Impact of a Stroke Recovery Program Integrating Modified Cardiac Rehabilitation on All-Cause Mortality, Cardiovascular Performance and Functional Performance

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Objective: Using a feasibility analysis and matched subgroup analysis, this study investigated the implementation/safety/outcomes of a stroke recovery program (SRP) integrating modified cardiac rehabilitation for stroke survivors.

Design: This prospective cohort study of 783 stroke survivors were discharged from an inpatient rehabilitation facility to an outpatient setting; 136 SRP-participants completed a feasibility study and received the SRP including modified cardiac rehabilitation, 473 chose standard of care rehabilitation (nonparticipants), and a group ($n = 174$) were excluded. The feasibility study assessed the following: safety/mortality/pre-post cardiovascular performance/pre-post function/patient/staff perspective. In addition to the feasibility study, a nonrandomized subgroup analysis compared SRP-participants ($n = 76$) to matched pairs of nonparticipants ($n = 66$, with 10 nonparticipants used more than once) for mortality/pre-post function.

Results: The feasibility study showed the SRP to have the following (*a*) excellent safety, (*b*) markedly low 1-yr poststroke mortality from hospital admission (1.47%) compared with national rate of 31%, (*c*) improved cardiovascular performance over 36 sessions (103% increase in metabolic equivalent of tasks times minutes), (*d*) improved function in Activity Measure of Post-Acute Care domains ($P < 0.001$), (*e*) positive reviews from SRP-participants/staff. Subgroup analysis showed the SRP to (*a*) positively impact mortality, nonparticipants had a 9.09 times higher hazard of mortality ($P = 0.039$), and (*b*) improve function in Activity Measure of Post-Acute Care domains ($P < 0.001$).

Conclusions: Stroke survivors receiving a SRP integrating modified cardiac rehabilitation may potentially benefit from reductions in all-cause mortality and improvements in cardiovascular performance and function.

Key Words: Cerebrovascular Disorders, Exercise, Mortality, Cardiac Rehabilitation

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Stroke survivors share many risk factors with patients with cardiovascular disease.[1,2] Cardiac rehabilitation (CR) led to a 45% reduction in 5-yr all-cause mortality rate in individuals with cardiovascular disease after percutaneous coronary intervention.[3] Although exercise after stroke improves overall function,[4–7] there is limited evidence demonstrating the impact of exercise on mortality after stroke.[8] There are several studies that investigate the CR model in patients with transient ischemic attack or minor stroke.[9–11] However, there is no study, to our knowledge, that investigates a modified CR program in patients with stroke that are medically complex and comply with inpatient rehabilitation facility (IRF) admission criteria.

The average unadjusted mortality rate from hospital admission to 1-yr poststroke is 31.1% nationally across *Get With The Guidelines-Stroke hospitals*.[12] Accordingly, the American Heart Association/American Stroke Association set a definitive *2020 Impact Goal*, to reduce deaths from stroke and other cardiovascular diseases by 20% by 2020.[1] Guiding this goal are benchmarks, also known as *Life's Simple 7*.[13] However, it is challenging to improve the *Life's Simple 7* benchmarks in a stroke population that has reduced activity levels.

The objectives of this study were to explore the benefits of an integrated modified CR protocol into an enhanced stroke recovery program (SRP) for stroke survivors in the following ways: (*a*) describe the implementation process of a modified CR protocol into an enhanced SRP, (*b*) assess feasibility, safety, and overall outcomes of SRP-participants including all-cause mortality, cardiovascular performance, and functional performance, and (*c*) compare a matched subgroup analysis between SRP-participants and nonparticipants on all-cause mortality and functional performance.

METHODS

General Design

The feasibility study assessed the following: safety/mortality/pre-post cardiovascular performance/pre-post function/patient/

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staff perspective (Fig. 1). A prospective feasibility study of the SRP-participants assessed the implementation of an enhanced SRP, which includes the following three components: physician visits, outpatient therapy, and modified CR. The SRP program evaluated the following outcome measures: safety, mortality, cardiovascular performance, functional performance, and patient/staff perspective.

In addition to the feasibility study, a nonrandomized subgroup analysis compared SRP-participants (n = 76) with matched pairs of nonparticipants (n = 66, with 10 nonparticipants used more than once) for mortality and pre-post function. The nonrandomized subgroup analysis included a cohort of the SRP-participants from the feasibility study in addition to a matched group of nonparticipants. Subjects were matched on gender/race/type of stroke and partially on age/baseline functional scores/medical complexity.

Study Population

Subjects

Beginning December 2015 to December 2017, this feasibility study included patients referred from acute care hospitals admitted to JFK Johnson Rehabilitation Institute after a stroke/cerebrovascular accident (e.g., ischemic, hemorrhagic, or subarachnoid hemorrhage) and consented to participation in a comprehensive SRP. The following outlines patient inclusion and exclusion criteria:

