

RESEARCH ARTICLE

Effect of acute bout of moderate-intensity physical exercise on parameters of stress and cognitive functions

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ABSTRACT

Background: Stress is harmful to the body and produces changes in physiological and biochemical parameters. Up to a certain limit, stress is useful for learning and memory, but excessive amount effects higher brain functions such as memory, attention, and concentration, leading to anxiety and depression as denoted by a U-shaped curve between stress and memory. Physical aerobic exercises promote positive changes in one's mental health, intelligence, and ability to cope with stressful encounters. The present study was designed to explore the role of single bout of moderate-intensity aerobic exercise on cognitive functions and stress parameters. **Aim and Objective:** This study aims to study the effect of single bout of exercise on stress parameters; memory test (recent memory time, attention-concentration score, and attention-concentration time) and Stroop test (neutral, interference, and facilitation) score and time. **Materials and Methods:** Basal parameters of cognitive tests (memory test and Stroop test) and stress parameters (pulse rate, blood pressure, isometric handgrip, and serum cortisol) were assessed. A single bout of moderate-intensity physical exercise (MIPE) was introduced and parameters were again assessed. Comparison was made between pre-exercise and post-exercise values. **Results:** Post-exercise values of stress parameters reported significant decrease over pre-exercise value. Handgrip and serum cortisol reflected no significant change. Post-exercise values of cognitive tests observed significant increase in score while significant decrease in time over pre-exercise value. **Conclusion:** Single bout of MIPE reduced stress level and improved cognitive functions though the effect was temporary.

KEY WORDS: Acute Bout of Exercise; Cognition; Stress Response; Handgrip; Moderate-intensity Physical Exercise


INTRODUCTION

Stress is any external factor that disrupts homeostasis.^[1] Both the stressful life events and daily life stresses have deleterious and cumulative effects on human body and brain functions.^[2] Stress has bad effects on various parameters of higher mental functions such as attention, concentration, learning, and memory.^[3] In general, all stressful events generate certain

category of emotions of varying intensity, which affect cognition and performance.^[4]

The cause of stress is described as an interaction between individual and environment, in which the individual assesses deficiencies in his/her coping strategies in response to demanding situations.^[5] The interaction involves four steps. First is the perception of an internal or external stimulus; second, the evaluation of that stimulus as a threat to well-being; third, the appraisal of cognitive and/or physical coping resources; and fourth, a complex set of cognitive and somatic responses known as the stress response.^[4]

Each individual responds differently to the same type of stress due to unique genetic makeup and personal childhood experience with major stressors/trauma and personality

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characteristics.^[6] Stress has been associated with life experiences and neuroticism (emotional instability, negativity, and maladjustment).^[7] Humans under chronic stress usually experience permanent changes in their physiological, emotional, and behavioral response. In response to stress, people will engage in unhealthy behavior such as poor dietary practices or lack of exercise as a means of emotion-focused coping.^[8]

Moderate- to vigorous-intensity exercise is an effective method for improving perceived stress, stress symptoms, and quality of life.^[9] Academic performance is strongly related with aerobic exercises and that the cardiovascular fitness has the strongest association.^[10] Acute exercise transiently improves a large number of cognitive functions. The information processing speed and number of executive functions including attention, working memory, problem-solving, cognitive flexibility, verbal fluency, decision-making, and inhibitory control all improve for a period of up to 2 h post-exercise. Single bout of physical exercise offers immediate benefits that can enhance the learning experiences.^[11]

A single bout of moderate aerobic exercise for as less as 30 min can improve some aspects of cognition, most prominently for memory, reasoning, and planning and it decreases the time taken to perform the tests.^[12] Results so far suggest that the timing of exercise relative to memory encoding or retrieval as well as exercise intensity might influence the effects of acute exercise on memory.^[13]

Models of memory consolidation emphasize the dynamic nature of memory representations by proposing two main memory stages: A label state, in which memories are susceptible to enhancements or improvements and a stable state, in which they are rather insensitive to any treatment.^[14] The transient label state is seen shortly after learning and after the reactivation of memory traces. Thus, memory might, especially, be modified by physical exercise when performed during early phases of memory consolidation. Effects of acute physical exercise on long-term memory are also beneficial if exercise is performed either before or during learning.^[15]

It is well known fact that each of us reacts differently to same type of stress because each of us is shaped by our experiences. Can single bout of exercise help reduce stress response? Does acute exercise effect memory and attention-concentration span? To answer these intriguing questions, the present study was designed to study acute effects of exercise on stress reactivity and cognitive flexibility.

MATERIALS AND METHODS

Ethical Statement

Ethical clearance for the study was taken from the Institutional Ethics Committee of Government Medical College, Jammu,

Jammu and Kashmir, India, wide no. IEC/Pharma/Thesis/Research/T₇B/C/2017/436 dated 26/10/2017. The subjects were briefed about study and informed written consent for participation in the study was taken.

