Daily Functioning and Quality of Life in a Randomized Controlled Trial of Therapeutic Exercise for Subacute Stroke Survivors

Stephanie Studenski, MD, MPH; Pamela W. Duncan, PhD, FAPTA; Subashan Perera, PhD; Dean Reker, RN, PhD; Sue Min Lai, PhD; Lorie Richards, PhD, FAOTA

Background and Purpose—The ability of therapeutic exercise after stroke to improve daily functioning and quality of life (QOL) remains controversial. We examined treatment effects on these outcomes in a randomized controlled trial (RCT) of exercise in subacute stroke survivors.

Methods—This is a secondary analysis of a single-blind RCT of a 12-week program versus usual care. Baseline, post-treatment and 6-month post-treatment daily functioning and QOL were assessed by Barthel index, Functional Independence Measure, instrumental activities of daily living, Medical Outcomes Study short-form 36-item questionnaire (SF-36), and Stroke Impact Scale (SIS).

Results—Of 100 randomized subjects, 93 completed the postintervention assessment, (mean age 70; 54% male; 81% white; mean Orpington Prognostic Score 3.4), and 80 had 6-month post-treatment assessment. Immediately after intervention, the intervention group improved more than usual care in SF-36 social function (14.0 points; $P=0.0051$) and in SIS (strength [9.2 points; $P=0.0003$], emotion [5.6 points; $P=0.0240$], social participation [6.6 points; $P=0.0488$], and physical function [5.0 points; $P=0.0145$]). Treatment was marginally more effective on Barthel score (3.3 points; $P=0.0510$), SF-36 (physical function [6.8 points; $P=0.0586$], physical role function [14.4 points; $P=0.0708$]), and SIS upper extremity function (7.2 points; $P=0.0790$). Effects were diluted 6 months after treatment ended.

Conclusion—This rehabilitation exercise program led to more rapid improvement in aspects of physical, social, and role function than usual care in persons with subacute stroke. Adherence interventions to promote continued exercise after treatment might be needed to continue benefit. (***Stroke*. 2005;36:1764-1770.)**

Key Words: disability ■ exercise ■ quality of life ■ rehabilitation ■ stroke

Poststroke exercise interventions should improve functional status and quality of life (QOL).[1–4] Evidence supporting the clinical impact of therapeutic exercise after stroke is limited and equivocal with the quality constrained by heterogeneity of participants, interventions, and outcome measures and by methodological concerns.[1–3] Interventions may be offered in the acute, subacute, or chronic phase of stroke and may include aerobic training, strength training, functional activities, or other strategies. Exercise studies in stroke survivors and older adults in general tend to capture effects on intermediate outcomes such as strength and physical abilities rather than on more integrated indicators such as functional status and QOL.[4] Common methodological limitations in stroke rehabilitation trials include failure to implement concealed allocation, blinding of the assessors, and intention to treat analyses, all of which help reduce bias in the findings.[1–3,5] To examine the benefits of a structured, progressive, physiologically based exercise intervention on recovery in persons with subacute stroke using trial methods recommended to overcome previous concerns, we designed and completed a randomized single-blind clinical trial.[6] This study used a reproducible intervention of strength, endurance, balance, and upper extremity and functional training, and incorporated the key aspects of research methodology noted above. It targeted persons during natural recovery <6 months after stroke. The study found significant benefits on primary outcomes of impairments and functional limitations such as endurance, balance, and mobility. The purpose of this report

Received April 21, 2005; accepted May 30, 2005.

From the Division of Geriatric Medicine (S.S., S.P.), University of Pittsburgh, Pa; GRECC (S.S.), VA Pittsburgh Healthcare System, Pa; Department of Health Services Research (P.W.D.), Management and Policy, University of Florida, Gainesville; Brooks Center for Rehabilitation Studies (P.W.D.), University of Florida, Gainesville; North Florida/South Georgia Veterans Health System (P.W.D., L.R.), Gainesville Department of Health Policy and Administration (D.R.), University of Kansas; Kansas City VA Medical Center (D.R.), Kansas; Department of Preventive Medicine and Public Health (S.M.L.), University of Kansas, Kansas City; and Department of Occupational Therapy (L.R.), University of Florida, Gainesville.

S.S. received funding for research from Eli Lilly and Co and Ortho-Biotech and is a consultant for Merck Co, Ortho-Biotech and Wyeth Pharmaceuticals. P.W.D. is a consultant for Glaxo-SmithKline and AstraZeneca. S.P. received funding for research from Eli Lilly and Co and Ortho-Biotech and is a past consultant for Teva Neuroscience.