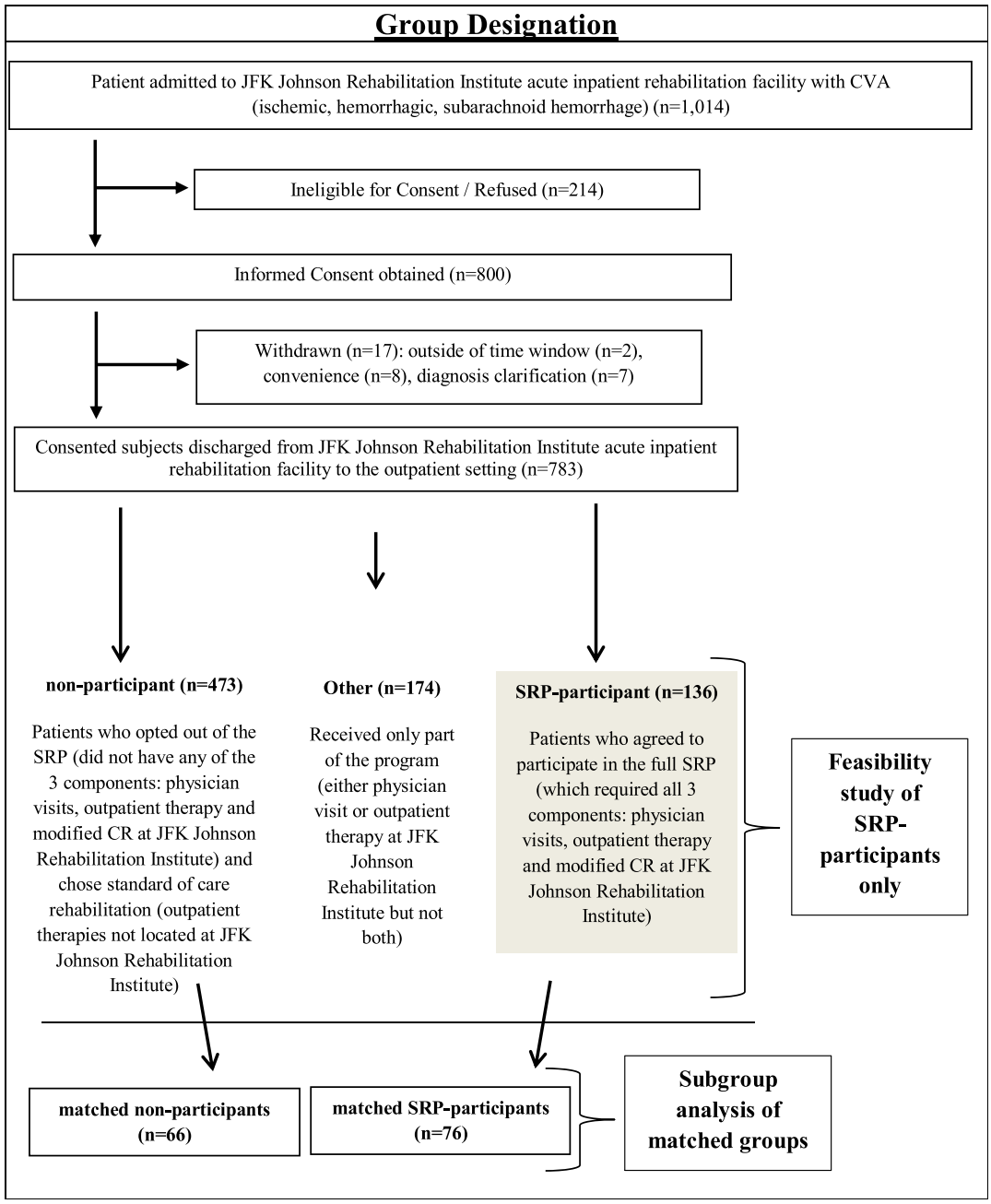


FIGURE 1. Stroke recovery program group designation.

Inclusion criteria are as follows: 18 yrs or older, be alert and able to follow simple commands, and provide consent either by the patient/their proxy.

Exclusion criteria are as follows: unable to follow simple commands and those with reduced alertness.

Ethical Approval

This study was approved by the institutional review boards of JFK Medical Center and Rutgers Robert Wood Johnson Medical School. Recruitment and data collection took place at the JFK Johnson Rehabilitation Institute in New Jersey. Study participation was voluntary and informed written consent was obtained by patient/their proxy.

Description of Groups

Group Designation

Of patients admitted to the JFK Johnson Rehabilitation Institute diagnosed with stroke (n = 1014), 214 were deemed ineligible or refused consent (Fig. 1). For the remaining 800 consented subjects, 17 were withdrawn from data collection/analysis for the following reasons: time window was clarified and did not meet cutoff criteria for days after neurologic event (n = 2), subjects declined participation in data collection for convenience's sake (n = 8), and diagnosis of cerebrovascular accident was erroneous (n = 7). A total of 783 consented subjects were discharged from the IRF to the outpatient setting at the JFK Johnson Rehabilitation Institute. Once discharged, they were divided and offered participation in subgroups based on treatment regimen (Fig. 1): SRP-participants, nonparticipants, and other groups.

SRP-Participants

All patients with a diagnosis of stroke, discharged from the acute IRF, were offered participation in the outpatient SRP. Patients who agreed to participate in the full SRP (which required all the following three components: physician visits, outpatient therapy, and modified CR at the JFK Johnson Rehabilitation Institute) were enrolled in the SRP-participant group (n = 136).

Nonparticipants

Patients who opted out of the SRP (did not have any of the three components: physician visits, outpatient therapy, and modified CR at the JFK Johnson Rehabilitation Institute) and chose standard of care rehabilitation (physical therapy, occupational therapy, and speech therapy when necessary) not located at the JFK Johnson Rehabilitation Institute were placed in the nonparticipant group (n = 473) and were used for matching comparison for subgroup analysis.

Other

A third group, other (n = 174), received only part of the program (either physician visit or outpatient therapy at the JFK Johnson Rehabilitation Institute but not both). These subjects were excluded from analysis to avoid variability.

General Description of Overall Program

Subject Recruitment

The JFK Johnson Rehabilitation Institute admitted patients with stroke from multiple acute care hospitals including three certified comprehensive stroke centers. During their stay, patients/caregivers were educated about the transition of care into the SRP integrating modified CR, and informed consent was obtained. Before discharge, the SRP coordinator worked with the patient and/or family to arrange an outpatient physician office visit and coordinated homecare services or outpatient therapy. All patients who were SRP-participants received cardiac clearance, while they were in the inpatient unit, before engaging in the outpatient modified CR.

Enhanced SRP Includes Three Components: Physician Visits, Outpatient Therapy, and Modified Cardiac Rehabilitation

Physician Visits

Physician visits were scheduled at time intervals after stroke: 30 ± 15, 60 ± 15, 90 ± 15, 120 ± 15 days, for all patients discharged from an IRF. At these appointments, risk factor education was provided according to *Life's Simple 7*[13] including the following: management of blood pressure (BP), cholesterol control, reduction of blood sugar, getting active, eating better, losing weight, and smoking cessation.

Standard of Care Outpatient Therapies

Traditional physical therapy, occupational therapy, and speech therapy services were prescribed according to standard of care.

Modified Cardiac Rehabilitation

The modified CR program consisted of group therapy of 4–5 patients with stroke, directed by a specially trained physical therapist and physical therapy assistant. A recumbent cross-training bicycle (manufactured by NuStep) provided a low-impact cardiovascular workout that could be used by subjects of any functional level. Custom straps and/or leg braces were used when clinically indicated for the hemiparetic arm and/or leg. The NuStep machine has an optional seat belt attachment and arm rests for additional support if needed. In addition, patients with poor sitting balance had more concentrated therapy supervision during the modified CR group sessions.

After obtaining cardiac clearance, patients were encouraged to participate in modified CR for 2–3 sessions per week for a total of 36 sessions. Sessions included a warm-up, interval cardiovascular training, and cooldown for a total of 30 mins with cardiopulmonary parameters monitored. The Borg-Rate of Perceived Exertion Scale (RPE range 0 = rest and 10 = maximal effort) was used, maintaining patients in a low to moderate level of exertion (1–6).[14] Patients started at 6 cycles of 4 mins of low-intensity exercise (RPE 1–3), followed by 1 min of rest for 30 mins. By the completion of 36 sessions, patients progressed to 3 cycles of 9 mins of moderate-intensity exercise (RPE 3–6), followed by 1 min of rest for 30 mins. Before starting the modified CR sessions, a physical therapist performed a baseline assessment of function including baseline cardiovascular function. This cardiovascular function was assessed in metabolic equivalent of tasks multiplied by minutes (MET-min), to determine their ability to perform low-intensity exercise (RPE 1–3) for 4 mins, while measuring heart rate, BP, and oxygen saturation. After therapy evaluation, patients were given a baseline MET level that they built upon as their modified CR sessions progressed. Sessions were discontinued for patients who exhibited unstable

vital signs or showed clinical signs of cardiac distress and were referred to their cardiologist.