Participants

The study was conducted on 35 healthy male volunteers chosen randomly in the age group of 20–30 years (mean ± Standard deviation, 24.42 ± 1.6). Subjects already involved in physical activity and with the past or present significant history, psychiatric illness, central nervous system disorder, drug or alcohol abuse, and any other known medical conditions were excluded from the study. Only male subjects were chosen because females have different levels of stress and stress reactivity during different phases of menstrual cycle.

Each subject served as his own control. Only educated volunteers were chosen for the reasons that adequate educational background is required for filling of questionnaires and visual time reaction measurements. All the experiments were done in forenoon to minimize the diurnal variations in cortisol level.

Procedure

Basal parameters of cognitive tests (memory test and Stroop test) and stress parameters (pulse rate (PR), blood pressure (BP), handgrip, and serum cortisol) were assessed. A single bout of moderate-intensity physical exercise (MIPE) was introduced and parameters were again assessed. Comparison was made between pre-exercise and post-exercise values.

Serum cortisol is a well-known biochemical marker of stress and was assessed through ADVIA Centaur Cortisol Assay.^[16] Isometric handgrip exercise is a resistance exercise that employs diastolic BP (DBP). It is a measure of sympathetic system outflow, for which handgrip dynamometer was used.^[17] PR was assessed through palpatory method by examining the radial artery.^[18] BP was measured with the help of sphygmomanometer by auscultatory method. Both systolic BP (SBP) and DBP were recorded.^[19] For assessing cognitive functions, Stroop color and word interference test^[20] for cognitive flexibility and postgraduate institute memory test^[21] for short-term memory and attention-concentration were used in the present study.

MIPE: Subject was instructed to walk briskly at the rate of 4 mph.^[22] Subjects were instructed to carry out a single bout of MIPE for 20 min.^[23]

Statistical Analysis

The statistical analysis was done using Stats tester version 3.1.2. Comparison of pre-exercise and post-exercise mean data was done by Student's *t*-test. The results were computed as significant at $P < 0.05$ level represented by *,

more significant at $P < 0.01$ level represented by **, and highly significant at $P < 0.001$ level represented by ***.

RESULTS

Post-exercise values of stress parameters PR, SBP, and DBP reported significant decrease on comparison with pre-exercise value. Handgrip and serum cortisol reflected no significant change. However, serum cortisol showed tendency to increase and dual response was observed. Seventeen subjects exhibited a significant increase and 18 subjects showed a significant decrease in serum concentration of pre- and post-exercise values [Table 1].

Post-exercise values of cognitive tests observed significant increase for attention-concentration score (ACS), Stroop test neutral score, Stroop test interference score, and Stroop test facilitation score while recent memory time,

attention-concentration time (ACT), Stroop test neutral time, Stroop test interference time, and Stroop test facilitation time exhibited a significant decrease over the pre-exercise value [Table 2 and Figure 2a and b].

DISCUSSION

The effects of aerobic exercise include mood upliftment, improvement in stress-coping behavior, and also improve a large number of cognitive functions such as attention, working memory, problem-solving, decision-making, and verbal memory. These effects are transient after single bout of exercise for a period of up to 2 h post-exercise and return to baseline in recovery period. The present study reported the effect of single bout practice of MIPE on various parameters of stress and cognitive functions. Single bout of exercise was performed for 20 min and it showed a significant decrease in stress reactivity in post-exercise period. Furthermore, there

Table 1: Pre-exercise and post-exercise values of stress parameters

Parameters	Pre-exercise value	Post-exercise value	P value	Significance
PR	76.74±4.63	74.42±3.82	0.02	*
BP				
SBP	118.28±2.39	117.02±1.99	0.02	*
DBP	75.77±3.30	73.82±3.11	0.015	*
IHG	24.51±4.09	23.65±3.77	0.36	NS
S. cortisol	12.48±4.21	12.80±4.54	0.76	NS
Increase n=17	12.86±4.35	16.02±4.13	0.04	*
Decrease n=18	12.31±4.04	9.77±2.25	0.04	*

PR: Pulse rate (bpm); SBP: Systolic blood pressure (mmHg); DBP: Diastolic BP (mmHg); IHG: Handgrip (mmHg); S. Cort: Serum cortisol (µg/dl). * P value<0.05

Table 2: Pre-exercise and post-exercise values of cognitive functions

Parameters	Pre-exercise value	Post-exercise value	P value	Significance
Memory test				
RMT	23.73±4.24	21.00±4.71	0.014	*
AC				
Score	36.57±7.62	41.91±7.27	0.004	**
Time	203.72±4.76	201.21±4.11	0.02	*
Stroop test				
Neutral				
Score	64.51±6.66	71.31±6.47	0.00006	***
Time	841.17±130.94	723.77±85.05	0.00004	***
Interference				
Score	73.57±3.81	75.45±3.87	0.04	*
Time	900.88±92.36	818.45±97.06	0.0006	***
Facilitation				
Score	77.62±3.23	79.62±4.83	0.04	*
Time	746.22±125.45	682.45±128.19	0.04	*

