

Integrating Aerobic Training Within Subacute Stroke Rehabilitation: A Feasibility Study

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Background. Aerobic activity positively affects patients recovering from stroke and is part of best practice guidelines, yet this evidence has not been translated to routine practice.

Objective. The objective of this study was to evaluate the feasibility of a model of care that integrated aerobic training in an inpatient rehabilitation setting for patients in the subacute stage of stroke recovery. Key elements of the program were personalized training prescription based on submaximal test results and supervision within a group setting.

Design. This was a prospective cohort study.

Methods. Participants (N=78) completed submaximal exercise testing prior to enrollment, and the test results were used by their treating physical therapists for exercise prescription. Feasibility was evaluated using enrollment, class attendance, adherence to prescription, and participant perceptions.

Results. Overall, 31 patients (40%) were referred to and completed the exercise program. Cardiac comorbidities were the main reason for nonreferral to the fitness group. Program attendance was 77%; scheduling conflicts were the primary barrier to participation. The majority of participants (63%) achieved 20 minutes of continuous exercise by the end of the program. No adverse events were reported, all participants felt they benefited from the program, and 80% of the participants expressed interest in continuing to exercise regularly after discharge.

Limitations. Cardiac comorbidities prevented enrollment in the program for 27% of the admitted patients, and strategies for inclusion in exercise programs in this population should be explored.

Conclusions. This individualized exercise program within a group delivery model was feasible; however, ensuring adequate aerobic targets were met was a challenge, and future work should focus on how best to include individuals with cardiac comorbidities.



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[Biasin L, Sage MD, Brunton K, et al. Integrating aerobic training within subacute stroke rehabilitation: a feasibility study. *Phys Ther*. 2014;94:1796–1806.]

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Published Ahead of Print: July 31, 2014

Accepted: July 17, 2014

Submitted: September 16, 2013

The majority of individuals recovering from a stroke are left with residual disability or activity limitations, which lead to a lower quality of life.^{1,2} Many of these limitations are associated with reduced aerobic capacity, which is common among people living with the effects of stroke.^{3–5} Additionally, for people recovering from a stroke, there is a high energy cost of performing everyday activities.^{6,7} The combination of elevated energy demands and low aerobic capacity leads to people with stroke working close to their physiological limits in order to accomplish basic activities of daily living.^{8,9} These challenges, in turn, can reduce participation in physical activity, which can further reduce aerobic capacity, leading to a cycle of reduced physical capacities and limited participation.

There is convincing evidence of the benefits of aerobic training to improve patients' recovery post-stroke, including improved cardiovascular function,^{8,10–12} reduced neurological impairment,^{13,14} and enhanced lower extremity function.^{10,15–18} In addition, animal models display the potential for aerobic exercise to augment neuroplastic events such as neurogenesis and synaptogenesis by promoting activity of neural growth factors.^{19,20} Aerobic exercise programs for individuals at all stages of stroke recovery have been shown to be effective at improving stroke-related outcomes, although the majority of work has been focused on patients with chronic (>6 months) stroke^{15,16,21,22} as opposed to those with subacute (<3 months) stroke.^{10,12,18} However, participation in aerobic exercise may be critical at the subacute stage; spontaneous recovery is greatest at this stage of recovery,²³ and aerobic exercise has potential to augment all aspects of rehabilitation.

Although there have been a substantial number of studies accumulating convincing evidence of the many benefits of aerobic exercise on patients' recovery after stroke, little attention has been paid to the feasibility of adapting and applying this evidence for individuals in a subacute stroke clinical setting. As such, there is a lack of translation of evidence to routine clinical practice. Traditional inpatient stroke rehabilitation programs tend to focus on improving sensorimotor control and specific functional outcomes.⁶ Typically, however, the cardiorespiratory system is not adequately challenged.^{24–26} We proposed a model of care that focused on individual exercise prescription informed by a structured graded submaximal exercise test with training and supervision/monitoring in a group delivery setting.

The main objective of this study was to determine the feasibility of the proposed model of aerobic training for individuals in the subacute stage of stroke recovery enrolled in an inpatient rehabilitation program. Feasibility was defined in terms of patient enrollment and whether aerobic targets were met. Additionally, patients' perceptions of benefits and feasibility of the exercise program, as well as barriers and facilitators, were evaluated. We hypothesized that the proposed model of care would be feasible at recruiting eligible participants and ensuring appropriate individualized aerobic targets (prescribed by clinicians based on results from exercise testing) are achieved during exercise sessions. Specifically, we hypothesized that at least 60% of all admitted patients would participate in the program, that they would attend 3 times per week for at least 20 minutes, and that they would exercise at appropriate intensities (50%–80% of age-predicted maximum heart rate [HR]).²⁷ Additionally, we hypothe-



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- [eAppendix 1](#): Submaximal Aerobic Capacity Assessment
- [eAppendix 2](#): Aerobic Training in Everyday Practice

sized that patients would perceive the program as a beneficial component of their poststroke recovery.

