-yoga on walking for people with chronic stroke.

<div align="center">Summary</div>

Stroke is a sudden medical event leading to significant long-term disability. Long-term disabilities frequently experienced after stroke include mobility limitations with walking impairment being a common long-term mobility limitation. Although several walking characteristics can be impaired after stroke, walking speed, walking distance, and spatiotemporal step parameter symmetry have emerged as important characteristics related to waking ability. All three of these characteristics can be reliably measured providing a mechanism for assessing efficacy of interventions designed to improve

<div align="center">22</div>

walking characteristics. Interventions developed to promote walking recovery after stroke are varied and tend to fall into 1 of 2 categories, impairment-based or task-practice based. Even though evidence has shown improvement with both types of interventions, long-term walking impairments continue to be a problem and neither type of intervention has emerged as superior. Due to lack of clear evidence on the "best" intervention for walking recovery after stroke, clinicians and researchers are considering complementary and alternative approaches such as yoga. Yoga has shown effectiveness in improving physical functioning in older adults. It has also been tested in people with neurological pathology including stroke. Even though the evidence for yoga in people with stroke is from small pilot and case study investigations, the preliminary evidence suggests that yoga might be an effective intervention strategy for improving physical functioning after stroke including walking.

Chapter 3: Methodology

Research Design

This project was a secondary data analysis using data derived from a prospective pilot study, "Yoga as a Complex Intervention for People with Stroke."[117] The primary study included 47 people with stroke who participated in 8 weeks of group therapeutic-yoga.[32] The final group of participants (n=12) were invited to complete an additional 4 weeks of yoga to assess the effect of 8 and 12 weeks of group therapeutic-yoga on outcome variables. These analyses include within-subject main effect of time on walking recovery measures in the 12 people who completed 8 and 12 weeks of group therapeutic-yoga.

Study Participants

Participants were a sub-sample (n=12) of adults with chronic stroke recruited for the primary study. Inclusion criteria for the current study included the following: survived a stroke; finished with rehabilitation; required OT or PT after the stroke; have residual physical deficits; at least 18 years old; score at least 4/6 on the short mini mental status exam; be able to stand and take steps with or without an assistive device; able and willing to attend twice weekly group therapeutic-yoga sessions; and a member of the group who completed 8 and 12 weeks of group therapeutic-yoga. Exclusion criteria included: medical co-morbidities limiting ability to exercise; inpatient drug or alcohol stay in the last year; inability to answer questions verbally or with pointing at answer sheets due to aphasia or cognitive deficits; unresolved transportation issues; and refusal to sign informed consent.

Intervention

Participants participated in 12 weeks, twice a week, group therapeutic-yoga. The intervention took place at the Indiana University School of Health and Rehabilitation Sciences Rehabilitation and Integrative Therapy (RIT) Lab and was led by a Certified

Yoga Therapist (CYT). Research staff, therapy students, and yoga instructor students were available to assist participants as needed with poses and transitions and participants were allowed to use upper extremity support and assistive devices as needed for safety. Participants were instructed in alternate activities as a substitute for any activities participants felt they could not complete safely. Blood pressure was taken at the beginning of each session. Participants with blood pressure greater than 200/100 were not allowed to participate in class activities. The intervention took place 2 times per week for one hour for a total of 12 weeks. Walking recovery measures were assessed at baseline, 8 weeks, and 12 weeks.

The intervention was developed by the CYT and included breathing, postures, and relaxation. The first two weeks of class included activities that could be performed while seated in a stable chair. After week 2, participants advanced to standing postures with physical assistance and light upper extremity weight bearing as needed and at week 5 participants advanced to floor activities. The sequence of activities in each session was: 1) Breathing focusing on breath in and out to promote awareness, chest expansion and filling, and parasympathetic influence; 2) Poses to work on strength, flexibility, and balance in the three postures (sitting, standing, and supine on floor); and 3) Guided relaxation in sitting for first 4 weeks and in supine last 4 weeks. During the additional 4 weeks, participants continued with the established 8 week program and added more complex breathing techniques and more controlled muscle activation and movements in the sitting and supine positions. (Table 3)

Table 3: Yoga-based Protocol

| Position | Description | Yoga-pose |
|---|---|---|
| Seated<br>Weeks 1-12 | Slower, deeper, rhythmic breathing, extended exhale<br>Bilateral eye movements & hold eyes steady<br>Cervical rotation, lateral flexion, axial extension<br>Scapular AROM & arm movements<br>Lower trunk extension, flexion, rotation, and lateral flexion<br>Hip external rotation and abduction with ankle and toe ROM<br>Hand to opposite knee | 2:1 breathing<br><br><br><br>Receptive gesture<br>Cow, cobra, half moon & fish king poses<br>Pigeon pose |
| Seated<br>Weeks 9-12 | Alternate nostril breathing<br>Pelvic floor isometrics<br>Hip flexion with knee extension | Alternate nostril breathing<br>Mulabanda |
| Standing<br>Weeks 3-12 | Standing with or without support<br>Heel rises<br>Hip extension while standing<br>Lunges<br>Shallow squats | Mountain pose<br>Chair pose<br>Locust pose<br>Warrior pose<br>Awkward pose |
| Supine<br>Weeks 5-12 | Straight leg raise stretch<br>Bridging<br>Single knee to chest<br>Supine relaxation | Big toe pose<br>Bridge pose<br>Energy releasing pose<br>Corpse pose |
| Supine<br>Weeks 9-12 | Double knee to chest with pelvic rotation | |

Participants had their own yoga mat and eye pillow (small pillow placed on the eyes to block out light and provide weight on the eyes) for use during the sessions which they took home with them at the end of the intervention. Water and heart healthy snacks were available during all sessions.

Data Collection

All data were collected at the Indiana School of Health and Rehabilitation Sciences on the IUPUI campus in Indianapolis, Indiana. Data were collected by one trained research assistant. Prior to data collection, participants were screened by phone and completed the informed consent form at the RIT lab. Participants wore a gait belt

and were guarded for safety during all walking tests. Participants were allowed to use assistive devices and orthotics as needed.

Demographics and Stroke Characteristics

Basic demographics including; age, gender, race, education level, and marital status were collected. Additionally stroke characteristics including time since stroke, side of stroke, type of stroke, and stroke severity were also collected.

Fast Walking Speed

Walking speed was measured with the 10MWT. Walking speed is a reliable measure of functional improvement in adults who have had a stroke.[5,74] Although walking speed categories defined by Perry are based on comfortable walking speed,[72] the maximum speed achieved safely is important for community ambulation activities such as crossing a street.[77] The 10MWT is a timed walking test in which people are timed as they walk along a 10 meter straight walkway. The 10MWT can be performed at comfortable self-selected or fast walking speed. The 10MWT is a reliable and valid measure of walking speed[12,17,66,74] with established MDC[12,15,17,66] in people with stroke. Specifically the 10MWT has demonstrated excellent test-retest reliability with intraclass correlation coefficients (ICC) of 0.94[17] and 0.88[74] with CGS and 0.97[17] with FGS in people with chronic stroke. The MDC has also been reported on the 10MWT in people with chronic stroke at 0.25 m/s (CGS) and 0.22 m/s (FGS).[17]

Participants were instructed to walk as quickly as they could safely along a straight 14 meter walkway. Participants were timed during the middle 10 meters. The 14 meter walkway allowed for a warm-up and slow-down period before and after the timed 10 meters. Participants performed 2 walks with a 30 second rest in between. The walkway was marked with orange cones. Time was recorded in seconds, averaged for the two walks, and converted to meters per second (m/s) speed.

