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The Effect of Single Bout of Exercise on Executive Function in Young Men:Stratified by BMI

KEYWORDS: Exercise; BMI; Executive function; Stroop test

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ABSTRACT ***Background:*** *A Single bout of exercise enhances executive function and whether it differs among different BMI young men is unknown. Hence, we evaluated the effect of a single bout of exercise on executive function in young men with different BMIs.*
Materials and methods: *Men (18 to 25 years) with normal BMI (18-24.9, n = 61) and with higher BMI (≥ 25, n = 59) performed moderate aerobic exercise on a bicycle ergometer. Stroop task was performed to assess their executive function both before and after the exercise.*
Results: *The latency of Stroop test significantly reduced in both the groups (p < .001). Number of correct responders improved in Stroop test in the higher BMI group (p < .001). The number of correct responders were significantly greater in normal BMI group compared to higher BMI group (p = .005) at baseline.*
Conclusion: *We conclude that a single bout of exercise enhances executive function independent of BMI and this beneficial effect may be better in higher BMI group.*

Introduction

Exercise is performed to improve and maintain fitness levels in sports and games. However, it also prevents non-communicable diseases like cardiovascular diseases and cerebrovascular accidents (Y. Wang, Li, Dong, Zhang, & Zhang, 2015). Exercise is also known to have beneficial effects in depression (Schuch et al., 2016). Hence, it is evident that exercise and thereby improving aerobic fitness has both physical and mental benefits. Exercise improves the cognitive levels of both children (Chaddock-Heyman, Erickson, et al., 2015) and adults (Chaddock-Heyman et al., 2013). Though there are many reasons stated for this effect, it is mediated predominantly through elevated levels of brain derived neurotrophic factor (BDNF) (Whiteman et al., 2014). The enhancement in the levels of BDNF is positively associated with increased intensity and duration of exercise (Matthew et al., 2013). Animal studies have shown that exercise can be used as a treatment for memory impairment in various disease conditions (Sim, 2014). The other lifestyle intervention which can be used to enhance cognition is through dietary management (Weiser, Butt, & Mohajeri, 2016). Therefore, exercise and diet are the two known lifestyle interventions to improve cognition.

It is evident from the literature that reduced physical activity, for instance, sitting for a long time, is detrimental to health (Hallman et al., 2015). Obese individuals are known for their sedentary behaviour and therefore are refrained from the physical as well as the cognitive benefits of exercise. Obesity per se has detrimental effect on the cognitive levels of the individual (C. Wang, Chan, Ren, & Yan, 2016). This trend can be prevented by dietary management and exercise. Even a single bout of exercise can prevent this decline in cognitive levels (Roig, Skriver, Lundbye-Jensen, Kiens, & Nielsen, 2012). The enhancement in cognition due to exercise is evident in all age groups (Chaddock-Heyman, Erickson, et al., 2015; Chaddock-Heyman, Mackenzie, et al., 2015). However, whether this beneficial effect differs between the normal weight and overweight young men is unknown. The beneficial effects of exercise is dependent on the intensity and duration of exercise (Matthew et al., 2013). Hence, we prescribed exercise for a specific period of time and quantified the intensity based on the Karvonen's equation and evaluated the executive function of young men before and after the exercise protocol. We evaluated whether the change in executive function after the single bout of prescribed exercise protocol differs between the normal and overweight young men.

Materials and Methods

Subjects: Hundred and twenty healthy young men between the ages of 18 to 25 years without any medical condition, which would prevent them from performing the exercise protocol or the cognitive test, were recruited. Athletes, yoga practitioners, individuals on calories restricted diet and individuals on any special diet were excluded. The Institutional Scientific and Ethics Review Board had approved the study and methods. Subjects reported to the lab at around 4 PM and briefed about the test. After obtaining the written informed consent, height was measured to the nearest 0.1 cm using a custom made stadiometer and weight was measured to the nearest 0.1 kg using a weighing scale (Krups, Dr. Beliram and Sons, New Delhi, India). BMI was calculated and subjects within 18 to 24.9 were assigned as group A (n= 61) and 25 and above as group B (n = 59).

