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Feasibility of a 6-month exercise and recreation program to improve executive functioning and memory of individuals with chronic stroke

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Abstract

Background—Physical activity has been shown to be beneficial for improving cognitive function in healthy older adults. However there is limited research on the benefits of physical activity on cognitive performance after stroke.

Objective—To determine if a combined exercise and recreation program can improve the executive functioning and memory in individuals with chronic stroke.

Methods—11 ambulatory subjects with chronic stroke (mean age 67±10.8 years) participated in a 6 month program of exercise for 2 hours and recreation for 1 hour weekly. Executive functions and memory were assessed at baseline, 3, and 6 months by a battery of standard neuropsychological tests including response inhibition, cognitive flexibility, dual task (motor plus cognitive) and memory. Motor ability was also assessed. Non-parametric statistics were used to assess the differences between the three assessments.

Results—At baseline, substantial deficits in all aspects of executive functioning were revealed. From baseline to 3 mo, the mean improvement was 10±14% ($\chi^2=9.3$, $p=0.0025$) for the dual task (Walking while Talking), -3±22% ($\chi^2=2.4$, $p>0.05$) for response inhibition (Stroop test) and 61±69% ($\chi^2=8.0$, $p=0.04$) for memory (Rey Auditory Verbal Learning Test - long delay). From baseline to 6 months, the mean improvement was 7±7.5% ($\chi^2=12.0$, $p=0.007$) for response inhibition (Stroop Test). In addition, knee strength and walking speed improved significantly at 3 months.

Conclusions—This pilot study suggests that exercise and recreation may improve memory and executive functions of community dwelling individuals with stroke. Further studies require a larger sample size and a control group.

Keywords

cognitive performance; executive functions; memory; CVA

INTRODUCTION

Impairments in executive function, attention and memory (short and long term)^{1,2} have been found in 43–78% of individuals with acute stroke, depending on the type, duration and location of injury^{2, 3}. Since executive function deficits are a predictor of poor functional recovery after stroke³, (including impaired balance and mobility⁴), it is important to explore interventions which may improve cognition to prevent restrictions in activities and participation in everyday life.

Cognitive rehabilitation programs for individuals after stroke are very limited. To date remedial interventions focusing on re-training executive functions are based on the principle of providing the individual with opportunities to choose, plan and problem solve during everyday tasks, especially during complex novel tasks or situations^{5, 6}. Cicerone et al. reviewed studies addressing remediation of executive functioning and problem solving however all of the trials included individuals with brain injury and not stroke⁷. Goal Management Training⁸ is a technique found to be effective in improving executive functioning in older adults⁹ but not tested in individuals with executive functions deficits poststroke. Rand et al.¹⁰ conducted a preliminary study which showed that a functional virtual environment of a supermarket could improve executive functioning and multitasking in participants with stroke.

An alternative or supplement to traditional cognitive rehabilitation may be participation in physical activity and recreation to improve cognition. Epidemiology studies have demonstrated that engagement in leisure activities of intellectual and social nature is associated with slower cognitive decline in older adults¹¹. However, no studies have attempted to determine whether the introduction of a social or recreation program enhances cognition after stroke.

Participation in physical activity has a positive impact on the cognitive ability of healthy adults, as well as individuals with a mild cognitive deficit¹². This is presumably obtained by reducing the risk of developing various chronic diseases in combination with improved plasticity/learning. Cassilhas et al.¹³ provided a 24 week resistance training program at two different intensities compared to a control group. Their findings revealed improved cognitive function (memory, attention, working memory, visual perception and intelligence) for both groups receiving resistance exercise. Aerobic physical activity that improves cardiorespiratory fitness in healthy older adults without cognitive impairments was associated with improved cognitive speed and auditory and visual attention¹⁴. Moderate levels of aerobic exercise were also found to improve cognitive deficits already present in older adults¹⁵.