Walking Distance

Walking distance (endurance) was measured with the 6MWT. Even though the 6MWT was developed as a walking capacity measure for people with cardiovascular problems,[118] it has been adopted as the primary walking distance measure for people with stroke.[7,17,66,71,83,84] The 6MWT is a reliable and valid measure of walking distance in people with stroke.[17,66,71,74] In people with chronic stroke living in the community, high test-retest reliability (ICC=0.99)[17,86] as well as an MDC of 36.6 m have been reported.[17]

The 6MWT requires people to walk as far as they can at a comfortable self-selected walking pace for 6 minutes. Participants were instructed to walk back and forth along a straight 30 meter walkway at a comfortable pace. Participants were instructed to make as many laps as possible in 6 minutes. Participants were allowed to stop and rest if needed, but the timer continued to run during rest breaks. The participants were updated on their time at each 1 minute interval and given verbal encouragement, "you're doing a good job; keep up the work," at each 1 minute interval. The walkway was marked with orange cones. The number of meters walked during the 6 minutes was recorded.

Spatiotemporal Step Parameters

Spatiotemporal step parameters were collected with the GAITRite mat. The GAITRite is a walking analysis system designed to collect spatiotemporal walking characteristics including base of support, average walking speed, step length, stride length, step time, swing time, stance time, single limb support time, and double limb support time.[8,119] Specifically assessed in this analysis were symmetry ratios for the following spatiotemporal step parameters; swing time, stance time, swing time/stance time ratio, and step length (see Table 1 for definitions of spatiotemporal parameters). The GAITRite collects data through a rubberized mat with embedded sensors that record foot activity as people walk over the mat.[8,119] The GAITRite is a reliable and valid

measure of spatiotemporal step parameters.[87,90-92,119] Good test-retest reliability of spatiotemporal symmetry measures has been reported in a population (n=26) of people with chronic stroke during both CGS and FGS tests.[59] ICC values for velocity, step length asymmetry, stance time asymmetry, and swing time asymmetry during CGS and FGS ranged from 0.92 to 0.98.[59] MDC values have also been reported for CGS (velocity, 0.20; step length asymmetry, 0.15; stance time asymmetry, 0.09; swing time symmetry, 0.26) and for FGS (velocity, 0.22; step length asymmetry, 0.19; stance time asymmetry, 0.10; swing time asymmetry, 0.20).[59]

The GAITRite mat was placed in the middle of the walkway during the 10MWT and 6MWT. Participants were instructed to walk over the GAITRite mat with each pass during both tests. Spatiotemporal step parameters were collected as participants walked over the GAITRite mat during the 10MWT and 6MWT.

Spatiotemporal step parameters were processed with the GAITRite software. Any walks suspended at the time of data collection were manually analyzed and cleaned to eliminate assistive device marks and confirm appropriate labeling of each step. Step parameter variables (spV) were calculated for FGS and CGS from the passes over the GAITRite mat during the 10MWT and 6MWT respectively. Spatial step parameters (step length) were measured in centimeters (cm) and averaged for each leg on the 10MWT and 6MWT. Temporal step parameters (swing time, step time) were measured in seconds (s) and averaged for each leg on the 10MWT and 6MWT passes. Swing-stance symmetry was calculated for each leg on each test as the ratio of the average swing time/average stance time, expressed as a numeric value, and averaged for each leg. Each spV was expressed as a symmetry ratio (spV larger/spV smaller) for analysis. The symmetry ratio was chosen for analysis due to its discriminative ability and relative ease of interpretation.[67]

Data Management

Hard copy data collected with source documents are stored in a locked cabinet in a locked office at the Roudebush Veterans Administration Medical Center. Electronic data are stored in pass word protected study folders on the secure Veterans Administration network. All processed data were entered into an Access data base and imported into SPSS 20.0 for analyses.

Data Analysis

Demographic and stroke characteristic data were analyzed with descriptive statistics. Normality of data was assessed with the Shapiro-Wilks test. Within subject main effects over 3 time points (1=baseline; 2=8 weeks; and 3=12 weeks) were assessed with a repeated measures (RM) ANOVA (Friedman's test for non-normal data) with $p \leq 0.05$. Sphericity of data was tested with Maulchy's test and corrected as indicated with the Huynh-Feldt correction to maintain an accurate F-statistic for interpretation of the RM ANOVA results. Post-hoc analyses on interaction effects were performed where appropriate on each variable between time points 1 and 2, 1 and 3, and 2 and 3. Due to the small sample size and within subject design, effect sizes for the intervention on each variable and the proportion of participants achieving improvement greater than or equal to the MDC for each variable was also calculated.

Effect sizes were calculated for each variable by dividing the mean score difference between time points 1 and 2, 1 and 3, and 2 and 3 by the pooled standard deviation.[120] Effect sizes were described as small (d=0.2), medium (d=0.5), or large (d=0.8) based on Cohen d classifications.[121]

Chapter 4: Results

Twelve people with chronic stroke were recruited and enrolled in the study. Three people (25%) dropped out and were lost to follow-up at the 12-week assessment. Reasons for dropping out were; 1) un-reported, 2) development of a new medical problem limiting ability to participate, and 3) moving away from the local area due to spouse job re-location. The age range for the whole sample (n=12) was 47-76 (mean=60). Other demographics and stroke characteristic data for the whole sample (n=12) include; 8 (66%) female, 4 (33%) married, 5 (41%) African American, 7 (58%) some college, 3(25%) <1 year chronicity, 7 (58%) left hemiparesis, 10 (38%) ischemic stroke, and 7 (58%) were dependent based on MRS score <3. Only data from participants who did not drop out (n=9) were included in the analyses except for spatiotemporal step parameter symmetry for the 12-week assessments which included only 8 of the participants due to equipment malfunction and failure of transmission of the data from the mat to the computer. There were no differences between participants who did (n=3) and did not (n=9) drop out except age, where younger participants were more likely to drop out (p=0.028). Refer to Table 4 for demographic and stroke characteristic data for both groups.

Table 4: Demographics and Stroke Characteristics

| Variable | Entire sample N=12 | Not drop out N=9 | Drop out N=3 | P-value |
|---|---|---|---|---|
| Age | 47-76 (60) | 55-76 (63) | 47-56 (52) | 0.028 |
| Gender (female) | 8 (66%) | 7 (77%) | 1 (33%) | 0.157 |
| Marital status (married) | 4 (33%) | 2 (22%) | 2 (66%) | 0.494 |
| Race (black) | 5 (41%) | 4 (44%) | 1 (33%) | 0.735 |
| Education (some college) | 7 (58%) | 5 (55%) | 2 (66%) | 0.662 |
| Chronicity (<1 year) | 3 (25%) | 2 (22%) | 1 (33%) | 0.563 |
| Hemiparesis (left) | 7 (58%) | 6 (66%) | 1 (33%) | 0.310 |
| Stroke type (ischemic) | 10 (38%) | 8 (88%) | 2 (66%) | 0.371 |
| Dependent (MRS<3) | 7(58%) | 5 (55%) | 2 (66%) | 0.735 |

Within Subject Main Effects

With-in subject main effects of time were not significant for any of the variables. Therefore no post hoc analyses were completed comparing baseline to 8 weeks, 8 weeks to 12 weeks, and baseline to 12 weeks. Refer to Table 5 for the repeated measures main effect results.