Method

Participants

Participants were recruited from consecutive admissions to the Toronto Rehabilitation Institute inpatient stroke rehabilitation service over a 6-month period. The primary treating physical therapists referred their patients who met the inclusion and exclusion criteria for the exercise program. In order to participate, patients had to be able to understand and follow simple instructions (eg, maintaining cadence), report any pain or discomfort (supportive or adapted strategies were utilized for patients with aphasia) and be able to utilize a semi-recumbent stepper (NuStep Inc, Ann Arbor, Michigan) with their legs only. Patients were excluded from the exercise program if they had: uncontrolled hypertension, uncontrolled diabetes, other cardiovascular morbidity that would limit exercise tolerance (eg, heart failure, abnormal blood pressure responses, ST-segment depression >2 mm, symptomatic aortic stenosis, complex arrhythmias), unstable angina, orthostatic blood pressure decrease of >20 mm Hg with symptoms, or musculoskeletal impairments or pain that would limit their ability to exercise.²⁸ Upon referral, patients performed a submaximal exercise test to further screen for contraindications to exercise and determine exercise prescription.

Procedure

Research ethics approval was received to collect a minimal data set (demographics, whether the patient was enrolled in the fitness group, and reason for nonenrollment in the fitness group, if applicable) from all individuals admitted over the 6-month period by chart review without informed consent; written

informed consent was obtained for additional data collection over the course of the study.

Submaximal exercise test. Exercise prescription and intensity of training were determined by a graded submaximal exercise test, which used a recumbent stepper and was administered by the primary treating physical therapist. After a 2-minute warm-up at level 0, patients performed 3-minute stages of exercise at a self-selected, comfortable cadence (mean=75.8 steps per minute, which was maintained during the test) using a semirecumbent stepper with legs only to minimize artifact with electrocardiography (ECG) tracings. Resistance was increased at every stage until the patient reached 60% (if taking beta-blockers or diabetic with comorbidities) or 70% of age-predicted maximum HR (defined as $208 - [0.7 \times \text{age}]$),²⁹ reported a rating of perceived exertion (RPE) of “strong” (5 out of 10), or was unable to maintain stepping cadence (decrease of 10 steps per minute). Pilot work indicated that many patients had difficulty maintaining cadence under the machine’s constant power setting. Patients with decreased attention or decreased motor control could become distracted. This slowing in cadence led to a significant increase in resistance (under constant power), which some participants could not overcome. Therefore, a stepwise progression using the manual resistance levels was utilized, with verbal reminders to maintain cadence. The stepwise progression (by either 1 or 2 levels of resistance per stage) was determined by the primary treating physical therapist’s perception of each patient’s response to exercise. The patient also was free to stop the test at any time. Heart rate, RPE, stepping rate, and workload were recorded at the end of every minute. Additional details regarding the submaximal

exercise testing procedure are provided in [eAppendix 1](#) (available at ptjournal.apta.org). The test also included 5-lead ECG monitoring. The ECG strips were printed at 1-minute intervals and scanned for abnormalities.

Exercise program. The supervised exercise program was delivered in a group setting that was available to patients 3 times a week. Five recumbent steppers (2 T5^{XR} devices and 1 T4 device [NuStep Inc] and 2 RST7000 devices [SciFit Inc, Tulsa, Oklahoma]) were available, 2 of which had optional leg stabilizer attachments. Recumbent steppers have been found to be effective for cardiovascular training among individuals with stroke.^{30,31} Eligible patients were enrolled in the exercise program as soon as possible after referral and completion of the submaximal exercise test.

The primary treating physical therapist was responsible for the patient’s overall physical rehabilitation. The primary treating physical therapist also conducted the submaximal aerobic exercise test and prescribed the initial exercise and progression guidelines for each patient. Exercise prescription indicated the initial training duration, workload, and progression (time and workload) parameters. A supervising physical therapist led the exercise group with support from trained assistants with a health-related background. The supervising physical therapist oversaw the day-to-day running of the group exercise program and, along with the assistants, monitored patient status and progress. The supervising physical therapist consulted with the primary treating physical therapist about individual progression of the patient’s exercise program. Assistants participated in an initial training program provided by the supervising physical therapist that included education on post-

stroke sequelae, comorbid conditions, and adverse event protocols.

A log was completed for each patient's exercise session, which recorded HR and RPE using the 10-point Borg category ratio (CR-10) scale^{32,33} at rest and every 5 minutes during aerobic training. Blood pressure was recorded prior to and immediately after exercise and, if recommended by the patient's primary treating physical therapist, during exercise. The goal was to first progress exercise duration to a minimum of 20 minutes before workload was increased. A typical exercise session began with a 2- to 5-minute warm-up, up to 30 minutes of aerobic training, and a 2-minute cool-down of low-intensity exercise.