Correspondence to Stephanie Studenski, MD, MPH, 3471 Fifth Ave, Suite 500, Pittsburgh, PA 15213. E-mail sas33@pitt.edu

***Stroke* is available at http://www.strokeaha.org** **DOI: 10.1161/01.STR.0000174192.87887.70**

was to describe the effects on daily functioning and QOL. Effects immediately and 6 months after treatment are examined.

Methods

The design and methods for this trial have been published previously[6] and are summarized here.

Design

This is a prospective, randomized, single-blind clinical intervention trial. The University of Kansas institutional review board, and each participating facility approved the study.

Subjects

The source of trial participants was the Kansas City Stroke Registry, made up of 17 participating facilities. Registry eligibility criteria included clinical stroke diagnosis consistent with the World Health Organization definition, confirmed by clinical assessment or imaging, age ≥50, stroke onset within 3 to 28 days, and residence within 50 miles. Trial eligibility criteria were: (1) stroke within 30 to 150 days; (2) independently ambulates 25 feet; and (3) mild-to-moderate stroke deficits by Fugl-Meyer Score of 27 to 90,[7] Orpington Prognostic Score (OPS) of 2.0 to 5.2[8] and palpable wrist extension, and Mini-Mental Status Exam score ≥16.[9] Each subject's primary care physician approved participation in the study.

Measures

Stroke severity was assessed using the OPS.[8] Outcome measures of daily functioning included the Functional Independence Measure (FIM),[10] Barthel index,[11] Lawton and Brody instrumental activities of daily living (ADL),[12] and gait speed thresholds (0.8 m/s) for community ambulation.[13] Measures of QOL included subscales of the Stroke Impact Scale (SIS)[14] and the Medical Outcomes Study short-form 36-item questionnaire (SF-36).[15] Potential cofactors included demographics, stroke severity by OPS at entry to the Stroke Registry within 2 weeks of the event, and previous functional status by prestroke SF-36 physical function.

Procedures

After a screening exercise stress test[16] for safety and baseline assessments, subjects were randomized in blocks of 6. Research staff blinded to treatment assignment performed interview- and laboratory-based outcome assessments. Participants were not blind to their assignment but were unaware of the study hypotheses or primary outcome measures. Outcomes were assessed at 3 months (immediately after the intervention phase) and 6 months after completing the intervention.

Intervention

The 36-session, 12-week, home-based exercise program, supervised by an occupational or physical therapist, targeted strength (major muscle groups of the upper and lower extremity using elastic bands and body weight), balance, and endurance (using an exercise bicycle), and encouraged use of the affected upper extremity.[6] There were structured protocols for the exercise tasks, criteria for progression, and guidelines for reintroducing therapy after intercurrent illness. After completing the intervention, participants received written guidelines for continued exercise.

Usual Care Controls

Usual care participants received rehabilitation services prescribed by their personal physician, and details of these services were recorded. Research staff visited usual care participants in their homes for ≈30 minutes every 2 weeks for health education, vital signs, and an oxygen saturation test. Participants were provided materials addressing health practices for preventing recurrent stroke and given feedback on physical assessments including blood pressure and oxygen saturation. About half of the controls received formal physical therapy (PT) or occupational therapy (OT) services during their first 3 month in the study.[6]

Statistical Analysis

A covariance analysis was performed, with treatment group as the primary factor and baseline measurement, stroke severity, and previous functional status as covariates to obtain adjusted group differences. The effect of adjusting for other covariates on main comparisons was investigated in additional analyses. Standardized means differences (SMDs) were computed by dividing group differences by within-group SD to quantify the effect size.[17] For dichotomous outcomes, similar analyses were performed using logistic models instead of general linear models. To account for possible missing value bias, multiple imputation was performed.[18] Five imputations for each missing value were generated, resulting in 5 imputed data sets. Next, each data set was analyzed using the above-described methods. Finally, results from the 5 analyses were combined to obtain intervention effects, SEs, and *P* values. Sensitivity analyses (data not shown) suggested no significant differences in effects based on various approaches to missing data.

Results

Participants were diverse in gender, ethnicity, and socioeconomic status, had mild-to-moderate deficits, prevalent comorbid conditions, and no differences in demographics, stroke severity, or comorbidity between completers and noncompleters (n=7) or between intervention and usual care groups (Table 1). Six months after treatment, noncompleters (n=20) were more likely to be receiving Medicare and entered the study sooner after their stroke than continued participants (n=80) (data not shown). Subject screening, exclusion, and dropout are reported in the Figure.