Table 5: Within Subject Main Effects

| Variable | Baseline | 8weeks | 12 weeks | P-value |
|---|---|---|---|---|
| Fast walking speed (meters/second) | 0.87±0.33 | 0.90±0.34 | 0.89±0.39 | 0.833 |
| Distance (meters) | 279±119 | 295±122 | 299±132 | 0.229 |
| Step length symmetry (FGS) | 1.21±0.39 | 1.35±0.61 | 1.28±0.37 | 0.091^ |
| Step length symmetry(CGS) | 1.34±0.34 | 1.17±0.19 | 2.21±3.09 | 0.140 ^ |
| Swing time symmetry (FGS) | 1.19±0.20 | 1.41±0.59 | 1.71±1.48 | 0.196 ^ |
| Swing time symmetry (CGS) | 1.22±0.27 | 1.61±1.05 | 1.86±1.80 | 0.217 ^ |
| Stance time symmetry (FGS) | 1.09±0.08 | 1.11±0.13 | 1.69±1.67 | 0.318 ^ |
| Stance time symmetry (CGS) | 1.07±0.07 | 1.18±0.12 | 1.32±0.43 | 0.741 ^ |
| Swing time stance time ratio symmetry (FGS) | 1.33±0.33 | 1.62±0.85 | 2.33±1.81 | 0.169 ^ |
| Swing time stance time ratio symmetry (CGS) | 1.33±0.40 | 1.57±0.79 | 2.60±3.41 | 0.674 ^ |

FGS = fast walking speed; CGS = comfortable walking speed; ^Friedman's nonparametric test

## Effect Size

Effect size calculations were less than 0.2 (small effect) for walking speed and walking distance scores between all three time point combinations (baseline to 8 weeks, 8 weeks to 12 weeks, and baseline to 12 weeks). Seven of eight of the spatiotemporal step parameter symmetry ratios demonstrated an effect size between 0.2-0.4 (small effect) between baseline and 8 weeks; 5 of 8 and 1 of 8 spatiotemporal step parameters demonstrated a small (0.2-0.4) and medium (0.5-0.7) effect size respectively between 8 weeks and 12 weeks; 3 of 8 and 4 of 8 demonstrated a small (0.2-0.4) and medium (0.5-0.7) effect size respectively between baseline and 12 weeks. Finally, 22 (91%) of the spatiotemporal step parameter measures across all three time points demonstrated a negative effect indicating less symmetry or increased asymmetry over time. Refer to Table 6 for effect size results.

Table 6: Effect Size Cohen (d) Values

| Variable | Baseline to 8 weeks (d) | 8 weeks to 12 weeks (d) | Baseline to 12 weeks (d) |
|---|---|---|---|
| Walking speed | 0.1 | 0.008 | 0.01 |
| Walking distance | 0.1 | 0.009 | 0.04 |
| Step length symmetry FGS | 0.2~ | 0.1 | 0.1~ |
| Step length symmetry CGS | 0.3 | 0.4~ | 0.3~ |
| Swing time symmetry FGS | 0.4~ | 0.2~ | 0.4~ |
| Swing time symmetry CGS | 0.5~ | 0.1~ | 0.4~ |
| Stance time symmetry FGS | 0.1~ | 0.4~ | 0.5~ |
| Stance time symmetry CGS | 0.3~ | 0.6~ | 0.6~ |
| Swing/stance symmetry FGS | 0.4~ | 0.4~ | 0.7~ |
| Swing/stance symmetry CGS | 0.3~ | 0.4~ | 0.5~ |

FGS = fast walking speed; CGS = comfortable walking speed; ~negative effect

### Minimal Detectable Change

The number of participants demonstrating change scores greater than or equal to the MDC value for each variable of interest at all three time point combinations (baseline to 8 weeks, 8 weeks to 12 weeks, and baseline to 12 weeks) ranged from 0-3. Refer to Table 7 for a summary of the MDC calculation results.

Table 7: Number of Participants Demonstrating Change Greater Than or Equal to MDC per Variable

| Variable | MDC | Number (%) Baseline to 8 weeks | Number (%) 8 weeks to 12 weeks | Number (%) Baseline to 12 weeks |
|---|---|---|---|---|
| Fast Walking Speed | 0.22 m/s[17] | 2 (22%) | 3 (33%) | 1 (11%) |
| Walking Distance | 36.6 m[17] | 2 (22%) | 3 (33%) | 2 (22%) |
| Step Length Symmetry Ratio (FGS) | 0.19[59] | 2 (22%) | 3 (37%)* | 0 (0%)* |
| Swing Time Symmetry Ratio (FGS) | 0.20[59] | 3 (33%) | 2 (25%)* | 1 (12%)* |
| Stance Time Symmetry Ratio (FGS) | 0.10[59] | 2 (22%) | 2 (25%)* | 1 (12%)* |
| Step Length Symmetry Ratio (CGS) | 0.15[59] | 1 (11%) | 1 (12%)* | 2 (25%)* |
| Swing Time Symmetry Ratio (CGS) | 0.26[59] | 2 (22%) | 2 (25%)* | 1 (12%)* |
| Stance Time Symmetry Ratio (CGS) | 0.09[59] | 2 (22%) | 3 (37%)* | 3 (37%)* |

FGS = fast walking speed; CGS = Comfortable walking speed; * total N=8 due to equipment malfunction

## Additional Analyses

Due to no significant main effects with repeated measures analysis and small sample size, additional analyses were run to compare mean change scores between each variable of interest at all three time point combinations. Paired T-tests (Wilcoxon for non-normal data) were used to compare baseline and 8 weeks, 8 weeks and 12 weeks, and baseline and 12 weeks. Although most of these analyses demonstrated no significant difference at $p \leq 0.05$, step length ratio symmetry at fast walking speed (p=0.05) demonstrated a significant change and walking distance (p=0.064) demonstrated a small improvement but not a significant difference between baseline and 12 weeks. See Tables 8-10 for results of related sample comparisons for all variables at each of the measurement time points.

Table 8: Related Sample Comparisons Baseline to 8 Weeks

| Variable | Baseline | 8 Weeks | P value |
|---|---|---|---|
| Fast walking speed (meters/second) | 0.87±0.33 | 0.90+0.34 | 0.498 |
| Distance (meters) | 279±119 | 295±122 | 0.200 |
| Step length symmetry (FGS) | 1.21±0.39 | 1.35±0.61 | 0.123^ |
| Step length symmetry(CGS) | 1.34±0.34 | 1.17±0.19 | 0.932^ |
| Swing time symmetry (FGS) | 1.19±0.20 | 1.41±0.59 | 0.128^ |
| Swing time symmetry (CGS) | 1.22±0.27 | 1.61±1.05 | 0.122^ |
| Stance time symmetry (FGS) | 1.09±0.08 | 1.11±0.13 | 0.553^ |
| Stance time symmetry (CGS) | 1.07±0.07 | 1.18±0.12 | 0.223^ |
| Swing time stance time ratio symmetry (FGS) | 1.33±0.33 | 1.62±0.85 | 0.092^ |
| Swing time stance time ratio symmetry (CGS) | 1.33±0.40 | 1.57±0.79 | 0.362^ |

FGS = fast walking speed; CGS = comfortable walking speed; ^ Wilcoxon nonparametric test

Table 9: Related Sample Comparisons 8 Weeks to 12 Weeks

| Variable | 8 Weeks | 12 weeks | P value |
|---|---|---|---|
| Fast walking speed (meters/second) | 0.90±0.34 | 0.89±0.39 | 0.869 |
| Distance (meters) | 295±122 | 299±132 | 0.758 |
| Step length symmetry (FGS) | 1.35±0.61 | 1.28±0.37 | 0.686^ |
| Step length symmetry(CGS) | 1.17±0.19 | 2.21±3.09 | 0.074^ |
| Swing time symmetry (FGS) | 1.41±0.59 | 1.71±1.48 | 0.326^ |
| Swing time symmetry (CGS) | 1.61±1.05 | 1.86±1.80 | 0.244^ |
| Stance time symmetry (FGS) | 1.11±0.13 | 1.69±1.67 | 0.779^ |
| Stance time symmetry (CGS) | 1.18±0.12 | 1.32±0.43 | 0.352^ |
| Swing time stance time ratio symmetry (FGS) | 1.62±0.85 | 2.33±1.81 | 0.183^ |
| Swing time stance time ratio symmetry (CGS) | 1.57±0.79 | 2.60±3.41 | 0.686^ |

FGS = fast walking speed; CGS = comfortable walking speed; ^ Wilcoxon nonparametric test

Table 10: Related Sample Comparisons Baseline to 12 Weeks

| Variable | Baseline | 12 Weeks | P value |
|---|---|---|---|
| Fast walking speed (meters/second) | 0.87±0.33 | 0.89±0.39 | 0.649 |
| Distance (meters) | 279±119 | 299±132 | 0.064* |
| Step length symmetry (FGS) | 1.21±0.39 | 1.28±0.37 | 0.050^* |
| Step length symmetry(CGS) | 1.34±0.34 | 2.21±3.09 | 0.108^ |
| Swing time symmetry (FGS) | 1.19±0.20 | 1.71±1.48 | 0.528^ |
| Swing time symmetry (CGS) | 1.22±0.27 | 1.86±1.80 | 0.092^ |
| Stance time symmetry (FGS) | 1.09±0.08 | 1.69±1.67 | 0.441^ |
| Stance time symmetry (CGS) | 1.07±0.07 | 1.32±0.43 | 0.344^ |
| Swing time stance time ratio symmetry (FGS) | 1.33±0.33 | 2.33±1.81 | 0.326^ |
| Swing time stance time ratio symmetry (CGS) | 1.33±0.40 | 2.60±3.41 | 0.160^ |

FGS = fast walking speed; CGS = comfortable walking speed; ^ Wilcoxon nonparametric test; *Significant or trending toward significant at p≤0.05

Also due to the small sample, scores across all three assessments are shown

per each participant in Figures 3-10. One consistent outlier (P4) was noted; therefore

analyses were run without the outlier. Baseline to 12-week change scores were p=0.028

for step length symmetry and p=0.055 for walking distance without the outlier, but still no

significant results were observed on the within subject main effects without the outlier.