Much less work has been reported on older patients after stroke. A randomized clinical pilot study¹⁶ compared the effects of 24 sessions of aerobic cycling training to a stretching exercise program in 38 individuals with chronic stroke. The aerobic exercise program improved elements of motor learning performed by the non-affected upper extremity compared to the control group. However, no group comparisons were significant for executive functioning of the individuals tested by the Trail Making, Wisconsin Card Sort Test, and Stroop Test. Also Ploughman et al.¹⁷ found that a single session of body-weight–supported treadmill exercise did not result in improved cognition in 21 individuals with stroke. This potential avenue of intervention needs further investigation. In addition, it has been reported that individuals with chronic stroke living in the community are very inactive, which can result in further functional limitations and restrictions in participation¹⁸.

Since engagement in recreation and social activities has been associated with reducing cognitive decline in older adults¹¹, and increasing physical activity has been reported to

improve executive functions in older adults, we decided to conduct this study with individuals with stroke. The objective of this pilot study was to determine if a combined exercise and recreation program delivered twice a week for 6 months could improve the executive functioning and memory of individuals with chronic stroke who already lived independently in the community. We expected that aspects of the participants' motor ability might improve given previous literature on exercise and improved motor function post-stroke¹⁹. However, we also hypothesized that this exercise and recreation program would improve memory and executive functioning. This is the first study to examine the effect of a long-term structured exercise and recreation program on cognitive function post-stroke. We chose to run the program for 6-months since this duration of resistance or aerobic exercise has improved executive function in older adults^{4, 12, 13}.

METHODS

Participants

This study was advertised in local newspapers and community centers. Inclusion criteria included sustaining a stroke at least 12 months prior to the study, lower extremity hemiparesis, community dwelling, 50 years and older and without a general cognitive deficit with scores above 24 points on the Mini Mental State examination (MMSE). In addition, participants were required to be able to walk 3 m without physical assistance (guarded supervision permitted) but could use assistive devices (cane, walker).

The study was approved by the local university ethics board, and all eligible subjects provided written informed consent prior to participating in the study. In addition, the family physician of each participant was provided with a description of the exercise and recreation program. The family physician completed a physical activity readiness questionnaire and recommended whether their patient was appropriate for the program. General demographics were collected (age, gender, time since stroke). In addition, Basic Activities of Daily Living (BADL) were assessed by using the self-report Functional Independence Measure²⁰ and the Lawton and Brody questionnaire^{21, 22} was used to assess Instrumental Activities of Daily Living (IADL).

Outcome Assessments

The assessments were conducted in a quiet room in a research laboratory by trained examiners. The battery of tests was administered in two separate sessions lasting an hour and a half each session, to minimize fatigue. The participant's cognitive and motor abilities were assessed three times: baseline measurement prior to the exercise program and three and six months after initiating the program. In addition, participants completed an assessment of all cognitive measures one week prior to the baseline to increase familiarization and reduce practice effects. A practice session of the motor assessments was not undertaken as these were not primary outcomes of the study. No significant differences were seen between the practice session to the baseline assessments one week later for all of the cognitive tests (t-test, $p > 0.05$).

Cognitive Performance—Executive functioning was assessed by a battery of standard neuropsychological tests targeted at response inhibition, cognitive flexibility, attention and memory. *The Stroop Test* was used to assess response inhibition,^{23,24} *The Verbal Digit Span Backward Test* measured complex attention and working memory²⁵. *The Digit Symbol Test* is a valid and reliable test of psychomotor performance²⁶. *The Trail Making Test (part B)*²⁷ was used to assess visuomotor scanning, divided attention and cognitive flexibility. *Walking while Talking (WWT)* requires the ability to divide and switch attention between 2 tasks during a 20-ft walk, turn and return²⁸. Subjects walked while reciting consecutive

letters of the alphabet aloud and while reciting alternate letters of the alphabet (i.e., a, c, e, ...). We report the time it took to walk while reciting alternate letters. *The Rey Auditory Verbal Learning Test (RAVLT)* is a 15 word list learning task with 5 learning trials which assesses learning, delayed recall and long-term memory.^{29, 30}

Depressive Symptoms

The Geriatric Depression scale, a self-rating screening tool³¹, has been used in patients post-stroke with major and minor depression. A cut-off point of 10 has been reported to yield a sensitivity of 88% and a specificity of 64%³².