At baseline, participants had mild deficits in self-care, and most had deficits in physical limitations and household and community activities. There were significant deficits in most indicators of QOL. Dropouts had slightly lower cognitive status by the FIM and better upper extremity function by the SIS. Baseline stroke function and QOL were similar between treatment arms, except usual care controls had slightly lower ADL status by SIS, borderline lower physical function by SF-36, and overall stroke QOL by SIS-16 combined score. For the long-term outcomes, there was more depression in those who eventually dropped out than in those who remained in the study (data not shown), and the usual care control group had slightly worse baseline physical function than the intervention arm.

The intervention and usual care groups demonstrated recovery of function over the 3 months between study entry and postintervention assessment. Each group increased the proportion of participants who were independent in basic ADLs (Barthel score) and who were independent in community ambulation. Both groups demonstrated increasing scores in motor FIM, SF-36, and SIS scales.

Immediate post-treatment outcomes are shown in Table 2. Multiple imputation is used to account for missing data attributable to losses to reduce bias attributable to differences between noncompleters and persistors. The gains in the intervention group were greater than in usual care in every domain and were significantly greater for SF-36 social function, SIS strength, emotion, social participation, and physical function. Treatment was marginally more effective for Barthel score, SF-36 physical function, physical role

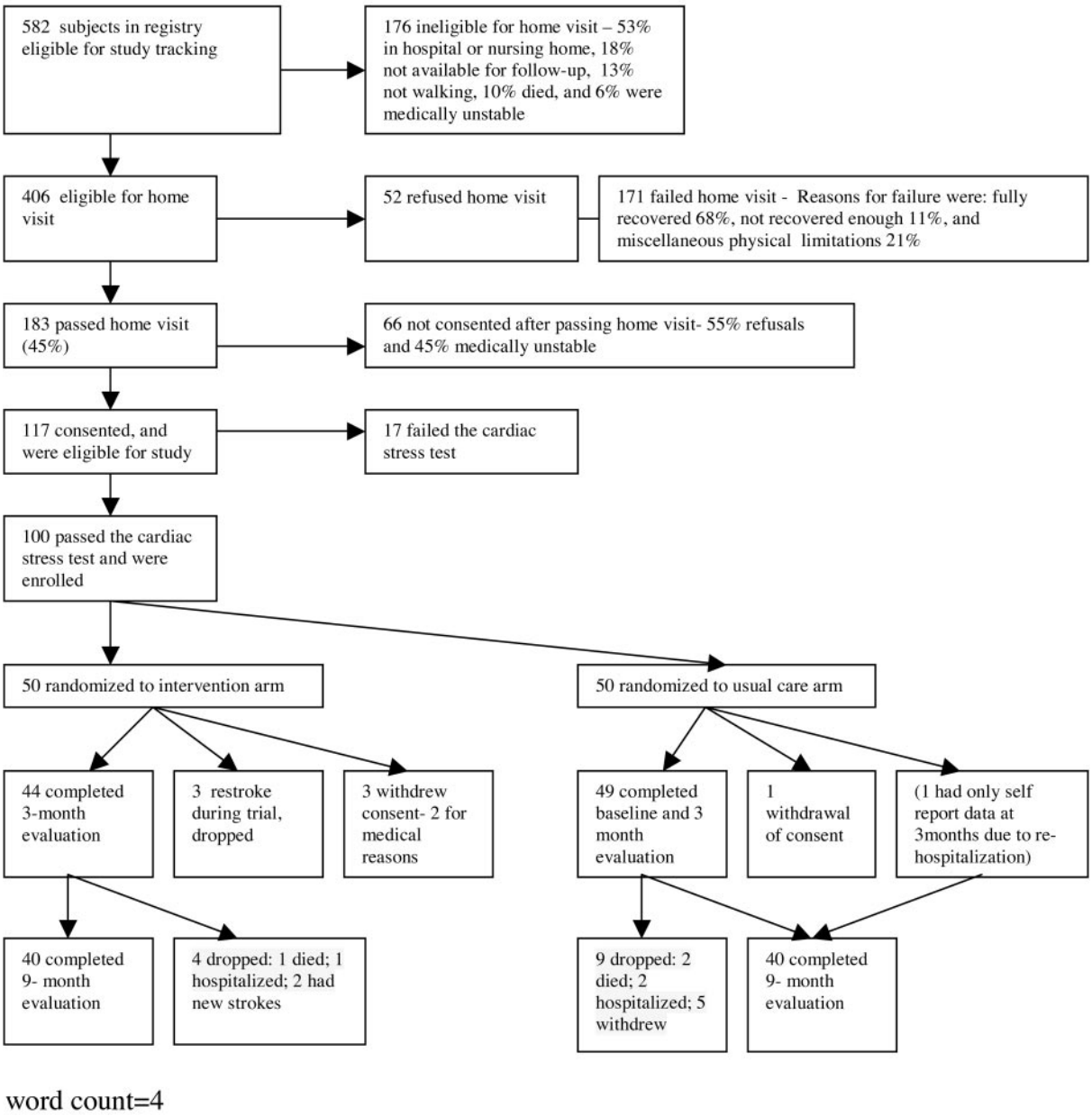
TABLE 1. Subject Characteristics and Baseline Measures (Mean [SD] or n [%])

