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EFFECT OF AEROBIC EXERCISE ON AUDITORY AND VISUAL REACTION TIMES : A PROSPECTIVE STUDY

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Abstract : Physical exercise provides multiple benefits to an individual. However, the beneficial effect of exercise on psychomotor performance remains controversial. The present study was undertaken to determine the effect of aerobic exercise on auditory reaction time (ART) and visual reaction time (VRT). Fifty subjects were enrolled consisting of healthy subjects who were not exercising (n=25; group I) and subjects doing regular aerobic exercisers (n=25; group II). ART and VRT were recorded using digital display response time apparatus equipped with three lights (red, green and yellow) and three auditory stimuli (low, medium and high pitched sounds). The mean VRT of group II subjects (318.24±6.709) was significantly lower than that of group I (505.73±16.961) (P<0.001). The mean ART of group II subjects (313.33±8.160) was significantly lower than that of group I (573.09±17.950) (P<0.001). Auditory and visual reaction times are better in aerobic exercisers as compared to non-exercisers irrespective of age and gender.

Key words : auditory reaction time, visual reaction time, aerobic exercise, psychomotor

INTRODUCTION

Reaction time (RT) is a reliable indicator of the speed of processing of sensory stimulus by central nervous system and its execution in the form of motor response. RT is defined as the time lapse between the onset of a stimulus and the initiation of a movement response (1). Reaction time study is an important method used for central information processing speed and fast coordinated peripheral movement response. It is an external indicator of the ability of the nervous system to receive process and initiate a response to incoming stimuli. Responses that take more time to initiate are assumed to require longer information processing times. Measurement of RT is a common method to evaluate psychomotor fitness.

Besides stimulus related factors like type

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of stimulus and stimulus intensity, other factors like arousal, age, gender, fatigue, alcohol and exercise are known to affect RT. One persistent finding in literature is the slowing of responses with age and faster RTs in males as compared to females (2-4).

Act of exercising has been shown to enhance numerous aspects of mental functioning, such as mood, self-esteem and general psychological well being (5). Although controversial, several studies have shown that physical exercises improve and protect the cerebral function, suggesting that physically active individuals have better cognitive function, and are at a lower risk to develop mental disorders compared to individuals with sedentary life style (6).

Aerobic exercise also affects cognition and psychomotor function. Aerobic exercise refers to exercise of moderate intensity which is undertaken for a long duration. Aerobic means "with oxygen", and refers to the use of oxygen in a muscle's energy-generating process. An effective aerobic exercise should involve 5-10 minutes of warming up at an intensity of 50-60% of maximum heart rate, followed by at least 20 minutes of exercise at an intensity of 70-80% of maximum heart rate, ending with 5-10 minutes of cooling down at an intensity of 50-60% of maximum heart rate (7).

The effect of aerobic exercise on visual and auditory RTs has escaped extensive examination and the existing data on the benefit of aerobic exercise on psychomotor performance is not conclusive (8-12). Indian data on this subject is very limited (13). Hence, this study was designed to compare the reaction times for auditory and visual stimuli among aerobic exercisers and non-exercisers.

METHODS

The study was conducted in 50 subjects in the department of Physiology. Subjects were divided in 2 groups consisting of 25 subjects each group. Group I included healthy subjects who did not perform regular exercise; and group II included persons who performed regular aerobic exercise for minimum of thirty minutes per day with a frequency of three to five days per week for a minimum duration of three to six weeks. All these subjects were in age range of 20-50 years.

Subjects who were smokers and/or alcoholics, who had clinical evidence of any illness, who had abnormal vision or hearing and who was on any medication which affects cognitive performance were excluded from the study. The study was approved by institutional ethics committee and written informed consent was obtained from all the subjects.

Study procedure

The aerobic exercises included exercises done by subjects in gymnasium with instructor. The aerobic exercise schedule involved 5-10 minutes of warming up at an intensity of 50-60% of maximum heart rate, followed by at least 20 minutes of exercise at an intensity of 70-80% of maximum heart rate, ending with 5-10 minutes of cooling down at an intensity of 50-60% of maximum heart rate (7).