Figure 3: Fast Walking Speed per Participant (n=9)
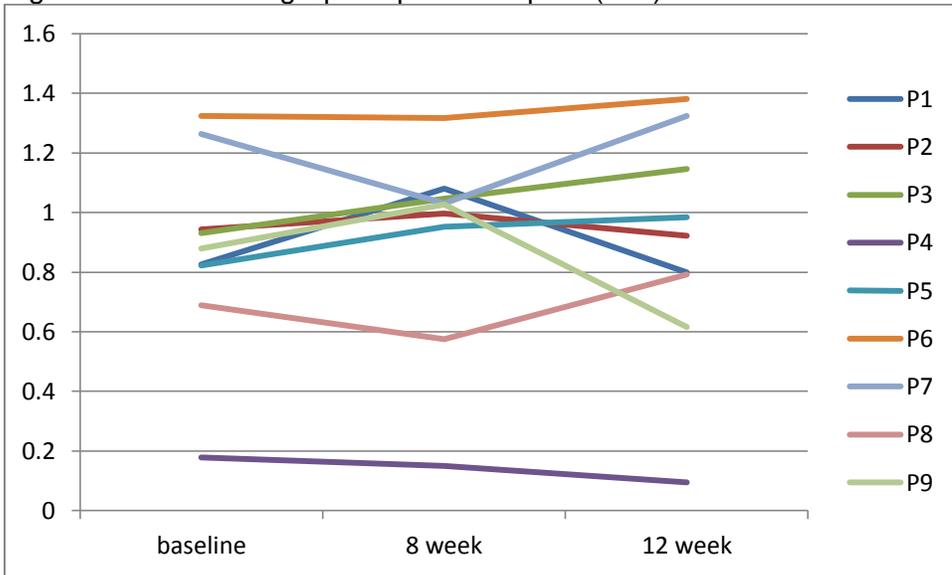


Vertical axis walking speed (meters/second)

Figure 4: Walking Distance per Participant (n=9)
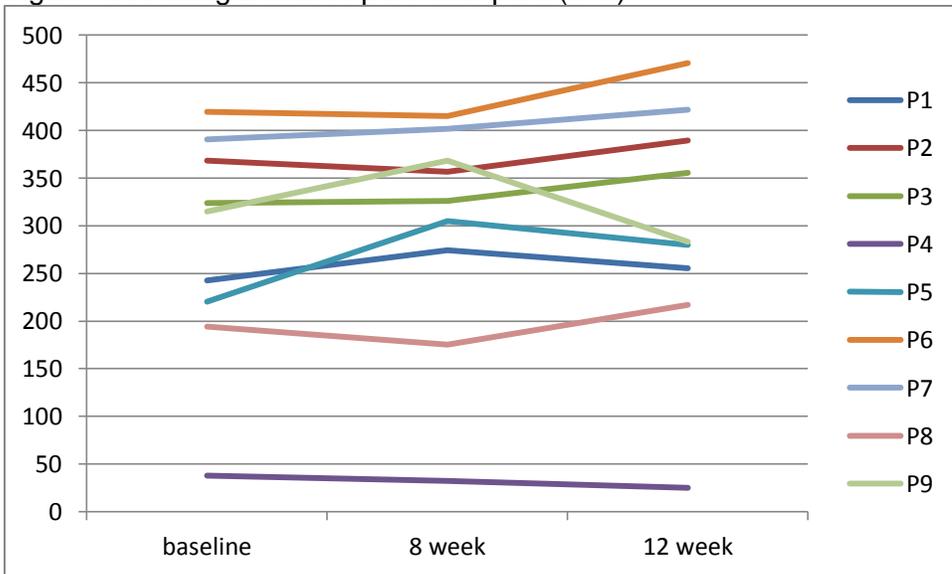


Vertical axis distance in 6 minutes (meters)

Figure 5: Step Length Symmetry Ratio (FGS) per Participant (n=8)
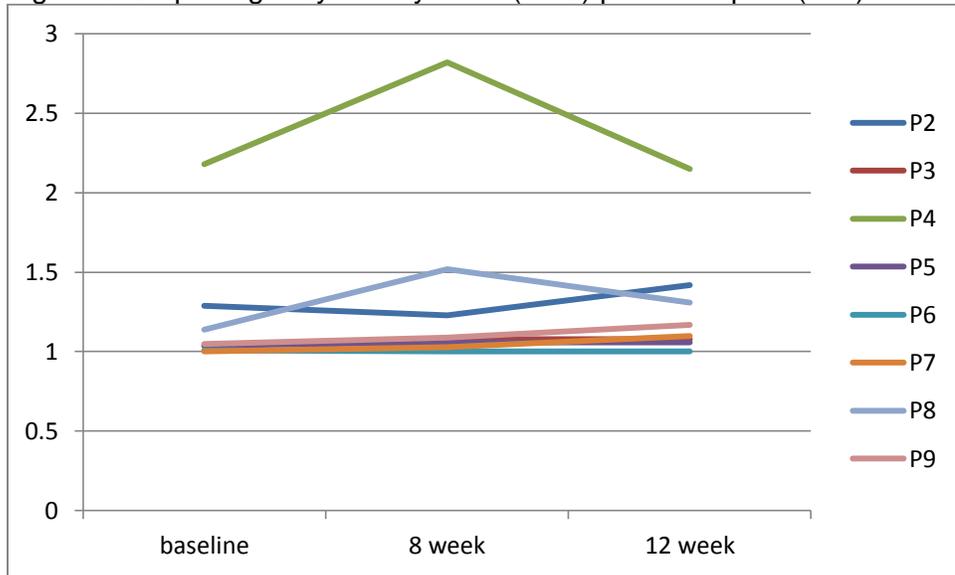


FGS = fast walking; Vertical axis symmetry ratio

Figure 6: Step Length Symmetry Ratio (CGS) per Participant (n=8)
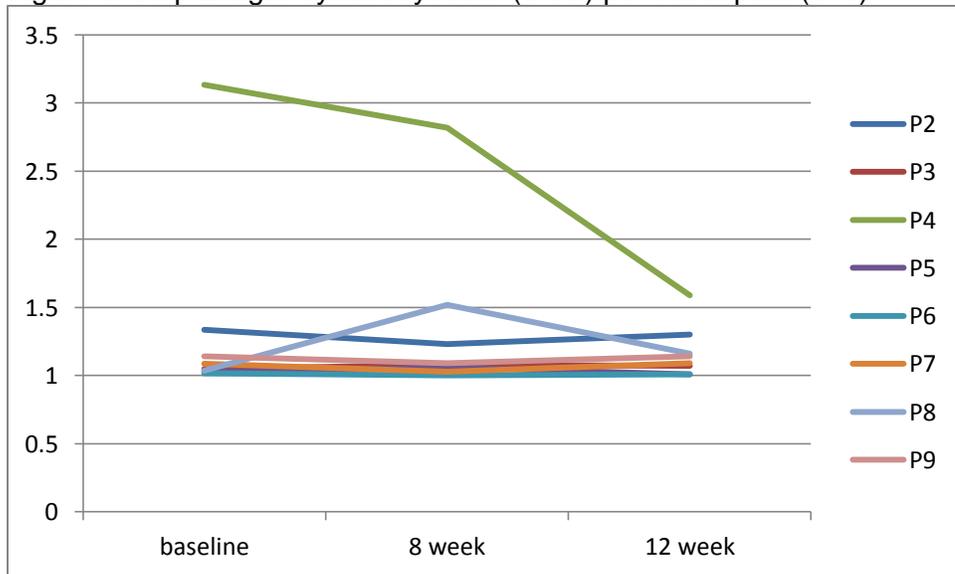