	In Study Immediately After Intervention Phase (n=93)	Losses During Intervention Phase (n=7)	Intervention Group (n=44)	Usual Care Group (n=49)
Age	69.5 (10.3)	74.0 (10.4)	68.5 (9.0)	70.4 (11.3)
Sex (male)	50 (53.8)	6 (85.7)	23 (52.3)	27 (55.1)
Race (Caucasian)	75 (80.7)	4 (57.1)	37 (84.1)	38 (77.6)
Prestroke SF-36 physical function	79.2 (20.5)	83.6 (19.7)	80.6 (19.7)	78.0 (21.3)
OPS	3.4 (0.8)	3.5 (0.7)	3.4 (0.8)	3.4 (0.8)
Stroke location				
Right hemisphere	45 (48.4)	2 (28.6)	22 (50.0)	23 (46.9)
Left hemisphere	40 (43.0)	4 (57.1)	18 (40.9)	22 (44.9)
Brain stem/other	8 (8.6)	1 (14.3)	4 (9.1)	4 (8.1)
Stroke type (ischemic)	83 (89.3)	7 (100.0)	39 (88.6)	44 (89.8)
Days after stroke	75.7 (27.8)	81.0 (27.9)	77.5 (28.7)	74.1 (27.2)
History of heart attack	7 (7.5)	0 (0.0)	2 (4.6)	5 (10.2)
Irregular heart rhythm	10 (10.8)	0 (0.0)	4 (9.1)	6 (12.2)
High blood pressure	67 (72.0)	6 (85.7)	30 (68.2)	37 (75.5)
Arthritis	42 (45.2)	5 (71.4)	19 (43.2)	23 (46.9)
Chronic pain	31 (33.3)	4 (57.1)	14 (31.8)	17 (34.7)
Depression/anxiety	25 (26.9)	1 (14.3)	12 (27.3)	13 (26.5)
Diabetes	24 (25.8)	1 (14.3)	11 (25)	13 (26.5)
Barthel ADL index				
Continuous score (0–100)	87.4 (11.5)	89.3 (8.9)	89.2 (11.8)	85.9 (11.0)
Independent (≥95)	33 (36.7)	3 (42.9)	21 (48.8)	12 (25.5)
Lawton IADL score	20.8 (3.5)	20.4 (5.1)	21.2 (3.0)	20.5 (3.9)
Community ambulation				
Gait speed ≥0.8 m/s	27 (29.0)	3 (42.9)	16 (36.4)	11 (22.5)
FIM				
Cognitive score	33.3 (1.7)	31.9 (2.7)†	33.3 (1.4)	33.2 (1.9)
Motor score	80.3 (7.6)	81.1 (4.9)	81.0 (8.2)	79.7 (7.0)
Medical Outcomes Study-36				
Physical function	43.5 (22.3)	54.3 (16.4)	47.6 (23.2)	39.9 (21.1)*
Role-physical	9.9 (18.1)	25.0 (32.3)	12.5 (19.1)	7.7 (17.1)
Social function	62.1 (25.8)	62.5 (14.4)	64.5 (25.3)	59.9 (26.3)
SIS				
Strength	54.4 (16.6)	50.0 (18.0)	55.8 (18.4)	53.2 (14.9)
Memory and thinking	79.9 (20.6)	66.3 (29.8)	82.5 (17.5)	77.6 (23.0)
Emotion	80.6 (14.4)	74.9 (19.3)	81.1 (14.3)	80.2 (14.6)
Communication	84.4 (17.6)	85.7 (16.4)	85.4 (17.4)	83.6 (17.9)
ADL/IADL	67.9 (15.9)	74.2 (17.3)	71.6 (17.3)	64.5 (13.8)†
Mobility	67.7 (15.9)	62.0 (13.0)	69.6 (16.8)	66.0 (15.0)
Upper extremity	46.2 (27.9)	66.7 (16.6)*	48.5 (27.5)	44.1 (28.3)
Social participation	50.1 (20.6)	56.8 (14.2)	52.0 (20.8)	48.4 (20.5)
Physical function	59.1 (14.3)	64.0 (12.7)	61.4 (15.5)	56.9 (13.0)
SIS-16	71.5 (13.8)	71.6 (15.0)	74.1 (14.9)	69.2 (12.4)*