Data Collection

Data were collected for all individuals admitted during the study period concerning reasons for non-enrollment, delayed enrollment, or withdrawal. These reasons were categorized by the assistants in conversation with the primary treating physical therapists into: aerobic exercise not deemed to be a priority, medical status (cardiac), medical status (non-cardiac), lack of interest, physical limitation, or cognitive limitation.

Data were extracted from patient health records and routine admission assessments for consenting participants. Clinical information included stroke type, lesion location, and any comorbid conditions. Neurologic deficit was evaluated using the National Institutes of Health Stroke Scale,³⁴ functional mobility was measured using the Clinical Outcome Variables Scale,³⁵ and motor recovery of the leg and foot was quantified with the Chedoke-McMaster Stroke Assessment (CMSA).³⁶

Feasibility Evaluation Criteria

Referral rate and withdrawals collected for all admissions during the

study period were used to evaluate enrollment targets. Attendance (frequency of sessions attended) and within-session adherence (exercise duration—time, and intensity) were recorded at each exercise session and used to determine achievement of attendance and adherence targets. Intensity was determined by using HR targets, as participants sometimes used different machines during training. Standard HR targets were defined as whether participants achieved greater than 50% of their age-predicted maximum HR during exercise, which has been suggested as the low range of beneficial training intensity.²⁷ Individual HR targets were defined as whether the primary treating physical therapist-prescribed HR range was achieved. Patient exercise progression was evaluated using exercise duration and intensity. Additionally, adverse events and reasons for missed exercise sessions were used to evaluate feasibility.

Participant Perceptions

A supplementary goal was to determine participant perceptions of the exercise program. Self-efficacy for exercise was assessed prior to starting the group exercise program and after discharge from the group programming by asking participants to rate from 0% to 100% how confident they were that they could exercise: (1) at a moderate intensity (defined as exercise that would make you breathe a little harder and your heart beat a little faster), (2) 3 times per week, and (3) for 20 minutes. Each participant's rating for the 3 questions was averaged to create a single rating of self-efficacy for exercise as a percentage from 0% to 100%.

Additionally, participants completed a structured exit interview that explored prestroke exercise behavior, perceived benefits of participation in the exercise group, satisfaction with the exercise program,

and postdischarge exercise plans. A structured questionnaire was administered during the interview by one of the authors who was not involved in patient clinical care (A.M.). Depending on the question, a number of response options were provided to the participant such as “yes/no/unsure,” a large list of options (>10 options), or a 5-option Likert-type scale (“completely satisfied” to “not satisfied at all”). Participants were given the opportunity to expand upon their answers. The questionnaire used is presented in [eAppendix 2](#) (available at ptjournal.apta.org).

Data Analysis

Descriptive data are presented as means and standard deviations or as counts and percentages, as appropriate, to summarize demographic, stroke, and exercise program characteristics. Paired *t* tests were utilized to evaluate change in outcome measures (self-efficacy, session duration, and exercise HR) from before to after the program using the SAS 9.2 software package (SAS Institute Inc, Cary, North Carolina).

Role of the Funding Source

Funding for the study was provided by Physiotherapy Foundation of Canada and The Heart and Stroke Foundation Centre for Stroke recovery. Dr Brooks is supported by a Canada Research Chair. Ms Inness is supported by a Canadian Institutes of Health Research Fellowship (Health Professions). The authors acknowledge the support of Toronto Rehabilitation Institute-UHN, which receives funding under the Provincial Rehabilitation Research Program from the Ministry of Health and Long-Term Care in Ontario. The authors also acknowledge NuStep Inc, Ann Arbor, Michigan, which provided one of the T5^{XR} semirecumbent steppers used in this study.