Differences Between Traditional Cardiac Rehabilitation and Modified Cardiac Rehabilitation

Comparisons are outlined in Table 1.[15–17]

Outcome Measures

General Description/Study Design

The SRP-participants and nonparticipants completed at least 135 days of follow-up between December 2015 and December 2017. A prospective feasibility study of the SRP-participants assessed the implementation of an enhanced SRP, which includes the following three components: physician visits, outpatient therapy, and modified CR. The SRP program evaluated the following outcome measures: safety, mortality, cardiovascular performance, functional performance, and patient/staff perspective. A secondary prospective subgroup analysis was also performed where SRP-participants were matched with nonparticipants for comparison of mortality and function. Subjects were matched on gender/race/type of stroke and partially on age/baseline functional scores/medical complexity.

Feasibility Study Without Matching

Safety

Safety in the SRP was assessed by measuring referrals to cardiology for cardiac symptoms (such as uncontrolled BP, chest/arm pain/pressure, etc.), measuring the medical reasons for early termination of the program, and number of falls during participation of the modified CR (Fig. 1).

Mortality

Feasibility was assessed comparing SRP-participants with national normative data. Regarding mortality, SRP-participants had physician follow-up or phone calls for approximately 1 yr after stroke. Deaths attributed to this study were recorded for up to 365 ± 15 days after stroke.

Cardiovascular Performance

Progression of cardiovascular aerobic conditioning was measured in MET-min. Individual baseline cardiovascular function was assessed/measured in MET-min at initial evaluation and then progressed through every interval cardiovascular training session for a total of 36 sessions. There was no normative data to compare this group.

Functional Performance

The Activity Measure of Post-Acute Care (AM-PAC) instrument was designed to measure functional status in adults across multiple postacute care settings.[18] Functional scores were obtained via the AM-PAC for basic mobility, daily activity, and applied cognitive domains. The AM-PAC was collected at the following time intervals after stroke: admission to IRF, discharge from IRF, and 30 ± 15, 60 ± 15, 90 ± 15, and 120 ± 15 days. The subject's proxy was used in cases where the subject was unable to respond (e.g., severe aphasia or cognitive deficits with an Applied Cognitive AM-PAC score ≤42).[18] There are no normative data for patients recovering from stroke at these specific time intervals.

Patient/Staff Perspective

Testimonials were collected based on individual experiences during the program.

Subgroup Analysis With Matching

Matching Strategy

This is a nonrandomized study; therefore, patients were matched on gender/race/type of stroke and partially on age/baseline functional scores/medical complexity. To optimize the validity of matching, a computerized algorithm was used, which maximized the number of unique nonparticipants (n = 66) matched to SRP-participants (n = 76). This resulted in 76 pairs of patients, and each pair included both a nonparticipant and an SRP-participant. For 10 of these pairs, the nonparticipants was used twice. This solution was chosen to avoid eliminating 10 SRP-participants, which would have reduced the overall sample size for the subanalysis with matching. Only similar pairs were used for matching; therefore,

TABLE 1. Differences between traditional CR and modified CR

	Traditional CR[15–17]	Modified CR
Equipment	Varied types (e.g., treadmill, arm ergometer, bicycle)	NuStep recumbent cross-training bicycle
Cardiac clearance by a cardiologist	Yes	Yes
Group therapy *vs.* individual therapy	Individual	Group therapy of 4–5 patients per group
Intensity	Low (to moderate) to high	Low to moderate
Progression/time	Risk stratification to determine exercise progression	Risk stratification to determine exercise progression
Time	At least 31 mins	At least 30 mins
No. sessions	36	36
Monitoring	Physiologic/telemetry monitoring by CR registered nurses done at every session	Physiologic monitoring by physical therapists and physical therapy assistants done at every session
Items monitored	BP, heart rate, oxygen saturation, blood glucose, METs, exercise minutes, modified RPE scale, rate perceived dyspnea scale	BP, heart rate, oxygen saturation, blood glucose, METs, exercise minutes, modified RPE scale
Education/management	BP, lipids, diabetes	BP, lipids, diabetes
Education/counseling	Tobacco cessation, physical activity, weight loss, psychosocial, nutritional	Tobacco cessation, physical activity, weight loss, psychosocial, nutritional (referrals made to rehabilitation psychologist and nutritionist if needed)

both nonparticipant and SRP-participant groups were comparable at baseline (Fig. 1; Table 2).

Mortality

All-cause mortality rates were compared between the SRP-participant group and the nonparticipant group up to 365 ± 15 days after stroke.

Cardiovascular Performance

Medical records from all nonparticipants were reviewed up to 4 mos after stroke to verify they did not participate in any modified CR. Patients with a recent cardiac event who were eligible based on medical diagnosis were referred to traditional CR. Because the nonparticipants did not participate in modified CR, MET-min were not obtained for this group. MET-min were recorded for the SRP-participant group.

Functional Performance

Functional assessment of the nonparticipants and SRP-participants were obtained using the AM-PAC and was collected at the following time intervals after stroke: admission to IRF, discharge from IRF, and 30 ± 15, 60 ± 15, 90 ± 15, and 120 ± 15 days.

Statistical Methods

Feasibility and Outcomes of SRP-Participant Group

Mortality

Direct comparison of SRP-participants with 1-yr average unadjusted mortality rate from hospital admission to 1-yr poststroke across *Get With The Guidelines-Stroke hospitals* was completed.[12]

Cardiovascular Performance

Student's paired *t* test was used to compare MET-min at baseline and after 9, 18, 27, and 36 sessions for all SRP-participants. An additional analysis was performed to include data for all sessions at once using a mixed-effects linear model for all SRP-participants. Patients who attended between 1 and 36 outpatient-modified CR sessions within 4 mos after stroke were included in the analysis.

Functional Performance

Improvement in functional scores for SRP-participants was analyzed using Student's paired *t* test, comparing IRF admission with 120 ± 15 days after stroke.

Subgroup Analysis With Matching Comparing SRP-Participants With Matched Nonparticipants

Mortality

Differences in mortality between SRP-participant group and nonparticipant group were analyzed by fitting a Cox proportional hazards model adjusted for age. Kaplan-Meier curves were also generated.

