The Acute Effects of Aerobic Exercise on Cognitive Control among People with Chronic Stroke

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Background: Over half of stroke survivors have cognitive impairment, which impedes rehabilitation and functional recovery. Evidence suggests a single session of aerobic exercise improves cognitive functions among healthy adults. Whether this holds true for stroke survivors is unclear. The objective of this study was to examine whether one session of moderate-intensity aerobic exercise improves the cognitive control and attention of stroke survivors. *Methods:* Nine people with chronic stroke (≥6 months poststroke) performed a modified Eriksen Flanker task with concurrent electroencephalography (EEG) before and immediately, 20 minutes, and 40 minutes after 20 minutes of moderate-intensity exercise and after 20 minutes of rest. The sessions were in randomized order. Accuracy and response time were recorded for congruent and incongruent stimuli. Differences in accuracy, response time, and event-related potentials (P300, reflective of decision making) were analyzed using repeated measures analysis of variance. *Results:* Improvements in EEG measures were noted after exercise. P300 amplitude at Fz was greater 40 minutes after exercise compared with after rest ($P = .007$). P300 latency was also shorter at 20 minutes after exercise compared with after rest for both congruent (465.8 milliseconds versus 500.0 milliseconds; $P = .02$) and incongruent (468.0 milliseconds versus 532.0 milliseconds; $P = .003$) conditions at the central electrode on the lesional side. Differences in behavioral performance after exercise were not significant. *Conclusions:* Preliminary results suggest that aerobic exercise improves cortical processes underlying cognitive control and attention 20-40 minutes postexercise. Future research should confirm results in a larger sample and examine whether attention-demanding rehabilitation in this window has improved outcomes.
Key Words: Stroke—chronic stroke—exercise—cognitive function—cognitive control—attention—electroencephalography.

Introduction

Stroke is a leading cause of adult disability.[1-3] Although traditional rehabilitation focuses primarily on physical impairments, over half of stroke survivors have cognitive impairment.[4] Cognitive impairment after stroke may impede rehabilitation and functional recovery.[5] In addition, people with cognitive impairment after stroke are less likely to live independently and report poorer quality of life.[5,6] Cognitive control and attention are arguably the most frequently impaired cognitive processes.[7,8] Cognitive control (alternatively referred to as "executive control"), in particular, is associated with reduced functional abilities among people with chronic stroke.[9]

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Aerobic exercise may improve physical recovery among stroke survivors.[10] Increasing evidence also suggests that aerobic exercise can improve cognitive functions,[11,12] although most studies have been conducted among healthy individuals. Exercise seems to exert a small, positive effect on cognitive functions after a single exercise session and after a period of exercise training.[11,12] Interestingly, cognitive control and attention, the cognitive processes most frequently affected after stroke, appear to be preferentially affected by exercise.[11] This suggests the possibility that aerobic exercise, already advocated for physical recovery, may improve cognitive functions after stroke.

Only one study has examined the influence of a single session of aerobic exercise on cognitive functions after stroke.[13] Skilled movement improved after aerobic exercise, but cognitive functioning did not.[13] However, this study was restricted by the use of paper-and-pencil cognitive measures which may not be sensitive enough to capture the effect of exercise on people with stroke whose physical impairments may cause more variability in the speed of movement. Event-related potentials (ERPs) recorded with electroencephalography (EEG) quantify the cortical processes underlying cognitive functioning and may be more sensitive to exercise-related changes in cognitive functions, especially among people with physical impairment who may have variable movement speed. Evidence suggests that attention allocated to a task (P300 amplitude) and speed of processing (P300 latency) improve during a task requiring cognitive control and attention after a single session of aerobic activity among healthy adults.[14-16]

Optimistically, if one session of aerobic exercise can improve cognitive functions for some time after exercise, then coupling aerobic exercise with traditional stroke rehabilitation may improve outcomes. The objective of this study was to examine the effect of a single session of aerobic exercise on cognitive control and attention for up to 40 minutes after exercise. Cognitive control was quantified with a computerized modified Flanker task with concurrent EEG (P300 ERP).[17] The Flanker task is a choice reaction time task that requires participants to react to a target stimulus and ignore the flanking distractor stimuli. Prior studies of acute exercise effects among healthy adults have used the Flanker task to characterize inhibitory control (incongruent condition where target and flanking stimuli are different) and attention (congruent condition where target and flanking stimuli are the same). (See References 14-16 for examples.) A secondary objective was to examine the time course of cognitive changes in order to define a potential treatment window.

Materials and Methods

Participants

Participants were recruited from the University of Waterloo Neurological Patients' Database, a registry of stroke survivors interested in participating in research, between October 2013 and February 2014. Eligibility criteria included (1) 18 years of age or older; (2) ischemic or hemorrhagic stroke at least 6 months prior; (3) sufficient cognitive ability to understand instructions; (4) full use of at least one arm and hand; and (5) no other orthopedic or neurological problems affecting the lower limb and trunk. Individuals were excluded if they had (1) uncontrolled diabetes, hypertension, or cardiovascular morbidity that limited exercise tolerance; (2) visual field deficits that would impact cognitive testing; or (3) major neurological comorbidities. Of 33 eligible candidates, 8 of the 10 who were interested were deemed safe to exercise by their physician. An additional community member expressed interest in participating and was eligible, leaving 9 participants. The study was approved by the University of Waterloo Office of Research Ethics. All participants provided informed consent.

Study Design

This study used a repeated measures design. Each participant completed a baseline session and 2 experimental sessions. During the baseline session, participants reported age, medical history, medications, and physical activity history and confirmed physician approval for exercise (using the Physical Activity Readiness Medical Examination).[18] Assessments included measurement of height and weight. The Chedoke-McMaster Stroke Assessment (arm and leg) was used to characterize physical impairment, and the Montreal Cognitive Assessment was used to characterize global cognitive function.[19,20] Stroke information was extracted from the Neurological Patients Database. A submaximal exercise test and 140 practice trials of the modified Eriksen Flanker task, the minimum number necessary to eliminate potential practice effects, were also conducted at baseline, as described below.[21]

Experimental sessions included a rest and an exercise session in randomized order (determined by a coin toss). Participants completed at least 30 practice trials of the modified Eriksen Flanker task prior to testing in each session. Participants then performed a modified Eriksen Flanker task with concurrent EEG recording before and immediately (0 minutes), 20 minutes, and 40 minutes after 20 minutes of quiet rest or moderate exercise on a semirecumbent stepper (NuStep, Ann Arbour, MI). Rest and exercise sessions were completed at the same time of day to limit circadian rhythm effects. All participants were asked to abstain from caffeinated beverages and exercise on testing days.

Submaximal Exercise Test

During the baseline session, participants completed a submaximal exercise test on the semirecumbent stepper to determine the work rate for the exercise session (45%-55% of heart rate [HR] reserve). The protocol was modified