Exercise Intensity Modulates the Change in Cerebral Blood Flow Following Aerobic Exercise in Chronic Stroke: a PCASL Study

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Target Audience: Those interested in exercise and cerebral hemodynamics.

Purpose: Stroke rehabilitation best practice guidelines list exercise intensity as a critical factor to elicit recovery and health benefits,[1] and recommend training at 40 to 70% of heart rate reserve (HRR).[2] There remain, however, unanswered questions about the relationships of frequency, intensity, duration and type of exercise with improvements in brain health. The purpose of the current study was to assess the intensity-effect of aerobic exercise on cerebral blood flow (CBF) immediately following low and moderate intensity cycling in a clinical cohort of stroke survivors.

Methods: Thirteen participants with prior stroke (age: 64 ± 15 years, 4 women, 11 with ischemic stroke, time post stroke: 19 ± 16 months) were recruited. Following a symptom-limited exercise stress test to determine cardiopulmonary fitness, participants engaged in 20 min of submaximal cycling exercise at low (45% HRR) and moderate (65% HRR) intensity on separate days. Magnetic resonance images were acquired at 3-T (Philips Achieva). Structural imaging included T1-weighted (voxel dimensions=0.9x0.7x1.2 mm^3, flip angle=8°, and TR/TE=9.5/2.3 ms) and fluid-attenuated inversion recovery acquisitions (voxel dimensions=0.4x0.4x3.0 mm^3, and TR/TI/TE=9000/2800/125 ms) to characterize the lesion burden. Pseudo-continuous arterial spin labeling (PCASL) was performed to estimate CBF before exercise, and at 30 and 50 min post-exercise. The PCASL sequence acquired 30 control and 30 tag images (voxels=3x3x5 mm^3, flip angle=90°, TR/TE=4000/9.6 ms, post-label delay=1600 ms). Post-processing of PCASL data included motion correction, control-tag differencing, and spatial smoothing (5-mm full-width half-max kernel). CBF quantification involved a proton density estimate and consensus parameter constants.[3] CBF images were registered to 3-mm isotropic standard space for voxel-wise comparison. One-way, repeated measures ANOVA were performed to assess the change in CBF over time using Randomise software (FSL) with 5000 permutations to characterize the null distribution.[4] Separate analyses were designed to test: 1) the effect of time (i.e., rmANOVA on the mean of the CBF images at each time point, collapsed across the low and moderate intensity exercise sessions); and 2) the interaction of time and exercise intensity (i.e., rmANOVA on the difference of the CBF images at each time point, between the low and moderate intensity exercise sessions). To account for type I error, without excessive stringency so as to invite type II errors, we used an uncorrected $p \leq 0.005$ and a cluster size≥10 voxels to identify significant brain regions.[5] Post-hoc, paired comparisons of CBF within the identified regions were completed to characterize the direction of the effects of time and intensity, using a false discovery rate (FDR; q=0.05) to correct for multiple comparisons.

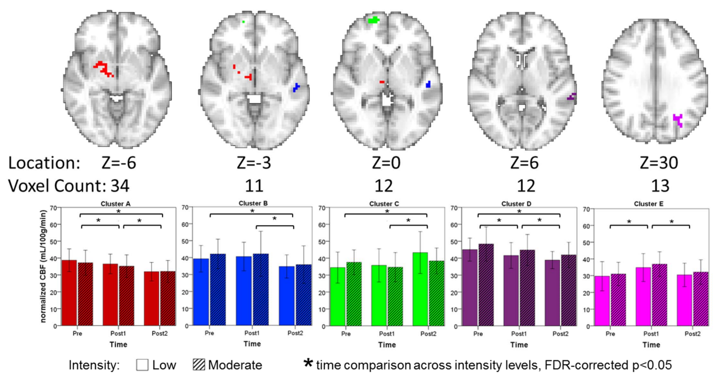

Figure 1. CBF 30 min (Post1) and 50 min (Post2) after cycling: regions of **similar response** to low (open bars) and moderate (hashed bars) intensity exercise.

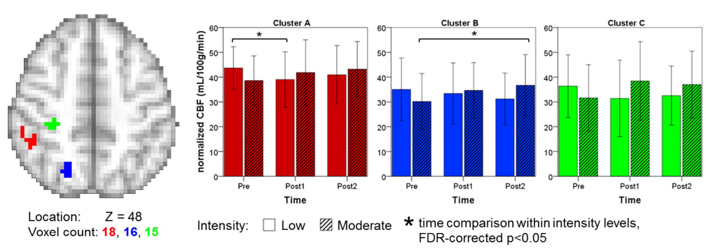

Figure 2. CBF 30 min (Post1) and 50 min (Post2) after cycling: regions of **differential response** to low (open bars) and moderate (hashed bars) intensity exercise.

Results: Up to 50 min following both low and moderate intensity exercise, CBF was elevated in the right frontal pole (Fig. 1, Cluster C). A more transient increase in CBF was noted in the left angular gyrus (Fig. 1, Cluster E). In contrast, CBF was reduced following exercise in the right lentiform nucleus, as well as in two clusters within the left superior temporal gyrus (Fig. 1, Clusters A, B and D). Regions of the right parietal lobe were sensitive to cycling intensity, with divergent responses between low and moderate exercise. CBF in the inferior parietal lobule decreased following low, but not moderate, intensity exercise (Fig.2 Cluster A). In the precuneus, however, CBF was increased following moderate, but not low, intensity exercise (Fig.2 Cluster B).

Discussion and Conclusion: This study demonstrates the utility of PCASL to detect CBF changes following acute exercise in chronic stroke, and a possible dose effect of exercise intensity. CBF was elevated in right post-central and parietal regions following moderate intensity cycling, relative to light exercise. The findings suggest that CBF in parietal regions may provide a sensitive biomarker of use in optimizing exercise-based stroke rehabilitation.

References:

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