*$0.05<P<0.10$; †$0.01<P<0.05$ for dropouts vs persistors or usual care vs intervention.

function, and SIS upper extremity function. There were no detectable effects on the motor or cognition scales of the FIM or on instrumental ADL (IADL) score.

Effect sizes are presented in Table 2. The effect size (SMD) was 0.31, 0.43, and 0.61 for physical function, physical role, and social function (SF-36), respectively, and 0.59, 0.39, 0.27, 0.32, and 0.35 for strength, emotion, upper extremity, social participation, and physical function (SIS), respectively. The proportion of participants considered independent in self-care (Barthel index ≥95) after the interven-



word count=4

Subject flow.

tion period was 29 of 44 (67.4%) in the intervention arm and 21 of 49 (45.7%) in the usual care arm, for a difference of 21.7%. Community ambulation (gait speed ≥0.8 m/s) was achieved in 25 of 44 (56.8%) of the intervention and 20 of 49 (42.6%) of usual care participants, for a benefit attributable to the treatment alone of 14%.

Longer-term benefit was assessed in 80 participants 6 months after intervention (Table 3). Participants in the intervention group were given written guidelines for a structured home program and were encouraged to exercise but without supervision or ongoing effort to promote adherence. The benefits of the intervention were dissipated by 9 months, largely because of continued recovery among the usual care participants. For example, average SF-36 physical function score improved only slightly from 56 to 58.9 in the intervention group, whereas it increased from 43.7 to 51.0 in the usual care group.

Discussion

This therapeutic exercise intervention for stroke survivors in the subacute phase of recovery appears to accelerate gains in function and QOL in the early months after completing usual acute rehabilitation. The intervention produced greater gains and higher rates of independence immediately after the intervention than did usual care. Much of the benefit appeared to have dissipated by 6 months after intervention, largely because of continued recovery in the usual care group and a plateau in functioning in the intervention group.

The effect of therapeutic exercise on function and QOL is much less clear than its effect on impairments and physical

TABLE 2. Immediate Effects of the Intervention Adjusted for Age, Prestroke Physical Function, and Stroke Severity, and Baseline Measurement of Outcome With Multiple Imputation for Dropouts

	Intervention Group (n=44) Mean (SD) or *n (%)*	Usual Care Group (n=49) Mean (SD) or *n (%)*	Adjusted Comparison of Intervention vs Usual Care		
			Difference (SE)/Odds Ratio	95% CI	SMD
Lawton IADL score	22.8 (3.2)	21.8 (3.9)	0.37 (0.48)	−0.57 to 1.30	0.10
Barthel ADL index					
Total score	94.4 (6.7)	89.6 (10.4)	3.35 (1.69)*	−0.01 to 6.71	0.38
Achieved 95+	*29 (67.4)*	*21 (45.7)*	*1.61*	0.62 to 4.15	...
Community ambulation					
0.8+ m/s	*25 (56.8)*	*20 (42.6)*	*1.15*	0.39 to 3.40	...
FIM					
Cognitive score	33.7 (1.1)	33.6 (1.2)	−0.05 (0.20)	−0.44 to 0.34	−0.04
Motor score	84.5 (5.8)	81.9 (8.3)	1.72 (1.11)	−0.46 to 3.90	0.24
SF-36					
Physical function	56.0 (22.1)	43.7 (21.2)	6.76 (3.50)*	−0.25 to 13.78	0.31
Role-physical	44.2 (33.6)	27.2 (33.3)	14.40 (7.86)*	−1.25 to 30.05	0.43
Social function	79.9 (21.0)	62.8 (24.6)	14.05 (4.83)‡	4.38 to 23.72	0.61
SIS					
Strength	66.1 (14.4)	56.1 (16.7)	9.23 (2.56)‡	4.22 to 14.24	0.59
Memory and thinking	85.6 (15.7)	78.2 (22.0)	3.27 (2.11)	−0.85 to 7.41	0.17
Emotion	83.0 (12.1)	76.5 (16.2)	5.58 (2.45)†	0.74 to 10.43	0.39
Communication	85.4 (17.9)	81.3 (18.3)	2.34 (2.15)	−1.88 to 6.56	0.13
ADL/IADL	79.2 (16.3)	73.0 (16.1)	1.90 (2.58)	−3.15 to 6.95	0.12
Mobility	76.3 (16.2)	71.7 (16.4)	2.84 (2.59)	−2.24 to 7.93	0.17
Upper extremity	66.7 (27.0)	57.7 (26.7)	7.18 (4.09)*	−0.83 to 15.20	0.27
Social participation	66.6 (22.9)	58.2 (18.5)	6.64 (3.37)†	0.04 to 13.24	0.32
Physical function	72.1 (15.0)	64.6 (14.0)	5.00 (2.05)†	0.99 to 9.01	0.35
SIS-16	81.3 (14.2)	75.3 (14.5)	2.92 (2.17)	−1.34 to 7.17	0.20