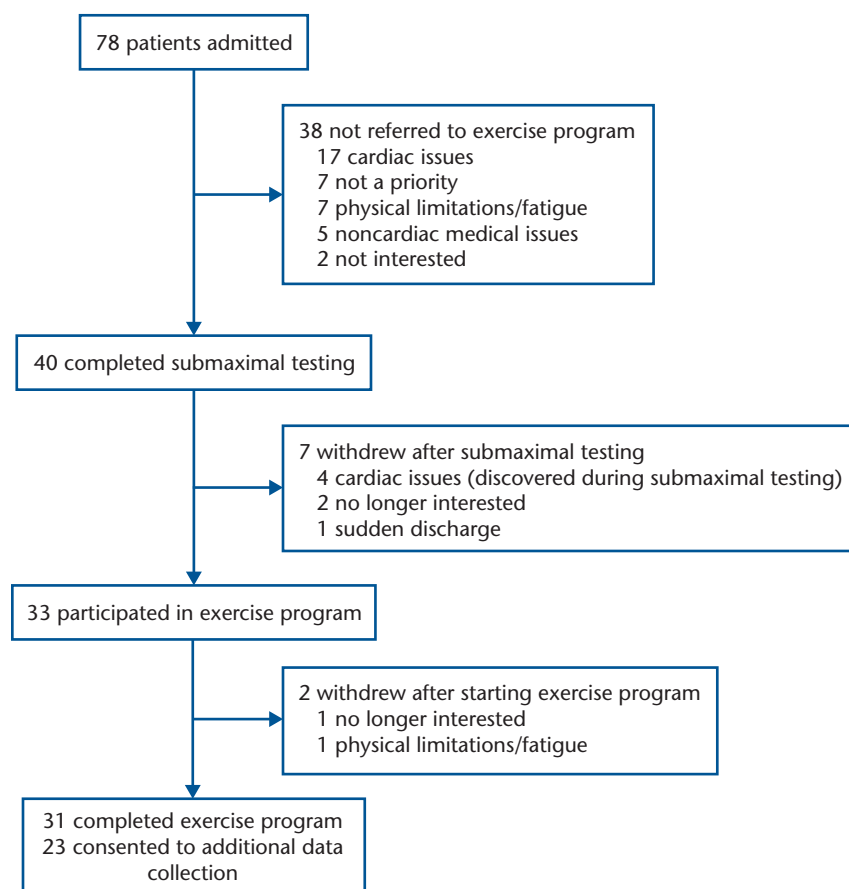


Figure.
Study flowchart.

Results

Enrollment

During the 6-month period, 78 patients were admitted to the stroke service. Of those, 40 (51%) were referred to the exercise program (Figure). Of those patients ($n=38$) who were not referred to the exercise program, 17 had cardiac comorbidity, 7 did not prioritize fitness group participation (eg, short length of stay, refused therapies), 7 had physical limitations or fatigue, 5 had noncardiac medical issues that precluded participation, and 2 were not interested. Seven participants were withdrawn following the submaximal testing. Four of those participants were withdrawn due to adverse events that arose during the submaximal test: 2 participants had previously unreported ST-segment

depression (1 patient referred for maximal fitness testing and 1 patient referred for diagnostic cardiac testing), 1 participant had high blood pressure (managed by treating physicians), and 1 participant reported chest pain (unknown follow-up). Of the remaining 33 participants, 2 voluntarily withdrew during the program (Figure). Overall, 31 participants (40% of all admissions) participated in the exercise program until discharge.

Of the 31 participants who completed the exercise program, 4 were not invited to participate in additional data collection due to their inability to understand English or cognitive issues preventing informed consent and 4 declined participation. Thus, 23 participants con-

sented to collection of additional data; 1 individual had a pacemaker and was not included in further analysis involving HR. Data for these 23 individuals are reported in the remainder of this section. Mean stroke-related impairment levels on the CMSA at admission to rehabilitation were 3.68 ($SD=0.95$) and 3.23 ($SD=1.48$) for the leg and foot, respectively, and 8 participants were able to walk independently at the time of enrollment (Tab. 1). Participants completed their enrollment submaximal test an average of 25.9 days ($SD=12.6$) after their stroke and remained in the program for an average of 19.9 days ($SD=13.4$), which equated to an average of 7.9 ($SD=4.6$) scheduled exercise sessions (Tab. 2). No adverse events were reported during exercise training sessions.

Adherence to Exercise Guidelines

Overall, the attendance rate for all exercise sessions was 76.7% (155/202). Scheduling conflicts (ie, other therapies) and patient fatigue were the 2 main reasons for missed exercise sessions (Tab. 3). With respect to duration, 15/23 participants (63%) achieved 20 minutes of exercise at least once during the program; only 1 participant exercised for at least 20 minutes at every exercise session (attended 4 sessions). Among the 15 participants who achieved 20 minutes of exercise, 59% (range=25%–100%) of their exercise sessions were at least 20 minutes in duration.

With respect to intensity, participants reached the standard HR target of 50% of age-predicted maximum during 72% (range=0%–100%) of their exercise sessions and spent, on average, 10.7 ($SD=7.9$) minutes with their HR above 50% of age-predicted maximum. Individual HR targets prescribed by the primary treating physical therapist were reached by participants in 65% (range=0%–100%) of their exercise sessions, and partic-

ipants spent, on average, 8.1 (SD=7.2) minutes within their prescribed aerobic training zone (3 people were not included in the analysis, as HR prescription was not an aerobic training zone; Tab. 4). Participants reported an RPE of at least 3/10 (corresponding to moderate exertion on the Borg CR-10 scale) in 85% (range=0%–100%) of their exercise sessions.

