UCL Exercise Neuroscience Research Group

Extensive prefrontal cortex haemodynamic changes provoked by intense aerobic exercise, measured via fNIRS

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INTRODUCTION

Physical exertion is sometimes associated with changes in cognitive function. The literature has focused particularly on effects of exercise in relation to age, with strong evidence to support beneficial effects on the ageing brain (Kramer et al., 2006). However, there is a dearth of literature surrounding the physiological basis of these associations and the impact of baseline fitness on cognition.

The aim of this study was to determine the acute effects of intense physical exercise on executive function and prefrontal cortex brain activity, and the impact of baseline fitness on these associations.

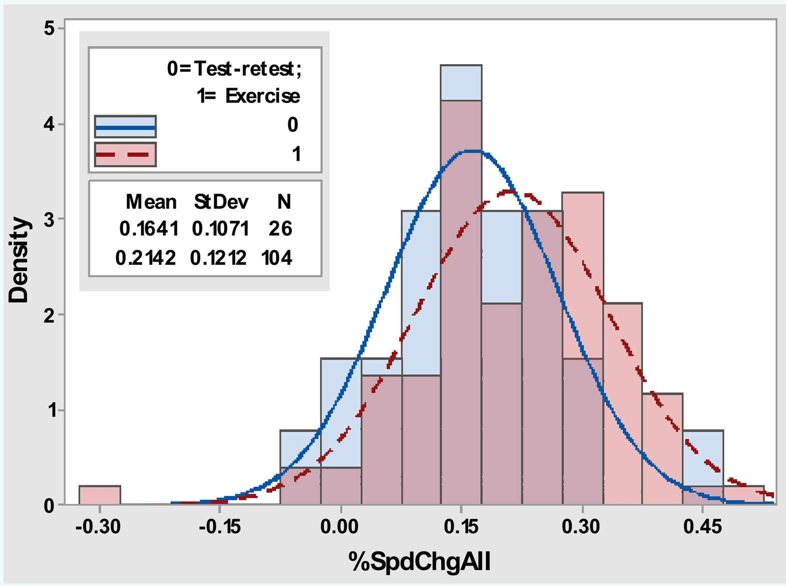

Figure 1 – Proportional speed changes after exercise by group. H = 4.81, p=0.28

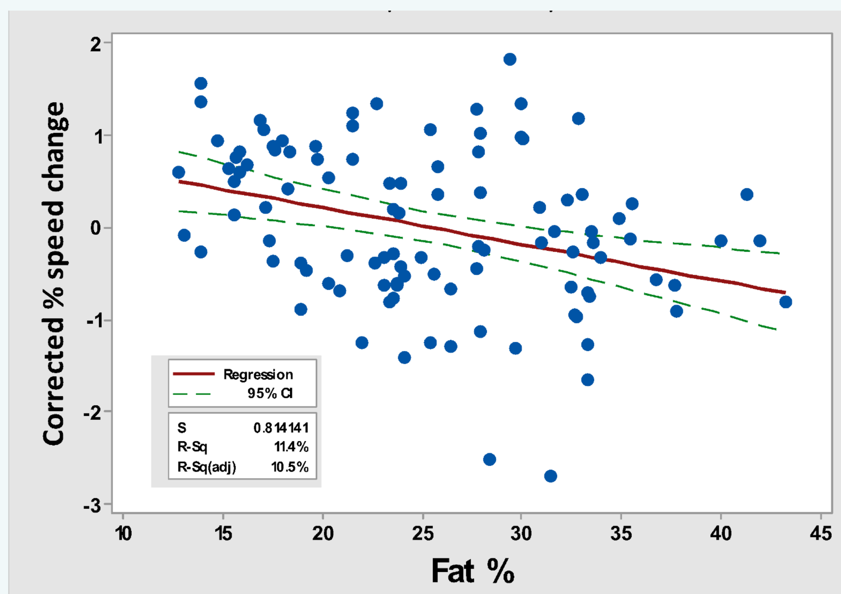

Figure 2 – Relationship between fat % and post-exercise speed change (p<.001)

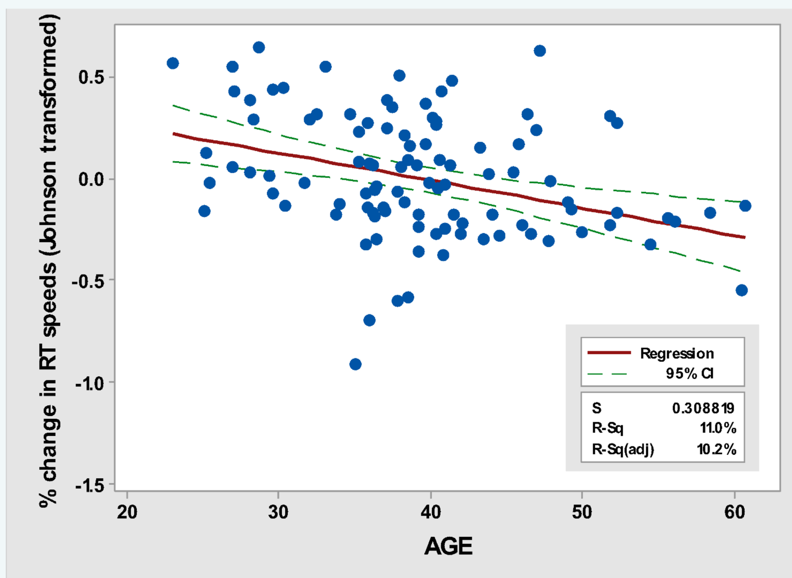

Figure 3 – Relationship between age and post-exercise speed change (p=.001)