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Procedure
Subjects familiarized the Stroop's test with many trials in the laboratory to overcome the practice effect and then performed the tasks. Aerobic exercise was prescribed immediately to them, as described below, after the cognitive assessment. The subjects were made to rest for a minimum period of 10 minutes post exercise and then the same cognitive test was repeated. Subjects performed the cognitive task on the desktop using the Superlab Pro 5 presentation software (Cedrus Corporation, San Pedro, USA) sitting at 1-meter distance and the responses were given using a response pad. The latency of the cognitive task was noted in milliseconds and the number of correct responses was also noted. The data was viewed using Cedrus Viewer software.

Stroop task: This test evaluates the executive function of an individual. The colour name was presented on the computer monitor in different ink colours. The subject had to respond, by pressing an appropriate button colour on the response pad, either to the word or to the ink colour in two different types of tasks. There were 12 trials presented for each set of task, cumulatively forming 24 trials. From the total 120 participants, 65 of them responded 22 and above stimuli correctly (50^{th} percentile) at the baseline test which was considered as cut off point. Participants who could response correctly 22 and above stimuli were considered as correct responder. The number of correct responders were used to analyse accuracy of response. The average latency of all the correct responses by each participant was noted as latency period.

Aerobic Exercise: Subjects performed exercise on a well ventilated room and they were advised to refrain from alcohol, any severe exercise 48 hours and caffeine 12 hours prior to the exercise protocol. Exercise was prescribed based on Karvonen's equation (Nakanishi et al., 2015). The resting heart rate of the subject was noted after 10 minutes of rest at sitting posture using a pulse oximeter (Easycare model-ECPO 250E, Ranish Impex Pvt Ltd, Mumbai, India). The maximum heart rate of the subject during peak exercise was calculated using the formula 220 – age. The heart rate reserve (HRR) was calculated by subtracting resting heart rate from maximum heart rate. 60% of the HRR was added to the resting heart rate which would be the target heart rate during exercise. The subject pedalled on a bicycle ergometer (model - Cosco fitness, Delhi, India) at this target heart rate, monitored using the pulse oximeter, for a period of 13 minutes with an initial one-minute warm up and a final one-minute warm down, totalling to 15 minutes. The resistance on the cycle was adjusted to the comfort of the subject and to maintain the target heart rate.

The tests were performed on a single visit and the present data were extracted from a large cognitive study done as part of our project.

Statistical Analysis: Descriptive statistics are expressed as mean and standard deviation. Baseline difference in latency in Stroop test, age, BMI between the groups was analysed using Student "t" test. Paired "t" test was used for the change in latency in Stroop test after the prescribed exercise protocol. McNemar test was used to find the intragroup change in accuracy of the responses due to exercise intervention for the Stroop task. The association of number of correct responders among the two groups at baseline (prior to exercise) was analysed using χ^2 test. Statistical significance was kept at $p < .050$ and all tests were two sided. The data were analysed using SPSS version 20.0.

Results
The descriptive data of the study population is given in table 1. The lower BMI men were younger ($p < .001$) and had significant lower BMI (< .001) than the higher BMI counterparts. The average latency in milliseconds was noted from all the correct responses. Baseline latency was comparable among the two group ($p = .617$).

Table 1: Descriptive statistics of the study population.

Characteristics	Men with BMI 18.5 to 24.5	Men with BMI ≥ 25	p value
Age	18.5±1	19.8±2	< .001
BMI	21.2±2.4	28.6±2.8	< .001

Data expressed as mean ± standard deviation, p value obtained from Student's test.

The latency of Stroop test significantly reduced in both the group ($p < .001$) due to exercise as depicted in the table 2. Participants who were able to answer 22 and above stimuli were considered as a correct responders. The group with normal BMI showed no significant improvement in the number of correct responders after the exercise (only 2 participants improved) as evident from table 3. The higher BMI group showed a significant improvement from 25 participants, prior to exercise, to 40 participants after a single bout of moderate exercise answering correctly ($p < .001$) and only 19 did not show improvement to the stipulated level. At baseline the normal BMI group had a significantly higher number of correct responders than the BMI group with ≥ 25 (41 vs 25, $p = .005$) based on chi-square test.