Motor Performance

Isometric muscle knee strength using a hand held dynamometer³³, self-selected gait speed over 5 m, and walking endurance using the six-minute-walk-test was assessed. The 5mWT is a reliable, valid and responsive measure for sub-acute stroke³⁴. The 6MWT is a reliable measure³⁵ of functional walking capacity.³⁶

Exercise and Recreation Program

The participants came to two sessions per week conducted in a gym in a rehabilitation center. The exercise program comprised two 1-hour sessions per week led by two fitness instructors. The exercises included stretching, balance, and task-specific exercises (steppers, fast walking, repetitive sit-to-stand). They were based on the Fitness and Mobility Exercise (FAME) program¹⁹ (<http://www.rehab.ubc.ca/jeng>) which has been shown to be beneficial for individuals with stroke for improving mobility, fitness and paretic leg muscle strength. The task specific exercises involved at least 20 min at a moderate aerobic challenge (“somewhat hard” on the Borg Rating of Perceived Exertion)³⁷. No equipment such as treadmills or bicycles were used. Participants were taught to work within their safely limitations but were “spotted” or supervised during any difficult exercises. The recreation and leisure sessions for 1 hour per week were led by a recreation programmer and included social activities as well as activities such as playing billiards, bowling, arts and crafts and cooking. The participants were occasionally introduced to other community-based exercise groups such as a walking and fitness class in the attempt to widen their knowledge about community resources. No cognitive training was done during these sessions but socialization and learning new skills were included.

Data Analysis

Descriptive statistics were used to characterize the sample and raw scores of the assessments. In addition, the effect size (Hedges’ g) and 95% confidence intervals are presented between baseline and 3 months, as well as baseline and 6 months. Small, medium and large effect sizes were labeled according to effect sizes of $d=0.2$, 0.5 , and 0.8 , respectively³⁸. Due to the small sample size, non-parametric statistics were used. Friedman Tests were used to assess differences among the three assessments for each variable. When significant differences were found, it was followed by Wilcoxon Tests to examine the differences between each two assessments. Data analysis was carried out using SPSS for Windows, version 15.0.

RESULTS

Participants

Twenty-five individuals requested information about the study. Fourteen subjects were excluded due to scheduling conflict to attend the sessions ($n=11$), cognitive impairment ($n=1$) and the presence of a medical problem ($n=2$; lung infection and hip replacement

surgery). Therefore, the exercise group (Table 1) included 11 participants, 3 women and 8 men. Their mean age was 67 ± 10.8 years (range 50–85 years). They were on average 4.4 ± 2 years post stroke and they all lived at home; 2 of them lived alone while 9 participants lived with a spouse. All 11 participants could walk independently; 5 required a walking aid. Their mean gait speed was 1.0 ± 0.51 m/s and they could walk a mean 248 ± 106 meters in 6 minutes. The mean MMSE score was 27 ± 2 (range 24–30). They were all independent in BADL (mean FIM score 121 ± 5.6 points) and in most of the IADL (20.5 ± 1.8 points out of the maximum 23 points on the IADL questionnaire). Ninety percent of the participants attended 90% of the sessions, which was considered satisfactory for this pilot study. One subject missed a few sessions due to shoulder pain from an old injury. One participant with a prior history of knee pain experienced increased knee pain with the exercise. The exercises were then adapted to reduce knee loading. All of the other participants attended all of the bi-weekly sessions. No subjects dropped out of the study.

Cognitive Performance and Depressive Symptoms—The mean raw scores on each of the three assessments are presented in Table 2. On the three month assessment, the Trail Making Test, RAVLT (short delay), RAVLT (long delay), and WWT all had means which were more than 10% improved from baseline values with small to medium effect sizes. On the six month assessment, the Digit span backwards, RAVLT (long delay) and the Stroop Test had means which were more than 7% improved from 3-month values with small effect sizes.

