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A Community-based Fitness and Mobility Exercise (FAME) Program for Older Adults with Chronic Stroke: a Randomized Controlled Trial

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Abstract

OBJECTIVES—To examine the effects of a community-based group exercise program for older individuals with chronic stroke.

DESIGN—Prospective, single-blind, randomized controlled intervention trial.

SETTING—Intervention was community-based. Data collection was performed in a research laboratory located in a rehabilitation hospital.

PARTICIPANTS—Sixty-three older individuals (≥ 50 years) with a chronic stroke (post-stroke duration ≥ 1 year) who were living in the community.

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Author Contributions:

Marco Y.C. Pang: study concept and design, acquisition of subjects and data, analysis and interpretation of data, preparation of manuscript

Janice J. Eng: study concept and design, preparation of manuscript

Andrew S. Dawson: study concept and design, preparation of manuscript

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INTERVENTION—Participants were randomized into intervention group (n=32) or control group (n=31). The intervention group underwent a Fitness and Mobility Exercise (FAME) program designed to improve cardiorespiratory fitness, mobility, leg muscle strength, balance and hip bone mineral density (BMD) (1-hour sessions, 3 sessions/week, for 19 weeks). The control group underwent a seated upper extremity program.

MEASUREMENTS—(1) cardiorespiratory fitness (maximal oxygen consumption), (2) mobility (Six Minute Walk Test), (3) leg muscle strength (isometric knee extension), (4) balance (Berg Balance Scale), (5) activity and participation (Physical Activity Scale for Individuals with Physical Disabilities) and (6) femoral neck BMD (Dual-energy X-ray absorptiometry).

RESULTS—The intervention group had significantly more gains in cardiorespiratory fitness, mobility, and paretic leg muscle strength than controls. Femoral neck BMD of the paretic leg was maintained in the intervention group whereas a significant decline of the same occurred in controls. There was no significant time $\times$ group interaction for balance, activity and participation, non-paretic leg muscle strength and non-paretic femoral neck BMD.

CONCLUSION—The FAME program is feasible and beneficial for improving some of the secondary complications resulting from physical inactivity in older adults living with stroke. It may serve as a good model of community-based fitness program for preventing secondary diseases in older adults living with chronic conditions.

Keywords

cerebrovascular accident; health promotion; osteoporosis; rehabilitation

The consequences of physical inactivity are particularly detrimental in older individuals with chronic disease. Impairments resulting from chronic disease (e.g., reduced mobility, pain), in addition to the lack of accessible and appropriate community-based exercise programs could lead to further sedentary lifestyle, and additional declines in functional status.¹ Physical inactivity could also contribute to secondary debilitating or life-threatening diseases. A recent study has found that approximately one third of cardiac disease and osteoporosis cases are attributable to lack of physical activity and have posed tremendous burden on the health care system.²

Stroke is one of the most common chronic conditions seen in older adults, with an incidence approximately doubling each decade after the age of 55.³ Most stroke survivors continue to live with residual physical impairments, which may promote a sedentary lifestyle and resultant secondary complications.⁴ One of the secondary complications commonly observed following stroke is poor cardiorespiratory fitness.^{5,6} Low cardiorespiratory fitness is related to poor functional performance⁷ and increased risk of stroke and cardiovascular disease.^{8,9} Indeed, cardiac events and recurrent stroke are major occurrences in stroke survivors.^{10,11}

Other common stroke impairments are poor balance and muscle weakness,^{12–14} which may contribute to the higher incidence of falls in older adults with stroke than the age-matched population.¹⁵ In addition, poor mobility and decreased loading of the hemiparetic leg may also result in decline of hip bone mineral density (BMD).^{16,17} The increased falls and

reduced bone health may in part explain the two to four time greater hip fracture risk among stroke survivors.¹⁸

These secondary conditions seen in stroke survivors are compounded by the fact that the number of older individuals with chronic stroke in the community is on the rise. Studies have shown that the incidence of stroke is increasing, particularly in older people.³ The mortality rate of stroke, however, has been declining³ and more stroke survivors are returning home instead of going into an inpatient rehabilitation program.¹⁹ These factors may translate into an increasing number of older adults living with a chronic stroke in the community, who have not attained optimal functional recovery and are at risk of developing secondary complications due to physical inactivity.

