Research Report

A Yoga-Based Exercise Program for People With Chronic Poststroke Hemiparesis

Background and Purpose. This was a preliminary investigation of the effects of a yoga-based exercise program on people with chronic (greater than 9 months) poststroke hemiparesis. Many people who have had a stroke report an impaired health status because of a reduced level of activity. Proponents of yoga contend that it offers a gentle alternative exercise program that can be easily adapted for people who have had a stroke. **Subjects and Methods.** Four subjects with chronic poststroke hemiparesis participated in this single-case study. The primary outcome measures were the Berg Balance Scale (BBS) and the Timed Movement Battery (TMB). A secondary outcome measure was the Stroke Impact Scale (SIS). The baseline testing phase varied for each subject and ranged from 4 to 7 weeks. The 8-week intervention phase consisted of 1.5-hour yoga sessions, 2 times per week, in the subject's home. The primary outcome data were collected each week, and the secondary outcome data were collected before the baseline testing phase and before and after the intervention phase. **Results.** Subjects 1, 2, and 4 had improved TMB scores, and subjects 3 and 4 had improved BBS scores. **Discussion and Conclusion.** The results suggest that yoga may be beneficial to people who have had a stroke. Further investigation is warranted to further examine the effects of yoga in this population. [Bastille JV, Gill-Body KM. A yoga-based exercise program for people with chronic poststroke hemiparesis. *Phys Ther.* 2004;84:33–48.]

Key Words: *Balance, Exercise, Hemiparesis, Mobility, Stroke, Yoga.*

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Stroke is the leading cause of adult disability in the United States, with more than 4.7 million people who have had a stroke alive in the United States today.[1] The majority of people who have had strokes have mild to moderate neurologic deficits.[2] Many are physically deconditioned and have a high prevalence of cardiovascular risk factors that are potentially modifiable with exercise.[3] Even the fittest people who have had a stroke tend to have an impaired health status compared with age-matched control subjects.[4] Many people who have had strokes experience adverse health events that can be attributed to a reduced level of activity.[3] Stroke is a condition associated with increased risk for falls.[5] Forster and Young[5] reported that 73% of elderly people who have had strokes fell within 6 months after discharge from the hospital. With the rising number of people surviving strokes today, there is a vital need for exercise programs designed to improve and maintain the physical fitness and quality of life of this population.

The majority of people who have had a stroke plateau in neurological and functional recovery and are not expected to make improvements more than 5 months after the stroke.[6] Several investigators, however, have found that improvements in muscle force, balance, aerobic capacity, and timed mobility in subjects with chronic poststroke hemiparesis can be achieved with exercise training. In subjects whose stroke occurred more than 1 year prior, Weiss et al[7] demonstrated improvements in muscle force, balance, and timed mobility after performing 12 weeks of a lower-extremity progressive resisted exercise training program at 70% of one repetition maximum. Potempa et al[8] and Macko et al[9] reported improved aerobic capacity in people greater than 6 months poststroke, following exercise with a bicycle ergometer[8] or after treadmill training.[9] Teixeira-Salmela et al[10] noted increases in muscle force and mobility in subjects greater than 9 months poststroke with a combination of lower-extremity progressive resistive exercises and aerobic endurance training utilizing a treadmill, stepping machine, or stationary cycle.[10] Dean et al[11] noted improved walking speed and lower-extremity force production in subjects greater than 3 months poststroke with a task-related circuit training regimen. The training regimen included 10 workstation tasks designed to improve muscle performance in the affected lower extremity and to provide practice of various locomotor skills.[11] Several investigators have demonstrated improved upper extremity motor ability in people who were more than 6 months[12] or 1 year[13–16] poststroke with the application of contraint-induced movement therapy. Contraint-induced movement therapy involves constraining movements of the less-affected upper extremity with a sling or glove for 90% of the waking hours for 2 weeks, while undergoing intensive training of the more affected limb 5 to 6 hours per day in a clinical setting and home-based activities.[17]

Yoga is one of India's oldest and most extensive psycho-spiritual traditions. It has evolved over 5,000 years to encompass a vast body of moral and ethical precepts, mental attitudes, and physical practices.[18] The word "yoga" is derived from the Sanskrit verb "*yuj*" meaning to yoke or unite. Commonly, yoga is translated to imply the union of body, mind, and spirit.[19] There are 8 main forms of yoga. *Hatha* yoga is the most recognized and practiced form of yoga in the Western world.[19] Many forms of yoga encompass 8 elements, known as the "eight-fold path" of yoga, which include *yamas* (moral disciplines), *niyamas* (self-restraint), *pranayama* (breath control), *asanas* (physical poses), *pratyahara* (sensory inhibition), *dharana* (concentration), *dhyana* (meditation), and *samadhi* (blissful state). All forms seek to achieve the goal of enlightenment, or the realization of one's true self.[20]

Yoga therapeutics is defined by International Association of Yoga Therapists as the application of yoga for health benefits.[21] Practitioners of yoga therapy integrate yoga concepts with Western medical and psychological knowledge,[21] for example, by using body awareness and breathing activities, physical postures, and meditation with an understanding of pathological conditions such as back pain or depression in the management of people with these conditions. Whereas traditional yoga practice is primarily concerned with personal enlightenment of people without pathology, yoga therapy focuses on a

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holistic treatment for people with various somatic or psychological dysfunctions. According to Feuerstein,[18] the goals of yoga therapy are to promote health benefits and to promote self-awareness for the purpose of enlightenment. Yoga therapy offers an alternative approach to conventional exercise training, and it also can be adapted to meet the needs of people with physical limitations.[19] Although there have been no studies that have investigated the effects of yoga on people who have had a stroke or hemiparesis, Bell and Seyfer[22] have described adaptations of yoga postures that can be applied to people with neurologic conditions such as multiple sclerosis and stroke.

Yoga therapy has been used for relief of stress and anxiety and to manage epilepsy. The one randomized controlled study conducted to compare the effects of yoga, sham yoga, and no yoga therapy on the management of people with epilepsy yielded inconclusive results.[23] Yoga's role in the management of depression has been investigated, and it has been reported to be beneficial for college students who exhibit a high level of depressive symptoms.[24] Yogic breathing exercises also have been found to lead to improvements in people with melancholic depression that are comparable to the use of imipramine.[25]

Proponents of yoga believe it offers a holistic approach to rehabilitation, which includes eliciting relaxation through meditation.[26] With the exception of a case report describing an application of yoga therapeutics to a patient with Parkinson disease,[27] there have been no studies investigating the effects of a yoga-based program on people with neurologic disorders. Eliciting relaxation, however, may promote positive effects on carotid atherosclerosis,[28] hypertension,[29,30] diabetes,[31] and coronary artery disease,[32–34] which are identified as risk factors associated with stroke occurrence[35] or reoccurrence.[36] Effects such as these may add substantial benefits to people following a stroke beyond the use of yoga as an alternate method of physical activity.