CGS = comfortable walking speed; Vertical axis symmetry ratio

Figure 7: Swing Time Symmetry Ratio (FGS) per Participant (n=8)
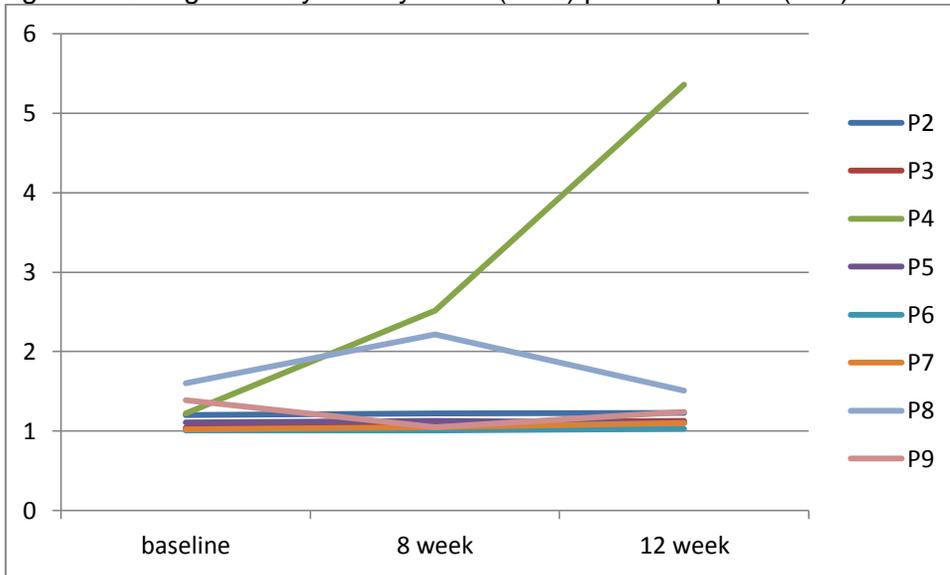


FGS = fast walking speed; Vertical axis symmetry ratio

Figure 8: Swing Time Symmetry Ratio (CGS) per Participant (n=8)
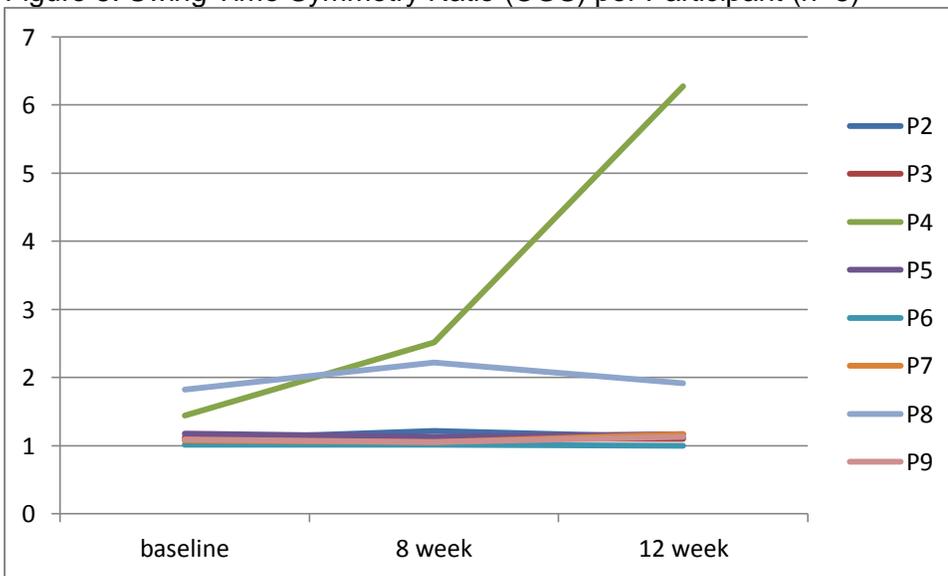


CGS comfortable walking speed; Vertical axis symmetry ratio

Figure 9: Stance Time Symmetry Ratio (FGS) per Participant (n=8)
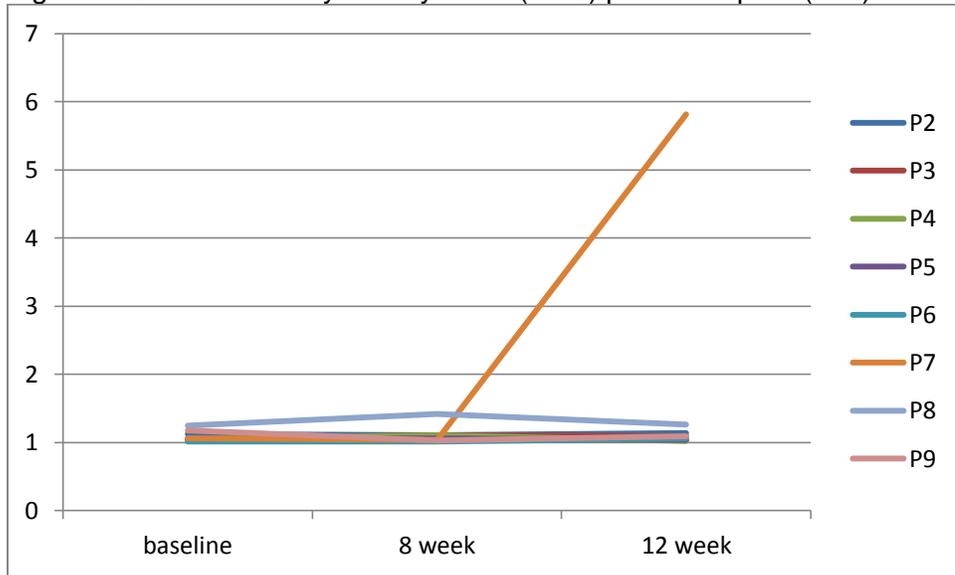


FGS fast walking speed; Vertical axis symmetry ratio

Figure 10: Stance Time Symmetry Ratio (CGS) per Participant (n=8)
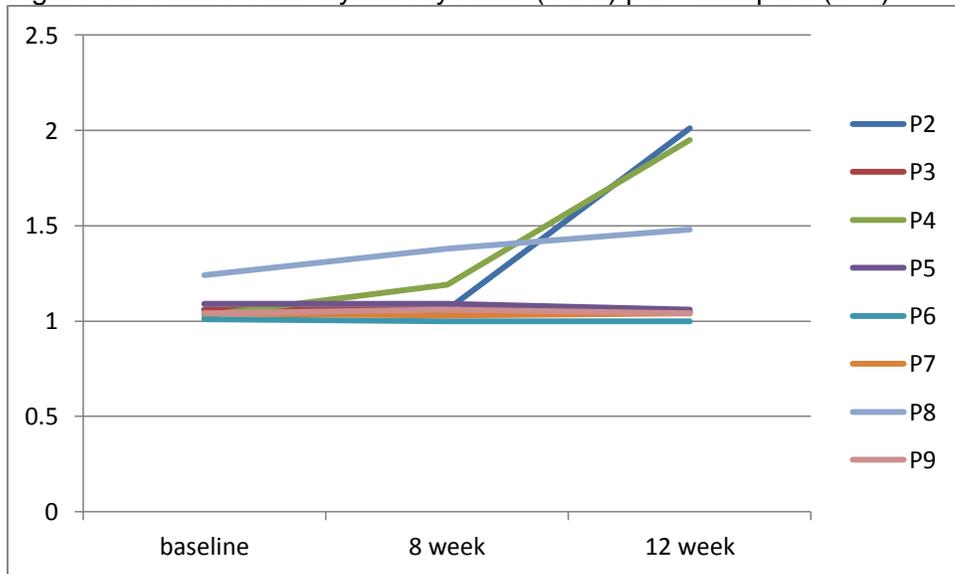