There has been an increasing recognition of the importance of health promotion for people with disabilities.²⁰ One of the key components of health promotion for people with disabilities is “the prevention of health complications (medical secondary conditions) and further disabling conditions”.²⁰ According to the conceptual model of health promotion proposed by Rimmer²⁰, community-based fitness programs play one important role in achieving this objective. Considering that physical inactivity in older adults with chronic stroke could lead to devastating secondary health complications, an accessible and multidimensional fitness program is urgently needed.²¹ Most exercise programs proposed for chronic stroke, however, are not community-based and have addressed only one or two of the impaired domains.^{5,6,22–24} Moreover, although it is known that stroke is a major risk factor for hip fracture,¹⁸ no study has examined the effects of exercise on hip BMD in stroke. This study aims to assess the efficacy of a multidimensional community-based fitness and mobility exercise (FAME) program for individuals with chronic stroke. This is the first study to examine the effects of exercise on hip BMD in this population. It was hypothesized that the individuals who underwent the FAME program would have significantly more improvement in cardiorespiratory fitness, mobility, leg muscle strength, balance, activity and participation, and hip BMD than those in the control group.

METHODS

Participants

Participants were recruited from a local rehabilitation hospital database, community stroke clubs and local newspaper advertisements. All potential participants were first screened by a telephone interview based on the following inclusion criteria: (1) a single stroke >1 year onset, (2) age ≥ 50 years, (3) ability to walk >10 meters independently (with or without walking aids), and (4) living at home. Exclusion criteria were: (1) history of serious cardiac disease (i.e. myocardial infarction), (2) uncontrolled blood pressure (systolic blood pressure >140, diastolic blood pressure >90), (3) pain while walking, (4) neurological conditions in addition to stroke, and (5) other serious diseases that preclude the individual from participating in the study.

Those who fulfilled the above criteria were required to provide informed and written consent. In addition, the primary care physician was required to provide written information regarding medical history of the individual (i.e. diagnosis, comorbid conditions) and his/her

recommendation about the participant's participation. The study was approved by the local university and hospital ethics committees. The experiments were conducted in accordance to the Helsinki Declaration.²⁵

Once the required consent and information were obtained, the participant was brought into the laboratory for further screening. First, the functional classification level of the American Heart Association Stroke Outcome Classification was used to measure residual disability in basic (e.g. dressing, bathing, grooming) and instrumental activities of daily living (e.g. shopping, preparing meals) (BADL and IADL) [level I = as independent as before the stroke; level V = completely dependent in BADL and IADL].²⁶ Second, the ability to pedal the cycle ergometer (Excalibur, Lode B.V. Medical Technology, Groningen, Netherlands) was tested. The participant had to be able to pedal at 60rpm and raise the heart rate to at least 60% maximal heart rate. Third, since significant cognitive deficits may adversely affect an individual's ability to follow instructions during the exercise sessions, the Mini Mental State Examination (MMSE) was administered and a score >22 had to be fulfilled for inclusion.²⁷

Study Design

A prospective, single-blind, randomized controlled intervention trial was undertaken. The participants were stratified according to gender because men tended to have higher $\text{VO}_{2\text{max}}$,²⁸ muscle strength,²⁸ and BMD²⁹ than women. The participants were then randomly assigned to the intervention or control group by drawing ballots marked "I" (i.e. intervention) or "C" (i.e. control). The randomization was performed by an individual who was not involved in enrollment or any of the screening and outcome assessments. The research personnel who performed the outcome assessments were blinded to the group assignment. Participants were not blinded to group assignment. They were informed that they were in either a lower extremity or upper extremity program. Participants were instructed not to tell the assessors about the group assignment or the treatment they received and not to discuss the protocol with the stroke community.

Interventions

Both the intervention and control groups underwent an exercise program for 19 weeks (1-hour sessions, 3 sessions per week) in the same multi-purpose room of a community hall. The community space was only occupied by the participants during the exercise sessions. The two groups exercised at different times of the day. In each session, 9–12 participants were supervised by a physical therapist, an occupational therapist and an exercise instructor. Hip protectors (SAFEHIP, Tutex, Denmark) were provided to those in the intervention group and they were instructed to wear them in each session.