A regular practice of yoga has been shown to improve flexibility and muscle force in adults without known pathology,[37] vital capacity in college students without pathology,[38] aerobic capacity in men without pathology,[39] and motor speed (frequency of successive finger taps in 30 seconds) in adults without pathology.[40] Tran and co-workers[37] reported improvements in upper- and lower-extremity torques measured with an isokinetic device at a speeds of 30°/s and 60°/s; ability to hold a lower-extremity isometric muscle contraction; shoulder, ankle, and spinal flexibility; and aerobic capacity in 10 adult subjects without known pathology after a practice of *hatha* yoga activities 2 times per week for 8 weeks. Birkel and Edgren[38] found improvements in the vital capacity of college students after practicing *hatha* yoga activities 2 times per week for 15 weeks. Ray et al[39] conducted a randomized controlled comparison of men without known pathology participating in either a *hatha* yoga regimen or an exercise training program for 1 hour daily for 6 months. Although both groups demonstrated improvement in several pulmonary function tests, only the yoga group improved in maximum oxygen uptake and decreased perceived exertion after maximal exercise testing with a bicycle ergometer. Dash and Telles[40] found improved motor speed in a 30-second finger-tapping test in adults without pathology who participated in yoga activities 8 hours per day for 30 days compared with a group of adults without pathology who received no intervention. Although Dash and Telles[40] reported improved motor speed in repetitive finger motion, it is unclear whether these changes can be generalized to repetitive motor activities of the lower extremities.

Balance and mobility require the ability to generate forces to control the body segments and position in space. Musculoskeletal components that influence stability and control include joint range of motion, spinal flexibility, and muscle properties such as force production and endurance. Musculoskeletal problems may greatly influence postural stability and control.[41] Decreased range of motion and muscle weakness have been observed in people following a stroke.[42] Studies of outcomes have revealed that voluntary muscle force is closely correlated to gait performance in people following a stroke,[43] and it may contribute to the balance and mobility problems of these people.[44,45] We were interested in knowing whether yoga therapy might be useful for people who have had a stroke. The purpose of this study, therefore, was to investigate the effects of a yoga-based exercise program on balance, mobility, and quality of life for people with chronic poststroke hemiparesis.

Method

Subjects

A single-subject study design was used with each of the 4 subjects who participated in this study. Nonconcurrent multiple baselines were used. The subjects were recruited from the community surrounding Keene, NH. Newspaper advertisements and postings at public bulletin boards and senior centers were used to recruit the subjects. People were considered for participation in the study if: (1) more than 9 months had elapsed since their stroke; (2) they were moderately impaired in lower-extremity motor function (a lower-extremity motor score between 15/34 and 27/34 on the Fugl-Meyer Sensorimotor Assessment[46]); (3) they were able to ambulate

Table 1.
Subject Characteristics[a]

	Subject 1	Subject 2	Subject 3	Subject 4
Age (y)	71	49	59	61
Height (cm) (in)	188 (74)	170 (67)	145 (57)	160 (63)
Weight (kg) (lb)	146 (325)	97 (215)	65 (144)	63 (140)
Years since stroke	8	1.5	4.25	0.75
Side of hemiparesis	Left	Left	Right	Right
Type of CVA	NA	NA	Ischemic	Ischemic
Folstein MMSE	29/30	30/30	30/30	15/30
No. of comorbid conditions	5	0	7	1
No. of prescription medications	10	1	17	1
History of falls (no. in past year)	3	1	0	0
Living environment	Lives alone in community	Lives with family in community	Assisted living	Lives alone in community
Ambulation status	Independent in household no devices, independent in community with cane	Independent in household and community, no devices	Independent in household with hemiwalker and AFO for 22.5 m–30 m (75–100 ft)	Independent household and community, no devices

[a] CVA=cerebrovascular accident, NA=not available, AFO=ankle-foot orthosis, MMSE=Mini-Mental State Examination. Measurements in nonmetric units shown in parentheses for height, weight, and ambulation status.

independently or with supervision, with or without an assistive device or orthosis; and (4) they had completed all rehabilitation. Subjects were excluded if they had: (1) a medical condition that interfered with participation in exercise programs, (2) a score of less than 15/30 on the Folstein Mini-Mental Status Examination,[47] or (3) receptive aphasia that interfered with the ability to follow 2-step commands.

Preliminary screening of subjects was done by use of telephone interview. The purpose and procedures of our study were explained, and verbal consent to participate was obtained. An interview and examination were then arranged in each subject's home. The subjects were again informed of our study's purpose and procedures, and they signed a written consent form. Five people were screened for possible inclusion in this study; 1 person was excluded because the Fugl-Meyer Sensorimotor Assessment lower-extremity score was 32/34.

Subject 1. Subject 1 was 71-year-old man who had a right cerebrovascular accident (CVA) 8 years before the start of our study, which caused left hemiparesis (Tab. 1). He had a history of hypertension, hypercholesterolemia, restless leg syndrome, sleep apnea, degenerative joint disease of both knees and shoulders, and chronic low back pain. Immediately following his stroke, he spent several weeks in acute care and inpatient rehabilitation facilities. He was discharged to his home and completed his rehabilitation in an outpatient setting. He had 2 seizures in the year following his stroke. He underwent a right total knee replacement (TKR) 2 years after his stroke and a left TKR 4 years after his stroke. After the left TKR, he received short-term inpatient and outpatient rehabilitation. He retired, approximately 6 years prior to his stroke, after working for 32 years as a computer hardware repair technician. He lived alone in a suburban single-story home and had 3 sons who lived out of the immediate area. He was active in several community and church programs. He could ambulate independently without the use of assistive or orthotic devices within the home; however, he used a railing when going up and down stairs and a straight cane when ambulating outside of his home. He reported that he occasionally stumbled and lost his balance.

He had fallen 3 times in the year before our study was initiated without sustaining a serious injury. He was independent in all self-care activities and did light household tasks. He drove, did his own grocery shopping, and managed the household finances. His Fugl-Meyer Sensorimotor Assessment scores are reported in Table 2. Before the initiation of this study, subject 1 had not received physical therapy or occupational therapy since completing rehabilitation following his TKR 4 years previously. He stated he did not routinely exercise but occasionally took a leisurely walk for approximately 1 block. He avoided walking long distances or walking

Table 2.
Fugl-Meyer Sensorimotor Assessment[28] Scores[a]

Fugl-Meyer Scale Subsection	Subject 1	Subject 2	Subject 3	Subject 4
Joint motion	30/40	30/40	24/40	39/40
Joint pain	36/40	32/40	27/40	38/40
Sensation	23/24	24/24	22/24	7/8
Total motor function	81/100	74/100	25/100	66/100
UE motor function	54/66	54/66	10/66	43/66
LE motor function	27/34	20/34	15/34	23/34
Total score	170/204	160/204	98/204	150/188

[a] UE=upper extremity, LE=lower extremity.

quickly because he said this activity increased his low back pain.

Subject 2. Subject 2 was a 49-year-old woman who had a right CVA with subsequent left hemiparesis 1.5 years before our study began (Tab. 1). She had a history of hypertension that began during a pregnancy 12 years before her stroke, but she had not been treated for hypertension since that time. After her stroke, she spent 3 weeks in an acute care hospital, followed by 5 weeks in an inpatient rehabilitation setting. She was discharged to her home and received several weeks of outpatient rehabilitation. She reported no other medical conditions. She resided in a rural environment in a single-story home with her husband, 1 young adult daughter, and 1 teenaged daughter. She had returned to driving and to working as a bookkeeper 20 to 30 hours per week approximately 6 months following her stroke.

She reported feeling off balance and occasionally stumbled while walking on uneven terrain. She had not fallen since being discharged from rehabilitation. She could perform all basic self-care activities independently. She had returned to performing most household duties but reported substantial fatigue at times and the need for frequent rests. She reported that grocery shopping was especially fatiguing. Her Fugl-Meyer Sensorimotor Assessment scores are reported in Table 2. She had not received physical therapy or occupational therapy more than 1 year before the start of our study. She performed a home exercise program that included standing balance and left lower-extremity weight-bearing activities or walked approximately 0.8 kg (0.5 mile) every day.

