IMAGING BRAIN RESPONSE TO EXERCISE FATIGUE AND EXHAUSTION: AN ASL PERFUSION STUDY

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Introduction

In everyday life, physical fatigue and mental stress are commonly reported and often occur simultaneously. Many previous studies have focused on how the brain perceives muscle fatigue and reactivates its signals to the fatiguing muscle [1-3]. Despite transcranial Doppler (TCD) and some other molecular modalities, recent studies have utilized noninvasive BOLD-fMRI to depict the neural activation [4]. However, the large-scale effects of exercise on the cardio-pulmonary systems may influence the blood oxygen level dependent (BOLD) signal independent of neuronal activation. Thus, arterial spin labeling (ASL), which is capable of acquiring regional CBF values noninvasively, was proposed here to depict the brain response to exercise fatigue and exhaustion.

Materials and Methods

Eight healthy college athletes (all males) were enrolled in the study. Peak oxygen consumption (VO_2 peak) was assessed using the Bicycle Ergometer Maximal Test Protocol ahead. According to their individual VO_2 values, subjects were instructed to pedal an ergometer cycle with ECG recording. For fatigue exercise, the initial power output was 90W, every subsequent 2 minutes with 30W added until the Borg Rating of Perceived Exertion (RPE) was reported above 19. For exhaustion part, the power was set to the level of 70% VO_2max until the pedal cadence could not maintain above 60 rpm for 5s. The subjects were randomly arranged to fatigue or exhaustion exercise, which were separated two weeks apart. Before each exercise, 3D FSPGR images and 2 min resting state PASL images were acquired on each participant, after the exercise, the MRI scanning starts 3 min later, acquiring the same 2min functional imaging. Imaging parameters: PICORE/QUIPSS Ⅱ; slice thickness/gap=8.0/2.0 mm with 2.9 x 2.9 mm^2 in-plane resolution, 64 x64 acquisition matrix; TR=3000ms; TE1=3.1ms; inversion time (TI)=1500ms [5]; 12 axial slices were placed covering the whole cerebrum and most of the cerebellum. The set consisted of 20 pair perfusion-weighted images. Mean CBF map for each subject in each condition was generated by Asltbx software (http:// www.cfn.upenn.edu/ ~zewang/ ASLtbx.php) with standard procedures. Global CBF and regional CBF values were statistically compared between pre- and post- state.

Table 1: Decreased CBF brain regions in response to exercise fatigue

Region	Cluster size	MNI coordinates x	y	z	Peak t	Cluster p (FDR corrected)
L-Middle Temporal Gyrus (BA 21)	602	-56	-22	-6	-9.20	0.000
R-Lentiform Nucleus ,Putmen	368	28	6	0	-8.54	0.005
L-Lentiform Nucleus , Putmen	198	-28	4	2	-6.30	0.041
R-Inferior Frontal Gyrus (BA47)	351	50	24	-8	-7.17	0.005

Table 2: Decreased CBF brain regions in response to exercise exhaustion

Region	Cluster size	MNI coordinates x	y	z	Peak t	Cluster p (FDR corrected)
R-Inferior Frontal Gyrus (BA47)	272	32	22	-16	-18.06	0.000
L-rostral ACC(BA 24)	644	-8	2	42	-14.54	0.005

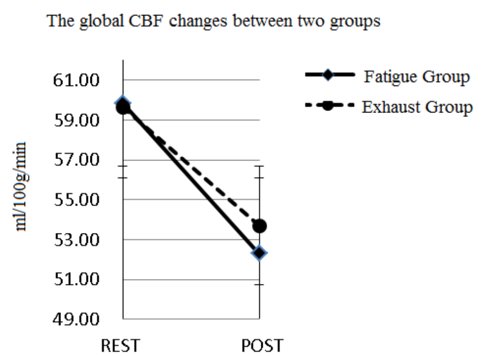

Figure 1: Significant reduction in global CBF was observed both after fatigue and exhausted exercise ($p<0.05$)

Results

Significant reduction in global CBF was observed both after fatigue and exhausted exercise ($p<0.05$, Figure 1). Decreased regional CBF in bilateral lentiform, left MTG and right IFG was statistically detected after the fatigue exercise (FDR $p<0.05$, $K>10$, Table 1 and Figure 2); for the exhaustion exercise, right IFG and left rACC were significantly deactivated (FDR $p<0.05$, $K>10$, Table 2 and Figure 3). No activation has been detected.

Discussion and Conclusion

Globally CBF reduction has been observed, which may attribute to severe hypoxia and hyperventilation induced by both strenuous exercises. The significant rCBF alteration in right IFG following two types of exercises might suggest an important clue: fatigue and vital stress caused nonsense of risk, which directly lead to danger. The basal ganglia, especially lentiform nucleus, was proved to be a substrate for fatigue in multiple sclerosis, In addition, left MTG is normally a region representing language function and auditory processing, decline in L-MTG may induce the loss of related functions. Furthermore, rACC's deactivation distinguished the exhaustion from normal fatigue with the significant inhibition of emotion experience.

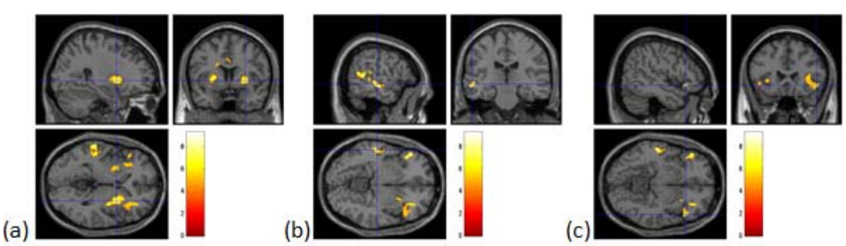

Figure 2. Brain regions with decreased CBF in response to exercise fatigue. (a) bilateral lentiform, (b) left MTG, (c) right IFG.

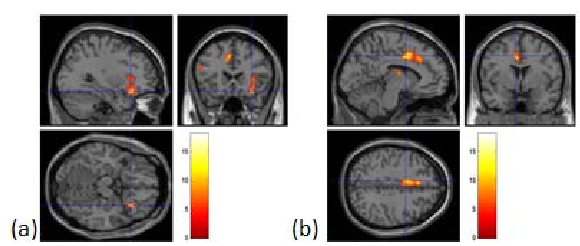

Figure 3. Brain regions with decreased CBF in response to exercise exhaustion. (a) right IPL, (b) left rACC

References

1. Kleinerman J, Sokoloff L. Fed Proc 1953; 2. Amann M et al. J Physiol 2006; 3. Blomstrand E et al. Acta Physiol Scand 2005; 4. Janse Van Rensburg et al. Psychopharmacology 2009; 5. J.Carson Smith et al. J Neuroscience Methods 2010.