To investigate progression over the course of the program, exercise duration and workload were compared between the first and last sessions attended (Tab. 2). Two participants were not included in this analysis because they attended only one exercise session. In terms of exercise duration, participants increased their exercise duration by a mean of 8.8 minutes (SD=6.8) from the first to last exercise session ($t_{20}=5.90$, $P<.0001$). Among individuals who achieved the target of 20 minutes of exercise ($n=15$), it took an average of 3.5 sessions (SD=1.1) until the 20-minute target was reached. Participants increased the amount of time their HR was above 50% of maximum by an average of 2.9 minutes from their first to last exercise session, although this increase was not statistically significant ($t_{19}=1.65$, $P=.12$). This increase represented 26.6% more time spent in the standard aerobic training zone ($n=18$; 2 participants had 0 minutes above 50% maximum HR in the first session, and a percent change could not be calculated).

Participant Perceptions

Sixteen participants were included in the analysis of self-efficacy for exercise; 7 participants did not complete the self-efficacy questions due to scheduling and language problems. Self-efficacy for exercise did not change after the aerobic exercise program ($t_{15}=0.81$, $P>.05$).

Table 1.
Participant Characteristics^a

Domain	$\bar{X}$ (SD) or Count (%)
Sex	
Male	12 (52%)
Female	11 (48%)
Age (y)	69.1 (13.4)
Time from stroke to enrollment (d)	25.9 (12.6)
Ambulatory status	
Independent walking ^b	8 (34.8%)
Assisted/supervised walking	15 (65.2%)
Participated in regular exercise prestroke	14 (70%) ^c
Body mass index (kg/m ²)	26.6 (5.2)
Paretic side	
Right	9 (39.1%)
Left	10 (43.5%)
Bilateral	3 (13.0%)
Unknown	1 (4.4%)
Stroke type	
Ischemic	18 (78.3%)
Hemorrhagic	4 (17.4%)
Unclear from brain scan	1 (4.4%)
Chedoke-McMaster Stroke Assessment ^d	
Leg	3.7 (1.0)
Foot	3.2 (1.5)
Clinical Outcome Variables Scale ^d	51.9 (19.5)
National Institutes of Health Stroke Scale ^d	3.9 (2.2)

^a Participants who consented to additional data collection ($n=23$).

^b Independent walking was defined as the ability to walk independently with or without assistive devices on level ground indoors.

^c $n=20$.

^d Measurements taken at admission to inpatient rehabilitation.

Twenty of the 23 participants who consented to additional data collection completed the exit interview; 3 participants did not complete the interview due to language and scheduling problems. All participants felt they benefited from the fitness program. The most common perceived benefits were increased strength (5/20) and overall stroke recovery (5/20). Additionally, 9/20 individuals indicated other benefits such as “improved endurance” or “earlier discharge” that could be generally classified under musculoskeletal, cardiovascular, or stroke recovery. Five participants stated they would have

liked to participate in the program more often (eg, every day). Participants were satisfied with the scheduling (19/20) and exercise intensity (15/20); however, 4 participants responded that the exercise intensity was too easy, and only 1 participant reported it to be too hard. Six participants did not regularly participate in exercise prior to their stroke. When asked about future plans after discharge, 16/20 participants (4/6 who were previously sedentary) expressed interest in routinely participating in exercise and indicated goals of continuing overall recovery (13/20), improving strength (4/20),

Table 2.

Participant Progression Over the Course of the Exercise Program

Variable	$\bar{X}$ (SD)	P Value (First vs Last Session) ^a
Program duration (d)	19.5 (13.6)	
Scheduled sessions (n)	7.9 (4.6)	
Sessions attended (n)	6.7 (4.0)	
Session duration (min) ^b		
First session	12.5 (4.3)	<.0001
Last session	21.3 (21.3)	
Time spent exercising above 50% of maximum heart rate (min) ^b		
First session	8.4 (6.1)	>.05
Last session	11.3 (10.2)	
Mean increase in time per exercise session (min/session) ^b	0.3 (1.1)	
Sessions until 20 min of exercise achieved (n) ^c	3.5 (1.1)	
Self-efficacy for exercise (%) ^d		
Preprogram	76.0 (23.2)	>.05
Postprogram	80.5 (15.4)	

^a The *P* value is for the paired *t* test comparing the first session and the last session (duration and maximum heart rate) or comparing preprogram and postprogram (self-efficacy for exercise).

^b *n*=21; 2 participants not included because they attended only one exercise session.

^c *n*=15 participants who achieved 20 minutes of exercise.

^d Data only available for 16 participants.

and improving overall health (4/20). However, when probed about post-discharge exercise plans, only 6/20 participants had a concrete plan to exercise for at least 20 minutes, 3 times per week.