Subject 3. Subject 3 was a 59-year-old woman who had a left CVA resulting in right hemiparesis 4.25 years before the start of our study (Tab. 1). She had been diagnosed with cerebrovasculitis 5 years ago, after sustaining a right CVA that led to mild left hemiparesis. Her medical history included having fibromyalgia, type 2 diabetes, pulmonary fibrosis, hypertension, congenital absence of the left internal carotid artery, depression, and anxiety. Following the left CVA, she spent several weeks in an acute care facility and then had inpatient rehabilitation. She was discharged to her home where she resided with her husband. She received home health services, including those from a nurse, a home health aide, a physical therapist, and an occupational therapist. She had 2 episodes of care consisting of outpatient physical therapy and occupational therapy after receiving median, ulnar, and tibial nerve blocks and botulinum toxin injections in the gastrocnemius, soleus, posterior tibialis, and flexor digitorum longus muscles to correct an equinovarus deformity and to improve her mobility and activities of daily living (ADL). These therapeutic interventions occurred approximately 1 to 2 years before the initiation of our study.

At the time of our study, subject 3 was divorced and lived in an assisted living facility. She had 2 adult children from a previous marriage. Before her stroke, she had worked as a clerk and a cake decorator. She had also played the organ for church services and as a hobby before the stroke. Most recently, she played the organ one-handed, created computer greeting cards, and attended support groups, activities, and outings organized at her assisted-living facility. She was discharged from outpatient physical therapy approximately 1 month before the start of our study. She required minimal assistance for climbing up to 14 steps and used one railing. She was independent in bed mobility and transfers using bed rails. Her primary mode of indoor locomotion was a manual wheelchair that she propelled with her left extremities. She used a power scooter for long distances outside the facility. She required assistance for lower-extremity dressing and for showering, but she was independent in all other basic self-care activities. She reported difficulty with problem solving and concentration and stated that she had blurred vision. She said she had a fear of falling, but had not fallen since her most recent stroke. Her Fugl-Meyer Sensorimotor Assessment scores are reported in Table 2. She exhibited moderate to severe resistance to passive movement in all joints of the right extremities. Before our study was initiated, she did daily passive and active-assistive range-of-motion activities with a certified nursing assistant and weekly active-assistive range-of-motion activities in a therapeutic pool with a certified nursing assistant. She also walked 22.5 to 30 m (75–100 ft) each day independently.

Subject 4. Subject 4 was a 61-year-old woman who had a left CVA 9 months before the start of our study, which resulted in right hemiparesis, nonfluent expressive aphasia, mild receptive aphasia, and mild apraxia (Tab. 1). She had 2 left CVAs at 12 months and 13 months prior to this latest CVA that left her with a mild right hemiparesis. Following her most recent stroke, she spent several weeks in acute care and inpatient rehabilitation before being discharged to her home. She was independent in self-care activities and mobility. Before her initial strokes, she had been employed as an assembly-line worker and enjoyed outdoor recreation, including biking. After her first 2 strokes, she had returned to driving and biking, but she was unable to return to work. She was an active volunteer at the local hospital. Since the most recent stroke, she had returned to driving, but had been unable to return to biking or volunteer work.

She was an active member of Al-Anon and attended therapeutic recreational activities every other week. She had been divorced for several years and lived in a suburban single-story home with her adult son who was developmentally disabled. She was independent in all basic self-care activities; however, she reported that all self-care and household tasks took a very long time to complete and were very fatiguing. She said she felt unsteady while walking on uneven terrain and walked slowly. She had fallen once in the year before our study without sustaining a serious injury. Her Fugl-Meyer Sensorimotor Assessment scores are shown in Table 2. Before the initiation of our study, she had not received physical therapy or occupational therapy for 5 months. She said she did not have a routine exercise program, but she did take leisurely walks 3 times per week for approximately 0.8 to 1.6 km (0.5–1 mile).

Procedure

An interview and examination were conducted with each subject. Demographic and descriptive information was obtained. Subjects were asked questions regarding their medical and social history and level of physical activity. To determine each subject's level of physical and cognitive impairment, testing consisting of the Fugl-Meyer Sensorimotor Assessment[46] and the Folstein Mini-Mental State Examination[47] was performed. The interviews and initial physical and cognitive examinations were conducted by a physical therapist with 17 years of clinical experience (JVB).

A physical therapist assistant (HM) and a physical therapist (SC) collected data on the primary outcome variables throughout the study. They conducted baseline testing on each subject after the subjects were accepted into our study and before their participation in the yoga exercise program, and they conducted testing each week during the intervention phase and at the completion of the intervention phase. Multiple baseline tests were conducted once a week for each subject at home. Primary outcome data were collected during the baseline phase for 5 weeks for subject 1, for 4 weeks for subject 2, for 7 weeks for subject 3, and for 6 weeks for subject 4. Because subjects became available at different times and had some limitations on how long they were able to be involved in the study, we determined the length of these baseline periods before our study began. Subjects were assigned baseline periods from the shortest to the longest in the order they began the study. At the completion of the baseline phase, each subject participated in an 8-week intervention phase during which the primary outcome data were collected weekly.

Tests and Measures

The primary outcome variables were balance (Berg Balance Scale [BBS][48]) and timed mobility (Timed Movement Battery [TMB][49]). A secondary outcome variable was perceived quality of life (Stroke Impact Scale [SIS] Version 2.0[50]). These variables were selected to reflect areas of known difficulty in this population. Balance has been found to be the most important factor associated with the ability to perform basic mobility in people with hemiparesis secondary to a stroke.[51] Only a small percentage of people who have had a stroke achieve the efficiency and skill needed for community ambulation.[52] In addition, many people who survive a stroke report that they have an impaired health status[4] and that they have difficulty engaging in recreational activities or social interactions.[53] Overall, our goal in selecting outcome measures was to include relevant tests that could be reliably and accurately administered and that were likely to detect possible changes in performance over time. We chose more than one outcome variable because we wanted to assess replication of the effects of the yoga intervention across both subjects and behaviors.[54]

The BBS[48] consists of 14 items that require a person to maintain or assume positions of varying difficulty. The ability to perform each task is graded from 0 to 4, with a total possible score of 56.[48] Intrarater and interrater reliability of BBS scores were found to be what we would consider excellent (intraclass correlation coefficient [ICC]=.97 and .98) in a combined group of 113 elderly subjects (mean age=83.5 years, SD=5.3) and 70 subjects (mean age=71.6 years, SD=10.1) who had had a stroke.[55] Strong correlations have been reported between BBS scores and both Barthel Index of Activities of Daily Living scores (r=.87–.93) and Fugl-Meyer Sensorimotor Assessment scores (r=.70–.82) over a 12-week period in 60 subjects with stroke, substantiating the construct validity of data obtained with this instrument in people who have had a stroke.[56] Stevenson[57] has reported that a change of ±6 points on the BBS is

