Feasibility of Aerobic Interval Training in Nonambulant Persons after Stroke

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ABSTRACT

Background: Modifiable cardiovascular risk factors are prevalent and poorly managed in people after stroke. Aerobic exercise is effective in reducing many modifiable cardiovascular risk factors after stroke but is challenging and under-researched in nonambulant persons. This pilot study aimed to investigate the feasibility of aerobic interval training in nonambulant persons after stroke.

Methods: Aerobic exercise was performed on an upright or semi-recumbent cycle ergometer. Participants were prescribed 4×4-min intervals of exercise at 85% maximum age-predicted heart rate ($APHR_{max}$) with a 3-min active recovery at 70%$APHR_{max}$ per 30-min session, 3 times per week for 10 weeks. Heart rate, rating of perceived exertion, workload, cadence, and duration of exercise achieved were recorded for each interval.

Results: Nine participants (mean ± SD; age 62 ± 12 y; 5 males) unable to walk without assistance after stroke (2.9 ± 3.9 y) were recruited. There were no adverse events reported, but there was one dropout (due to bronchitis). Attendance for the remaining participants was 93 ± 6%. The mean training %$APHR_{max}$ was 72 ± 14% for the higher intensity interval and 57 ± 21% for the recovery interval. The mean increase in training workload between weeks 1 and 10 was 11.2 ± 11.6 W (27 ± 28%) for the higher intensity interval and 4.0 ± 7.7W (17 ± 33%) for the recovery interval. The mean increase in VO_{2peak} was 2.3 ± 2.9 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ (18 ± 22%) over the 10-week intervention.

Conclusion: Aerobic interval training at a moderate-vigorous intensity on an upright or recumbent cycle ergometer is feasible for nonambulant persons after stroke. Aerobic interval training should be further investigated to determine its potential to improve cardiorespiratory fitness after stroke and risk factors for recurrent stroke. *Journal of Clinical Exercise Physiology*. 2019;8(3):97–101.

Keywords: exercise, physical activity, cardiovascular risk, secondary prevention

INTRODUCTION

People with stroke are at increased risk of subsequent cardiovascular events, with the cumulative risk of stroke recurrence being 26.4% at 5 years (1). Modifiable cardiovascular risk factors (e.g., obesity, hypertension, hyperglycemia, and dyslipidemia) are extremely prevalent and poorly managed in people with mild-to-moderate hemiparetic weakness after stroke (2,3).

A recent meta-analysis reported the effectiveness of aerobic exercise in reducing many modifiable cardiovascular

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TABLE 1. Eligibility criteria for participants recruited for the upper limb rehabilitation study.

Inclusion Criteria
≥16 years old
Clinical diagnosis of ischemic or hemorrhagic stroke
Upper limb movement deficit, i.e., score <52 on the ARAT or <63 on the WMFT
Able to undertake aerobic exercise training
Medical clearance
Exclusion Criteria
Upper limb movement deficits attributable to nonstroke pathology
Unable to lift hand off lap when asked to place hand behind head (gross motor task from the ARAT)
Severe fixed contractures of elbow or wrist (i.e., grade 4 on the modified Ashworth scale)
Moderate to severe receptive aphasia (<10 on 'receptive skills' of Sheffield Screening Test for Acquired Language Disorders)

ARAT = Action Research Arm Test; WMFT = Wolf Motor Function Test

risk factors after stroke, including reducing systolic blood pressure, fasting glucose, and fasting insulin, and increasing high-density lipoprotein cholesterol, providing evidence for its use as a secondary prevention strategy (4). The current guidelines for physical activity and exercise after stroke state that multiple shorter bouts of moderate-intensity exercise may be better tolerated by stroke survivors than longer continuous exercise (5). Continuous vigorous exercise may be challenging to sustain for many people after stroke, which may decrease exercise adherence (6). Interval training involves concentrated bouts of relatively vigorous exercise interspersed with bouts of recovery of varying duration and intensity and is feasible in the subacute stage of recovery from mild-moderate stroke (7). A study examining the effects of 3 different exercise interventions reported that 30 min of moderate-intensity aerobic exercise was more effective in reducing systolic and diastolic blood pressure, total cholesterol, and triglycerides than either 60 min of lower intensity aerobic exercise or nonaerobic exercise in persons independently ambulant after stroke (8).

The recent meta-analysis by D'Isabella et al. (4) reported that only 1 of the 18 studies included had enrolled severe or nonambulatory participants, and this study used only low-intensity aerobic exercise (9). Another meta-analysis highlighted the lack of studies investigating whether improved levels of cardiorespiratory fitness (CRF) can be obtained in those with greater impairments after stroke (10). Considering the risks of sedentary behavior for secondary stroke (11), as well as the sedentary nature of being nonambulant after stroke, it is reasonable to assume that these individuals are at a high risk of secondary events. Although it may be more challenging to establish effective exercise interventions for them, given the potential for greater benefits and better tolerability of interval training compared to longer continuous exercise, further research to establish its feasibility was warranted. This pilot study aimed to investigate the feasibility of aerobic interval training in nonambulant persons after stroke.