ART and VRT were recorded using digital

display response time apparatus (Model No. RTM 608Medicaid:Ambala, India). The apparatus is equipped with 3 light stimuli: red, green and yellow and 3 auditory stimuli; low, medium and high pitched sounds (14). All the subjects were thoroughly acquainted with the apparatus and three practice trials were given to every subject before taking the reading.

Visual reaction time (VRT)

Any one of the three stimuli for light i.e. red, green, and yellow light was presented randomly and the subject responded to above stimuli by pressing the knob of digital display apparatus by switching off the given colored light. Reaction time displayed on apparatus was recorded in milliseconds (msec). Three readings were recorded for each colour and the lowest of three readings was taken as the value for reaction time task for that color. The readings for red, yellow and green color were denoted as VRT_R, VRT_Y and VRT_G respectively.

Auditory reaction time (ART)

The subject was presented randomly with one of the three sound stimuli (low, medium or high pitch) by the observer and subject responded by pressing the knob of digital display apparatus by turning off the produced sound. Reaction time displayed on apparatus was recorded in msec. Three readings were recorded for each sound stimulus and the lowest of the three readings was taken as the reaction time value for that stimulus. The readings for low, medium or high pitch sound were denoted as ART_1, ART_2 and ART_3 respectively.

Statistical analysis was done using analysis of variance (ANOVA). Data is represented as mean±SEM. Subgroup analysis was done for age and gender as earlier studies indicate alternation in VRT and ART with age and gender (2-4). Posthoc test was applied for comparing VRT_R, VRT_Y, VRT_G and ART_1, ART_2, ART_3 within both the groups as well as for subgroup comparison. $P<0.05$ was considered as statistically significant.

RESULTS

The demographic profile of subjects was comparable in two groups. The mean age of group I subjects (32.12±1.3) was not significantly different from group II subjects (30.96±1.4) (p=0.546). Males compromised 52% of the subjects in group I and 44% as in group II (p=0.775). The mean pulse rate (per min), systolic blood pressure (mm Hg) and diastolic blood pressure (mm Hg) of group I subjects was not significantly different from group II subjects (72.9±0.8 and 70.8±1.1, p=0.129; 122.1±2.3 and 122.4±1.5, p=0.93; and 77.2±1.3 and 76.4±1.2, p=0.653 respectively). The mean weight of subjects in group I (73.80±1.9 kg) was significantly higher than that of group II (66.00±2.4 kg, p=0.014).

The mean VRT of subjects (Table I) in group I was 505.73±16.961, which was significantly higher than that of subjects in group II (318.24±6.709; P<0.001). Further comparison of the VRT_R, VRT_G and VRT_Y values of subjects in group I and group II is shown in table II. The mean VRT_R, VRT_G and VRT_Y values of subjects in group I were significantly higher than those in group II (P<0.001 for each sub-group). The values of VRT_R, VRT_G and VRT_Y within each group were not significantly different from each other.

A sub-group analysis of the VRT according to age and sex is shown in Table II. In all the age groups (20-30 years, 31-40 years and 41-50 years), the mean±SEM of all the three parameters (VRT_R, VRT_G and VRT_Y) of group I was found to be significantly higher than those of group II. The highest difference was found in the age group of 20-30 years. Similarly, both in the male and female sub-groups, group I subjects had significantly higher VRT values for all the three parameters (VRT_R, VRT_G and VRT_Y) as compared to group II. The subgroup analysis also shows the delayed VRT in females as compared to males and with increasing age in both groups, although statistically not significant.

The mean ART of subjects (Table III) in group I (573.09±17.950) was significantly higher than that of subjects in group II (313.33±8.160) (P<0.001). The mean ART_1, ART_2 and ART_3 values of group I was significantly higher as compared to group II. The values of ART_1, ART_2 and ART_3 within each group were not significantly different from each other.

TABLE I : Comparison of visual reaction time (VRT) and auditory reaction time (ART) of subjects in group I (n=25) and group II (n=25).