Table 3.
Yoga Therapy Session Format

Activity	Description
Education (5–10 min)	Subjects were given a brief description of basic anatomical structures (musculoskeletal, nervous, and circulatory structures) and explanations of yoga concepts related to the week's theme. The goal was to facilitate a greater understanding of one's physical body and thought processes.
Body awareness (10–15 min)	The instructor verbally led the subject through bringing conscious awareness to various parts of the body and to notice one's thoughts. The goal was to promote awareness of body sensation, position, and awareness of the activity of the mind.
Pranayama (breathing) (5 min)	Voluntary breathing activities were taught and practiced such as diaphragmatic breathing, 3-part complete breath, *ujjayi* (breathing with the throat partially closed to create a snoring sound), and *nadhi shodhana* (alternate nostril breathing). The goals were to promote awareness of the sensations of the breath in the body and awareness of how the breath can facilitate movement of body segments and to promote concentration.
Asana (physical poses) (30–40 min)	The subjects were instructed and assisted as necessary in performing a variety of modified yoga poses related to the week's theme. The goal was to improve in flexibility, muscle force, endurance, balance, and coordination of body segments.
Guided imagery/relaxation (10–15 min)	The subjects were read a guided imagery script incorporating visualization and then allowed to rest in silence. The goal was to elicit a relaxation response.
Seated silent meditation (5 min)	The subjects were asked to return to a seated position on the floor, in a chair, or at bedside and to remain in this position in silence, focusing on the sound of the breath. The goal was to promote mental clarity (clear one's mind of extraneous thoughts).
Expression/sharing (5 min)	The subjects were invited to express their experiences of each session verbally or through drawing. The goal was to integrate the experiences of the session and facilitate awareness of any physical, mental, or emotional changes that may have occurred.
Weekly Themes	**Focus**
Week 1 Establishing a solid foundation	Ankle flexibility
Week 2 Activating the power of the legs	Strengthening the thighs
Week 3 Opening the hips	Hip flexibility
Week 4 Aligning the spine	Postural alignment and spinal flexibility
Week 5 The flow of life	Circulatory system and emotions
Week 6 Integrating the senses	Energy pathways/*prana-vayus* (yoga philosophy of main pathways of energy flow through the body)
Week 7 Creating better balance	Postural stability/mind-body connection
Week 8 Creating peace of mind	Relaxation and peace

necessary to be 90% confident that a clinically meaningful change has occurred in people who have had a stroke.

The TMB[49] is designed to measure mobility and consists of 11 movement tasks performed at 2 speeds, self-selected (SS) and maximum movement (MM). The time for each of the movement tasks has been reported to have what we would again consider excellent intrarater reliability (ICC=.998–.999) and interrater reliability (ICC=.87–.999) in a group of 20 frail elderly subjects (mean age=81.2 years, SD=6.44, range=69–94), which included people who had had a stroke.[58] The TMB scores demonstrated moderate to high correlations in 30 community-dwelling subjects (mean age=77.5 years, SD=7.0, range=65–92) with scores on an 18-item ADL/instrumental activities of daily living (IADL) scale (r_s=.84 [SS], .84 [MM]), BBS scores (r_s=−.83 [SS], −.80 [MM]), Barthel Index of Activities of Daily Living scores (r_s=−.73 [SS], −.67 [MM]), and Timed Up & Go Test values (r=.89 [SS], .79 [MM]), supporting the construct and concurrent validity in community-dwelling elderly people with and without difficulty in ADL.[49] The validity of data obtained with the TMB has not been reported for people who have had strokes. It is not known how much change in the TMB scores reflect a genuine and meaningful change in performance.

Seven movement tasks were timed with subject 3, 8 movement tasks were timed with subject 1, and all 11 movement tasks were timed with subjects 2 and 4. All 11 movement tasks were not used with subjects 1 and 3 because of physical or environmental constraints. Subjects 1 and 3 were unable to perform the floor-stand task without assistance. Subject 1 did not have more than 2 steps in his home to perform up-and-down-steps tasks. Subject 3 also was unable to step over a 15-cm (6-in) obstacle or perform up-and-down-steps tasks without assistance. Each movement task was timed at both SS and MM speeds. The difference between the SS and MM scores indicates the *reserve speed* (RS), which is considered a capacity measure and is defined as the ability to safely perform activities at speeds faster than usual. Reserve speed may be an important measure of how people can adapt to the various temporal demands in the environment necessary for efficient community mobility[49] and was therefore included as a measure in our study.

For all subjects, perceived quality of life was measured using the SIS Version 2.0[50] 3 times: at baseline testing, just before the intervention period, and after the intervention period. The SIS was administered to all subjects by the primary author (JVB). The SIS is a stroke-specific quality-of-life instrument administered by direct interview, and it includes 64 items within 8 domains. There are 4 physical domains (strength, hand function, mobility, and ADL/IADL) as well as emotion, communication, memory, and participation domains. The subject also rates perceived percentage of recovery on a visual analog scale. Intraclass correlation coefficients for test-retest reliability of the scores for all domains have been shown to be high (ICC=.70–.92), except for the emotion domain (ICC=.57) in 25 subjects with mild to moderate stroke.[50] Validity of the SIS scores was examined by comparing the SIS scores with scores obtained with existing stroke outcome measures (Fugl-Meyer Sensorimotor Assessment, Functional Independence Measure, Barthel Index of Activities of Daily Living, Medical Outcomes Study 36-Item Short-Form Health Survey [SF-36[, Geriatric Depression Scale, Instrumental Activities of Daily Living Scale, Duke Mobility Scale, National Institutes of Health Stroke Scale, and Folstein Mini-Mental State Examination). The correlations were what we consider moderate to strong (ICC=.44–.84) in people who had had a mild to moderate stroke and who were in the acute phase of recovery (1–6 months after a stroke).[50] Scores for the SIS domains appear responsive to change during recovery 1 to 6 months after a stroke.[50] According to Duncan and co-workers,[50] a change of SIS domain scores of at least 10 points represents a clinically meaningful change in perceived quality of life.

Reliability Testing of Tests and Measures

Before the study was initiated, reliability testing of the primary outcome measures as we used them in our study was done between the primary author and the 2 data collectors. Three subjects who had had a stroke were simultaneously rated by 3 raters on the BBS and TMB tasks. Reliability was determined by calculating the percentage of exact agreements for the scores on the BBS items and by agreement within 0.2 second on the TMB scores. Agreement across the individual BBS scores averaged 89%, and agreement for the TMB SS and MM scores averaged 64% and 61%, respectively, across these 3 subjects. Additional protocol clarification and education of the raters regarding specific timing endpoints for the TMB walking tasks and timed tasks of the BBS improved the level of agreement with an additional subject to 93% for the BBS items and 100% agreement (±0.2 second) for both the TMB SS and MM individual task scores.

(Week 1)

Warm- up Activities	**Standing *Asanas***
(seated in chair)	(with chair for support)
Toe extension stretches	Standing mountain pose
Seated ankle circles	Clock drill (weight shifting)
Seated marching	Chair pose
Shoulder circles	Chairlift squat
Neck flexion/extension	Ankle struts
Neck half circles	Ankle lunge stretch
Seated *Asanas*	**Supine *Asanas***
Seated mountain pose	Single knee to chest pose
Seated back bend	Four-square pose
Seated side bends	Knee down spinal twist
Seated spinal twists	Supine butterfly
Seated forward bend	Relaxation pose
Daily Home Work	
Seated mountain pose	Leg lifts (lateral and posterior)
Seated back bend	Single knee to chest pose
Seated spinal twist	Bridge pose
Chair lift squat	Relaxation pose (10-20 min) (with diaphragmatic breathing)
Standing mountain pose	
Ankle lunge stretch	

Figure 1.
Example of Modified Yoga *Asanas* (Physical Poses)[15,17,59–61]

Intervention

For all subjects in our study, the intervention phase began after the 4- to 7-week baseline period. A physical therapist who was a certified Integrative Yoga Therapy teacher registered with the Yoga Alliance (JVB) guided each subject through a yoga-based exercise program. Subjects were seen in their own homes for 1.5-hour sessions 2 times per week. The intervention followed an intervention protocol with individual modifications as necessary. Table 3 describes the yoga therapy session format and weekly themes. Subjects were given written instructions for an independent home exercise program and asked to continue a daily practice of 5 to 11 yoga activities and 20 minutes of relaxation in the supine position throughout the intervention phase. Figure 1[15,17,59–61] provides an example of the physical activities for a yoga therapy session and the independent home exercises. All subjects were questioned at every session after the first session as to whether they were