In the intervention group, the Fitness and Mobility Exercise (FAME) program was provided (Table 1). To determine cardiorespiratory training intensity, the maximum heart rate achieved at the end of the cycle ergometer test was used to calculate the heart rate reserve (HRR).²⁸ As the trial progressed, both the exercise intensity and duration was increased as tolerated (Table 1), as adapted from the guidelines recommended by American College of Sports Medicine.²⁸ During aerobic exercise training, the participant wore a heart rate

monitor (Polar A3, Polar Electro Inc., Woodbury, NY, USA) and was instructed to exercise within the set target heart rate zone. The average heart rate attained, the duration over which the target heart rate was sustained, and the specific exercises completed in each session were recorded. The control group underwent a seated upper extremity program (Table 2). No aerobic exercises, leg strengthening and balance training were given. Adverse events (e.g. falls) were monitored and recorded. A fall was defined as unintentionally coming to rest on the floor or another lower level.

Outcomes

All outcomes were measured by the same trained assessors immediately before the commencement of the interventions, and again immediately after the termination of the interventions.

Maximal oxygen consumption (VO_2max) was considered to be the criterion measure of cardiorespiratory fitness.²⁸ Each participant underwent a maximal exercise test on the Excalibur cycle ergometer. A 12-lead electrocardiography system (Quark C12, COSMED Srl, Rome, Italy) was used to monitor cardiac activity by a physician. Participants wore a face mask and VO_2 was continuously measured using a portable metabolic unit, which performed breath by breath gas analysis (Cosmed K4 b² system; COSMED Srl; Rome, Italy). The level of perceived exertion was monitored by the 16-point Borg Rating of Perceived Exertion scale.³⁰ Blood pressure was measured at rest and also at the end of the test. The testing protocol was adjusted to the capabilities of the individuals.²⁸ The workload started at 20W and increased by 20W/min for 29 participants. For the other 34 participants who were more severely impaired, the workload started at 10W with increments of 10W/min. For each participant, the same seat height and testing protocol were used at baseline and 19 weeks. Participants were required to pedal at 60 rpm. The test continued until the participant volitionally fatigued. The respiratory exchange ratio (RER) at the end of the test was noted. The VO_2 data were averaged at a rate of every 15 seconds. The maximal value obtained was considered to be the VO_2max (ml/kg/min).

Six Minute Walk Test (6MWT) was used to assess mobility.³¹ The distance walked in 6 minutes were recorded. 6MWT has been shown to be a reliable method to assess walking performance in individuals with stroke.³² Hand-held dynamometry (Nicholas MMT, Lafayette Instruments, Lafayette, IN, USA) was used to evaluate isometric knee extension strength. The participant was sitting upright in a chair with back support. The knee was placed in 90° flexion and the thigh was stabilized by the assessor in order to eliminate synergistic movements. Each participant was asked to perform a maximal isometric contraction of knee extension. Three trials were performed on each side and force data [Newtons (N)] were averaged. Hand-held dynamometry is a reliable method to assess muscle strength in stroke.³³ Functional balance was assessed by Berg Balance Scale (maximal score = 56), which has shown to be a reliable and valid tool to assess balance in older adults.³⁴ Activity participation was measured by the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD).³⁵ It is a 13-item questionnaire which assesses the amount of participation in physical activities of different intensities for the past

7 days. Each activity was assigned a specific metabolic equivalent (MET) value and the maximal score was 199.5 MET hour/day. The validity of PASIPD has been established.³⁵

Bilateral hip scans were performed using dual-energy X-ray absorptiometry (DXA; Hologic QDR 4500, Hologic Inc., Waltham, MA, USA). All scans were performed by the same technician using standard procedures (Hologic User's Manual). Femoral neck BMD (g/cm^2) was reported as the primary outcome, since femoral neck is the most common site of fracture in stroke.¹⁸ Each participant was classified as having osteoporosis or osteopenia according to the definitions of the World Health Organization,³⁶ using the reference data provided by Looker et al.²⁹ Regarding the precision of the DXA scanner, the coefficient of variation for femoral neck BMD was .93%.

Statistical Methods

The sample size was based on predictions of change for cardiorespiratory fitness. A power of .80 and a $P < .05$ were desired for the calculation. Based on an average VO_2max of 17.3 $\text{ml}/\text{kg}/\text{min}$ ($\text{SD} = 3.0$)⁵ and a desired 15% change,⁶ 21 participants per group were required. To account for a 20% attrition rate, at least 26 participants per group should be recruited.

