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# Improving Cognitive Performance via High Intensity Interval Aerobic Exercise: A Randomized Controlled Trial

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## ABSTRACT

**May RW, Hutchinson M, Seibert GS, Fincham F, Sanchez-Gonzalez MA.** Improving Cognitive Performance via High Intensity Interval Aerobic Exercise: A Randomized Controlled Trial. **JEPonline** 2017;20(5):141-146. The purpose of this study was to evaluate the impact of a high intensity interval training (HIIT) program on cognitive performance in young adults. Sixty college students (age, 18.55 ± 0.99 yrs, 82% female) were randomly assigned to one of two groups: (a) HIIT; and (b) CON. Both groups were evaluated for math and reading working memory as well as maximum oxygen consumption ($VO_2$ max) before and after a 4-wk period. The working memory tasks were performed via E-Prime® software and the $VO_2$ max scores were collected via a cycling test. The HIIT training sessions (~20 min) were conducted by trained instructors 3 times·$wk^{-1}$ for 4 wks. Repeated measures ANOVA results with follow-up contrast testing indicated that HIIT, but not CON significantly ($P<0.01$) improved $VO_2$ max from pre-test to post-test (Δ3.30 ± 0.10 mL·$kg^{-1}$·$min^{-1}$). Regarding cognitive performance, HIIT significantly ($P<0.01$) improved both math (Δ4.30 ± 0.10) and reading working memory (Δ1.30 ± 0.10). Correlations demonstrated that increases in $VO_2$ max change scores corresponded to increases in mathematic ($r = .36$, $P<0.05$) and reading ($r = .40$, $P<0.05$) working memory scores. Results demonstrated that HIIT improved working memory and that $VO_2$ max was responsible for enhancing cognition. This study provides support for designing HIIT based interventions aimed at improving cognitive functioning.

**Key Words:** Cognition, Exercise, Training, $VO_2$ max

## INTRODUCTION

Exercise training provides physical health benefits to individuals, such as increased physical endurance and improved cardiovascular performance (5). Additionally, evidence suggests that exercise training may have implications regarding neurocognitive functioning and brain health (10). However, conclusions examining underlying mechanisms associated with optimization of cognition via exercise training modalities are still under investigation. As the search for contributing mechanisms of cognitive change regarding physical activity continues, one proposed method for increasing fitness is high-intensity interval training (HIIT) that consists of rapid, intensive workout intervals between 80 and 95% of maximum heart rate. It is a relatively brief workout. But, when performed routinely, it elicits significant increases in aerobic and anaerobic fitness (4). Although the physiological health benefits of HIIT are improved cardiovascular health, decreased insulin sensitivity, and decreased body fat (4), the relationship between HIIT and cognition is still unclear.

Given the literature to date (1,3,6), the HIIT sessions have for the most part shown little to no statistically significant improvement in cognition functioning in contrast to control conditions except for completion time. However, these studies are hampered by low statistical power (N per condition is approximately 15). A closer observation of the direction of the mean changes in the majority of studies suggests that HIIT improves cognitive functioning. Furthermore, since the majority of the research has focused on school-aged children, middle-aged adults, and older adults, little is known regarding the relationship between HIIT and cognitive functioning in college students aged 18 to 25 yrs (2). Cognitive functioning in emerging adult populations is pivotal as recent studies indicate that age-related decline in cognition may begin in the early 20s (11).

Due to the aforementioned prior study limitations and the limited evidence regarding HIIT improving cognition, the current study reports on the changes in cognitive performance after a 4-wk HIIT cycling intervention in young adults (N = 60). Given the mean changes of prior HIIT-cognition studies, we hypothesized that in contrast to a wait-list control condition, HIIT would improve cognitive performance. Cognitive performance was evaluated before and after the 4-wk intervention via mathematic and reading working memory tasks. Furthermore, as suggested by Beekley et al. (3), we hypothesized maximum oxygen consumption ($VO_2$ max) during aerobic activity is the mechanism that links HIIT to enhanced cognition.

## METHODS

### Subjects

A total of 60 undergraduate college students (mean age, 18.55 yrs; SD, ± 0.99; 82% female) were randomly assigned to one of two groups: HIIT and CON. The inclusion criteria were: (a) college freshmen students (men and women); (b) blood pressure (BP) less than 150/90mmHg; (c) age between 18 and 30; and (d); and a BMI between 20 and 39 $kg·m^{-2}$. The exclusion criteria were: (a) BP ≥150/90 mmHg; (b) diagnosed with a disease process or taking medications, which would influence the outcome variables; and (c) pregnancy.

### Procedures

All subjects were recruited from university classes at a major southeastern university in the United States where the current study was offered as one form of extra credit. Prior to participation, all subjects provided their written consent to participate in the study as approved by the institutional review board. The consenting subjects were sent an online survey containing instructions to the nature and design of the study, a questionnaire containing the demographics, and a physical health history questionnaire. Groups (HIIT vs. CON) were evaluated before (pre-test) and after (post-test) a 4-wk intervention period on cognitive functioning with working memory tasks.