RMT: Recent memory time; ACS: Attention-concentration score; ACT: Attention-concentration time. RMT and ACT are measured in seconds. STNS: Stroop test neutral score; STNT: Stroop test neutral time; STIS: Stroop test interference score; STIT: Stroop test interference time; STFS: Stroop test facilitation score; STFT: Stroop test facilitation time. Stroop test time is measured in milliseconds, * P value<0.05; ** P value<0.01; *** P value<0.001

was a significant decrease in recent memory time and ACT with significant increase in ACS in post-exercise period. Stroop test exhibited significant improvement in all subtests for both score and time in recovery period.

During single bout exercise, there was a significant decrease in resting PR value in post-exercise period. Significant findings of decrease in heart rate in post-exercise period (5–30 min after exercise) were reported in a similar study. These effects were temporary and returned back to basal level in recovery period.^[24]

Single bout of MIPE reported a significant decrease in resting level of SBP and DBP. Carpio-Rivera *et al.*^[25] demonstrated a significant decrease in resting level of SBP at $P < 0.01$ level and DBP at $P < 0.02$ level following acute bout of exercise. These changes were temporary and values returned back to basal level within 24 h. The physical activity associated decrease in resting BP reactivity levels observed may reflect a downregulation of sympathetic activity.^[26]

Handgrip value exhibited a tendency to decrease after single bout exercise from basal level though it was not significant. A study reported no significant reduction in DBP following single bout of isometric handgrip exercise (resistance exercise) compared to single bout of moderate aerobic exercise, the results were temporary.^[27] In the present study, DBP was employed in isometric handgrip testing. The tendency of handgrip value to decrease may be due to the effect of single bout of aerobic exercise rather than isometric exercise effect.

Statistically non-significant change in serum cortisol level was observed. There was diabolic response. Seventeen subjects showed a significant increase and 18 subjects were observed to have a significant decrease in serum levels. Both the type and intensity of exercise in relation to individual training levels provoke alterations in hormone responses that make it somewhat difficult to identify them.^[28] Rosa *et al.*^[29] in their study on the acute effects of physical exercise on serum cortisol observed significant reduction in cortisol level. Another study reported rise of serum cortisol level that was linked with the intensity of exercise performed. Significant increase in serum cortisol level was observed following single bout of vigorous-intensity (90% of maximum heart rate) exercise performed and returned to baseline during recovery period.^[30]

The single bout of MIPE exerted statistically significant effect on both recent memory time and attention-concentration over basal value. While recent memory time and ACT exhibited significant decrease in level, ACS observed significant increase in value. A study demonstrated that the group performing single bout of MIPE exhibited better motor learning skills than control group at $P = 0.017$ and this increases in motor acquisition diminished 1 h post-exercise.^[31] Chen *et al.*^[32] concluded that there was an increase in ACS

from 162.41 during pre-exercise to 206.29 in post-exercise period after acute aerobic exercise.

Acute bout of aerobic exercise increases cerebral oxygenated blood flow level accounting for increase in motor acquisition skills.^[33] Aerobic exercises activate connections of neural networks between cerebellum and frontal cortex and also elevate the level of brain-derived neurotrophic factor in blood. These increased levels of brain-derived neurotrophic factor play an important role in improving brain functions such as attention spans, concentration, and working memories.^[34,35]

The effect of single bout of MIPE on Stroop test yielded significant improvement for all subtests in score and reduction in time. Similar study reported that acute aerobic exercises improve performance in all forms of Stroop test.^[36]

Limitations of the Study

The present study was performed with small sample size for assessing the effect of single bout of MIPE on stress and cognitive functions. The results of the study may be specific to the type of subject chosen, individual variation in physical fitness, and activities performed in daily routine. However, the study gave us important insight into the fact that there was temporary improvement across domains of cognition and stress reactivity with a single bout of exercise. Further studies need to look at cognitive effects and stress response of exercise in larger number of subjects.

CONCLUSION

It can be inferred that 20 min of brisk walking produced significant decrease in resting level of PR, SBP, and DBP in post-exercise/recovery period (after 10–20 min of rest). This temporary decrease was to allow larger range over which exercise could be performed. Handgrip value did exhibit a tendency to decrease indicating decrease in stress response. Serum cortisol did not change with single bout of MIPE and exhibited a tendency to increase indicating physiological strain of single bout exercise training. Memory test and Stroop test improved temporarily and significantly after single bout of MIPE due to increase in oxygen supply to brain indicating temporary increase in cognitive brain function. Single bout of exercise produces temporary effects in physiological and cognitive parameters.

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