Baseline variables between the two groups were compared using independent t-tests (for continuous variables) and Chi-Square (for categorical variables). Intention-to-treat analysis was performed. For dropouts, it was conservatively assumed that no changes occurred in any of the outcome measures at 19 weeks. Therefore, the missing values at 19 weeks were inputted using baseline values for these individuals.³⁷ To reduce the probability of type I error from multiple comparisons, a single multivariate analysis of variance (MANOVA) incorporating all primary outcomes was performed to determine whether there was an overall significant time $\times$ group interaction. Two-way ANOVA (within factor: time; between factor: group) were then performed to analyse the data post-hoc. The difference between the pre-test and post-test scores and 95% confidence interval for each outcome variable were also reported. All statistical analyses were performed using SPSS11.5 software (SPSS Inc.) using a significance level of 0.05 (2-tailed).

RESULTS

Sixty three individuals fulfilled all criteria and were enrolled in the study (Figure 1). There were 3 dropouts. Two dropped out of the intervention group: 1 withdrew after 6 sessions because of the inability to commit the time, 1 withdrew after 9 sessions because he found the exercise too fatiguing. One dropped out of the control group after 8 sessions because of the inability to commit the time. The dropouts tended to have better balance (mean Berg = 54.0) and mobility (mean 6MWT distance = 498.3m). There was no significant difference in any of the variables between the intervention and control groups at baseline ($P > .200$ for all variables) (Table 3 and 4).

On average, the two groups attended a similar number of sessions (intervention group: 81.4%; controls group: 80.4%). For cardiorespiratory training in the intervention group, six participants could not progress beyond the initial target heart rate zone (40–50% HRR). These 6 participants tended to have poorer balance (mean Berg = 41.2) and mobility (mean

6MWT distance = 193.9m) at baseline. None of these six participants were on beta-blockers. Seven participants were trained at 70–80% HRR at the end of the trial. An additional 12 and 5 participants reached 60–70% and 50–60% HRR, respectively. On average, the target heart rate was sustained for 15 minutes.

Multivariate analysis showed a significant time $\times$ group interaction (Wilk's Lambda = .670, $P = .004$), indicating that overall, the FAME program produced more gains than the control treatment. Elimination of the 3 dropouts from the analysis produced similar results (Wilk's Lambda = .644, $P = .003$). Post-hoc analysis (Table 4) revealed that the intervention group had significantly more improvements in VO_2max , 6MWT distance, and paretic leg muscle strength than controls. A significant time $\times$ group interaction was also found for the paretic femoral neck BMD where there was a 2.5% decline in controls but a maintenance of BMD in the intervention group. Both groups improved in balance and PASIPD score, but there was no significant time $\times$ group interaction.

Given the positive improvements from the FAME Program, additional post-hoc analyses were performed to examine the relationship between the initial level of impairment and the amount of improvement (i.e., change score) in the intervention group using Pearson's correlations for each primary outcome. In the intervention group, there was a significant negative correlation between the baseline score and the change score for two of the primary outcomes, namely, Berg ($r = -.817$, $P < .001$) and PASIPD ($r = -.358$, $P = .044$). However, correlations were not significant between the baseline and change scores for the other outcome measures (i.e. VO_2max , 6MWT distance, leg muscle strength, and femoral neck BMD).

There were 5 falls (4 participants) in the intervention group. Three falls occurred with the participant still holding onto a support (e.g., knee gave way while in a squat position) but were still considered falls as the participant came to rest on a lower level. One fall occurred when the participant was kicking a ball. Another fall occurred when the participant was stepping down from a 2-inch-thick foam. In both cases, the participants were being spotted and were able to recover independently immediately after the fall. Most falls were thus low-impact. One fall occurred in the control group while the participant was walking. No injuries were reported.

DISCUSSION

The study showed that the proposed FAME program is feasible and beneficial for improving cardiorespiratory fitness, mobility, paretic leg muscle strength and maintaining hip BMD in individuals with chronic stroke. The program may provide a good model for community-based fitness programs for older people with chronic disabilities.

The results support the hypothesis that the intervention group would have significantly more gains in cardiorespiratory fitness. The FAME program resulted in significantly more improvement in VO_2max (10.7%) than controls (2.2%). The amount of gain in VO_2max is comparable to other stroke programs (duration: 10–12 weeks) which used a cycle ergometer or treadmill for cardiorespiratory training.^{6,24,37} The difference in results between the

intervention and control groups could not be due to difference in effort during the maximal exercise test, since the RER achieved at the end of the ergometer test showed no group $\times$ time interaction. The average baseline VO_2max obtained in the participants of this study was approximately at the 10th percentile of the age and sex-matched population, indicating poor cardiorespiratory fitness.²⁸ Individuals with low VO_2max values need to work at a higher relative exercise intensity to complete the same daily functional activities, when compared with others who have higher VO_2max . This reduction in fitness reserve can contribute to reduced activity endurance, which was identified as the most striking area of difficulty for older adults with stroke living in the community.¹⁹ Thus, improvement in VO_2max in older adults with stroke may have tremendous impact on functional abilities.