The HIT protocol was adapted from Gillen et al. (8) and involved 12 supervised sessions over 4 wks (Monday, Wednesday, and Friday each week). Each session consisted of 10 x 60-sec cycling bouts interspersed with a 60-sec recovery. Training was performed on an ergometer set in constant watt mode (fixed resistance) at a pedal cadence of 80 to 100 $rev \cdot min^{-1}$. The subjects' workloads were selected to elicit a heart rate (HR) of ~90% of their age predicted maximum (220 – Age = max heart rate) or peak power output during the intervals. The HR recorded at the end of each interval was used to calculate $VO_2$ max using the YMCA submaximal test as previously described by Beekley and colleagues (3). During the 60-sec recovery, the subjects rested or pedaled slowly at a resistance of 50 W. The training sessions included a 3-min warm-up and a 2-min cool-down at 50 W for a total time commitment of 25 min.

The working memory span measures were automated computerized versions of the common reading and mathematics (operation) working memory span tasks that were developed by Unsworth et al. (12) via E-Prime® software. The span tasks required the subjects to remember target letters while performing a concurrent reading comprehension (reading span) or arithmetic task (operation span). The number of targets in a trial set varied between 2 and 5, with 3 trials at each size for each of the tests.

## Statistical Analyses

Factorial repeated measures ANOVA evaluated between condition (HIIT vs. CON) pre-post differences in regards to operation (math) span and reading span working memory scores as well as $VO_2$ max scores. Statistically significant interactions were further evaluated via follow-up univariate contrasts. Finally, relationships between $VO_2$ max change scores ($VO_2$ max post-test minus $VO_2$ max pre-test) and working memory scores were evaluated via Pearson correlations. Statistical significance was set at $P<0.05$. All statistical analyses were performed using SPSS version 19 (SPSS, Chicago, IL). As this research is novel and prior effect sizes regarding the intervention and study outcomes undiscovered, a power analysis using G*Power 3.5 was conducted with the expectation of a small to moderate effect size (Cohen's $d$ = .3). With the alpha set at .05 and power at .8, a repeated measures ANOVA required approximately n = 30 per condition for the selected effect size.

## RESULTS

Factorial repeated measures ANOVA results indicated significant condition (HIIT vs. CON) by pre-posttest interactions for both working memory and $VO_2$ max scores ($P<0.05$). Follow-up univariate contrasts indicated that from pre-test to post-test HIIT, but not CON, significantly ($P<0.01$) improved operation span working memory ($\Delta 4.30 \pm 0.10$), reading span working memory ($\Delta 1.30 \pm 0.10$), and $VO_2$ max ($\Delta 3.30 \pm 0.10$ $mL \cdot kg^{-1} \cdot min^{-1}$). The correlations demonstrated that increases in $VO_2$ max change scores corresponded to increases in both mathematic ($r = .36$, $P<0.05$) and reading ($r = .40$, $P<0.05$) working memory scores.