Discussion

The focus of the current study was to examine the feasibility of individualized aerobic exercise as part of a group fitness program during inpatient stroke rehabilitation. Overall,

31/78 (40%) of the admitted patients participated in the exercise group. Among the group that consented to additional data collection (*n*=23), 77% of classes were attended, and participants approached the guidelines of 20 minutes' duration and prescribed intensity. Additionally, patients generally felt they benefited from the exercise program, and the majority expressed interest in continuing to exercise regularly. Importantly, it was possible to individually guide exercise prescription using a structured submaximal test and progress duration and intensity within a group training model, although issues related to improving intensity and duration of exercise persist. We advocate for the critical role of submaximal testing with ECG to ensure suitability for such exercise programs, as 4 of our patients (approximately 10% of referrals) were excluded based on issues raised during submaximal testing. However, it is important to note that there were no adverse effects during training. Overall, evidence for feasibility was mixed; those enrolled had high attendance levels and were satisfied with the program, but intensity and duration targets were not always met. Ensuring clinicians are using exercise test results to prescribe exercise intensity and progression at appropriate levels was a challenge in this subacute setting. Additionally, future work needs to investigate strategies to include more participants, particularly those with cardiac comorbidities.

Enrollment

One major challenge in the study was a low enrollment rate, which was below our goal of 60% of all inpatients. This enrollment rate reflects a high proportion of comorbid cardiac conditions (17/78; 22% of all patients). Furthermore, another 4 patients were excluded after cardiac issues were discovered during submaximal exercise test-

Table 3.

Reasons for Missed Appointments^a

Reason	No. of Sessions
Schedule conflict	
Core therapy appointment (physical therapy, occupational therapy, speech and language pathology, social work)	9/47 (19%)
Other appointments (eg, dentist, external doctor)	11/47 (21%)
Declined	
Fatigue	15/47 (32%)
From other therapies	6/47 (13%)
Other (eg, lack of sleep)	9/47 (19%)
Feeling unwell/sick/injured (unrelated to exercise group)	4/47 (9%)
Busy with visitors	3/47 (6%)
Other ^b	5/47 (11%)

^a Of 202 scheduled exercise sessions, 47 sessions were missed.

^b Includes patient who had already exercised during regular therapy, exercise prescription was not yet prepared by treating therapist, and undocumented reason.

Table 4.Exercise Session Data by Individual^a

Patient No.	No. of Sessions Attended	Session Duration (min)	Physical Therapist Prescription (% of Maximum Heart Rate)	Time in Physical Therapist-Prescribed Aerobic Training Zone (min)	Time Spent at >50% of Maximum Heart Rate (min)
1	6	18.5 (15–20)	59–68	13.3 (10–20)	18.5 (15–20)
2	5	6.0 (5–8)	47–57	6.0 (5–8)	4.0 (0–8)
3	5	12.2 (10–15)	48–58	6.0 (5–8)	12.2 (10–15)
4	6	22.5 (17–26)	63–73	0 (0–0)	22.5 (17–26)
5	5	22.8 (17–28)	54–64	12.4 (0–25)	17.4 (0–28)
6	9	8.0 (4–12)	60–75	1.8 (0–8)	8.0 (4–12)
7	6	20.2 (15–25)	70–80	5.2 (0–12)	20.2 (15–25)
8	9	19.9 (8–32)	54–64	0.6 (0–5)	1.1 (0–5)
9	3	10.0 (7–13)	54–64	2.3 (0–7)	10.0 (7–13)
10	5	9.7 (7.25–11)	53–63	8.4 (5–11)	8.4 (5–11)
11	16	17.6 (10–25)	55–65	9.8 (0–23)	17.6 (10–25)
12	15	25.4 (13–32)	57–67	23.4 (13–32)	25.4 (13–32)
13	1	18.0 (18–18)	<60 ^b		18.0 (18–18)
14	3	19.7 (18–23)	47–57	10.0 (10–10)	1.0 (0–3)
15	7	17.7 (10–26)	50–60	14.6 (0–21)	12.9 (0–20)
16	4	21.5 (4–30)	44–54	22.8 (13–30)	3.3 (0–7)
17	10	20.5 (10–28)	57–67	3.9 (0–15)	13.8 (0–28)
18	4	18.0 (14–24)	45–55	0 (0–0)	0 (0–0)
19	7	17.9 (11–24)	45–55	14.3 (5–20)	3.4 (0–19)
20	7	22.1 (17–27)	<75 ^b		3.6 (0–10)
21	7	12.0 (10–14)	Pacemaker ^c	Pacemaker ^c	Pacemaker ^c
22	1	10.0 (10–10)	<64 ^b		0 (0–0)
23	14	30.6 (13–40)	66–75	0 (0–0)	14.9 (0–40)