Cardiovascular Performance

Because nonparticipants did not complete any portion of the modified CR, improvement in MET-min was observed only in SRP-participants from baseline to the end of participation.

Functional Performance

Functional outcomes (AM-PAC Basic Mobility, Daily Activity, and Applied Cognitive) for nonparticipants and SRP-participants were analyzed using Student's paired *t* test to compare difference in function between both groups at 120 ± 15 days after stroke.

This calculation for functional performance used 76 SRP-participants and 66 nonparticipants (with 10 SRP-participants used twice). Difference in functional outcome improvement from IRF discharge to 120 ± 15 days after stroke was also analyzed using Student's paired *t* test and mixed-effects linear models.

General

All statistical analyses used R3.5.0 software from the R Foundation for Statistical Computing.

RESULTS

Feasibility Study Without Matching

Demographics and Other Characteristics of SRP-Participant Group

Table 2 shows the demographics of the participants in the SRP group (SRPP column).

Safety

In this cohort, 26 of 136 SRP-participants ended the modified CR early because of medical complications. There were four referrals to cardiologists because of clinical findings during the cardiovascular training (e.g., uncontrolled BP, chest/arm pain/pressure, etc.). These individuals were treated and transitioned to traditional CR. Additional reasons for stopping the program early included the following: orthopedic/arthritis ($n = 3$), persistent abnormal BP ($n = 4$), fatigue/cognitive deficits ($n = 4$), falls outside of the program ($n = 3$), repeat stroke ($n = 1$), seizure ($n = 3$), and other general medical issues ($n = 4$). During the modified CR, there were no recorded falls, injury from equipment, or overuse injuries reported.

Mortality

One-year poststroke follow-up phone calls revealed that there were two deaths in the SRP-participant group, yielding a 1.47% 1-yr unadjusted mortality rate. This is significantly lower than the average unadjusted mortality rate from hospital admission to 1-yr poststroke (31.1%) across *Get With The Guidelines-Stroke hospitals*.[12]

Cardiovascular Performance

On average, the SRP-participant group completed 28.09 of 36 sessions of modified CR.

Figure 2 shows the overall average progression of MET-min and Figure 2 shows the average percent improvement from baseline of MET-min over 36 sessions. These figures also include the 95% confidence intervals (CIs) and *P* values yielded from using Student's paired *t* test to compare MET-min at baseline and after 9, 18, 27, and 36 sessions. After 36 sessions, there was an average difference in MET-min from baseline of 46–95 (mean difference [MD] = 47.29, standard error [SE] = 3.40, 95% CI = 40.53 to 54.05, $P < 0.001$). There was an overall average progression of 103% MET-min over the 36 sessions (mean percent difference = 103.31, SE = 6.77, 95% CI = 89.86 to 116.76, $P < 0.001$).

A mixed-effects linear model estimated that a patient could expect a statistically significant improvement of 1.28 MET-min

TABLE 2. Descriptive characteristics of the entire cohort and matched-pair group stratified by participation in the SRP

	Entire Cohort			Matched Group		
Variables	**NP (*n* = 473)**	**SRPP (*n* = 136)**	***P***	**NP (*n* = 66)**	**SRPP (*n* = 76)**	***P***
Age	71.3 ± 14.6	65.9 ± 15	<0.001	69.6 ± 12.4	70.4 ± 11.6	NS
Gender			NS			NS
Male	245 (52)	75 (55)		33 (50)	40 (53)	
Hispanic ethnicity	48 (10)	19 (14)	NS	7 (11)	5 (7)	NS
Race			NS			NS
White	266 (56)	73 (54)		39 (59)	47 (62)	
Black	115 (24)	29 (21)		16 (24)	17 (22)	
Other	92 (19)	34 (25)		11 (17)	12 (16)	
Insurance			<0.001			NS
Medicaid	11 (2)	7 (5)		3 (5)	1 (1)	
Medicare	306 (65)	63 (46)		37 (56)	40 (53)	
Private/other	156 (33)	66 (49)		26 (39)	35 (46)	
Education level	13.1 ± 2.8	13.6 ± 2.9	NS	12.9 ± 2.1	13.6 ± 2.9	NS
Type of stroke			NS			NS
Hemorrhagic	67 (14)	21 (15)		4 (6)	4 (5)	
Ischemic	392 (83)	110 (81)		61 (92)	71 (93)	
Subarachnoid hemorrhage	14 (3)	5 (4)		1 (2)	1 (1)	
Left hemiparesis	208 (44)	51 (38)	NS	30 (45)	32 (42)	NS
Right hemiparesis	158 (33)	52 (38)	NS	24 (36)	31 (41)	NS
Bilateral hemiparesis	24 (5)	1 (1)	0.045	0 (0)	0 (0)	NA
Balance deficits	427 (90)	120 (88)	NS	62 (94)	67 (88)	NS
Communication/cognitive deficits	364 (77)	94 (69)	NS	48 (73)	55 (72)	NS
Dysphagia	207 (44)	36 (26)	<0.001	21 (32)	27 (36)	NS
Spasticity	15 (3)	0 (0)	NS	3 (5)	0 (0)	NS
ACH LOS	9.1 ± 7.9	6.3 ± 5.5	<0.001	8.7 ± 7.7	5.4 ± 4	0.002
ACH NIHSS	8.8 ± 7.7	6.1 ± 6.5	0.001	7 ± 7.8	6.9 ± 7.7	NS
ACH Interventions (tPA/MER)	91 (19)	30 (22)	NS	14 (21)	20 (26)	NS
ARH LOS	17.3 ± 7.8	13.2 ± 6.2	<0.001	15 ± 9.7	14 ± 5.4	NS
Medical complexity	106.8 ± 2.5	104.7 ± 2	<0.001	105.4 ± 2	105 ± 2	NS
AM-PAC Admission Basic Mobility	31.1 ± 9.9	37.6 ± 5.3	<0.001	37.2 ± 5.6	36.8 ± 5.2	NS
AM-PAC Admission Daily Activity	30.9 ± 10.1	36.6 ± 7.1	<0.001	35.4 ± 7.6	36.2 ± 6.6	NS
AM-PAC Admission Applied Cognitive	24.4 ± 20.4	35.3 ± 14.7	<0.001	33.6 ± 15.2	33.6 ± 13.7	NS
AM-PAC Discharge Basic Mobility	38.4 ± 11.7	49.9 ± 12.4	<0.001	43.9 ± 10.3	45.8 ± 9.4	NS
AM-PAC Discharge Daily Activity	37.1 ± 11.7	46.1 ± 11	<0.001	41.8 ± 9.9	43.5 ± 9.9	NS
AM-PAC Discharge Applied Cognitive	29.5 ± 18.2	39.4 ± 14.9	<0.001	36.8 ± 11.7	37.9 ± 12.3	NS
Deceased	60 (13)	2 (1)	<0.001	10 (15)	1 (1)	0.006
Atrial fibrillation	125 (26)	25 (18)	NS	14 (21)	15 (20)	NS
Coronary artery disease/myocardial infarction	138 (29)	26 (19)	0.026	13 (20)	19 (25)	NS
Carotid stenosis	56 (12)	11 (8)	NS	7 (11)	9 (12)	NS
Depression	48 (10)	16 (12)	NS	5 (8)	11 (14)	NS
Diabetes mellitus	218 (46)	42 (31)	0.002	29 (44)	22 (29)	NS
Substance abuse (drugs/alcohol)	26 (5)	10 (7)	NS	2 (3)	7 (9)	NS
Dyslipidemia	252 (53)	57 (42)	0.025	35 (53)	33 (43)	NS
Family history of stroke	45 (10)	16 (12)	NS	6 (9)	9 (12)	NS
Heart failure	56 (12)	11 (8)	NS	7 (11)	6 (8)	NS
Hypertension	410 (87)	109 (80)	NS	59 (89)	66 (87)	NS
Migraine	6 (1)	4 (3)	NS	0 (0)	1 (1)	NS
Obesity	72 (15)	16 (12)	NS	11 (17)	9 (12)	NS
Previous stroke	121 (26)	21 (15)	0.019	21 (32)	16 (21)	NS
Previous transient ischemic attack	32 (7)	6 (4)	NS	5 (8)	5 (7)	NS
Peripheral vascular disease	16 (3)	6 (4)	NS	3 (5)	5 (7)	NS
Renal insufficiency	63 (13)	11 (8)	NS	9 (14)	6 (8)	NS
Sleep apnea	22 (5)	12 (9)	NS	3 (5)	8 (11)	NS