*$0.05<P<0.10$; †$0.01<P<0.05$; ‡$P<0.01$.

performance. In a recent meta-analysis of home-based stroke rehabilitation intervention trials, substantial heterogeneity of populations and interventions was found.[19] Overall benefit, estimated using the SMD, was 0.14 for basic ADL and 0.17 for IADL compared with our estimate of 0.38 for basic daily functioning by Barthel score and 0.10 for IADL. None of the 3 recent pooled analyses of stroke rehabilitation based on studies completed by 2002 reported effect sizes for QOL indicators; whereas our estimates range from 0.31 to 0.61 for SF-36 and 0.12 to 0.59 for stroke-specific SIS scales.[1–3] More recent intervention studies have had mixed results. Aerobic training during the subacute phase of stroke recovery produced gains in performance and conditioning but did not directly impact daily function and social activities at 6 months after stroke.[20,21] A treadmill and overground walking program for persons with chronic stroke produced gain in walking but not handicap using the sickness impact profile.[22] An early intensive intervention based on increased daily duration of exercise during the first 2 weeks after hospitalization did not produce gains in ADL by Barthel index at 2 weeks or 6 months.[23] A high-intensity strength training program compared with stretching in chronic stroke survivors produced significant differences in lower extremity strength and in 3 of 10 subscales of the late life disability index, with treatment differences attributable to improvements in the exercisers and declines in the comparison group.[24] Our multimodal exercise program produced gains in impairments and functional limitations such as endurance, balance, and mobility,[6] which may have influenced aspects of daily functioning and QOL. The main differences between our intervention and that offered in the usual care group were the inclusion of aerobic training, the explicit progression of all types of exercise, and the increased attention. We do not know what combination of these treatment differences produced the observed effects. Our results contribute to the evidence supporting the benefit of supervised exercise for daily functioning and QOL after stroke.

Our intervention appears to accelerate recovery in the subacute phase compared with usual postrehabilitation community care but did not provide sustained benefit 6 months later. More rapid return to community ambulation and improved QOL may provide additional months of reduced caregiver stress and personal satisfaction that have societal and personal value. Most of the eventual loss of treatment effect by 9 months after randomization was attributable to the continued recovery of the usual care group, with little additional change in the intervention group. We do not know whether the intervention group reached a plateau of functional

TABLE 3. Six-Month Posttreatment Effects of the Intervention Adjusted for Age, Prestroke Physical Function, Stroke Severity, and Baseline Measurement of Outcome With Multiple Imputation for Dropouts