Table 4.
Changes in Individual Timed Movement Battery Tasks Performed at Self-Selected Speed[a]

Subject No.	STL	LTS	STS	FW	BW	2 OB	6 OB	FIG 8	FTS	ASC STEPS	DES STEPS
1				−1.0 s[b]	−1.0 s[b]	−0.4 s[b]		−1.4 s[b]	NA	NA	NA
2	−0.8s[b]			−1.6 s[b]	−1.4 s[b]	−0.9 s[b]		−2.8 s[b]		−1.6 s[b]	
3			NA				NA		NA	NA	NA
4								−0.9 s[b]	−3.5 s[b]		

[a] STL=sit to lie, LTS=lie to sit, STS=sit to stand, FW=forward walk, BW=backward walk, 2 OB=2-in obstacle, 6 OB=6-in obstacle; FIG 8=figure-8, FTS=supine on floor to stand, ASC=ascend 4 steps, DES=descend 4 steps, NA=not assessed.
[b] Improvements using the 2-standard-deviation-band method, mean difference values expressed in seconds.

Table 5.
Changes in Individual Timed Movements Battery Tasks Performed at Maximum Movement Speed

Subject No.	STL	LTS	STS	FW	BW	2 OB	6 OB	FIG 8	FTS	ASC STEPS	DES STEPS
1	−0.6 s[b]								NA	NA	NA
2		−1.0 s[b]	−0.7 s[b]		−1.4 s[b]	−1.3 s[b]	−1.2 s[b]	−2.3 s[b]	−3.5 s[b]	−0.9 s[b]	
3			NA				NA		NA	NA	NA
4								−1.1 s[b]	−3.6 s[b]		

[a] STL=sit to lie, LTS=lie to sit, STS=sit to stand, FW=forward walk, BW=backward walk, 2 OB=2-in obstacle, 6 OB=6-in obstacle; FIG 8=figure-8, FTS=supine on floor to stand, ASC=ascend 4 steps, DES=descend 4 steps, NA=not assessed.
[b] Improvements using the 2-standard-deviation-band method, mean difference values expressed in seconds.

adhering to the home exercises and whether they needed any clarification in how to perform the exercises.

Data Analysis

Data were visually analyzed to determine stability and trends in the baseline and intervention phases. We used Ottenbacher's suggestion that the baseline should be considered stable if 80% to 90% of the data points in the baseline phase fall within 15% of the mean.[54] Because some authors[62] have argued that visual analysis alone may not be a reliable and accurate method for supporting clinical decisions, we used the 2-standard-deviation–band method to determine if changes occurred in balance and timed mobility between the baseline and intervention phases for each subject. We chose the 2-standard-deviation band–method over the split-middle method because the variability of some of the baseline data and because some subjects did not show an obvious baseline trend. According to Ottenbacher,[54] the 2 advantages of the 2-standard-deviation–band method are that it can be used with a small (less than 10) number of data points in the baseline, and it can be applied to baseline data that are fluctuating. With the 2-standard-deviation–band method, fluctuations in baseline data lead to a larger standard-deviation band that is used for comparison to performance during the intervention phase; an overall larger change in performance then is required to conclude that a genuine change in performance has occurred.[54]

Two consecutive data points beyond the 2-standard-deviation band were used to determine whether there was a change for the BBS and TMB data.[62] We considered a clinically meaningful change in performance of the BBS to be present if the BBS changed by at least 6 points. Because it is not known how much TMB scores would have to change to represent a meaningful difference, we calculated the amount of change in scores between the baseline and intervention phases for each movement task for each subject and reported statistically significant changes in Tables 4 and 5. According to Duncan and co-workers,[50] changes in SIS domain scores of at least 10 points represent clinically meaningful change, and this criterion was used to interpret SIS scores in this study.

Results

Berg Balance Scale

Visual analysis of the BBS data revealed some variability in baseline scores for all subjects. Only subjects 1 and 3, however, demonstrated unstable baselines according to Ottenbacher's criteria.[40] The results of the data analysis for the primary outcome variables using the 2-standard-deviation–band method are summarized in Table 5. Individual data trends for the BBS scores for all subjects are displayed in Figure 2. For 3 of the 4 subjects (subjects 2, 3, and 4), there was an improvement in BBS scores in the intervention phase with at least 2 consecutive data points above the 2-standard–deviation band. Only sub-

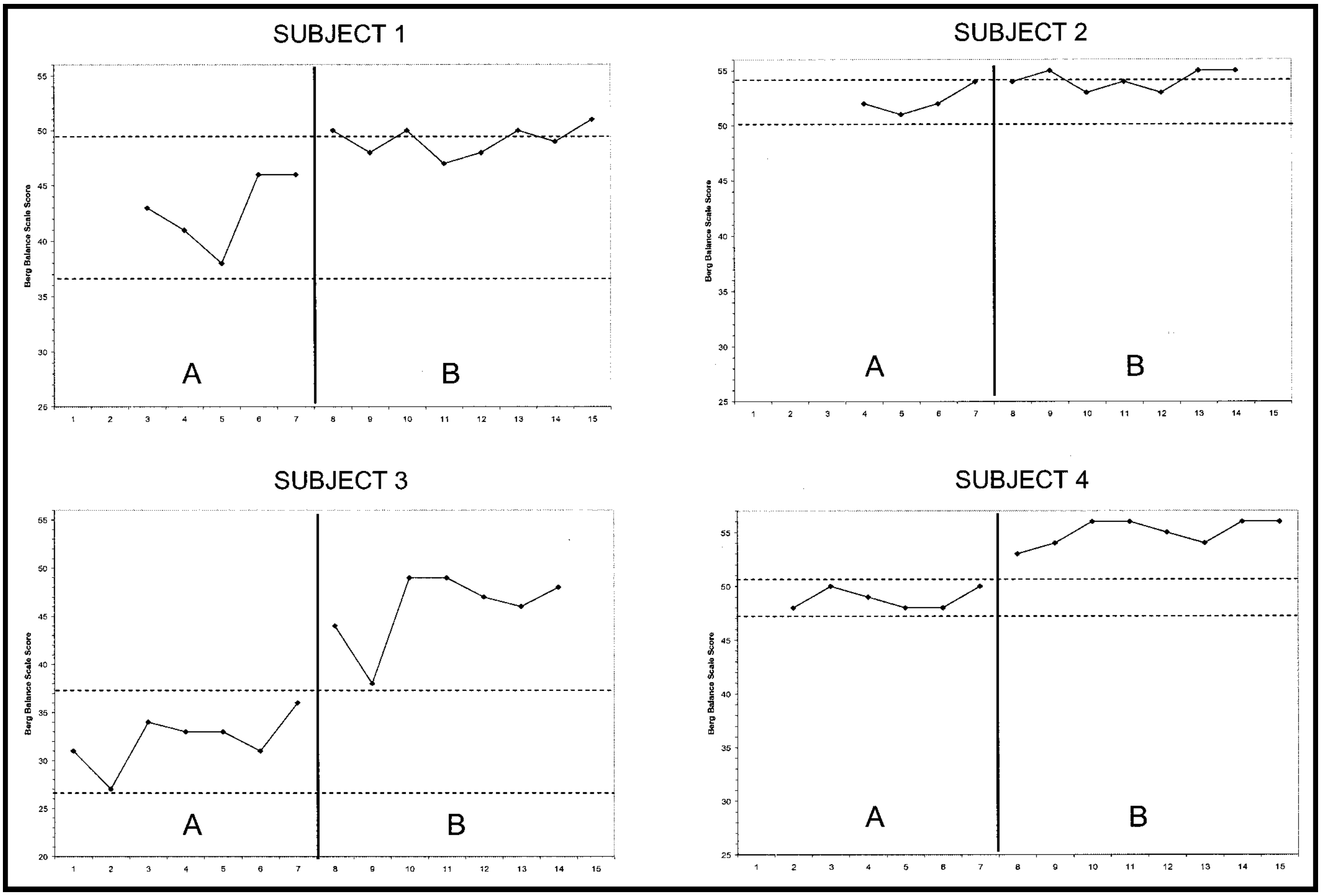

Figure 2.
Berg Balance Scale (BBS) outcome data for subjects 1 through 4. Dotted lines indicate 2 standard-deviation bands. A=baseline phase, B=intervention phase.