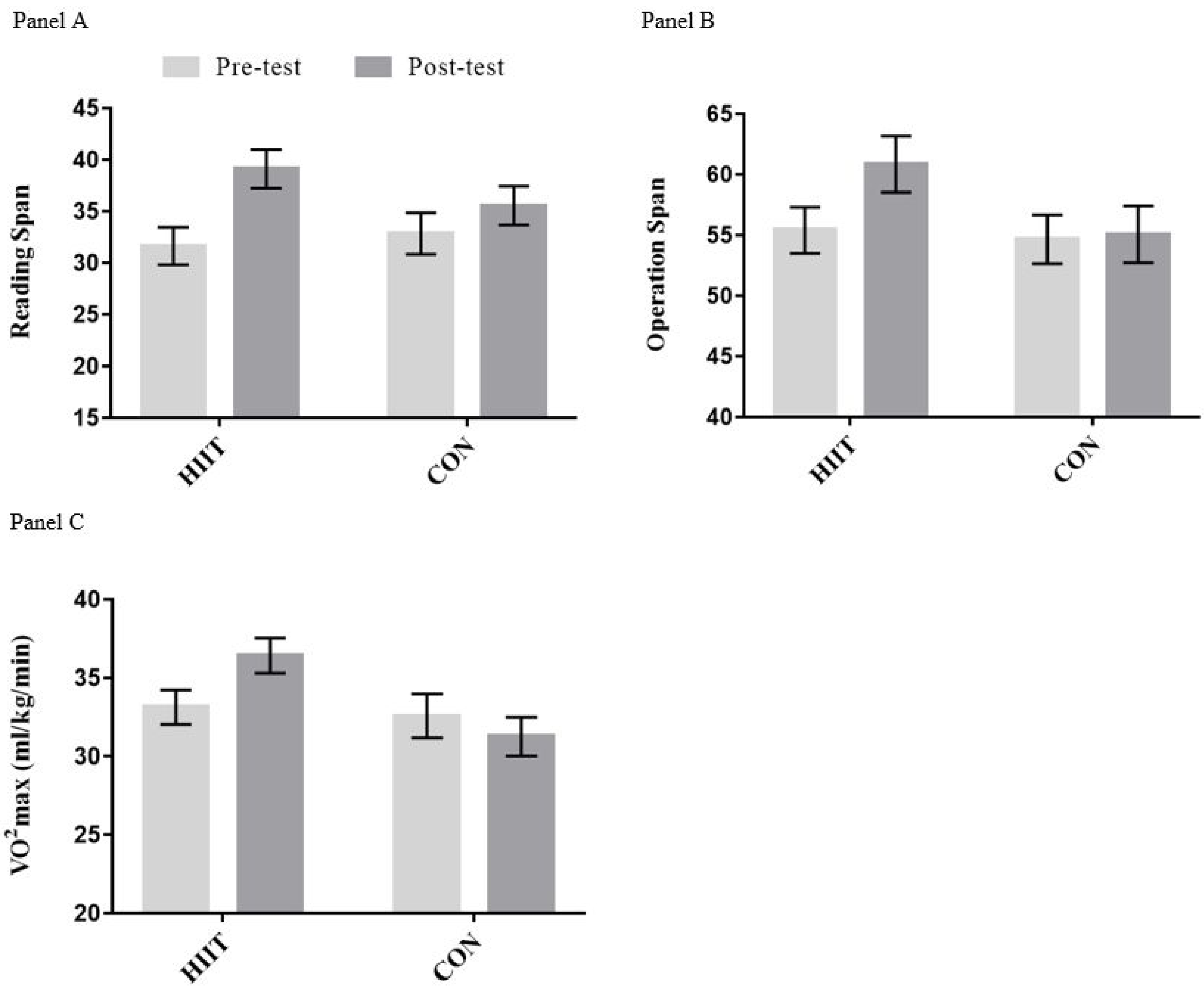


**Figure 1. Condition by Pre-Posttest Interactions for Reading Span (Panel A), Operation Span (Panel B) and $VO_2$ max (Panel C). HIIT** = High Intensity Interval Aerobic Training; **CON** = Control Condition

## DISCUSSION

The purpose of this study was to evaluate the impact of a 4-wk HIIT intervention on cognitive performance in emerging adults. In contrast to a wait-list control condition, results demonstrated that subjects undertaking HIIT improved their mathematic and reading working memory scores from pre-test to post-test. Furthermore, the findings implicate $VO_2$ max (i.e., aerobic fitness) as the mechanism attributable to enhancing cognition following HIIT. This study serves to provide groundwork for designing HIIT based interventions aimed at improving cognition and identifies a mechanism linking HIIT and enhanced cognitive functioning.

The cardiovascular hypothesis, which suggest that aerobic fitness, as measured by maximal oxygen consumption, is the main physiological mediator in exercise regimens that determines changes in cognitive functioning, has received mixed support in the literature (3,7). However, findings from the current study provide support for the cardiovascular hypothesis and the role maximal oxygen consumption plays in improving cognition.

In addition to $VO_2$ max, other potential mechanisms have been suggested to account for the increase in cognition due to exercise activities. For example, brain-derived neurotrophic factor (BDNF) and insulin-like growth factor (IGF-I), both of which are critical factors for neuronal growth and maintenance. They have been implicated in the exercise-cognition relationship. BDNF and IGF-I also play a critical role in helping neurons thrive and aid in dendritic branching and synapsis (9). Thus, it is important to continue the exploration into multiple other mechanisms beyond $VO_2$ max to fully understand the relationship between HIIT and cognition.

### Limitations in this Study

Notwithstanding the strengths of the present study, it is appropriate to consider several limitations of the present study as well as the potential future research directions. First, as the data pertain to mostly females, an important limitation is that our findings are generally limited to one gender. Second, while it was the intention of this study to provide an examination of young adults, the findings do not speak to the potential range of age-related effects. Lastly, and in a similar vein as previously noted limitation of evaluating only one physiological mechanism ($VO_2$ max), this study was limited in regards to measures related to cognitive functioning, specifically working memory. However, given the findings of this study, future research that investigates other domains of cognition appears fruitful.

## CONCLUSIONS

The present study evaluated the impact of a HIIT intervention on cognitive performance in young adults. The results demonstrate that HIIT improved the subjects' working memory. Also, the findings indicate that maximal oxygen consumption is the mechanism responsible for enhancing cognition. This study provides support for designing HIIT based interventions aimed at improving cognitive functioning.

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