CGS comfortable walking speed; Vertical axis symmetry ratio

Chapter 5: Discussion

This study explored the effect of 12 weeks of group therapeutic-yoga on walking recovery after stroke in 12 individuals with chronic stroke. There was not a significant main effect of time on: fast walking speed, walking distance, step length symmetry, swing time symmetry, stance time symmetry, or swing/stance time ratio symmetry. Several of the spatiotemporal step parameter symmetry ratios did demonstrate a small (d=0.2-0.4) to medium (d=0.5-0.7) effect size when calculated between 3 measurement time point comparisons (baseline, 8 weeks, and 12 weeks). However, most (91%) of the spatiotemporal parameters that changed demonstrated a negative effect indicating increased asymmetry. The percentage of individual participants demonstrating a change score greater than or equal to the MDC for each variable ranged from 0%-37% depending on the variable and time point comparison. Finally, additional analyses demonstrated a significant change towards more asymmetry in mean step length symmetry (p=0.05) during fast walking from baseline to 12 weeks, and a small but non-significant change in mean walking distance (p=0.064) from baseline to 12 weeks.

Walking Speed

Walking speed is used as a measure of walking recovery and function after stroke.[12,73] Walking speed has been reported to improve significantly (0.54m/s to 0.75 m/s, p<0.001) in previous work testing a 14-week community-based light exercise intervention in 18 people with subacute to chronic stroke.[97] In contrast to the current study where no significant change (0.87m/s to 0.89m/s, p=0.649) in walking speed was observed. This difference between the results of the two studies may be related to baseline differences in the samples from each of the studies. In Cramp and colleagues' study, referred to above, the average baseline walking speed was 0.54m/s[97] while in the current study, the average baseline walking speed was 0.87m/s. Therefore, interventions for walking that are exercise based such as therapeutic-yoga may be more effective for

people with slower baseline walking speeds. It may be necessary to include only people who have a baseline walking speed of <0.8 allowing study participants room for improvement.

## Walking Distance

Walking distance is a commonly used measure to assess changes in walking ability in people post-stroke.[69] Improved walking distance in people post-stroke has been reported after implementation of a variety of interventions.[7,10,23,26,103,105] Specifically, Leroux et al. demonstrated a trend towards improvement in walking distance after an 8-week community-based exercise program for 20 people with chronic stroke (170.7m to 188.8m, p=0.012).[99] Likewise, a small non-significant change (279 m to 299 m, p=0.064) was also observed in the current study, which to my knowledge is the first study to report on the effect of group therapeutic yoga on walking distance after stroke. This observed small non-significant change in a small sample provides a strong rationale for further testing of group therapeutic-yoga on walking distance after stroke. A study with a larger sample would be powered better for detecting a change in walking distance. Walking distance is important for achieving functional community ambulation[17,61] and it has been reported as important to people with stroke.[64,82] Therefore further testing with a larger sample is warranted.

## Spatiotemporal Step Parameters

Another potentially important finding in this study is the significant and negative (more asymmetry) mean change score (1.21$\pm$0.37 to 1.28$\pm$0.39, p=0.05) between baseline and 12 weeks in step length symmetry at fast walking speed. Step length symmetry has been used to assess walking ability in people with stroke,[54,60,67,68] but has not to my knowledge been reported in people with stroke after participation in group therapeutic-yoga. This variable's relationship to other walking measures is not completely understood. Step length symmetry has not consistently shown an association

44

with walking speed measures,[54] but it has shown associations with compensatory movement patterns such as decreased paretic hip flexor moment and reduced paretic leg plantarflexor moment after stroke.[60]

Compensatory movement patterns such as altered hip flexor or plantarflexor moments were not documented or measured in the current study but may need to be included in future studies examining step length symmetry. Also related to movement patterns is joint range of motion (ROM) which may be influenced by therapeutic-yoga. In the primary study for the current study, participants demonstrated improved hip joint ROM.[122] Improved ROM likely increases the degrees of freedom during movement tasks such as walking. The newly developed ROM or degrees of freedom may not be integrated into the movement patterns demonstrated while walking immediately following the intervention. Walking movement patterns may be highly variable and inconsistent immediately following the intervention, which could influence step length symmetry. Walking measures, like step length symmetry that may be influenced by movement patterns should be measured both immediately following the intervention and at a 3-6 month follow-up interval. Therefore, future studies should include both compensatory movement pattern measures as well as long-term follow-up measures to better understand the effect of the intervention on spatiotemporal step parameters like step length symmetry.

The negative effect or increase asymmetry noted with step length was also observed in several other spatiotemporal step parameters. The reasons for the increased asymmetry are not understood but may be related to compensatory movement patterns expressed after stroke. Patterson, et al.[68] have reported a tendency for worsening spatial and temporal symmetry longitudinally after stroke. Additionally, the use of assistive devices has been reported to have an impact on walking symmetry and speed.[54] Participants in the current study were all in the chronic stage post-stroke and

45

were allowed to use assistive devices as needed for the assessment. Therefore, it may be important to assess walking symmetry in both the acute and chronic stages post-stroke and limit assistive device use as a compensatory strategy during walking tests designed to measure walking symmetry.

Impaired walking symmetry after stroke is a problem that needs further investigation. Even though walking symmetry did not improve or make significant changes in this study, the sample did demonstrate asymmetry greater than expected in a healthy population based on normative data (6% or symmetry ratio $\leq$1.06).[54] While the implication, progression, and remediation of walking asymmetry after stroke is not understood, the data from this study support the need for continued research related to the problem. The remediation of walking asymmetry after stroke is believed to reflect restorative recovery (return to pre-stroke body function & activity) as opposed to compensatory recovery (adaptation of a new post-stroke body function & activity). Better understanding of restorative vs. compensatory recovery is needed to optimize implementation of interventions that maximize both neural and functional recovery after stroke.

Finally, based on the results of the current study, consideration of the intervention as it relates to walking recovery is warranted. The effect of group therapeutic-yoga on walking recovery in this sample of adults with chronic stroke was mostly negative. This may be due to lack of task specificity of therapeutic-yoga for walking recovery. Therapeutic-yoga involves highly repetitive work on stability (maintaining a posture with good alignment) and controlled mobility (movement of the center of gravity within the base of support), but only low repetitive work on transitional movements (movement between postures involving a change in the base of support). Walking is a transitional movement. Therefore some of the lack of effect may be related to low task specificity for walking from this intervention. Further research is needed to

investigate this issue and determine if therapeutic-yoga is a good choice to improve walking recovery in the chronic stroke population.

<div align="center">Limitations</div>

As with any study, this study had several limitations. One of the most significant limitations was the small sample size which limits generalizability to the larger stroke population. The results of a small sample can be significantly influenced by individual participant personal factors such as "wearing the wrong shoes" as reported by one participant at the 8 week assessment and wearing a knee brace due to "twisting my leg" as reported by another participant at the 12 week assessment.

Additionally unexpected issues with lab space accessibility and equipment malfunction may have impacted the data and results. Two space and equipment issues were experienced during this study. The first was the relocation of the assessment area during the 8-week assessments due to lab remodeling and construction in the RIT lab. The RIT lab construction relocated the walking tests to another hallway in the same building with a different floor surface. The second was the malfunction of the GAITRite mat during the 12-week assessment for 1 participant which created missing data for a participant who did not drop-out of the study.