(Continued on next page)

TABLE 2. *(Continued)*

Variables	Entire Cohort			Matched Group		
	NP (n = 473)	SRPP (n = 136)	P	NP (n = 66)	SRPP (n = 76)	P
Smoker	114 (24)	45 (33)	0.046	12 (18)	34 (45)	0.001
Body mass index	27.8 ± 6.1	29.1 ± 6.5	0.042	27.4 ± 5.6	28.1 ± 6.6	NS
Systolic BP	141.6 ± 21.9	144.4 ± 21.2	NS	144.1 ± 21.7	146.6 ± 21.5	NS
Diastolic BP	75 ± 11.4	75.9 ± 10.7	NS	77.9 ± 11.7	74.9 ± 10	NS
Low density lipoprotein	89.5 ± 36.3	93.1 ± 39.8	NS	89.6 ± 33.8	89.5 ± 39.2	NS
Hemoglobin A1c	6.6 ± 1.9	6.5 ± 2	NS	6.9 ± 2.5	6.2 ± 1.7	NS

Bold variables were used for matching. Values are n (%) for categorical variables and mean ± SD when appropriate.

ACH, acute care hospital; ARH, acute rehabilitation hospital; LOS, length of stay (days); MER, mechanical endovascular reperfusion; NA, significance test not applicable; NP, nonparticipant; NS, not significant at the $\alpha = 0.05$ significance level; SRPP, stroke recovery program-participant; tPA, tissue plasminogen activator.

from baseline for every additional session they completed (estimate = 1.28, SE = 0.07, 95% CI = 1.14 to 1.42, $P < 0.001$). This model further demonstrated that a patient could expect a statistically significant improvement of 8.74 MET-min for every unit increase in the average number of sessions per week they completed (estimate = 8.74, SE = 2.81, 95% CI = 3.18 to 14.30, $P = 0.002$).

Functional Performance

Functional scores in SRP-participants were obtained using the AM-PAC measured at each time point including the following: IRF admission, IRF discharge, 30 ± 15, 60 ± 15, 90 ± 15, and 120 ± 15 days after stroke (Fig. 3).

For the Basic Mobility score, the average admission score for SRP-participants was 38, suggesting limited indoor mobility requiring assistance. By day 120, the average score for SRP-participants was 64, indicating independent indoor mobility and emerging comfort with community-level mobility. This showed an average improvement of the SRP-participant Basic Mobility score of 26 points (MD = 26.41, SE = 0.94, 95% CI = 24.54 to 28.28, $P < 0.001$), which is much greater than the minimally detectable change of 4, representing the amount of change needed to exceed measurement variation.[19]

For the Daily Activity score, the average admission score for SRP-participants was 37, indicating that daily tasks will require assistance for completion. By day 120, the average score for SRP-participants was 63, suggesting an easier ability to perform self-care tasks, although housekeeping and laundry may still require assistance. This showed an average improvement of the SRP-participant Daily Activity score of 26 points (MD = 26.40, SE = 1.60, 95% CI = 23.24 to 29.56, $P < 0.001$), which is much greater than the minimally detectable change of 4.[19]

For the Applied Cognitive score, the average admission score for SRP-participants was 35, suggesting difficulty with cognitive processing and communication. By day 120, the average score for SRP-participants was 51, indicating the ability to complete complex tasks and communication without difficulty. This showed an average improvement of the SRP-participant

