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COGNITIVE ENHANCEMENT DUE TO ACUTE EXERCISE IS NOT INFLUENCED BY BMI IN YOUNG MEN.

Physiology

Rajesh Jeniton Fernando	Department of Physiology, Pondicherry Institute of Medical Sciences, Pondicherry, India.
Sathiyamoorthy P*	Department of Physiology, Pondicherry Institute of Medical Sciences, Pondicherry, India. *Corresponding Author
Sudharshanam S	3rd YEAR MBBS Student, Pondicherry Institute of Medical Sciences, Pondicherry, India.
Ravichandran K	Department of Biostatistics, Pondicherry Institute of Medical Sciences, Pondicherry, India.

ABSTRACT

Background: Obese men have low cognitive abilities. Acute exercise improves cognition and whether BMI influences this is not clear. Hence, we assess the role of BMI in cognitive benefits due to acute exercise.

Materials and methods: Hundred and twenty males, aged between 18 to 23 years, were divided into group A (n=61) within BMI 18 to 24.9 and group B (n=59) with BMI 25 and above. Cognitive functions like visual reaction time, Go No Go task, Stroop test and N back tests were performed immediately before and after a moderate aerobic exercise. The latency in milliseconds in cognitive tests were compared within group due to exercise. The change in latency in cognitive tests due to exercise was compared between the two groups.

Results: Among group A visual reaction time showed improvement ($p = .010$) and among group B latency in N back test showed improvement ($p = .030$). Latency in Stroop test showed improvement among both the groups ($p < .001$). Go No Go task did not show any improvement in both the groups. The change in latency in all cognitive tests due to acute exercise was not significantly different between the groups.

Conclusion: Acute exercise showed enhancement in executive function, cognitive inhibition and working memory among young men and this change was not influenced by BMI.

KEYWORDS

Acute exercise; cognitive functions; body composition; young men

Introduction:

Exercise is any purposive, planned, structured and repetitive body movements performed to enhance or to maintain physical fitness (Caspersen, Powell, & Christenson, 1985). Exercise is primarily performed for sports and athletic endeavours. Exercise has many physical health benefits like preventing chronic noncommunicable diseases (Watson & Baar, 2014). Exercise, apart from the physical benefits, also has many mental health benefits (Schuch et al., 2016). Scientific evidence has also demonstrated the efficacy of exercise improving cognitive abilities across the human life span (Gomez-Pinilla & Hillman, 2013). This cognitive benefits were demonstrated even due to a single bout of exercise (also known as acute exercise) (Chang, Labban, Gapin, & Etnier, 2012). Studies have predominantly demonstrated the cognitive benefits after a single session of aerobic exercise, while this effect was evident after a single bout of resistance exercise as well (Tsukamoto et al., 2017). The other lifestyle intervention which has cognitive beneficial effect is dietary management (Moritani & Akamatsu, 2015). Hence, Exercise and diet are two modifiable lifestyle factors which can enhance cognitive abilities (Moritani & Akamatsu, 2015).

It is evident from literature that acute exercise improves cognitive functions. This cognitive enhancement due to acute exercise is mediated predominantly through raised levels of brain derived neurotrophic factor (BDNF) (Whiteman et al., 2014).The parameters which can modulate these cognitive benefits due to acute exercise were dose and duration of the prescribed exercise (Chang et al., 2015), fitness level of the participant and the type of cognitive test which is performed (Chang et al., 2012). Generally obese individuals refrain from exercise and its benefits. Obesity by itself reduces the cognitive abilities across lifespan (Wang, Chan, Ren, & Yan, 2016). Whether the cognitive benefits due to acute exercise is modulated by obesity is unknown. Moderate aerobic exercise for short duration was found to have beneficial effects on cognitive functions (Chang et al., 2015). Since the intensity of the exercise has a confounding effect on the cognitive benefits, we quantified the intensity of exercise to be moderate based on the observed heart rate during exercise in our study. Motivation and educational qualification are known facts which can influence the cognitive functions. Studies have demonstrated gender differences in cognitive abilities (Upadhayay & Guragain, 2014). Therefore, we selected male students of the same educational qualification and designed a study to evaluate the effect of BMI on cognitive benefits due to acute moderate intensity exercise for 15 minutes duration.

Materials and Methods

Subjects

Hundred and twenty healthy young male volunteers between the ages of 18 to 25 years without any medical condition, which would prevent them from performing the exercise protocol as well as the cognitive tests, were recruited. Athletes, yoga practitioners and individuals on calories restricted 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 were briefed about the test. After obtaining 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 by dividing the weight (in kilogram) by squaring the height (in meter) of the subject (Quetelet index). Subjects within the BMI of 18 to 24.9 were assigned as group A (n= 61) and BMI of 25 and above as group B (n = 59).