METHODS

This is a convenience sample of participants recruited for a pilot, randomized, controlled, upper limb rehabilitation study that used aerobic interval exercise training in one arm of the study (eligibility criteria presented in Table 1) (12,13). This brief report presents pre-post data on the subgroup of participants who were not ambulant and were randomized to the intervention that included aerobic interval exercise.

Aerobic interval training was performed in a university exercise rehabilitation research laboratory on a low entry level upright (928G3, Monark, Sweden) or semi-recumbent (RT2, Monark, Sweden) cycle ergometer. The specific ergometer was prescribed according to individual ability and impairment. Age-predicted maximum heart rate ($APHR_{max}$) was calculated as 220-age, as recommended by the physical activity and exercise guidelines for stroke survivors (5,14). Participants were prescribed 4×4-min intervals of high-intensity exercise (85% of $APHR_{max}$) with a 3-min active recovery (70% of $APHR_{max}$) period between each interval (7), 3 times a week for 10 weeks. Heart rate (T31, Polar), rating of perceived exertion (Borg 6–20) (RPE), workload in Watts (W), cadence (RPM), and duration of exercise achieved were recorded by an exercise scientist in the last 15 seconds of each interval. Workload was progressively adjusted with the aim of maintaining the target heart rates or, where not tolerable, an RPE of 14 to 16 during the higher intensity interval and 12 to 13 for the recovery interval.

An incremental cycle ergometer test was performed at baseline and follow-up during which oxygen consumption was measured by a portable metabolic system (K4b2, Cosmed, Rome, Italy), while cardiac rhythm and HR were recorded by a portable electrocardiogram (ECG) (Quark T12, Cosmed, Rome, Italy). Participants pedaled at 50 to 60 RPM beginning at a workload of 20W. Workload increased by 10W increments every 30 seconds by adjusting resistance. Gas exchange data were collected breath-by-breath and averaged over 30 second intervals. Peak oxygen consumption (VO_{2peak}), HR_{peak}, and peak respiratory exchange ratio (RER) were determined as the highest value obtained during 30 seconds of exercise. HR and RPE (15) were also manually recorded every 30 seconds.

Descriptive statistics were calculated and presented as means and standard deviations, or counts and percentages. The primary outcome of this study was the mean training $\%APHR_{max}$ values during the intervals. Effect sizes were calculated as Cohen's *d*.

RESULTS

Nine participants nonambulant after a stroke were recruited. Table 2 presents participant characteristics at baseline.

There were no adverse events reported, but 1 participant dropped out due to bronchitis. Attendance for the remaining 8 participants was 93±6% (i.e., 28±2 out of 30 sessions). The mean training $\%APHR_{max}$ at the end of each interval was 72±14% for the higher intensity interval and 57±21% for the recovery interval. When the mean training HR values were expressed relative to peak HR achieved in the baseline incremental cycle ergometer test, this was 92±9% HR_{peak} for the higher intensity interval and 83±6% HR_{peak} for the recovery interval. All participants except one achieved ≥85% APHR at least once during the program with the mean number of times being 28±49 of the 120 intervals over the 30 sessions. The mean change in training workload was 11.2±11.5W (27±28%) for the higher intensity interval and 4.0±7.7W (17±33%) for the recovery interval. The mean VO_{2peak} was 13±4.5 $mL \cdot kg^{-1} \cdot min^{-1}$ at baseline and 15.3±3.8 $mL \cdot kg^{-1} \cdot min^{-1}$ at follow-up, showing a mean improvement of 2.3±2.9 $mL \cdot kg^{-1} \cdot min^{-1}$ (18±22%) over the 10-week intervention period. The mean RER was 1.09±0.17 at baseline and 1.22±0.17 at follow-up. The mean peak HR was 77±17%$APHR_{max}$ at baseline and 79±15%$APHR_{max}$ at follow-up. The mean workload was 68±33W at baseline and 84±37W at follow-up, showing a mean increase of 17±23W (25±34%).

Using the effect sizes of change in VO_2 ($d=0.55$) and peak workload ($d=0.47$) from this study, the estimated sample size for a subsequent randomized controlled trial to investigate efficacy of aerobic interval training is 53 participants per group to detect a statistically significant 2.3±2.9 $mL \cdot kg^{-1} \cdot min^{-1}$ change in VO_{2peak}, and 77 participants per group to detect a statistically significant 17±23W change in peak workload ($\alpha=0.05$, $\beta=0.8$).