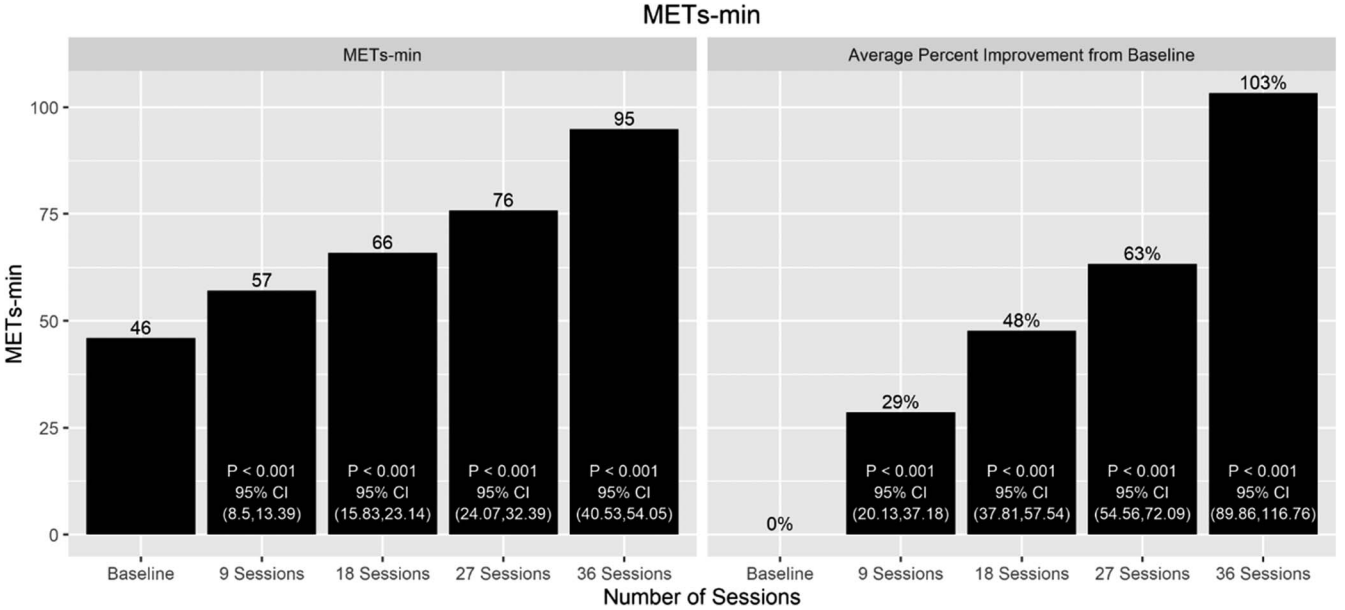
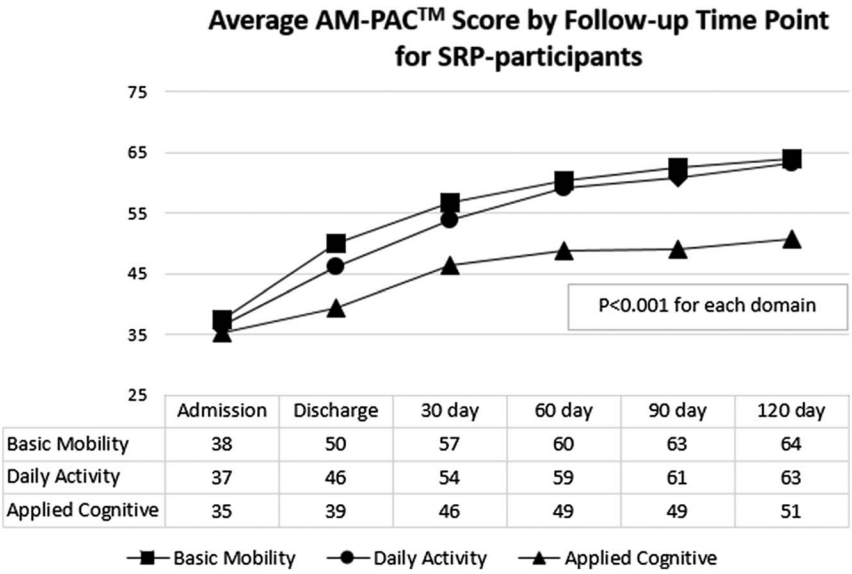


FIGURE 2. A and B, MET-min progression over number of sessions for SRP-participants.



	Admission	Discharge	30 day	60 day	90 day	120 day
Basic Mobility	38	50	57	60	63	64
Daily Activity	37	46	54	59	61	63
Applied Cognitive	35	39	46	49	49	51

FIGURE 3. Average AM-PAC score by follow-up time point for SRP-participants.

Applied Cognitive score of 16 points (MD = 15.90, SE = 1.32, 95% CI = 13.28 to 18.53, $P < 0.001$), which is much greater than the minimally detectable change of 7.[19]

Patient/Staff Perspective

Table 3 summarizes comments.

Subgroup Analysis Comparing SRP-Participants With Matched Nonparticipants

The 142 patients in the matched cohort consisted of nonparticipants ($n = 66$) and SRP-participants ($n = 76$). After matching between nonparticipants and SRP-participants, no clinical difference was noted in demographic, clinical, and/or functional characteristics with the exception of acute care hospital length of stay and smoking status (Table 2).

Mortality

During a median follow-up of 85 days (1 day to approximately 1 yr), there were 2 deaths (1%) in the SRP-participant group (of 136 SRP-participants), compared with 60 deaths (13%) in the nonparticipant group (of 473 nonparticipants). After matching, 1 death (1.3%) was reported in the SRP-participant group (of 76 SRP-participants) compared with 10 deaths (15.2%) in the nonparticipant group (of 66 nonparticipants). This shows a difference in mortality of 13.9%. Kaplan-Meier curves for each of the groups in the matched cohort are shown in Figure 4. After fitting a Cox proportional hazards model, a

TABLE 3. Patient/staff perspective of the SRP

Individual	Comment
Patient #1	"I was very depressed. I was sitting home and started worrying about my family and kids. I wasn't able to talk, walk or move my arms or legs. I would recommend the SRP to everybody. The SRP helped me get back to normal."
Patient #2	"There is life after stroke. I feel that I have a second chance. With the help of the doctors and therapists in the SRP, I've learned a lot about what I need to do to stay healthy."
Patient #3	"I would recommend the SRP to anybody who had a stroke. If I had stayed home, I never would have gotten this far in my recovery."
Patient #4	"I really think the SRP is an important program but I am on a fixed income. The biggest problem that I had was paying the copayments for my therapy sessions, but I'm glad I did it."
Patient #5	"It took commitment for me to complete all 36 cardiac rehab sessions, but it was worth it."
Staff #1 (physical therapist)	"Patients are really motivated to participate in the cardiovascular conditioning program, not only for endurance, but also for socialization. It gives them positive energy towards their recovery. As a therapist, I have seen that the addition of the modified CR program has enhanced patient performance allowing for more functional gains."
Staff #2 (speech therapist)	"The program has fostered a multidisciplinary approach. This has impacted the quality of life and outcomes of patients after a stroke in a positive direction."
Staff #3 (research staff)	"Although we had interest from many of our patients to participate in the SRP, there were patients who expressed concerns as to why they did not want to participate (e.g., transportation issues, financial limitations for therapy copayments, relocation, scheduling conflicts, lack of interest in the program, lack of family support, decreased motivation and inability to commit to the therapy schedule)."