	Intervention Group (n=40) Mean (SD) or *n (%)*	Usual Care Group (n=40) Mean (SD) or *n (%)*	Adjusted Comparison of Intervention vs Usual Care		
			Difference (SE)/*OR*	95% CI	SMD
Lawton IADL Score	23.2 (3.7)	22.4 (4.3)	0.26 (0.69)	−1.12 to 1.63	0.06
Barthel ADL Index					
Total score	92.6 (9.5)	94.3 (7.8)	−1.50 (2.13)	−5.97 to 2.97	−0.17
Achieved 95+	*24 (60.0)*	*28 (77.8)*	*0.46*	0.16 to 1.35	...
Community ambulation					
0.8+ m/s	*20 (54.1)*	*14 (38.9)*	*1.09*	0.32 to 3.68	...
FIM					
Cognitive score	33.9 (0.6)	33.5 (2.00)	0.33 (0.35)	−0.37 to 1.03	0.22
Motor score	84.5 (6.2)	82.6 (10.5)	0.83 (1.47)	−2.13 to 3.80	0.10
SF-36					
Physical function	58.9 (22.7)	51.0 (22.9)	2.74 (4.30)	−5.83 to 11.32	0.12
Role-physical	50.0 (37.6)	40.0 (32.9)	12.4 (7.66)	−2.71 to 27.57	0.35
Social function	80.6 (19.2)	70.0 (26.2)	8.29 (4.97)	−1.63 to 18.21	0.36
SIS					
Strength	61.1 (14.4)	62.4 (14.7)	−0.39 (2.77)	−5.90 to 5.12	−0.03
Memory and thinking	82.4 (17.3)	78.1 (20.2)	0.16 (2.63)	−5.39 to 5.08	0.01
Emotion	81.1 (14.1)	80.2 (16.8)	−1.18 (2.99)	−7.12 to 4.75	−0.08
Communication	84.7 (15.5)	81.8 (19.2)	0.41 (2.12)	−4.62 to 3.80	0.07
ADL/IADL	79.6 (14.8)	73.1 (18.3)	0.71 (2.49)	−4.22 to 5.64	0.04
Mobility	75.7 (15.8)	73.5 (18.2)	1.80 (2.63)	−7.03 to 3.43	0.11
Upper extremity	64.9 (25.6)	58.9 (28.7)	4.15 (4.38)	−4.55 to 12.85	0.15
Social participation	72.0 (20.2)	66.5 (22.4)	2.41 (4.00)	−5.54 to 10.37	0.11
Physical function	70.3 (14.2)	67.0 (16.0)	0.50 (2.12)	−3.72 to 4.70	0.03
SIS-16	80.9 (13.7)	75.9 (15.7)	0.18 (2.01)	−3.81 to 4.17	0.01

*$0.05<P<0.10$; †$0.01<P<0.05$; ‡$P<0.01$

capacity earlier than the usual care group or whether explicit support for continued exercise might have sustained a treatment benefit. Our intervention did not support participants during the transition to self-maintained exercise or record adherence to exercise in the postintervention phase. Self-maintenance of exercise after a supervised program may require explicit attention to motivational and cognitive behavioral strategies that we did not incorporate into our program.[25]

The effects of spontaneous recovery on outcomes, observed mostly in acute and subacute stroke and less in chronic stroke, must be considered when evaluating clinical trials of exercise in stroke. In clinical trials of stable chronic stroke patients, the lack of spontaneous gains in the comparison group makes between-group treatment effects easier to detect because controls are not improving. Chronic stroke trials are less relevant to real-world poststroke rehabilitation services. Interventions are probably best tested in populations still in the recovery phase and should expect to detect spontaneous gains in controls.

This study has numerous strengths. It is fairly large and offers a physiologically based and highly reproducible intervention that could be implemented by others using our protocols. Outcome assessment was blinded, as was treatment allocation, and primary analyses were performed with multiple imputation to reduce missing data bias. The participants represent a clinically relevant group of stroke survivors: those who return to the community with significant stroke deficits after completing acute rehabilitation. The study also has limitations. Participants could not be blinded to treatment assignment. Because virtually all measures of daily functioning and QOL are based on self-report, knowledge of treatment assignment could bias findings. There were also differences in the amount of attention paid to participants in the 2 arms; treatment participants had more direct contact time from research staff than did usual care participants. We attempted to reduce the attention effect by providing structured visits with tangible benefits to the usual care group. By the final 9-month assessment, we had lost 20% of participants because of medical and nonmedical causes. Losses create missing data, which can bias findings. We attempted to examine potential bias through sensitivity analyses.

Summary

A structured exercise intervention during the subacute phase of stroke recovery resulted in accelerated gains in daily

functioning and QOL compared with usual care, but additional benefit of the intervention had dissipated by 6 months after the intervention. Earlier recovery of function may have benefit to stroke survivors. Effective exercise interventions in rehabilitation, as in other types of exercise programs, might need to be more explicitly coupled to a motivational adherence intervention for continued benefit.

Acknowledgments

This study was conducted at the Center on Aging, University of Kansas Medical Center and was funded by the National Institute on Aging, Kansas, Claude D. Pepper Center (P60AG14635). The resources and facilities of the North Florida/South Georgia VA Health System and the University of Pittsburgh also supported this work.