^a Values presented are mean (range).^b Three individuals were not prescribed a heart rate range but were prescribed a maximum heart rate to stay below during exercise.^c One individual used a pacemaker and, therefore, was not included in heart rate analyses.

ing.^{4,37} Together, 27% (21/78) of all patients had cardiac issues that prevented enrollment in the exercise program, highlighting one significant enrollment challenge with implementing aerobic exercise early after stroke. Future work should explore the specifics of these cardiac issues to determine whether they are true barriers to exercise. It is possible that the nature or acuity of the patients' cardiac conditions precluded them from exercise. However, it also is possible that therapist comfort level in assessment and exercise prescription of patients

with cardiac comorbidities was the main barrier. Even after cardiac procedures, individuals can be expected to complete graduated exercise programs. One way to boost enrollment may be to determine optimum low-level, interval-type training for these individuals, whereas other patients with significant cardiac histories may benefit from formal cardiopulmonary exercise assessment. Thus, future work needs to determine how best to incorporate aerobic training for these 27% of people recovering from a stroke who have severe comorbid cardiac issues. Survivors of

stroke with limited ability to walk and comorbid cardiac issues may be particularly vulnerable to further aerobic deconditioning.

As noted, adverse events did occur during submaximal exercise testing, as this testing identified 4 patients with previously unknown potential cardiovascular issues, which highlights the additional value of exercise testing as a screening tool. Although the gold standard of exercise testing is maximum oxygen consumption ($\dot{V}O_2$) testing,²⁸ the majority of physical therapists report that $\dot{V}O_2$ testing

is not available to them,³⁸ and it may not be feasible in patients at low functional levels. Submaximum $\dot{V}O_2$ tests, however, have excellent test-retest reliability among individuals recovering from a stroke and moderate to high concurrent validity with maximum $\dot{V}O_2$ tests in healthy individuals.³⁹ Furthermore, among patients 3 weeks to 4 months post-stroke, no adverse incidents were encountered following more than 200 symptom-limited treadmill exercise tests.⁸ The information gained from observing a patient's physiological response during submaximal testing allows for more thorough screening at this critical stage of poststroke rehabilitation.

It is worth noting that we enrolled patients at low levels of function, as evident by the low mean motor recovery scores on the CMSA of 3.7 and 3.2 for the leg and foot, respectively. These CMSA scores indicate greater impairment compared with a similar exercise trial among individuals in the subacute stage of stroke recovery that used semirecumbent cycling (CMSA leg score=4.4).¹² Additionally, the majority of patients in the current study (15/23) were not independently ambulatory at enrollment. In contrast, exercise trials in the subacute stage have tended to require individuals to be ambulatory at enrollment.^{10,18} We were able to train patients at low levels of function through use of equipment that was suitable for individuals with impaired lower extremity motor control. The ability to incorporate arms in exercise training may allow for even more individuals with impairment to participate and provide more aerobically challenging exercise intensity. However, the aerobic benefits of including the arms must be weighed against the potential for compensatory strategies (ie, use of the unaffected limbs limiting use of the affected limbs) to be adopted by the individual. Alterna-

tive modalities (eg, walking overground, using a treadmill) may be a more suitable option for patients with a higher level of functioning, although it should be noted that people need to walk at high speeds to achieve aerobic workloads, which may be difficult to achieve in the early phases of recovery. Additionally, training using semirecumbent exercise machines is a feasible modality for group delivery of exercise in this population, as it requires minimal direct supervision.

Attendance and Exercise Targets

Although our program was successful, as enrolled individuals had high attendance and satisfaction with the program, ensuring participants achieve appropriate exercise intensity levels remains a significant feasibility challenge. We focused on increasing exercise time to 20 minutes, a level sufficient to achieve benefit among people who have had a stroke,⁴⁰ before increasing resistance. However, the patients' treating therapists initially tended to provide prescriptions recommending increasing exercise time by only 2 to 3 minutes per session. This conservative strategy resulted in only 15/23 participants ever achieving a 20-minute duration, and it is likely that those who did achieve this duration took significantly longer to achieve this target than if the duration had been increased as per individual tolerance. Furthermore, despite the results of the submaximal exercise test, there was a tendency for patients to be initially prescribed low exercise duration and resistance to achieve primary treating physical therapist-prescribed HR targets, which resulted in less time spent with HR at a sufficient level for aerobic training. Additionally, 20% of the patients indicated that they would have liked to exercise at a higher intensity compared with a single individual who felt the intensity was too high. The conservative

approach to exercise prescription (low initial resistance, slow progression of time) in this sample is somewhat surprising given the information available from the submaximal assessment. However, this approach is in line with physical therapists treating patients with neurological conditions who reported lower-than-recommended exercise intensity and duration among their patients, likely due to their concern over cardiac comorbidities and a lack of specific screening and prescription guidelines.³⁸ In addition, the format of the program—starting with prescribed initial workload and time and progressing slowly to 20 minutes before increasing intensity—contributed to generally lower exercise intensities. It is important to note that there were no adverse events in the exercise group training, which supports the possibility of more intense initial exercise prescription.