Although the drop-out rate (25%) was relatively low for an intervention study, the loss of data for analyses was significant in the context of a small sample. The low drop-out rate is encouraging for future studies implementing a group therapeutic-yoga intervention, suggesting that 12-weeks of group therapeutic-yoga is feasible in a population of people with chronic stroke. Finally, the inclusion and exclusion criteria for the current study were consistent with the primary study which was based on a primary outcome of balance and fear of falling instead of walking recovery. These inclusion criteria create a limitation to these analyses due to inclusion of participants with little room for improvement in walking outcome measures.

Future Research

Future studies using group therapeutic-yoga to assess effect on walking measures should be designed with walking measures as the main outcome. The main outcomes in the primary study for these analyses were balance and fear of falling. The inclusion and exclusion criteria were determined based on those outcome measures instead of walking. Specifically, therapeutic-yoga studies designed with walking measures as the main outcome should include the following additional inclusion criteria; 1) walk at speeds $\leq$0.8 m/s, 2) residual strength deficits in the affected lower extremity, 3) ambulate 10 meters without orthotics, and 4) willing to walk with the least restrictive assistive device required for fall safety with stand by assist guarding.

In addition, future studies should also include a comparison group such as a usual care control group, an impairment-based exercise control group, and a hybrid intervention (therapeutic-yoga and walking practice) control group. This will help improve understanding of the effect of group therapeutic-yoga on walking recovery after stroke. These recommendations are both feasible and important in the long-term research plan to better understand walking recovery after stroke.

Chapter 6: Conclusion

Stroke is a prevalent and disabling medical problem worldwide. Impaired walking ability is common after stroke impacting long-term disability and physical limitations.[1-3,6,7] Several rehabilitation interventions have been tested demonstrating efficacy for improving walking after stroke.[9,10,18-27] However, the best intervention for maximizing walking recovery after stroke has not been established. Therefore the purpose of this study was to assess the effect of a 12-week group therapeutic-yoga intervention on walking recovery after stroke.

This was a secondary data analysis with walking recovery variables including walking speed, walking distance, and spatiotemporal step parameter symmetry. The data were collected as secondary outcomes in a randomized pilot study originally designed to test the efficacy of an 8-week group therapeutic-yoga intervention on balance and fear of falling. Since data were collected at baseline, 8-weeks, and 12-weeks, the main analysis was a RM ANOVA to determine the main effect of time on the variables of interest. In addition, effect size calculations and number of participants achieving change scores greater than or equal to MDC for each variable between each measurement time point combination were also calculated.

The results did not demonstrate a main effect of time on the any of the variables of interest. However, walking distance demonstrated a small insignificant improvement between baseline and 12-weeks while step length symmetry demonstrated a significant change (more asymmetry) between baseline and 12-weeks. Step length symmetry along with several other spatiotemporal parameters demonstrated small to medium effect sizes that were negative effects, meaning the parameters became more asymmetric. The reasons for increased asymmetry are not understood and cannot be explained from the current data.

Although the results lacked significance for most analyses, this study provides important information for future research. Both walking distance and spatiotemporal step parameter symmetry, particularly step length, should be tested in a larger sample with a study protocol designed specifically for walking outcomes. Outcomes should be tested immediately following an intervention and at long-term follow-up, and movement pattern measurements should be added to complement spatiotemporal step parameter symmetry data. Finally, implementation of a 12-week group therapeutic-yoga intervention appears feasible and is appropriate to test in a larger sample of people with chronic stroke.

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117. Schmid AA. Healthy after stroke; A yoga based intervention for veterans who have sustained a stroke. Roudebush VAMC & Indiana University School of Health and Rehabilitation Sciences: VA QUERI RRP; 2010.
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122. Miller KK, Dierks T, Van Puymbroeck M, et al. Therapeutic-yoga: Impact on pain and physical inpairments after stroke. *Archives of Physical Medicine and Rehabilitation.* 2011;92(10):1713-1714.

CURRICULUM VITAE

**Kristine Kay Miller**

**Education:**
Doctor of Philosophy in Health and Rehabilitation Sciences – June 2013
Indiana University
Indianapolis, IN

Master of Science in Therapeutic Outcomes Research – August 2008
Indiana University
Indianapolis, IN

Bachelor of Science in Physical Therapy – May 1989
Indiana University, School of Health and Rehabilitation Sciences, Physical Therapy Program
Indianapolis, IN

**Licensure and Certification:**
Indiana Physical Therapist License
August 1989 – Present

American Heart Association
BLS for Healthcare Providers
Expires January, 2014

American Physical Therapy Association
Credentialed Clinical Instructor

**Professional Experience:**
Research Coordinator & Research Physical Therapist
June 2010 – Present
Richard L. Roudebush Veterans Administration Medical Center
Indianapolis, IN

Registry Physical Therapist
June 2010 – October 2011
Saint John's Health System, Erskine Rehabilitation & Regional Balance Center
Anderson, IN

Staff Physical Therapist
May 2005 – June 2010
Saint John's Health System, Erskine Rehabilitation & Regional Balance Center
Anderson, IN

Staff Physical Therapist
May 2000 – May 2005
Easter Seals Crossroads Rehabilitation Center
Indianapolis, IN

Senior Physical Therapist
May 1992 – May 2000
Rehabilitation Hospital of Indiana
Indianapolis, IN

Staff Physical Therapist
May 1989 – May 1992
Saint John's Health System, Bennett Rehabilitation Center
Anderson, IN

**Teaching Activities – College/University Courses:**
Adjunct Faculty
August 2006 – Present
Indiana University, School of Health and Rehabilitation Sciences, Physical Therapy Program
Indianapolis, IN

Assistant Instructor
August 1997 – December 2003
Indiana University, School of Health and Rehabilitation Sciences, Physical Therapy Program
Indianapolis, IN

Guest Lecturer
August 1996
January 2001 – May 2003
University of Indianapolis, Krannert School of Physical Therapy
Indianapolis, IN

**Invited Presentations:**
**Miller, KK.** Activity dependent cortical plasticity: Implications for clinical decision making. Indiana Brain Injury Association Conference, Indianapolis, IN, September 2009.

**Miller KK.** Stroke awareness and risk factors. Women's Health Day, Anderson, IN, April 2008.

**Miller KK.** Exercise post-stroke. Central Indiana Stroke Support Groups, Anderson, Columbus, Fort Wayne, Kokomo, and Indianapolis, IN, June 2007 – January 2008.

**Miller KK.** Physical therapy management of patients with TBI. RHI Brain Injury Awareness Education Day, Indianapolis, IN, October 1999.

**Miller KK.** Therapeutic management of spasticity. Indiana Brain Injury Association Conference, Indianapolis, IN, September 1997.

**Posters & Platform Presentations Without Published Abstract:**
Altenburger PA, Dierks T, **Miller KK,** Combs S, Van Puymbroeck M, Schmid AA. Examination of sustained gait speed in individuals with chronic stroke deficits. Accepted poster for American Physical Therapy Association Combined Sections Meeting, San Diego, CA, January 2013.

Combs SA, Van Puymbroeck M, Altenburger PA, **Miller KK,** Dierks TA, Schmid AA. Is walking faster or walking farther more important to persons with chronic stroke? Accepted platform for American Physical Therapy Association Combined Sections Meeting, San Diego, CA, January 2013.

Schmid AA, Van Puymbroeck M, **Miller KK,** Altenburger PA. Balance impairment is associated with quality of life during chronic stroke. Accepted poster for American Congress of Rehabilitation Medicine, Vancouver, Canada, October, 2012.

Schmid AA, Van Puymbroeck M, Altenburger PA, Dierks T, **Miller KK,** Schalk N, DeBaun E, Damush T, Williams LS, Chagdes S, Dye L, Moore R, Racine L. Yoga-based rehabilitation intervention improves quality of life, activity, and participation. Poster for American Occupational Therapy Association, Indianapolis, IN, April 2012.