Apart from its influence on function, low VO_2max has also been related to an increased risk of various forms of cardiovascular diseases^{8,39} and premature death from all causes and specifically from cardiovascular disease.^{40,41} Our findings thus have important implications for stroke survivors, considering that poor VO_2max is prevalent in this group^{5,6} and that a large proportion (up to 75%) of older individuals with stroke demonstrate some form of cardiovascular disease.¹⁰ Cardiac disease is also the leading cause of death in stroke survivors.¹⁰

Six participants were unable to progress beyond the initial training target heart rate zone. Reduced ambulatory and balance skills may make it more difficult for them to increase walking speed as training progressed. Despite the failure to train beyond 40–50% HRR, these six individuals still averaged an impressive 18.4% increase in VO_2max . These individuals (3 women, 3 men) tended to have lower baseline VO_2max (mean = 20.2 ml/kg/min), which would partially explain their higher percent gain. Thus, positive outcomes can be obtained despite training at low intensities. This is in agreement with the previous finding that intensity as low as 30% VO_2 reserve (i.e. the difference between maximum and resting VO_2) was effective in improving cardiorespiratory fitness in less fit, but healthy individuals.⁴²

The intervention group also improved significantly more in 6MWT distance and paretic leg muscle strength than the control group, as predicted by the research hypothesis. The improvement in 6MWT distance is particularly important, given that the deficit in walking endurance is strikingly pronounced in individuals with chronic stroke.¹⁹ Muscle strength is correlated with gait velocity,³² walking endurance^{32,43} and BMD⁴⁴ in individuals with stroke. Since decreased ambulatory capacity^{19,32} and osteoporosis^{16,44} are major concerns for this group, increasing muscle strength may also have important implications.

Previous studies in older adults have reported beneficial effects of exercise on bone health. For example, Vincent and Braith reported that a 6-month high-intensity resistance exercise program resulted in a significant 2.0% increase in femoral neck BMD in elderly men and women while the controls had a 1.6% decrease of the same.⁴⁵ A 1-year high-impact aerobic exercise program for older adults over 50 years of age resulted in a maintenance of hip BMD compared to a significant 1.9% reduction of the same in controls.⁴⁶

This study provides the first evidence that regular exercise is beneficial for hip bone health in the chronic stroke population. Femoral neck BMD on the paretic side was maintained in the intervention group whereas a significant 2.5 % decrease was observed in controls. In this study, it was assumed that the pre-test and post-test scores for each primary outcome variable were the same for the dropouts. It is thus possible that the paretic hip BMD of the dropout in the control group may have been overestimated. However, this possibility would not affect the interpretation of the results. First, the number of dropouts in the control group is small ($n = 1$). Second, overestimating the post-test paretic hip BMD value of dropouts in the control group would actually tend to underestimate the difference in post-test scores between the intervention and control groups. Despite this, the results remained statistically significant.

The reduction of BMD in the control group (2.5%) is consistent with the study by Ramnemark et al.,¹⁶ who reported a 2.2% decline in proximal femur BMD in a 5-month period in a sample containing mostly ambulatory subjects with stroke. The reduction in BMD reported in this study is clinically significant, considering that femoral neck BMD in older men and women (70–79 years) is only 5.5% and 9.4% lower than those 10 years younger, respectively.³⁶ With the presence of risk factors such as poor balance and mobility, any departure from healthy BMD values would further increase the risk of hip fractures.⁴⁷ It is well known that mechanical loading is important to maintain bone mineral.⁴⁸ Reduced VO_2 max, poor mobility and reduced weight-bearing have also been linked to low femoral neck BMD.^{17,49} By targeting these specific impairments and incorporating weight-bearing activities with the paretic leg, the FAME program succeeded in maintaining femoral neck BMD in chronic stroke.