Table 6.
Areas of Clinically Meaningful Improvement in Balance and Timed Mobility Tests[a]

Subject No.	BBS	TMB SS	TMB MM	TMB RS
1		−6.0 s[b]		
2	+2 points[b]	−9.8 s[b]	−10.0 s[b]	
3	+14 points[b,c]			
4	+6 points[b,c]	−4.6 s[b]		

[a] BBS=Berg Balance Scale, TMB=Timed Movement Battery, SS=self-selected speed, MM=maximum movement speed, RS=reserve speed.
[b] Improvements using 2-standard-deviation-band method.
[c] Clinically meaningful change (±6 points).

jects 3 and 4, however, demonstrated what we consider clinically meaningful changes in balance performance.

Timed Movement Battery

Visual analysis of the TMB data revealed some variability in baseline scores for all subjects. Unstable baselines occurred in subject 1's TMB SS scores, in subject 3's TMB SS and MM scores, and in subject 4's TMB MM scores. The results of the data analysis for all subjects using the 2-standard-deviation–band method are summarized in Table 6 (total TMB scores) and in Tables 4 and 5 (individual TMB scores). Individual trends in TMB data for each subject are displayed in Figures 3 and 4. Using the 2-standard-deviation–band method, 3 of 4 subjects improved on total TMB SS scores, whereas only 1 subject improved on the total TMB MM scores. There was no difference in TMB RS scores between the 2 phases for any subject. Subjects demonstrated variability in the individual TMB tasks that improved during the intervention phase (Tabs. 4 and 5), with subjects 1 and 2 demonstrating improvements in the greatest number of movements at SS speed and subject 2 demonstrating the greatest number of improvements in MM speed tasks. Subject 3 demonstrated no difference in performance of any TMB SS or MM speed task.

Stroke Impact Scale, Version 2.0

The SIS scores for all subjects are displayed in Figure 5. Subject 1 demonstrated what we considered meaningful improvement in the physical, emotion, and participation domains between preintervention and postintervention scores. Subject 2 demonstrated what we define as mean-

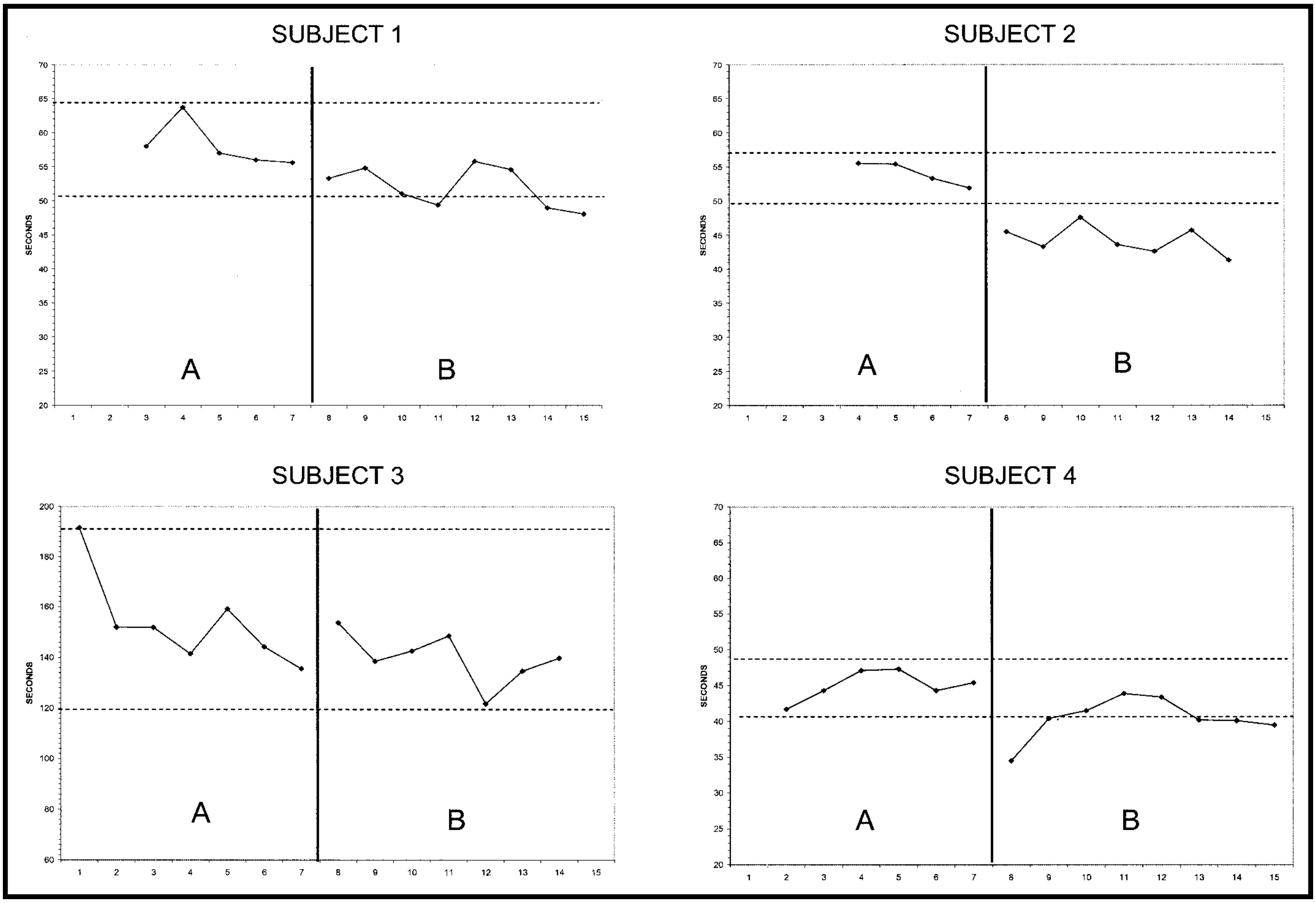

Figure 3.
Timed Movement Battery (TMB) self-selected speed scores for subjects 1 through 4. Dotted lines indicate 2 standard-deviation bands. A=baseline phase, B=intervention phase.

ingful improvement in scores for all domains between prebaseline and preintervention scores and further improvement between the preintervention and postintervention scores in the physical and memory domains. Subject 3 demonstrated meaningful improvement between prebaseline and preintervention scores and between preintervention and postintervention scores in the communication, emotional, and social participation domains, but not in the physical or memory domains. Subject 4 demonstrated meaningful improvement between the preintervention and postintervention scores in the memory, emotion, and participation domains.