Significant main effects (time) were found for the RAVLT (long delay) ($\chi^2=8.0$, $p=0.04$), WWT ($\chi^2=9.3$, $p=0.0025$) and Stroop Test ($\chi^2=12.0$, $p=0.007$). Post-hoc analysis of the main effect found significant improvements with a small to medium effect size for the RAVLT (long delay) from baseline to 3 months ($z=-2.17$, $p=0.03$). In addition, we found significant improvements with a small effect size of the WWT from baseline to 3 months ($z=-2.0$, $p=0.04$). Lastly, there was a significant improvement for the Stroop Test with a small effect size from baseline to 6 months ($z=-0.6$, $p=0.02$). No significant changes were seen for the scores of the Geriatric Depression Scale. Although there was a medium effect size for the Trail Making Test from baseline to 3 months and baseline to 6 months, this effect was not significant likely from a type II error given the small sample size. (AU: speaking of statistical errors, at some point you ought to account for multiple testing of outcomes)

Motor Performance

Motor abilities (Table 3) improved over the three time points for all measures, knee strength ($\chi^2=6.0$, $p=0.05$), gait speed ($\chi^2=7.8$, $p=0.02$), and 6MWT ($\chi^2=15.2$, $p=0.001$). The majority of the improvements occurred between baseline and 3 months and a plateau occurred from 3 to 6 months. Between baseline and 3 months, knee strength improved 49% (medium to large effect size, $z=-2.3$, $p=0.01$), gait speed improved 16.1% ($z=-2.0$, $p=0.03$) and 6MWT improved 13.9% ($z=-2.8$, $p=0.005$). 6MWT improved by an additional 1% between 3 and 6 months with a small effect size ($z=-2.9$, $p=.003$).

DISCUSSION

The eleven participants in this 6-month recreation and exercise program were relatively high functioning in basic activities of daily living. Although they all walked independently, their gait speed and walking endurance was not sufficient for independence in community activities³⁹. On baseline, their gait speed ranged from 0.3–1.3 m/s and only one subject succeeded in walking 400 m during the six-minute walk test. A walking distance less than 400 m within 6-minutes has been associated with higher risk of mortality⁴⁰.

Although our participants achieved high scores on the MMSE, indicating that they did not have dementia, they demonstrated deficits in all measures of executive functioning. The MMSE is known to be relatively insensitive to executive function deficits⁴¹. Specifically, deficits in divided attention, cognitive flexibility, working memory, learning and retention were found compared to values from the literature of healthy older adults^{42–44} and seniors in retirement facilities⁴⁵. For example, on baseline our participants could recall 3.5 words after a short delay and 4.2 words after a long delay from the 15-word RAVLT. This is approximately 70% less than subjects aged 60 years old and 50% less than subjects aged 75 years old⁴³. Our participants also presented decreased abilities in executive functions even after the 6-month program, as assessed by the Stroop Test and Trail Making Test. The completion time of the Stroop test of our sample at baseline and at 6 months was 48% and 44%, slower than 140 senior women who lived independently in the community⁴⁴ (using the identical Stroop version). The scores of the Digit Symbol Test of our subjects were approximately 50% lower than those of seniors living in retirement facilities⁴⁵, which demonstrates psychomotor slowness.

During the group intervention, as demonstrated in other studies^{18,46}, the motor abilities of the participants improved significantly between baseline and the 3-month assessment and for walking endurance an additional improvement was seen from 3 to 6 months. On baseline, 6 of the 11 individuals had walking speeds less than 1.1 m/s but at 6-months, all but 3 subjects had reached or passed the threshold of 1.1 m/s. Walking speed of 1.1 to 1.5 m/s is considered to be adequate to cross the road safely³⁹. The mean improvement in walking endurance for our group was 42 meters which is outside of the 18.6 m standard error of the measure⁴⁷.