The results, however, do not support the hypothesis that the intervention group would have more improvement in balance and PASIPD scores than the control group. The improvement of balance in the control group may be due to the undertaking of several activities which involved trunk stability and reaching function, which may improve lower limb weight-bearing and sit-to-stand function.²² The absence of between-group difference in PASIPD score may be explained by the fact that the control group also underwent an intensive exercise program, which may in turn promote activity and participation.

The study has several limitations. First, the results are generalizable to a selected group of community-dwelling individuals with chronic stroke only. Second, except for balance and PASIPD, the amount of improvement in the intervention group was not specific to the initial level of impairment and perhaps factors like motivation played an important role. More improvement in balance was correlated with a lower baseline Berg score. However, this correlation should be interpreted with caution as the Berg scale does have a ceiling effect with higher levels of balance function.⁵⁰ Third, no attempts were made to help participants to develop exercise habits on a long-term basis. It is not known whether the participants continued to exercise after the termination of the program. A larger sample size and long-term follow-up would be required to determine the long-term benefits as well as adherence to an ongoing exercise program. It would also be interesting to determine whether the FAME program would reduce the actual risk of cardiac events, osteoporosis or fractures. Whether extending the duration of the program would increase femoral neck BMD also requires

further study. Nevertheless, the positive outcomes from this trial justify a multi-centered trial to further study the efficacy and cost-effectiveness of the FAME program.

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Figure 1. Study Flow Chart

Sixty three individuals were enrolled in the study and were randomly assigned to either the intervention (n=32) or control group (n=31). Thirty individuals in each group completed the program.

Table 1**Fitness and Mobility Exercise Program (FAME) Provided to Intervention Group**

Station 1: Cardiorespiratory fitness and mobility

- 1** Brisk walking
- 2** Sit-to-stand: progressed by reducing the height of chair.
- 3** Alternate stepping onto low risers: progressed by increasing the height of the stepper and/or reducing arm support.

Duration:

10 minutes initially, with increment of 5 minutes every week, up to 30 minutes of continuous exercise as tolerated.

Intensity:

Started at 40–50% HRR, with increment of 10% HRR every 4 weeks, up to 70–80% HRR, as tolerated.

Station 2: Mobility and balance

- 1** Walking in different directions
- 2** Tandem walking
- 3** Walking through an obstacle course
- 4** Sudden stops and turns during walking
- 5** Walking on different surfaces (carpet, foam)
- 6** Standing on a foam, balance disc or wobble board
- 7** Standing with one foot in front of the other
- 8** Kicking ball with either foot

Progressed by reducing arm support and/or by increasing speed of movement.

Station 3: Leg muscle strength

- 1** Partial squats: progressed by increasing movement magnitude.
- 2** Toe rises: progressed from bilateral to unilateral rises on either side.

Progressed by increasing number of repetitions (from 2 sets of 10 to 3 sets of 15) and/or by reducing arm support.

HRR = heart rate reserve

Table 2**Upper Extremity Program Provided to Control Group**

Station 1: Shoulder muscle strength

- 1** Theraband exercises (movements: shoulder flexion, abduction, extension, external rotation)
Progressed by increasing the resistance of theraband and increasing number of repetitions (from 2 sets of 10 to 3 sets of 15).

Station 2: Elbow/wrist muscle strength and range of motion

- 1** Dumbbell/wrist cuff weight exercises (movements: elbow flexion and extension, wrist flexion and extension)
Progressed by increasing the weight and/or increasing number of repetitions (from 2 sets of 10 to 3 sets of 15).
- 2** Passive or self-assisted range of motion to paralyzed joints.
- 3** Upper extremity weight-bearing on physio ball.

Station 3: Hand activities

- 1** Hand muscle strengthening exercises using putty and grippers (movements: pinch, grip, finger extension)
Progressed by increasing the resistance of the putty/grippers and/or increasing number of repetitions (from 2 sets of 10 to 3 sets of 15).
 - 2** Playing cards
 - 3** Picking up objects of various sizes and shapes
 - 4** Electrical stimulation (Neurotrac Sports, Verity Medical Ltd., Hampshire, England) to wrist extensors (only for those with no active wrist movements, 10 subjects)

Protocol:
Frequency: 100 Hertz; pulse duration: 150 microseconds, ON time: 10 seconds; OFF time: 10 seconds; ramp: 1 second; treatment time: 10–15 minutes.
-