Procedure

Cognitive test: Subjects familiarized all the cognitive tests with many trials in the laboratory to overcome the practice effect and then performed the tasks. After obtaining the baseline values of cognitive functions aerobic exercise was prescribed to them as described below. 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 (RB 730, Cedrus Corporation, San Pedro, USA). The latencies of the cognitive task were noted in milliseconds. The data was viewed using Cedrus Viewer software.

1. **Visual reaction time (VRT):** Visual reaction time is a measure of visual processing speed and visual attention (Bhabhor et al., 2013). The subject had to respond to a visual stimulus (appearance of a green circle on the desktop) by pressing an appropriate button on the response pad as fast as possible. Six trials were performed

and the average response latency in milliseconds was noted as visual reaction time.

2. **Go-No-Go task (GNG):** This is a test for response inhibition and more so for sustained attention. The subject had to respond only to the target (green colour circle) visual stimuli while withholding the response to the non-target (red colour circle) visual stimuli. There were 13 trials and the average latency in milliseconds of all the correct answered responses was noted as latency period.
3. **Stroop task:** This test evaluates for the executive function (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006). A colour name was presented in a different ink colour. The subject had to respond either to the words or to the ink colours in two different type of tasks. There were 12 such trials presented in each set of tasks which cumulatively formed 24 trials. The average latency of all the correct responses by each participant was noted as latency period.
4. **N-back task:** This is a test to gauge the working memory. A string of stimuli was presented to the participant. If the presenting stimulus was a repetition of the stimulus presented before two trails, the subject had to respond by pressing a button. There were 38 such stimuli presented in one string of task. The average latency of all correct responses was noted as latency period.

Aerobic Exercise: Subjects performed exercise in a well-ventilated room and 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.

The cognitive tests were performed on a single visit and all responses were evaluated for latency (in milliseconds) before and after the prescribed exercise. The change in latency due to acute exercise was compared both within group and between the groups.

Statistical Analysis

Shapiro's test was applied for evaluating normal distribution. Descriptive statistics are expressed as mean, standard deviation for normally distributed data and as median, 25th and 75th percentile for data which are not normally distributed. Wilcoxon Signed Ranked test was used to find the differences between the latency among the paired data which were not normally distributed, while paired "t" test was used for the normally distributed data. Comparison of change in latency after the exercise between the two groups was performed using Mann Whitney U test for non-parametric test and Student "t" test for normally distributed data. 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 statistics of the study population is given in Table 1. There was significant difference between the groups in BMI and normal BMI group was younger compared to the obese counterparts.

Table 1: Descriptive statistics of the study population.

Characteristics	Group with BMI 18.5 to 24.9 (n=61)	Group with BMI 25 and above (n=59)	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 "t" test.

The latency before and after exercise within groups of all the performed cognitive tests are summarized in table 2. The change in latency due to exercise among the two BMI groups is summarized in table 3.

Visual reaction time (VRT): The latency of VRT reduced significantly due to exercise only in the normal BMI group (p = .010). The latency of the higher BMI group did not show any such trend. The change in latency in VRT due to exercise was not significant different among the two BMI groups as depicted in table 2.

Go No Go task (GNG): The latency of GNG did not show any appreciable change in both the groups due to exercise. The change in latency due to exercise also did not show any significant difference among the two groups.

Stroop test: The latency was found to be reduced due to exercise in both the groups which was statistically significant (p < .001) as depicted in table 2. There was no significant difference in the change in latency due to exercise among the two groups as tabulated in table 3.

Table 2: comparison of latency periods in milliseconds in all cognitive tests before and after the exercise protocol within groups

	Before Exercise	After Exercise	p value
Visual reaction time			
Group with BMI 18.5 to 24.5*	371 (333 – 430)	357 (315 – 433)	.010 b
Group with BMI 25 and above*	345 (308 – 388)	346 (314 – 412)	.830 b
Go No Go task latency			
Group with BMI 18.5 to 24.5*	461(407 – 509)	471(402 – 525)	.760 b
Group with BMI 25 and above*	447 (400 – 490)	439 (402 – 500)	.720 b
Stroop test latency period			
Group with BMI 18.5 to 24.5#	1103±154	1029±137	< .001 a
Group with BMI 25 and above#	1087± 195	1015±169	< .001 a
N - back test latency			
Group with BMI 18.5 to 24.5*	656 (541 – 795)	651 (537 – 751)	.350 b
Group with BMI 25 and above*	620 (503 – 760)	540 (472 – 770)	.030 b

a - p value obtained from paired t test, b - p value obtained from Wilcoxon Signed Ranks test, Group with BMI 18.5 to 24.9 n = 61, Group with BMI 25 and above n = 59, * data expressed as median, 25th and 75th percentile, # data expressed as mean and standard deviation.