Parameter	*Group I (Control)* Mean±SEM	*Group II (Exercisers)* Mean±SEM	*P value*
VRT_R	502.16±28.729	307.24±10.977	<0.001
VRT_G	495.40±31.056	323.48±10.984	<0.001
VRT_Y	519.64±29.295	324.00±12.950	<0.001
ART_1	610.24±28.863	324.60±11.733	<0.001
ART_2	576.88±34.392	307.84±11.889	<0.001
ART_3	532.16±28.924	307.56±18.136	<0.001

VRT_R, VRT_Y and VRT_G denote VRT for red, yellow and green color respectively.
ART_1, ART_2 and ART_3 denote ART for low, medium and high pitch sound respectively.

TABLE II : Sub-group analysis of visual reaction time (VRT) (msec) in group I (n=25) and group II (n=25).

Parameters	*Group I (Control) Mean±SEM*			*Group II (Exercisers) Mean±SEM*			*P value*
	VRT_R	*VRT_G*	*VRT_Y*	*VRT_R*	*VRT_G*	*VRT_Y*	
Age (years)							
20-30	460.55±44.471	465.27±43.579	464.91±34.922	298.40±12.240	317.80±11.380	314.80±15.370	<0.001*
31-40	491.20±36.366	475.10±42.792	536.60±42.139	299.60±21.340	324.40±22.400	315.40±18.580	<0.001*
41-50	644.25±68.057	629.00±99.788	627.75±107.380	368.700±23.310	345.00±48.770	389.70±63.490	<0.01#
Sex							
Male	501.00±36.413	477.54±42.611	500.77±45.114	286.73±18.499	332.73±16.487	320.91±20.038	<0.001*
Female	503.42±46.737	514.75±46.614	540.08±37.716	323.36±12.041	316.21±14.974	326.43±17.581	<0.001*

* # as compared to group I.
No significant difference between age groups and gender in-between subgroups of group I.
No significant difference between age groups and gender in-between subgroups of group II.

TABLE III : Sub-group analysis of auditory reaction time (ART) (msec) in group I (n=25) and group II (n=25).

Parameters	Group I (Control) Mean±SEM			Group II (Exercisers) Mean±SEM			P value
	ART_1	ART_2	ART_3	ART_1	ART_2	ART_3	
Age (years)							
20-30	626.55±45.433	563.00±61.359	510.64±53.691	311.20±16.70	294.23±15.377	280.60±13.640	<0.001*
31-40	598.10±46.431	540.00±38.260	522.20±35.311	323.10±15.160	307.00±21204	299.70±36.800	<0.001*
41-50	595.75±78.273	707.25±81.704	616.25±56.460	387.00±37.650	369.33±17.285	448.00±16.500	<0.001#
Sex							
Male	596.16±42.324	556.92±49.088	537.46±40.694	300.63±18.423	302.72±24.067	295.27±34.33	<0.001*
Female	625.50±40.360	598.50±49.468	526.42±42.892	343.43±13.665	311.86±10.634	317.51±18.860	<0.001*

*# as compared to group I.
No significant difference between age groups and gender in-between subgroups of group I.
No significant difference between age groups and gender in-between subgroups of group II.

A sub-group analysis of ART values according to age and sex is shown in table III. In all the age groups (20-30, 31-40 and 41-50 years) the mean±SEM of all the three parameters (ART_1, ART_2 and ART_3) of group I was found to be significantly higher than that of group II. The highest difference was found in the age group of 20-30 years. Similarly, the ART_1, ART_2 and ART_3 of both the male and female sub-groups of group I was found to be significantly higher those of group II. The subgroup analysis also shows the delayed ART in females as compared to males and with increasing age in both groups, although statistically not significant.

DISCUSSION

In today's society, lack of vigorous physical activity has caused much concern as it causes low levels of fitness and increases incidence of various health related problems such as cardiovascular diseases. This causes greater physiological as well as psychological stress on the individual. It is already known that participating in regular exercise can prevent coronary heart disease, hypertension, obesity and improve flexibility. Further, fitness and exercise are generally considered to promote psychological well-being. It improves mood and concentration and reduces stress. Individuals feel and do better as a result of engaging in some type of aerobic exercise program if continued for a number of weeks.