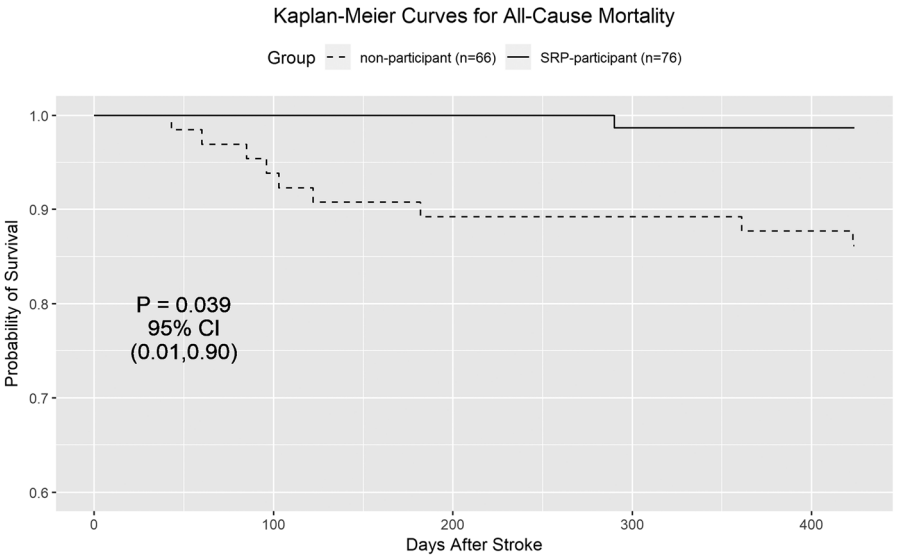


FIGURE 4. Survival curves for all-cause mortality in SRP-participants and nonparticipants.

hazard ratio of 0.11 (SE = 1.07, 95% CI = 0.01 to 0.90, $P = 0.039$) was obtained for the effect of participant group, adjusted for the effect of age (Fig. 4). The results of this model suggest that nonparticipants have a 9.09 times higher hazard of mortality. The corresponding CI and P value of 0.039 suggest that this result is statistically significant.

Cardiovascular Performance

Only SRP-participants enrolled in modified CR, and thus, there is no matched group to compare with this group.

Functional Performance

Comparing functional improvement at day 120 ± 15 days between SRP-participants and nonparticipants using Student's paired t test. Figure 5 compares functional scores using the AM-PAC between nonparticipants and SRP-participants from IRF admission to 120 ± 15 days after stroke.

For the Basic Mobility score, the average admission score for nonparticipants was 37, compared with the average admission score for SRP-participants of 37, which is not clinically significant. By day 120, the average score for nonparticipants was 55, compared with the average score for SRP-participants of 62, with a difference of 7 points (MD = 8.04, SE = 1.73, 95% CI = 4.55 to 11.52, $P < 0.001$), showing clinical significance.[19]

For the Daily Activity score, the average admission score for nonparticipants was 35, compared with the average admission score for SRP-participants of 36, which is not clinically significant. By day 120, the average score for nonparticipants was 52, compared with the average score for SRP-participants of 59, with a difference of 7 points (MD = 8.14, SE = 2.61, 95% CI = 2.86 to 13.42, $P < 0.001$), which has clinical significance.[19]

For the Applied Cognitive score, the average admission score for nonparticipants was 34 compared with the average admission score for SRP-participants of 34, which is not clinically significant. By day 120, the average score for nonparticipants was 44, compared with the average score for SRP-participants of 49, with a difference of 5 points (MD = 4.58, SE = 2.32, 95% CI = −0.11 to 9.27, $P = 0.056$), showing partial clinical significance.[19]

Comparing functional improvement from IRF discharge to day 120 ± 15 days between SRP-participants to nonparticipants using mixed-effects linear model (Figs. 5A–C). The CIs and P values correspond to the results yielded after using a mixed-effect linear model. The estimates for participant group effect adjusted for the effect of age for Basic Mobility (estimate = 8.46, SE = 1.18, 95% CI = 6.12 to 10.80, $P < 0.001$), Daily Activity (estimate = 7.67, SE = 1.61, 95% CI = 4.47 to 10.88, $P < 0.001$), and Applied Cognitive scores (estimate = 6.69, SE = 1.53, 95% CI = 3.65 to 9.74, $P < 0.001$) were all positive and statistically significant. The results of this model suggest that a patient in the SRP-participant group can expect to have greater improvement over time than a patient in the nonparticipant group in all AM-PAC score domains.

DISCUSSION

Using a feasibility analysis and matched subgroup analysis, this study investigated the implementation, safety, and outcomes of a SRP integrating modified CR for stroke survivors. The results of this feasibility analysis demonstrate that implementation of an enhanced SRP was safe and beneficial for improvements in cardiac and functional performance and showed a markedly low mortality. The patient/staff perspective overall was vastly positive. Matched subgroup comparison showed that implementation of a specialized outpatient SRP with modified CR led to a statistically significant reduction of all-cause mortality, as well as improvement of cardiovascular capacity and overall function.

This study is unique because it uses a modified CR protocol and physiatrist monitoring as part of an enhanced SRP. The SRP uses an innovative approach to help patients with stroke achieve the American Heart Association/American Stroke Association's *Life's Simple 7*.[13] To our knowledge, there are no similar comparison studies. Just as traditional CR has been implemented at a national level for patients with cardiac disease that comply with appropriate diagnostic criteria, the SRP