Specifically, we advocate for higher-intensity HR and RPE targets within the bounds of the submaximal exercise assessment. Given the potential for large gains in motor function and aerobic capacity in a short period during the subacute period, we recommend increasing exercise duration as per individual tolerance rather than maintaining strict criteria. Such a strategy will ensure that exercise programs such as this achieve appropriate, recommended exercise guidelines. However, future work is needed to determine specific exercise prescription guidelines (particularly the starting exercise duration and intensity) using information from a structured exercise assessment to help clinicians prescribe exercise of optimal intensity for their patients.

Balancing fitness training with patient availability and fatigue was a challenge to implementing this program. Scheduling concerns were the main reason for missed fitness group

participation. In line with previous work,⁴¹ fatigue, either from other therapies or more general concerns (ie, poor sleeping), also was found to be a common barrier to participation in fitness group sessions. To ensure patient availability and participation, scheduling the group sessions at non-peak therapy times is crucial. Additionally, where resources permit, offering the group sessions at more times during the week would likely alleviate scheduling pressure and patient suitability (ie, fatigue). By considering these factors, inpatient exercise programs may achieve an even greater rate of adherence and ensure all patients receive the maximum benefit of aerobic training.

Participant Perceptions

After completion of the exercise program, 80% of the participants indicated plans to continue routine exercise postdischarge. Additionally, 4/6 participants who did not exercise regularly before their stroke reported plans to continue exercising postdischarge. Inpatient rehabilitation is likely an ideal starting point to begin a new exercise regimen, as lifestyle changes and positive habits may be formed prior to patient discharge. Of concern, self-efficacy for exercise, an important determinant of exercise participation,⁴² did not change over the course of the fitness program. However, it should be noted that our modest evaluation of self-efficacy for exercise may not have been sensitive enough to elicit change in self-efficacy. Additionally, only 6 participants had a clearly articulated plan for exercise postdischarge. Thus, although participants had the intention to continue to exercise, they may not sustain their exercise behavior due to barriers, including low self-efficacy for exercise and lack of a plan. Indeed, physical activity levels are low among all individuals with stroke after discharge into the community, includ-

ing those who complete structured aerobic exercise during rehabilitation.⁴³ Previous research has suggested that aerobic gains made over the course of an exercise program are not maintained after a follow-up period.⁴⁴ Given the short length of time in the exercise program (approximately 3 weeks, with 8 scheduled sessions), inpatient exercise programs can be considered an essential beginning to exercise participation that will need to be continued in outpatient and community settings to achieve maximum gains. Thus, future work should investigate models of care to increase physical activity postdischarge. Furthermore, strategies to ease the postdischarge transition into the community and facilitate long-term behavioral change are critical areas for future work.

In conclusion, we investigated the feasibility of a model of care that instituted an individualized exercise program within a group setting in inpatient rehabilitation for patients in the subacute stage of stroke recovery. This model was successful in providing a setting where patients could exercise safely; however, we did not achieve enrollment targets, and ensuring participants achieved adequate aerobic targets was a challenge. Future work should explore how to include individuals with cardiac comorbidities and simple strategies to prescribe exercise intensity based on results of an exercise test.

All authors provided concept/idea/research design, writing, and consultation (including review of manuscript before submission). Mr Biasin, Ms Brunton, Ms Fraser, Dr Mansfield, and Ms Inness provided data collection. Mr Biasin, Mr Sage, Ms Fraser, Dr Bayley, Dr Brooks, Dr Mansfield, and Ms Inness provided data analysis. Mr Biasin, Ms Fraser, and Ms Inness provided project management. Dr McIlroy and Ms Inness provided fund procurement. Dr Bayley provided participants. Dr Bayley and Dr McIlroy provided facilities/equipment.

The study was approved by the Toronto Rehabilitation Institute's Research Ethics Board.

Part of this study was presented as a poster at the Canadian Stroke Congress; October 2–4, 2011; Quebec City, Canada.

Funding for the study was provided by Physiotherapy Foundation of Canada and The Heart and Stroke Foundation Centre for Stroke recovery. Dr Brooks is supported by a Canada Research Chair. Ms Inness is supported by a Canadian Institutes of Health Research Fellowship (Health Professions).

The authors acknowledge the support of Toronto Rehabilitation Institute–UHN, which receives funding under the Provincial Rehabilitation Research Program from the Ministry of Health and Long-Term Care in Ontario. The authors also acknowledge NuStep Inc, Ann Arbor, Michigan, which provided one of the T5^{XR} semirecumbent steppers used in this study.

DOI: 10.2522/ptj.20130404

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