The present study was designed to explore the relationship between physical fitness and psychomotor performance. ART and VRT were used to evaluate processing by central nervous system and coordination between sensory and motor functions. We observed that RT for auditory and visual stimuli was significantly lower in subjects who performed regular aerobic exercises, compared to non-exercisers, irrespective of the age and gender sub-groups. Similar results regarding the positive effect of exercise on RT time have been reported previously (8-10, 13). In one study faster RTs for both auditory and visual stimuli were reported among aerobic exercisers compared to controls (13). Two other studies reported faster RTs among physically fit subjects and among basketball/baseball players (8, 10). Another study reported that the fastest RTs were observed when the subjects were exercising sufficiently to produce a heart rate of 115 beats per minute (9). Studies on older subjects had also reported the beneficial effects of aerobic exercise (15). Our study findings indicate that using 30 minutes of regular aerobic exercises in gymnasium improved reaction time. The improvement was found irrespective of age and gender. There was a trend for delayed reaction times with increasing age and in females as reported earlier also (2-4).

Various mechanisms have been proposed for faster RT in aerobic exercisers. This may be due to improved concentration, alertness, better muscular co-ordination and improved performance in the speed and accuracy (16, 17). Aerobic activity leads to enhanced cognitive performance, in particular cognitive flexibility, a measure of executive function (18). Exercise training elicits an adaptive increase in mitochondrial content and respiratory capacity of those skeletal muscles which were being used during the exercise training leading to sparing of glycogen and increased capacity to oxidise fatty acid, thus prolongation in work time, delay in fatigue and increase in enzymatic activity, increasing oxidation of ketones and increased removal (19, 20). Aerobic physical exercise may also protect the central nervous system (CNS) from oxidant stress by increasing the oxidant enzyme activity, in a similar way to what happens in other tissues such as the skeletal muscle, thus increasing the defence ability against the damages caused by reactive oxygen species (21, 22). Another important mechanism by which exercise improves performance in aerobic exercisers is through its ability to improve neurological functioning by increasing blood circulation within the brain (23). When more blood is allowed to flow through the brain, more nutrients, such as glucose and oxygen, are able to be delivered to important structures that influence an individual's cognitive functioning (6). Frequent aerobic exercise plays a large role in the maintenance of cerebrovascular activity and cardiorespiratory functioning, which can in turn help to sustain cognitive aptitude. Alterations in the level of certain neurotransmitters, such as serotonin, norepinephrine and dopamine by physical exercise may play a key role in various aspects of cognitive functioning, such as enhancement of both working and long-term memory (24).

On the contrary, few studies have reported that exercise does not lead to a significant decrease in RT (1, 11, 12). Two studies found no effect of exercise on RT in soccer players (25, 26). Another study reported that choice RT and error rate in soccer players were not affected by exercise on a stationary bicycle (27). Another study found no post-exercise effect in runners, but did find that exercise improved RT during the exercise (28). They attributed this to increased arousal during the exercise. The type of exercises used in these studies were different than used in our study.

An earlier study reported that the response latency for green colour was lesser than red i.e., green colour evoked faster response due to its strong stimulation on visual receptors and hence it had minimum reaction time (29). However, in our study, the VRT values for red, green and yellow colour were not significantly different from each other in both the groups.

To conclude, the faster RT in aerobic exercisers (the bridge between physical exercise and cognitive functioning) can serve as an important link to optimize the process of performance. As a competitive sport depends on mental processes and peripheral elements of the movement system, psychomotor fitness due to aerobic exercises can be useful for coaches and athletes in assembling strategies that involves attention and decision, thus reinforcing a good sportive performance. This bridge can also help the elderly to prevent the effect of aging on cognition and multiple task performance. Thus, the use of physical exercise to improve cognitive function can be applicable as a cheap and non-pharmacological alternative to optimize process of performance in all age groups and genders.

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