DISCUSSION

Aerobic interval training on a cycle ergometer is feasible in nonambulant persons after stroke. Attendance was good, there were no adverse events, and there was only 1 drop-out unrelated to the study intervention. Compliance to the exercise training protocol was good with participants demonstrating an ability to perform high-intensity training, and on average performed at a vigorous intensity (72±14%), as measured by $APHR_{max}$. Although this vigorous intensity was lower than targeted (85% $APHR_{max}$), higher intensities may not be achievable in this population as this represented 92±9%HR_{peak} for the higher intensity interval and 83±6% HR_{peak} for the recovery interval based on the HR_{peak} of the baseline incremental cycle ergometer test. Comparable interval parameters have previously been shown to be feasible for persons with mild to moderate impairment after stroke, who were able to perform aerobic interval training at 85% to 95% of HR_{peak} (7) but, to our knowledge, this is the first study to show that this intensity of interval training is also feasible for nonambulant persons after stroke.

TABLE 2. Participant characteristics at baseline. Data are mean±SD or n (%).

Age (y)	62.1±11.7
Male	5 (56)
Months since stroke	34.6±46.3
Paresis of prestroke dominant side	6±67
No comorbidities	4 (44)
Comorbidities	
Hypertension	4 (44)
Atrial Fibrillation	1 (11)
Heart valve replacement	1 (11)
Bilateral lung transplant	1 (11)
Shortness of breath	2 (22)
Asthma	1 (11)
Bilateral knee replacement	2 (22)
Osteoporosis	1 (11)
Thyroid disease	1 (11)
Factor V Leiden mutation	1 (11)
BMI	26.9±5.5
WHR	
Males	0.95±0.04
Females	0.82±0.04
MoCA	22±5
FAS	28.1±8.0
IPAQ	1.8±0.7

BMI = Body Mass Index; WHR = Waist-to-Hip Ratio; MoCA = Montreal Cognitive Assessment (max = 30; normal ≥ 26); FAS = Fatigue Assessment Scale (max = 50; fatigue cut-off ≥24); IPAQ = International Physical Activity Questionnaire (1 = low, 2 = moderate, 3 = high)

It should be noted that the physical activity and exercise guidelines for stroke survivors state that prescribing exercise training based on data from a symptom-limited (other than cardiopulmonary limited) exercise test may result in a lower training intensity than desired, as HR_{peak} may underestimate true HR_{max}. Conversely, $APHR_{max}$ may overestimate true HR_{max}, resulting in a higher intensity than desired. This prescription challenge is reflected in the variance between the $\%APHR_{max}$ and $\%HR_{peak}$ values exhibited by our participants during training. HR_{peak} from an incremental cycling test after stroke often occurs at approximately 74% to 86% of $APHR_{max}$ (5), as was observed in our participants who peaked at 77±17%$APHR_{max}$ at baseline and 79±15%$APHR_{max}$ at follow up.

Our participants improved CRF by 2.3±2.9 $mL·kg^{-1}·min^{-1}$ (18±22%) with 10 weeks of training 3 times per week. A previous meta-analysis calculated that a 2 $mL·kg^{-1}·min^{-1}$ or 10% to 15% improvement in CRF can be achieved by people with stroke after an exercise training intervention (10). Data from our small sample indicates that nonambulant persons may have the same capacity to improve CRF as ambulant persons after stroke. Improving CRF lowers the risk of first-ever stroke and mortality in persons with and without atrial fibrillation, diabetes mellitus, and hypertension (16,17). Given the sedentary nature of this population, the importance of exercising at an intensity sufficient to improve CRF is reflected by a large study (n=26,483) in people without known cardiovascular disease that found that estimated CRF, but not physical activity, abolishes the increased odds of cardiovascular risk factors associated with sedentary behavior which is ubiquitous after stroke (18,19).

Further research is needed to determine the importance of CRF in the prevention of secondary stroke, as well as the effectiveness of aerobic interval training in improving CRF and cardiovascular risk factors for nonambulant persons after stroke. Developing exercise interventions to avoid subsequent stroke has been identified as a *top ten* research priority by persons after stroke, as well as their caregivers and therapists (20).

CONCLUSION

Aerobic interval training at a moderate-vigorous intensity on an upright or recumbent cycle ergometer is feasible and safe for nonambulant persons after stroke. It should be further researched to investigate its potential to improve CRF after stroke and risk factors for recurrent stroke.

Clinical Implications

- Moderate-vigorous aerobic interval training on a cycle ergometer is feasible in nonambulant persons after stroke.
- A small sample of nonambulant persons after stroke demonstrated similar capacity to improve cardiorespiratory fitness as their ambulant peers.

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