Our results suggest that exercise and recreation had a positive effect on verbal memory, but not working memory. Long delayed recall improved to norms of healthy older adults,⁴³ reaching 6.8 words at 6 months. On the other hand, our exercise and recreation program did not affect working memory as assessed by the Digit Backwards Test. Although deficits in both verbal and working memory were present in our sample, potential for cognitive improvements are likely to depend in part on the size and location of the stroke. The type of rehabilitation may influence the outcome on specific cognitive domains, such as the Digit Span.⁴⁸

Although our exercise and recreation program did not specifically practice dual task activities, we found that cognitive flexibility, as assessed by the WWT, improved. Our program did challenge dual task interference, because all the exercise activities required participants to simultaneously perform physical activities while performing cognitive tasks such as counting, following verbal instructions and performing group exercises. Interference between cognition and gait or postural control is elevated in individuals with stroke^{49–51}. Improvements in executive function may allow the individual to allocate the appropriate attentional resources to motor tasks.

The changes with duration of exercise have important implications for the prescription of exercise to improve cognition. Although 20 minutes of treadmill training have been found to improve executive functions in normative populations⁵², Ploughman et al.¹⁷ found that a single session of body-weight-supported treadmill exercise did not result in improved cognition (including the Trail Making Test A and B, Symbol Digit Substitution Test, and Paced Auditory Serial Addition Test) in 21 individuals with stroke. Quaney et al.¹⁶ did find that 8 weeks of aerobic training improved selected cognitive domains related to motor learning, but not the executive functioning of individuals with chronic stroke. The majority of changes in cognitive performance in our study occurred after 3 months of training and suggests that sustained physical activity and recreation over several months is required for

cognitive improvements. An exception was the significant improvement for the Stroop, which was seen only at 6 months. Although aerobic programs have demonstrated improvements in the Stroop after 3 months in older adults⁵³, these aerobic-based programs had a high level of intensity and perhaps more potential for inducing neuroplasticity.

A large variance was seen in the baseline cognitive abilities and changes post-intervention of the 11 subjects. This variance may stem from the different lesions in our sample as well as gender effects. Studies that included more women than men resulted in a much higher average effect size for exercise interventions on cognitive function (0.60) compared to studies with samples which included more men than women (0.15)⁵⁴.

Scientists have offered various explanations for the possible effect of physical activity on cognitive performance in healthy individuals and animal populations^{55, 18} but not for the stroke population. For example, in rats, aerobic training increases levels of brain-derived neurotrophin factors (BDNF)^{56, 57} among other important neurochemicals⁵⁷, which, in turn, increases neuronal survival⁵⁸, synaptic development, and plasticity⁵⁹. This results in a more efficient, plastic, and adaptive brain, which translates into improved learning and performance in adult animals⁶⁰. Furthermore, neuroanatomical studies show that the same benefits seen in aging animals may extend to aging humans⁶¹. These effects were greatest in the frontal, prefrontal, and parietal cortices⁶¹. These regions of cortex also show the greatest age-related declines in humans and are thought to support executive-controlled processes. Exercise can improve mood and lessen depression, which may affect cognitive function⁶², although we did not find significant changes in depressive symptoms.

Limitations

Limitations of this pilot study include the lack of a control group receiving an alternative program of equal intensity but perhaps with different components. The study also included a very small sample size of individuals with diverse lesions. Given the selected alpha of 0.05 and our inclusion of 16 statistical comparisons, it is possible that one comparison was significant by chance alone. No adjustment for multiple endpoints were made since in a proof-of-concept study a Type II error is of more concern than a Type I error⁶³. More so, our program offered only a modest intensity of aerobic exercise and other activities. The group format promoted social engagement while the recreation program facilitated leisure activities. Perhaps the addition of social and recreation engagement to exercise is one reason why our study demonstrated improvements in executive functioning. Leisure activity and social engagement⁶⁴ are associated with better cognitive function in older adults, but the dose is unclear. We cannot determine whether the positive impact on executive functions was due to exercise, recreation social aspects of the programs or a combination of these components. The results of this pilot study do suggest that a combined exercise and recreation program may improve executive functioning and memory of individuals living independently in the community with chronic stroke.