Schmid AA, Van Puymbroeck M, **Miller KK,** Altenburger PA, Dierks T. Balance confidence, a primary predictor of activity and participation after stroke. Poster for American Occupational Therapy Association, Indianapolis, IN, April 2012.

Schmid AA, Van Puymbroeck M, Schalk N, Altenburger PA, Dierks T, **Miller KK,** DeBaun E, Damush T, Crabtree J, Neumann D, Williams LS. Eight-week intervention improves quality of life, activity, and social participation after stroke. Poster for Indiana University School of Health and Rehabilitation Sciences Alumni Association Interdisciplinary Research Conference, Indianapolis, IN, November 2011.

Schmid AA, Van Puymbroeck M, Altenburger PA, Dierks T, Schalk N, **Miller KK,** Williams LS, Damush T. Yoga improves balance and balance confidence after stroke. Poster for Indiana University School of Health and Rehabilitation Sciences Alumni Association Interdisciplinary Research Conference, Indianapolis, IN, November 2011.

**Poster & Platform Presentations With Published Abstract:**
Schmid AA, Van Puymbroeck M, **Miller KK,** Altenburger PA. Post-stroke balance coordination is associated with quality of life. Journal of Sport and Exercise Psychology, 2012; 34: S183. Poster for North American Society for the Psychology of Sport and Physical Activity, Honolulu, HI, June 2012.

Schmid AA, **Miller KK,** Van Puymbroeck M, Dierks TA, Altenburger PA, Schalk N, Williams LS, DeBaun E, Damush T. Physical improvements after yoga for people with chronic stroke. Medicine and Science in Sports and Exercise, 2012; 44(5): S250. Poster for American College of Sports Medicine 59th Annual Meeting and 3rd World Congress on Exercise in Medicine, San Francisco, CA, May 2012.

Dierks TA, Altenburger PA, **Miller KK,** Schmid AA. The effect of balance exercise therapy on gait parameters in individuals with chronic stroke. Medicine and Science in Sports and Exercise, 2012; 44(5): S284. Poster for American College of Sports Medicine 59th Annual Meeting and 3rd World Congress on Exercise in Medicine, San Francisco, CA, May 2012.

Schmid AA, Van Puymbroeck M, **Miller KK,** Schalk N. Group yoga intervention leads to improved balance and balance self-efficacy after stroke. BMC Complementary and Alternative Medicine, 2012; 12 (Suppl 1) P222. Poster for International Research Congress on Integrative Medicine and Health, Portland, OR, May 2012.

Van Puymbroeck M, Schmid AA, **Miller KK,** Schalk N. Improved activity, participation, and quality of life for individuals with chronic stroke following an 8-week yoga intervention. BMC Complementary and Alternative Medicine, 2012; 12(Suppl 1): 039. Poster for International Research Congress on Integrative Medicine and Health, Portland, OR, May 2012.

Van Puymbroeck M, Schmid AA, **Miller KK,** Schalk N. Yoga is a feasible intervention for veterans with chronic stroke. BMC Complementary and Alternative Medicine, 2012; 12(Suppl 1) P418. Poster for International Research Congress on Integrative Medicine and Health, Portland, OR, May 2012.

Schmid AA, Van Puymbroeck M, Altenburger PA, Dierks T, **Miller KK,** Schalk N, Damush T, Crabtree J, Neumann D, Williams LS. Eight-week yoga intervention improves quality of life, activity, and social participation after stroke. Archives of Physical Medicine and Rehabilitation, 2011; 92(10): 1713 - 1714. Poster for American Congress of Rehabilitation Medicine, Atlanta, GA, October 2011.

Schmid AA, Altenburger PA, Dierks TA, Van Puymbroeck M, Schalk N, **Miller KK,** Williams LS, Damush T. Yoga improves balance and balance confidence after stroke. Archives of Physical Medicine and Rehabilitation, 2011; 92(10): 1713. Archives of Physical Medicine and Rehabilitation, 2011; 92(10): 1713 - 1714. Poster for American Congress of Rehabilitation Medicine, Atlanta, GA, October 2011.

**Miller KK,** Dierks T, Van Puymbroeck M, Altenburger PA, Schalk N, Damush T, Williams LS, Schmid AA. Therapeutic-yoga: Impact on pain and physical impairments after stroke. Archives of Physical Medicine and Rehabilitation, 2011; 92(10): 1713. . Archives of Physical Medicine and Rehabilitation, 2011; 92(10): 1713 - 1714. Poster for American Congress of Rehabilitation Medicine, Atlanta, GA, October 2011.

Schmid AA, Van Puymbroeck M, Altenburger PA, Dierks T, **Miller KK,** Schalk N, Damush T, Cradtree J, Neumann D, Williams LS. Eight-week yoga improves quality of life, activity, and social participation after stroke. International Journal of Yoga Therapy, 2011; supplement: 29. Poster for Symposium on Yoga Research, Lenox, MA, September 2011.

**Miller KK.** Adherence with physical therapy HEP 1-6 months after discharge in individuals post-stroke. Stroke, 2009; 40(4). Poster for International Stroke Conference, San Diego, CA, February 2009.

**Peer Reviewed Manuscripts:**
*Published*
Schmid AA, Van Puymbroeck M, Altenburger PA, Schalk NA, Dierks, TA, **Miller KK,** Damush TM, Bravata DM, Williams LS. Post-stroke balance improves with yoga: A randomized pilot study. Stroke, 43 (epub ahead of print).

Schmid AA, Van Puymbroeck M, Altenburger PA, Dierks TA, **Miller KK,** Damush TM, Williams LS. Balance and balance self-efficacy are associated with activity and participation after stroke: A cross-sectional study in people with chronic stroke. Archives of Physical Medicine and Rehabilitation, 2012; 93:1101-7

*Accepted in Press*
**Miller KK,** Combs SA, Van Puymbroek M, Altenburger PA, Kean J, Dierks TA. Post-stroke fatigue and pain: relationships with physical performance and patient beliefs. In Press, Topics in Stroke Rehabilitation.

Combs SA, Van Puymbroeck M, Altenburger PA, **Miller KK,** Dierks TA, Schmid AA. Is walking faster or walking farther more important to persons with chronic stroke? In Press. Disability and Rehabilitation.

Schmid AA, Van Puymbroeck M, Altenburger PA, **Miller KK,** Combs SA, Page SJ. Post-stroke balance is associated with quality of life. In Review, Topics in Stroke Rehabilitation.

*In Review*
Van Puymbroeck M, Altenburger PA, Combs SA, **Miller KK,** Kean J, Schmid AA. The influence of mood related variables on activity and participation in individuals with chronic stroke. In Review, Topics in Stroke Rehabilitation.

*In Preparation*
**Miller KK,** Porter RE, Debaun E, Van Puymbroeck M, Schmid AA. Exercise after stroke: patient adherence and beliefs.

**Professional Development – Service Activities:**
Physical Therapy Affiliate Member
Indiana University Rehabilitation & Neuroimaging Signature Center
Indianapolis, IN
2012 – Present

NPTE Exam Development Committee
Federation of State Boards of Physical Therapy
Alexandria, VA
2012 – 1 meeting
2011 – 3 meetings
2010 – 4 meetings
2009 – 3 meetings
2008 – 4 meetings

Community Balance Screener
*Women's Health Day*
Anderson, IN

April 2007
*Madison County 4-H Fair*
Alexandria, IN
July 2005

NPTE Item Writer
Federation of State Boards of Physical Therapy
Alexandria, VA
2006

Central Indiana Rehabilitation Sub-Committee & Speakers Bureau
American Stroke Association
Indianapolis, IN
2002 – 2004

Moderator
Stroke Survivor & Caregiver Symposium
Indianapolis, IN
2003

Horse leader & back rider
*Agape Therapeutic Riding Center*
Cicero, IN
1995 – 2000
*East Central Indiana Therapeutic Riding Center*
Muncie, IN
1990 - 1992

**Professional Development – Organization Memberships**
American Physical Therapy Association
      Neurology Section
      Geriatric Section
American Society of Neurological Rehabilitation