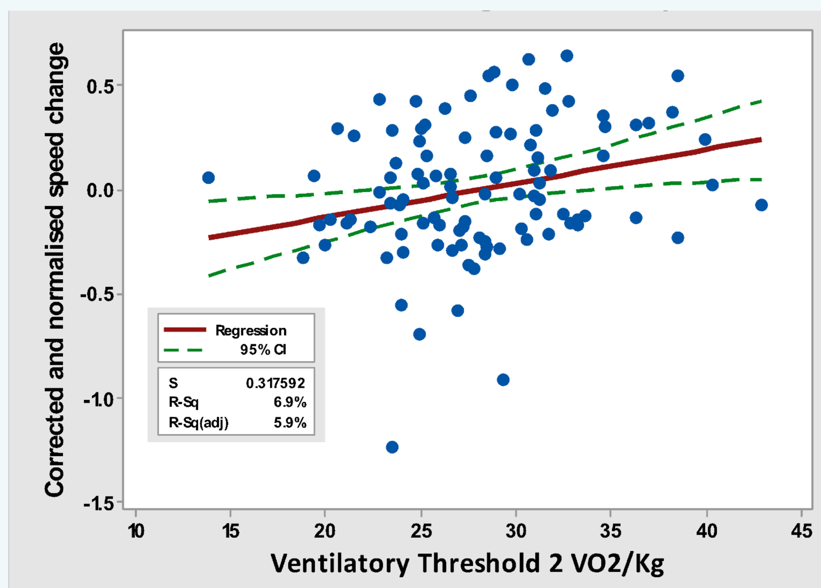

Figure 4 – Relationship between anaerobic threshold and post-exercise speed change (p=.008)

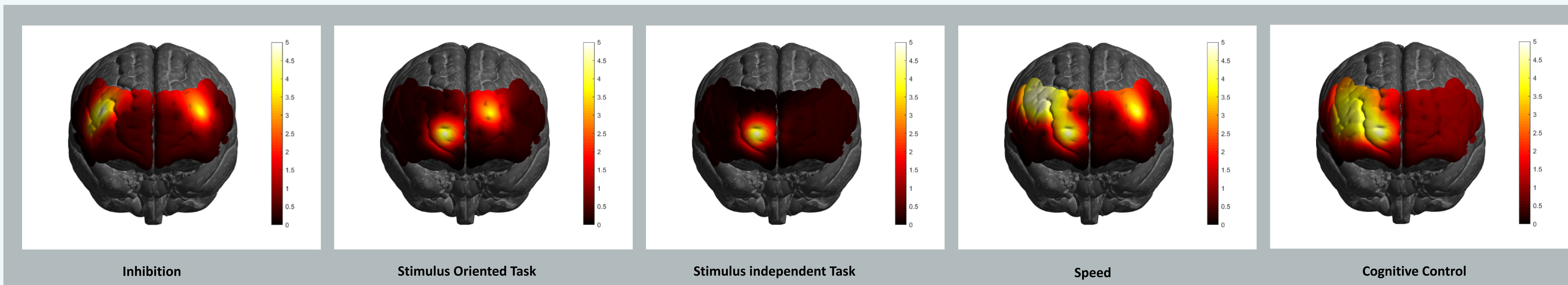

Figure 5 – Changes in oxygenation between exercise and control groups, post VO2max test and post resting, respectively. Lighter colours indicate higher oxygenation in the exercise group compared to the control group, during each respective cognitive test (a < .05, FDR corrected).

METHODS

103 participants (F = 29, M= 74; Age = 40 ± 8) completed tests of executive function before and after undergoing a VO_2max test with a Bruce Treadmill Protocol. A comparison control group of 32 participants matched for age, birth sex and fitness completed the same tests before and after active rest. Body fat % was determined via bioelectrical impedance and VO_2max via gas analysis.

Speed (reaction time, RT) was measured during tests of simple RT, Inhibition, stimulus-oriented & stimulus-independent attending (Burgess et al., 2007), and source memory. Brain activity of the prefrontal cortex was measured during the pre- and post-exercise cognitive tests using functional Near Infrared Spectroscopy (fNIRS) (Pinti et al., 2019).

RESULTS

The cohort's mean body fat was 25 ± 7 %, Anaerobic Threshold (AT) was 28 ± 5 ml/kg/min and VO_2max was 38 ± 7 ml/kg/min. At baseline, there was no association between body fat % or VO_2max and cognitive test performance.

Following exercise, participants showed significantly improved cognitive speed with no decrease in accuracy ($F = 28.1$; $p<.001$) (Figure 1). These exercise-related cognitive speed improvements were significantly negatively associated with body fat % ($R^2 = 11.4\%$; $p = .001$) (Figure 2) and with age ($R^2 = 11.0\%$; $p = .001$) (Figure 3) and were positively correlated with $VO_{2/kg}$ at AT ($R^2 = 6.9\%$, $p = .008$) (Figure 4) and VO_2max ($p = .003$).

The degree to which individual participants showed this exercise-related cognitive enhancement was reflected in changes in oxygen utilisation in the prefrontal cortex, in the regions associated with performances on the individual tasks, beyond those occurring in the no-exercise control group ($n = 92$, $\alpha < .05$, FDR corrected).

CONCLUSION

In line with previous research which found increased cortical excitability and executive function following light exercise (Morris et al., 2019), in this study, vigorous exercise improved prefrontal cortex brain activity and cognitive processing speed with no detriment to accuracy in executive function in healthy adults. As reported by Stillman et al. (2020), age significantly affected cognitive responses both at rest and after exercise. Although all participants improved after exercise, those with a higher body fat percentage, lower cardiovascular fitness and older age showed proportionally less improvement.

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