Table 3**Subject Characteristics**

	Intervention Group (n=32)	Control Group (n=31)
Demographics		
Female gender (n)	13	13
Age (years)	65.8(9.1)	64.7(8.4)
Caucasian/Asian/Black (n)	20/11/1	18/13/0
Walking aid (walker/crutch/quad cane/cane) (n)	6/1/1/3	5/0/2/2
AHA Stroke Functional Classification (I/II/III/IV/V) (n)	5/17/9/1/0	2/19/8/2/0
Mini Mental Status Examination score	27.6(2.3)	28.2(1.9)
Education (years)	13.9(3.8)	13.9(3.4)
Had inpatient rehabilitation after acute hospital stay (n)	24	26
Had outpatient physical therapy after discharge home (n)	20	21
Stroke characteristics		
Paretic side (left) (n)	19	22
Ischemic stroke (n)	18	19
Post-stroke duration (years)	5.2(5.0)	5.1(3.6)
Comorbidity		
Hypertension (n)	17	20
Diabetes (n)	4	6
Arthritis (n)	6	6
Depression (n)	7	8
Osteopenia/osteoporosis		
Paretic femoral neck (n)	17/3	14/6
Non-paretic femoral neck (n)	19/2	15/5
Medications/supplements		
Beta-blockers (n)	4	5
Bone resorption inhibitors (n)	2	3
Calcium (n)	6	6
Multivitamins (n)	8	7

The mean values are presented unless indicated otherwise. The standard deviations are in brackets.

n = number of participants; AHA = American Heart Association

Table 4

Outcome Measurements

Outcome Measures		Intervention group (n=32)			Control group (n=31)			P
		Pre-test	Post-test	(95%CI)*	Pre-test	Post-test	(95%CI)*	
Primary outcomes								
VO ₂ max (ml/kg/min)	22.5 (5.2)	24.5 (5.3)	2.0 (0.8,3.1)	21.5 (4.3)	21.8 (4.5)	0.3 (-0.8,1.4)	.034 [‡]	
6MWT distance (m)	328.1 (143.5)	392.7 (151.1)	64.5 (45.3,83.8)	304.1 (123.8)	342.4 (133.4)	38.4 (25.6,51.1)	.025 [‡]	
Paretic leg muscle strength (N)	182.6 (74.3)	223.2 (99.9)	40.6 (21.0,60.2)	194.9 (68.8)	205.3 (79.4)	10.4 (-5.1,25.9)	.017 [‡]	
Non-paretic leg muscle strength (N)	248.5 (85.6)	276.7 (88.8)	28.2 (7.4,49.2)	265.6 (87.8)	272.0 (84.0)	6.4 (-12.4,25.2)	.119	
Berg Balance Score [‡]	47.6 (6.7)	49.6 (4.4)	2.1 (0.8,3.3)	47.3 (6.1)	49.2 (5.8)	1.9 (0.8,3.0)	.846	
PASIPD (MET/100/day) [§]	7.9 (7.8)	13.7 (10.9)	5.8 (1.9,9.7)	10.6 (9.8)	18.6 (16.8)	8.0 (3.6,12.4)	.452	
Paretic femoral neck BMD (g/cm ²)	0.73 (0.13)	0.72 (0.14)	-0.00 (-0.02,0.01)	0.72 (0.15)	0.70 (0.15)	-0.02 (-0.03, -0.01)	.043 [‡]	
Non-paretic femoral neck BMD (g/cm ²)	0.72 (0.12)	0.72 (0.12)	-0.01 (-0.02,0.00)	0.74 (0.17)	0.74 (0.17)	0.00 (-0.01, 0.01)	.113	
Secondary outcomes (cycle ergometry)								
RER	1.13 (0.13)	1.17 (0.14)	0.04 (0.00,0.09)	1.11 (0.11)	1.19 (0.13)	0.08 (0.03,0.12)	.233	

VO₂max=maximal oxygen consumption; 6MWT=Six Minute Walk Test; N=Newtons; PASIPD=Physical Activity Scale for Individuals with Physical Disabilities; MET=metabolic equivalents; BMD=bone mineral density; RER=respiratory exchange ratio

Standard deviations and confidence intervals are in brackets.

* (95% CI)=change from pre-test to post-test (95% confidence interval, paired t-tests)

[‡] P<.050 (time × group interaction, 2-way analysis of variance)

[‡] Total range of scores for Berg balance test = 0–56

[§] Total range of scores for PASIPD = 0.0–199.5 MET hour/day