N-Back test: The latency of N-back showed a reduction in the higher BMI group after exercise which was statistically significant (p = .030). Though the latency showed a reduction in the lower BMI group, this was not statistically significant (p = .350) as shown in table 1. However, the reduction in the latency was not statistically different between the two BMI groups as shown in the table 3.

Table 3: Comparison of difference in latency in milliseconds before and after exercise between the groups

Difference in latency (pre-post exercise)	Group with BMI 18.5 to 24.9 (n=61)	Group with BMI 25 and above (n=59)	p value
Visual reaction time*	11(-16 to 80)	8.5 (-31 to 38)	.090 a
Go No Go test*	- 4.2 (- 42 to 41)	0 (- 46 to 35)	.990 a
Stroop test#	74 ± 151	73 ± 129	.900 b
N back test#	33 ± 200	50 ± 178	.600 b

a - p value obtained using Mann Whitney U test, b - p value obtained using independent Student test, * data expressed as median, 25th and 75th percentile, # data expressed as mean and standard deviation.

Thus, we found a significant reduction of latency in VRT in the normal BMI group, in Stroop test in both the BMI groups and in N-back test in higher BMI group after a single bout of exercise. We also observed that the change in latency due to exercise was not statistically different among the two BMI groups for any of the cognitive tests.

DISCUSSION

The principal finding in our study is that the change in latencies among all the measured cognitive parameters were not statistically different between the normal BMI and higher BMI men. We observed improvement in latency period in Stroop test due to acute exercise in both the groups. Acute exercise improved latency in visual reaction time among the normal BMI men and improved latency in N-back task among higher BMI men.

The beneficial effect of acute exercise on cognitive abilities were small, yet well evaluated by meta-analysis (Chang et al., 2012; Lambourne & Tomporowski, 2010). The factors which influence the cognitive benefits were the intensity and duration of exercise, fitness of the participants and the type of cognitive parameters measured (Chang et al., 2012). Similar to this metanalysis we found in our study that the benefits were different for different cognitive abilities due to acute exercise. Stroop test showed improvement due to acute exercise while Go No Go task did not have any effect among both the study group. The physiological explanation proposed for the cognitive benefits of exercise were increased cerebral blood flow and this important adaptation enhances improved delivery and upregulation of neurotrophins to areas in the brain specially to hippocampus (Stimpson, Davison, & Javadi, 2018). Exercise also prevents the cognitive decline due to old age (Colcombe & Kramer, 2003).

Our study demonstrated improvement in Stroop test due to acute exercise and this was not influenced by BMI. Stroop test evaluates cognitive inhibition, cognitive flexibility, processing speed and executive function. Thus, Stroop test is used to assess multiple facets in cognitive functions (Scarpina & Tagini, 2017). In obese individuals reduced executive function occurs through reduces levels of brain derived neurotrophic factors (Kaur et al., 2016). An acute bout of exercise improves levels of brain derived neurotrophic factors (Matthew et al., 2013). Hence, based on the results of our study young men should be encouraged to perform exercise to improve these multiple facets of cognitive function assessed using Stroop test. Visual reaction time showed improvement only among the normal BMI group and did not show enhancement among the higher BMI group. Similarly, N back test showed improvement only among the higher BMI group. This could be due to the type of cognitive tests assessed.

Our study demonstrated that BMI did not show a confounding effect on cognitive enhancement due to acute exercise. Obesity reduces cognitive ability through reduced synaptic markers and microglial morphology (Bocarsly et al., 2015). This decline in cognitive abilities due to obesity is observed across all age group (Wang et al., 2016). Obesity was associated with reduced brain volume in cognitively normal adults (Raji et al., 2010). Obese individuals are less physically active and reduced physical activity has a negative impact on cognitive abilities. Dietary restriction, in the form of calorific restriction, is a known way to improve cognition (Pani, 2015). Hence, obese individuals should be encouraged to do exercise with appropriate nutritional restriction for improving their cognitive abilities.

One of the limitations of our study is that we did not have a control group to evaluate for the Hawthornean effect. However, we did give adequate practice in the beginning to nullify this effect. Moreover, we assessed BMI among the participants which is a rough estimation of obesity.

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