References

1. Legg L, Langhorne P. Rehabilitation therapy services for stroke patients living at home: systematic review of randomised trials. *Lancet*. 2004;363:352–356.
2. Pollock A, Baer G, Pomeroy V, Langhorne P. Physiotherapy treatment approaches for the recovery of postural control and lower limb function following stroke. *Cochrane Database Syst Rev*. 2003:CD001920.
3. Saunders DH, Greig CA, Young A, Mead GE. Physical fitness training for stroke patients. *Cochrane Database Syst Rev*. 2004:CD003316.
4. Keysor JJ, Jette AM. Have we oversold the benefit of late-life exercise? *J Gerontol A Biol Sci Med Sci*. 2001;56:M412–M423.
5. Mulrow CD, Oxman AD. Cochrane Collaboration Handbook. Cochrane Library update software, 1997.
6. Duncan P, Studenski S, Richards L Gollub S, Lai SM, Reker D, Perera S, Yates J, Koch V, Rigler S, Johnson D. Randomized clinical trial of therapeutic exercise in subacute stroke. *Stroke*. 2003;34:2173–2180.
7. Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Steglind S. The post-stroke hemiplegic patient. A method for evaluation of physical performance. *Scand J Rehabil Med*. 1975;7:13–31.
8. Kalra L, Crome P. The role of prognostic scores in targeting stroke rehabilitation in elderly patients. *J Am Geriatr Soc*. 1993;41:396–400.
9. Folstein MF, Folstein SE, McHugh PR. "Mini mental state." a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12:189–198.
10. Linacre JM, Heinemann AW, Wright BD, Granger CV, Hamilton BB. The structure and stability of the Functional Independence Measure. *Arch Phys Med Rehabil*. 1994;75:127–132.
11. Mahoney FI, Barthel DW. Functional evaluation: the Barthel Index. *Md State Med J*. 1965;14:61–65.
12. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist*. 1969;9:179–186.
13. Lord SE, McPherson K, McNaughton HK, Rochester L, Weatherall M. Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? *Arch Phys Med Rehabil*. 2004;85:234–239.
14. Duncan PW, Wallace D, Lai SM, Johnson D, Embretson S, Laster LJ. The Stroke Impact Scale version 2.0. Evaluation of reliability, validity, and sensitivity to change. *Stroke*. 1999;30:2131–2140.
15. Ware JF Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care*. 1992;30:473–483.
16. Yates JS, Studenski S, Gollub S, Whitman R, Perera S, Lai SM, Duncan PW. Bicycle ergometry in subacute-stroke survivors: feasibility, safety, and exercise performance. *J Aging Phys Act*. 2004;12:64–74.
17. Cohen J. *Statistical Power Analysis for the Behavioral Sciences.* 2nd ed. Hillsdale, NJ: Lawrence Earlbaum Associates; 1988.
18. Rubin DB. *Multiple Imputation for Nonresponse in Surveys.* New York, NY: Wiley; 1987.
19. Outpatient Service Trialists. Therapy-based rehabilitation services for stroke patients at home. *Cochrane Database Syst Rev*. 2003;1:CD002925.
20. Katz-Leurer M, Shochina M, Carmeli E, Friedlander Y. The influence of early aerobic training on the functional capacity in patients with cerebrovascular accident at the subacute stage. *Arch Phys Med Rehabil*. 2003;84:1609–1614.
21. Katz-Leurer M, Carmeli E, Shochina M. The effect of early aerobic training on independence six months post stroke. *Clin Rehabil*. 2003;17:735–741.
22. Ada L, Dean CM, Hall JM, Bampton J, Crompton S. A treadmill and overground walking program improves walking in persons residing in the community after stroke: a placebo-controlled, randomized trial. *Arch Phys Med Rehabil*. 2003;84:1486–1491.
23. Di Lauro A, Pellegrino L, Savastano G, Ferraro C, Fusco M, Balzarano F, Franco MM, Biancardi LG, Grasso A. A randomized trial on the efficacy of intensive rehabilitation in the acute phase of ischemic stroke. *J Neurol*. 2003;250:1206–1208.
24. Ouellette MM, LeBrasseur NK, Bean JF, Phillips E, Stein J, Frontera WR, Fielding RA. High-intensity resistance training improves muscle strength, self-reported function, and disability in long-term stroke survivors. *Stroke*. 2004;35:1404–1409.
25. Van der Bij AK, Laurant MG, Wensing M. Effectiveness of physical activity interventions for older adults: a review. *Am J Prev Med*. 2002;22:120–133.