Discussion

The single-case experimental design can provide researchers with valuable information about people's response to an intervention and the characteristics of subjects that show beneficial results versus the characteristics of those who do not demonstrate such results. Traditional experimental designs (ie, one-group or control group pretest-posttest designs) deal with generalizations and often overlook an individual's characteristics. Although generalizations are necessary to understand outcomes within a specific population, we believe that this information is most helpful to the clinician when it can be used to understand or predict individual performance.[62]

All subjects in our study demonstrated some positive effect in the primary and secondary outcome variables. Not all of the subjects had similar responses to the yoga intervention, and there were several differences among the subjects that may have contributed to the variance in the results. Subject 1 had improvement in total TMB SS scores but not in the BBS or total TMB MM scores (Tab. 6). Using the criteria suggested by Ottenbacher,[54] however, the TMB SS baseline phase was not stable. Our confidence about whether there was really an improvement in TMB SS scores after the intervention phase would have been strengthened if a longer baseline period would have led to greater stability in baseline scores.

Subject 1 reported that he did not adhere to the daily independent yoga activities. Low adherence to home-

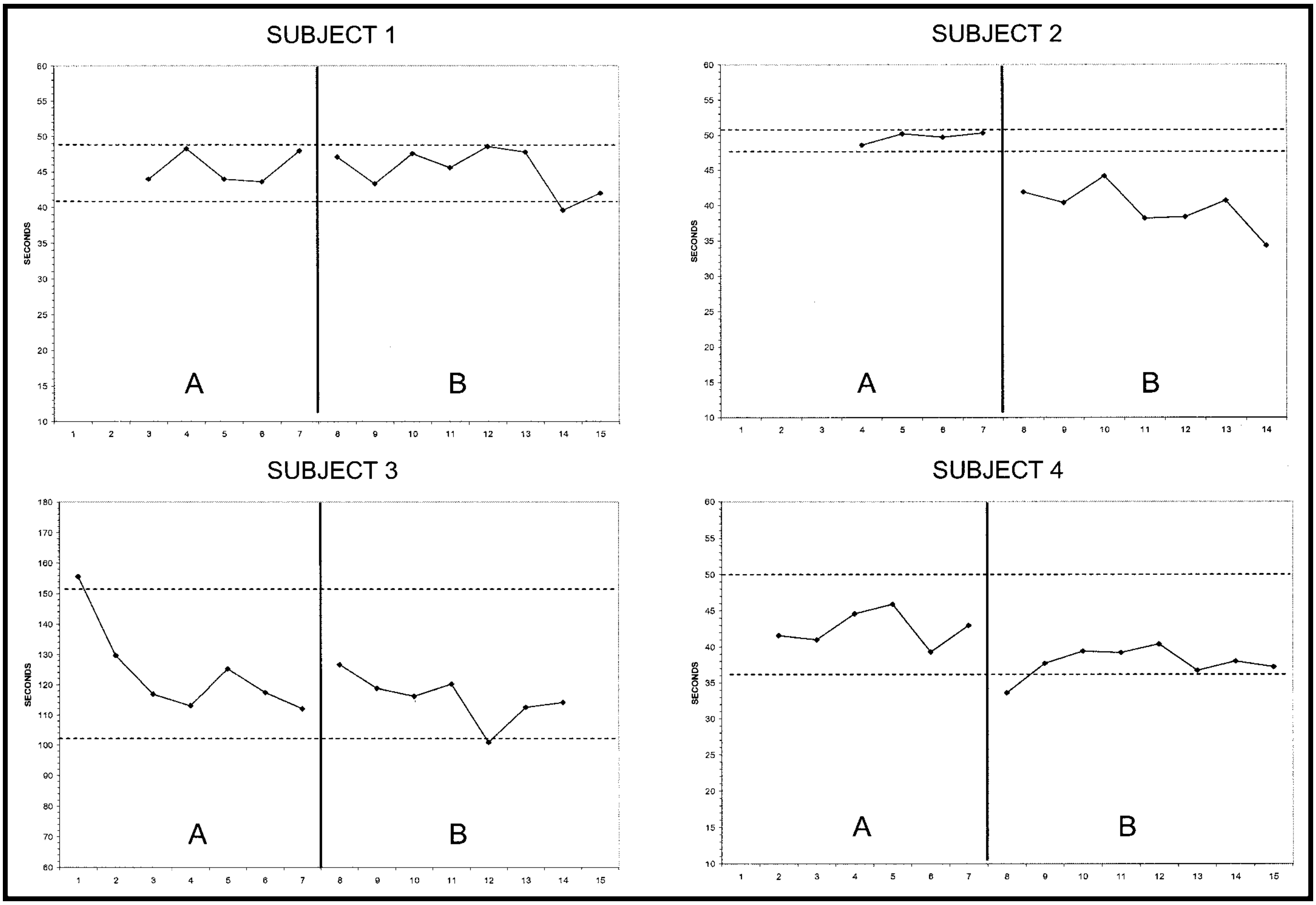

Figure 4.
Timed Movement Battery (TMB) maximum movement speed scores for subjects 1 through 4. Dotted lines indicate 2 standard-deviation bands. A=baseline phase, B=intervention phase.

based exercise protocols in older adults has been reported previously.[63,64] Jette and co-workers[65] reported an 89% rate of adherence to a home-based exercise program among elderly people with the use of behavioral incentives to encourage adherence. The use of behavioral incentives may have improved adherence to the independent yoga activities.

Subject 2 demonstrated the greatest number of changes compared with the other subjects (Tabs. 4–6). The baseline BBS scores were considered to be stable; however, the scores were becoming greater at each test session. Improvements in BBS scores after the introduction of the yoga intervention met the criteria for change using the 2 standard-deviation–band method; however, in our opinion, the 2-point gain in BBS scores does not represent a clinically meaningful change. The results of the total TMB scores indicate there was an improvement in the speed of performing the mobility tasks at both SS and MM speeds.

Subject 2 reported consistent adherence to the daily independent yoga activities throughout our study. She demonstrated a commitment to self-improvement by committing to a daily exercise routine on her own after rehabilitation ended and before the initiation of our study. We believe this may explain the trend of improvements during the baseline phase. The total TMB RS score initially declined in the baseline phase, indicating less capacity to move faster than her usual speed. This appears to have happened primarily because the SS scores improved during the baseline phase, with little change in the MM scores during the baseline phase (Fig. 3). During the intervention phase, the RS scores increased steadily back to the initial baseline level. There was approximately a 14-second improvement in both total SS and MM scores from the beginning of baseline testing to the end of the intervention. Subject 2 demonstrated a return to the initial RS score; however, she was performing the tasks at faster speeds.