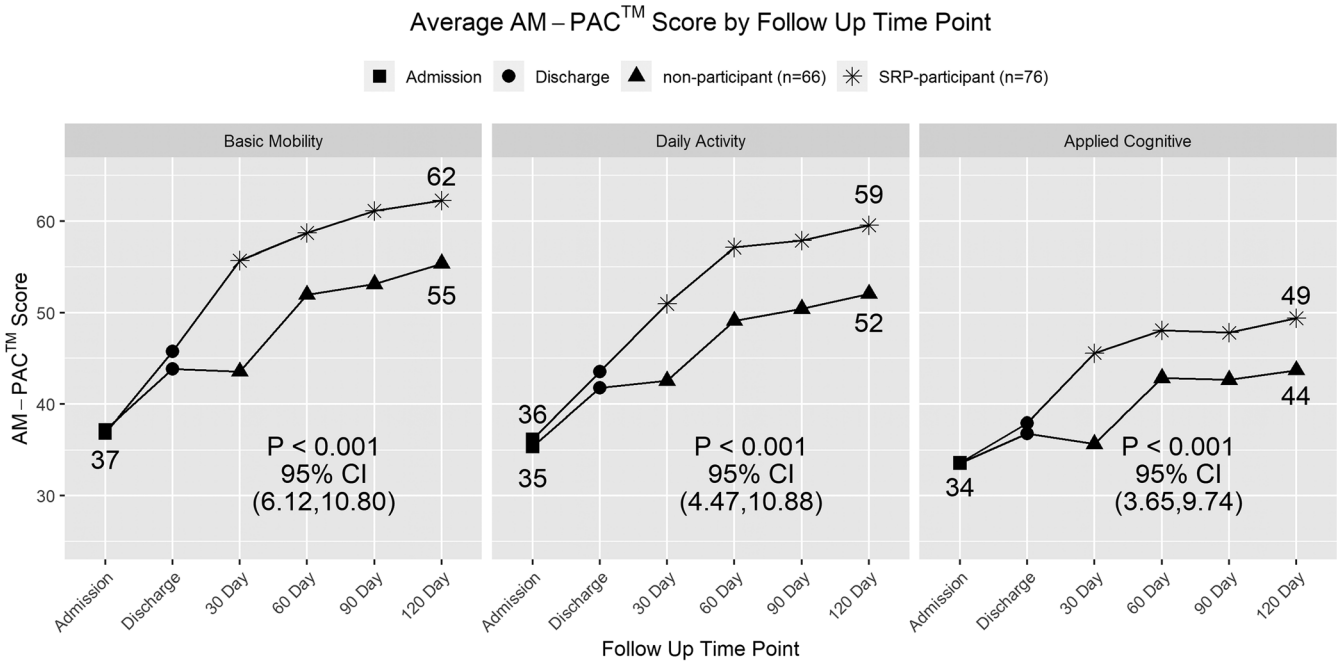


FIGURE 5. A, B, and C, Comparison of AM-PAC scores for SRP-participants to nonparticipants up to 120 days.

with modified CR shows promise to be implemented nationally in outpatient settings for patients recovering from stroke.

Because of the comprehensive nature of the SRP, it is challenging to isolate which elements of SRP are responsible for these outcomes including the following: increased care time, increased physical activity, improved exercise capacity, improved medication adherence, increased motivation, and overall surveillance poststroke. Potential benefits of regular exercise in patients with stroke include improved functional capacity and reduced risk of additional cardiovascular events.[20] Benefits of regular exercise in the general population include the following: increased exercise tolerance, decreased BP, and increased insulin sensitivity.[21] Psychosocial benefits also include improved health-related quality of life.[6]

This data set focuses on patients discharged from an acute IRF who start an outpatient rehabilitation program within 30 ± 15 days after stroke. As such, it does not include patients discharged from an acute care hospital directly to home, a skilled nursing facility, or a long-term care facility. The referral of patients to an IRF was included in recent guidelines for stroke rehabilitation.[22]

With respect to formal recommendations from the American Heart Association/American Stroke Association, it is well documented that physical activity and exercise prescription should be incorporated into the management of stroke survivors, with a focus on low- to moderate-intensity aerobic activity, muscle-strengthening activity, reduction of sedentary behavior, and risk management for secondary prevention of stroke.[20] The SRP accomplishes these tasks with direct medical supervision combined with formal therapy and interval cardiovascular training.

Although other programs include general exercise as a component of stroke rehabilitation, this feasibility study is the first to use a medically supervised, interval cardiovascular training program within an enhanced SRP that is safe and efficacious. The SRP has been proven to be safe because of surveillance by a physiatrist, medication monitoring, cardiovascular clearance, and support by cardiologists and neurologists. The modified CR was well tolerated. Cardiologists were engaged when cardiac symptomatology presented. The importance of a safe program is paramount, because of the comorbid medical conditions that many patients recovering from stroke have. Traditional CR has been proven to be safe in various studies.[23–25]

The feasibility analysis without matching showed progression of total MET-min and percent increase of MET-min, which suggests improvement in exercise capacity through the SRP. Improvement in exercise capacity was detected as few as 9 sessions and continued throughout the 36 sessions. The results indicate that the improvement was statistically significant for every number of sessions. This trend is apparent in traditional CR literature,[26,27] but there is limited evidence documenting this phenomenon in patients with stroke.[4–7] Improvements in exercise capacity may have had the secondary benefit of augmenting improvements in mortality and function. All-cause mortality rate (1.47%) for the SRP-participants was significantly lower than the average unadjusted mortality rate from hospital admission to 1-yr poststroke (31.1%) across *Get With The Guidelines*-Stroke hospitals.[12] The AM-PAC has been validated in postacute care patients with major neurological, orthopedic, and major medical conditions.[18] A functional evaluation was completed using AM-PAC scores showing a statistically significant improvement in functional scores in all three AM-PAC domains ($P < 0.001$).

Subgroup analysis showed a statistically significant difference in mortality between nonparticipants and SRP-participants. The SRP-participants showed nine times reduced risk of death compared with the nonparticipants. In comparison with the traditional CR literature, a reduction in mortality was also seen by various studies.[3,26] After matching, 1 death (1.3%) was reported in the SRP-participant group compared with 10 deaths (15.2%) in the nonparticipant group.

A more detailed evaluation of function was completed using the AM-PAC scores across all three domains. The AM-PAC has been found to be reliable and valid in patients with stroke.[18] The SRP-participants showed a clinical and statistically significant improvement in functional scores in all three AM-PAC domains ($P < 0.001$).[19] As expected, nonparticipants and SRP-participants showed similar IRF admission and discharge AM-PAC score changes. The SRP intervention diverges after acute IRF discharge, with the 30-day time point as the first time point showing a difference between the groups.

Because of the comprehensive nature of the SRP, when executing a subgroup analysis comparing SRP-participants with matched nonparticipants, it is acknowledged that there was additional care time afforded to the SRP-participants that the nonparticipants did not receive with the standard of care. Because a limitation of nonparticipant self-reporting of care time was inconsistent and problematic to record, it is not possible to exclude the possibility that the better outcomes in the SRP-participants may be in part due to additional care time.

Another limitation of this nonrandomized study is its observational nature. Patients were matched as described previously. However, the experimental design did not allow randomization of the treatment and this may be a source of selection bias. Additional data collection will increase the statistical power in future analyses of this ongoing study. However, this study has significant strengths, including the longitudinal follow-up, the completeness of data collection, the multidisciplinary comprehensive nature of the program, and determination of improvements after implementation of the program.

The data demonstrate that a comprehensive SRP integrating modified CR provides clinically and significant reduction in mortality, in addition to a functional improvement across three separate outcome tests designed to measure function throughout the postacute care continuum. For the subgroup analysis, the sample size of SRP-participants ($n = 76$) and nonparticipants ($n = 66$) after matching was used for this initial ongoing study. This study provides additional support for structured exercise training poststroke as a standard of postacute care. This study also provides a foundation for supporting clinical practice guidelines for many stroke survivors who currently have limited resources for postacute stroke care and rehabilitation.

CONCLUSIONS

The study showed that the SRP integrating modified CR was safe, well received, and showed an increase in cardiovascular and functional performance as well as a decrease in all-cause mortality. Similar to the documented benefits of traditional CR, stroke survivors benefit from coordinated access to physical medicine and rehabilitation physicians, cardiologists, and neurologists throughout the postacute care continuum. Continued research in this area is necessary to support healthcare policy change to benefit stroke survivors.

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