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Table 1

Individual demographic and stroke information

Subject	Age	Sex	Years of education	Affected hemisphere	Stroke type	First/recurrent stroke	Years since stroke	MMSE
01	70	F	15	Left	Ischemic	First	1.2	27
02	51	M	12	Right	Ischemic	First	1.6	28
03	72	M	15	Left	Ischemic	First	8	25
04	50	F	9	Left	Ischemic	Recurrent	9.5	29
05	69	M	12	Right	Hemorrhage	First	8	25
06	70	M	14	Right	Ischemic	First	3.5	29
07	85	M	15	Right	Hemorrhage	First	4.5	24
08	75	M	12	Right	Ischemic	First	5.5	29
09	70	M	13	Left	Ischemic	First	4.5	26
10	55	M	14	Right	Ischemic	First	1	25
11	74	F	11	Right	Ischemic	Recurrent	2	30

MMSE – Mini Mental State Examination; F- Female; M- Male

Table 2

The mean, SD and range of the raw scores of the Neuropsychological assessments and depressive symptoms at three points in time. The effect sizes and 95%CI of the 0–3 months and 0–6 months are presented as well.

Assessment	Baseline	3 months	6 months
	Mean±SD Range	Mean±SD Range Effect size 0–3 months (95%CI)	Mean±SD Range Effect size 0–6 months (95%CI)
Digit backwards (0–14)	2.0±1.9 0–6	2.1±1.8 0–6 -0.05 (-0.89, 0.78)	2.2±2.0 0–6 -0.09 (0.93, 0.74)
Trail Making Test (sec)	191.0± 92.6 74–344	152.5±58.4 78–265 0.48 (-0.37, 1.33)	145.3±52.2 82–233 0.58 (-0.27, 1.44)
RAVLT (short delay) (0–15)	5.5±2.9 0–11	6.6±2.6 2–11 -0.04 (-0.88, 0.97)	6.9±2.9 1–11 -0.04 (-0.88, 0.79)
RAVLT (long delay) (0–15)*	5.3±3.2 0–11	7.0±2.2 3–12 -0.59 (-1.45, -0.26)	6.8±3.5 1–13 -0.43 (-1.28, 0.42)
Walking While Talking (sec)*	21.2±6.6 10–30	18.6±5.1 10–26 0.42 (-0.42, 1.27)	19.3±6.4 10–30 0.28 (-0.56, 1.12)
Digit symbol	17.8±6.8 5–29	18.0±5.7 10–28 -0.03 (-0.87, 0.81)	18.6±6.2 8–29 -0.11 (-0.95, 0.72)
Stroop Test (sec)#	184.3±89.3 106–402	186.1±91.3 100–422 -0.02 (-0.86, 0.81)	173.4±84.3 89–371 0.12 (-0.72, 0.96)
Geriatric Depression Scale	4.2±4.7 0–16	6.0±5.8 0–17 -0.32 (-1.17, 0.51)	5.2±6.4 0–17 -0.17 (-1.01, 0.67)

Significance difference between baseline and 3-months (*), baseline and 6-months (#) Negative effect size indicates improvement for Digit Backwards, RAVLT, and Digit Symbol.

Table 3

The mean, SD and range of the mobility measures at three points in time. The effect sizes and 95% CI of the 0–3 months and 0–6 months are presented as well.

Assessment	Baseline	3-months	6-months
	Mean±SD Range	Mean±SD Range Effect size 0–3 months (95% CI)	Mean±SD Range Effect size 0–6 months (95% CI)
Knee strength (kg)*	12.3±4.5 2.8–19.8	16.0±5.4 10.7–26.6 -0.71 (1.58–0.15)	16.0±6.7 5.5–24.4 -0.62 (1.48, 0.23)
Gait speed (m/s)*	1.0± 0.51 0.32–1.86	1.17± 0.47 0.56–1.91 -0.33 (-1.17, 0.51)	1.1±0.50 0.6–2.0 -0.19 (-1.03, 0.65)
6MWT (distance in meters)*#	248.4±105.9 112–454	288.4±108.5 127–476 -0.35 (-1.20, 0.48)	291.0±105.8 155–511 -0.38 (-1.23, 0.46)

Significance difference between baseline and 3-months (*), baseline and 6-months (#) Negative effect size indicates improvement in knee strength, gait speed and 6MWT.