Table 2: Comparison of latency periods in milliseconds (ms) in Executive Function (Stroop test) before and after the exercise protocol within groups.

	Before Exercise	After Exercise	p value
Men with BMI 18.5 to 24.5 (n = 61)	1103±154 (ms)	1029±137 (ms)	< .001
Men with BMI 25 and above (n = 59)	1087± 195 (ms)	1015±169 (ms)	< .001

Data expressed as mean ± standard deviation, p value obtained from Student's paired t test.

Table 3: Cross tabulation of number of correct and not correct responses in Stroop test among normal BMI (18.5 to 24.9) group and higher BMI (≥ 25) both pre and post exercise.

Stroop Test These have to the correct boxes			Post-exercise Responses		Total	p value
			correct	Not correct		
Normal BMI group (n = 61)	Pre-exercise Responses	Correct	41	0	41	.500
		Not correct	2	18	20	
	Total		43	18	61	

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High BMI group (n = 59)	Pre-exercise Responses	Correct	25	0	25	< .001
		Not correct	15	19	34	
	Total		40	19	59	

p value obtained using McNemar test using binomial distribution; when 22 and above stimuli were answered out of the 24, then the participant was considered as a correct responder.

Hence, it is evident from our study that the latency of Stroop test has reduced after a single bout of moderate exercise in all young men independent of BMI. The number of men with BMI ≥ 25 who could answer to the stipulated cut-off point improved significantly and this trend was not observed in men with BMI 18 to 24.9.

Discussion

The main finding in our study is the latency in Stroop's test reduced, signifying improvement in executive cognitive function, due to a single bout of exercise independent of the BMI of young men. Cognitive improvement due to exercise has been established in both animals and humans (Moritani & Akamatsu, 2015). This improvement was documented to be mediated through reduced insulin levels (Tarumi et al., 2013) and increase levels of BDNF (Gomez-Pinilla & Hillman, 2013). Exercise and thereby improving aerobic fitness enhances cognitive functions in children (Chaddock-Heyman et al., 2013) as well as in elderly individuals (Hindin & Zelinski, 2012). Hence, exercise can improve cognition in individual of all age group.

Obese individuals have low cognitive functions and this is primarily mediated through low levels of BDNF (Kaur et al., 2016). Therefore, we can assume that this reduction in cognition can be ameliorated by regular exercise which would increase BDNF. The increase in the level of BDNF is proportion to the intensity and the duration of exercise (Matthew et al., 2013). Hence, intensity of the exercise was kept constant based on the Karvonen's equation and the duration was fixed for 13 minutes in our study. The latency of the Stroop test significantly reduced in both BMI groups and this could have been mediated through raised levels of BDNF, which is conventionally used as a biomarker for memory and other cognitive functions in adults (Komulainen et al., 2008). There was greater number of correct responders in normal BMI group as compared to higher BMI group at the baseline. This is in agreement with earlier studies which showed that the levels of BDNF would be lower in men with higher abdominal adiposity (Kaur et al., 2016). The number of participants who improved to answer correctly (n = 15) to the stipulated cut-off level (i.e. 22 and above) was significantly greater in higher BMI men. Hence, overweight men should be encouraged to do exercise for their cognitive benefits. These effects could have been mediated through enhanced levels of BDNF and can be protective against future dementia and Alzheimer disease (Weinstein et al., 2014). Regular exercise (Schuch et al., 2016) as well as calorific restricted diet (Pani, 2015) have be proven to prevent neural degeneration. The accuracy in Stroop test did not improve among normal BMI men since the numbers were high at baseline itself.

Limitations: The reduction in latency and improvement in accuracy of the Stroop test due to practice effect could not be completely avoided, albeit, we tried to overcome this by several practice sessions. The other limitations were BDNF not measured and girls were not included in the study.

Conclusion: A single bout of moderate exercise improved the latency of executive function in young men irrespective of their BMI and its accuracy improved in the higher BMI group. Men with all BMI range should be encouraged to do moderate exercise to improve their cognitive abilities and this may prevent future memory disorders like dementia and Alzheimer.

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