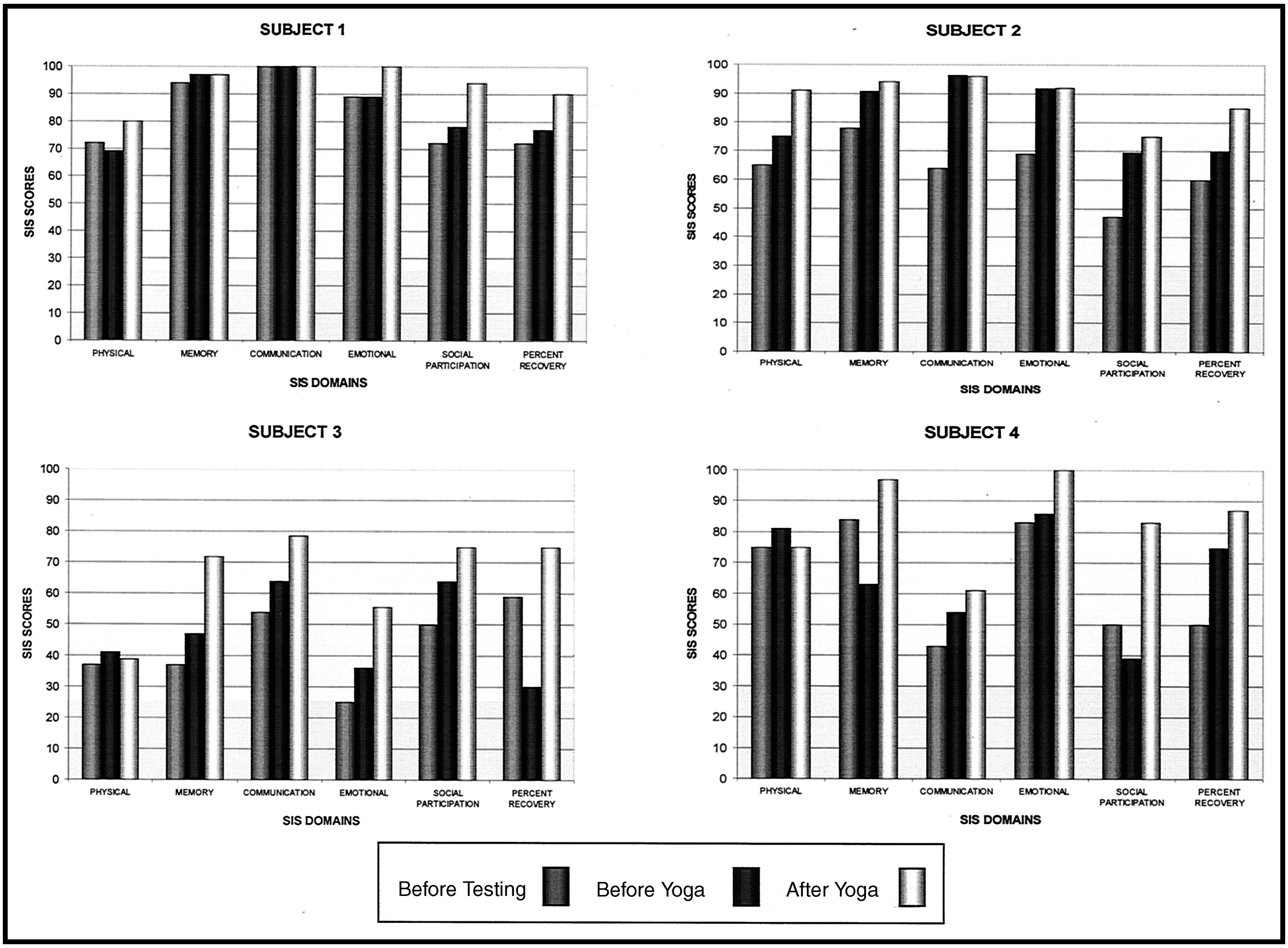

Figure 5.
Stroke Impact Scale (SIS) outcome data for subjects 1 through 4.

Collectively, our data may suggest that subject 2 gained the capacity to move at faster than usual speeds. The SIS scores for subject 2 demonstrated improvement in all domains after the baseline phase, and the scores were unchanged or continued to improve after the intervention phase (Fig. 5). These results appear to indicate that there was a perceived improvement across all domains before the introduction of the intervention. We cannot determine whether the attention given to her by the investigators, her desire for self-improvement, the yoga intervention, or some combination of these factors contributed to this perceived improvement.

Subject 3 did not show improvement in any movement task of the TMB (Tabs. 4 and 5). Among all subjects, she had the greatest number of impairments, comorbid conditions, and prescription medications. She also had the most limitations in mobility. Over the course of the intervention phase, she participated less in the *asanas* portion of the program because of increasing complaints of pain. She stated she feared getting into some of the more challenging yoga postures because of concerns that they might have increased her pain severity. She continued with all other less physically demanding aspects of the program, including performing portions of the daily independent yoga activities. During the expression/sharing segments of the program, she expressed emotional and spiritual issues of frustration, feelings of isolation, fear and uncertainty about her future, and questions concerning the meaning and purpose of her life. Emotional dysfunction has been strongly associated with health-related quality of life[66] and limitations in physical functioning, work, and leisure pursuits in people after a stroke.[4]

Yoga therapy practitioners believe that acknowledgment and empathetic support given while a person expresses emotional and spiritual feelings may greatly facilitate healing of the person's body, mind, and spirit.[20] Despite her limited participation in the *asanas* portion of the intervention, subject 3 demonstrated what we believe is a clinically meaningful improvement in BBS scores after the intervention. Perhaps daily participation in some of the yoga activities enhanced her attention and concentration and decreased her physical impairments enough to affect her postural stability and control while performing the BBS tasks. It would have been interesting to determine whether changes in her perception of overall physical functioning and measures of mobility would have improved with a longer duration of the yoga intervention.

Subject 4 reported that she did not adhere to the independent yoga exercise program. Because of her aphasia, it was difficult to determine if she understood the instructions for the independent yoga activities even though demonstration was used and illustrations were provided. She indicated that she understood what to do, but she did not do the activities routinely because of time constraints and fatigue from performing daily household chores and going on frequent social outings. Her aphasia did not appear to hinder her participation in the physical segment of the yoga intervention. Her ability to verbally participate in the sharing segments, however, was limited. We found it difficult to ascertain whether she understood or received benefit from the educational segments or body awareness activities, because she was unable to express her experiences or discuss how she incorporated the yoga concepts into her daily life.

Despite the limitations imposed by her communication deficits, subject 4 showed what we consider to be a clinically meaningful improvement in balance. She was able to participate fully in the *asanas* portions of the program in the presence and guidance of the yoga-therapy teacher. These results appear consistent with the results of other investigations into the effects of various exercise training programs on people with long-standing poststroke hemiparesis.[7,11] The results of the SIS appear to indicate meaningful improvement in subject 4's perception of memory, emotion, and social participation after the yoga intervention. The scores for the physical domain showed very little change after both the baseline and intervention phases. We question the interpretation of the SIS results with this subject, because the SIS has not been tested with people with communication difficulties.[50]

Overall, our results suggest that yoga may be beneficial for people with chronic poststroke hemiparesis, but further investigation is warranted. Our data suggest that the BBS may not be sensitive to detect changes that may occur in some people with high-level balance deficits, a finding previously reported by other authors.[67] For example, subject 2's mean BBS baseline score was 4 points from the maximum possible score before the intervention began. In future studies, we recommend that measures sensitive to changes in postural stability, such as the Dynamic Gait Index[41] or measures of postural sway, be used. In contrast, we believe the TMB appears to be an appropriate measure of timed mobility for this patient population, but this does not provide information about the factors that may be influencing speed of movement. In addition, no information is available to determine what are clinically meaningful changes in TMB scores. Our recommendation for future investigations is to include additional impairment measures to clarify the relationship between changes in impairments and changes in speed of performing movement tasks to be able to determine the effects of yoga on flexibility, muscle force, endurance, and motor function in people with chronic poststroke hemiparesis.

Conclusion

This preliminary investigation of the effects of a yoga-based exercise program lends support to the growing evidence that improvements in impairments and mobility limitations can be achieved with people with chronic poststroke hemiparesis.[7–11] The differences in the outcomes demonstrated by the subjects in our study may be explained by the differing characteristics of each subject. The subject who demonstrated the most improvements in balance and mobility was the most adherent to the yoga program on a daily basis. Subjects who practiced the yoga activities less frequently showed some improvement in balance and mobility, but may have needed a longer duration for the intervention than was offered in this study. Future studies with larger samples and control subjects are needed to offer more conclusive evidence of the benefits of a yoga-based exercise program on balance, mobility, and quality of life for this population.

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