Original article:

Effect of aerobic exercise on parasympathetic system

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Abstract:

Introduction: Aerobic exercise is a physical exercise that is performed at moderate level of intensity over a relatively longer period of time. It depends primarily on aerobic energy generating process. There is a direct correlation between physical inactivity and cardiovascular morbidity and mortality. In this study, we show effect of aerobic exercise on parasympathetic function in healthy young adult. Aim of this study is to quantify parasympathetic function in study and control group before and after 3 months of aerobic exercise.

Material and method: The present study was carried out at autonomic function test laboratory in the department of physiology, K. G. M. U., Lucknow, after ethical clearance. 60 apparently healthy untrained male subjects with normal physical activity and BMI18.5-24.5 kg/m2, aged 18- 35 years were enrolled in this interventional study and divided into 2 equal groups, exercise and control group. 30 subjects of exercise group performed aerobic exercise by running on treadmill (20 minuts, alternate day) for 12 weeks and 30 subjects of controlled group continued sedentary life style. To quantify parasympathetic function, following parameters were measured: [1) Heart rate response to standing from supine position (30:15 ratio). 2) Heart rate response to slow deep breathing (E:I ratio). 3) Heart rate response to Valsalva maneuver] of all the subjects were recorded at day 1 and after 3 months, with the help of PC based cardiac autonomic neuropathy analysis system.

Result: Parasympathetic functions (30:15 ratio, E:I ratio, and Valsalva ratio) are found to be significantly higher in exercise group as compared to control group. Significant differences were found in the above mentioned parameters among the exercise group but no significant change was observed among control group.

Conclusion: The study suggests that parasympathetic function shows favorable changes with aerobic exercise.

Keywords: Exercise, aerobic exercise, parasympathetic system, autonomic system, cardiovascular system

Introduction

Physical exercise is an acute bout of bodily exertion that is planned and structured, requires energy above resting level, results voluntary movement and enhances or maintains physical fitness and overall health and wellness.In aerobic exercise, the metabolic system used for energy supply to exercising muscles is aerobic system. Aerobic system is the oxidation of foodstuffs in the mitochondria to provide energy. Glucose, fatty acids and amino acids from the foodstuffs after some intermediate processing combine with oxygen to release tremendous amount of energy that are used to convert AMP and ADP to ATP. Phosphagen system is used by exercising muscles for 8-10 seconds, Glycogen-lactic acid system for 1.3 – 1.6 minutes and aerobic system for unlimited time as long as nutrient last. In this way it is clear that the phosphagen system is the one used by the muscles for power surges of a few seconds, and the aerobic system is required for prolong athletic activity, in between is the glycogen-lactic acid system ,which is especially important for giving extra power during such intermediate races as the 200 to 800 meter runs.

Exercise of moderate intensity (50% of Vo_2 max or 50% increase in heart rate from basal value or 55% - 69% of MHR during exercise) done for longer period of time comes under aerobic training. Exercise is performed for various reasons , including strengthening muscles and cardiovascular system, improving athletic skills , or weight loss. Frequent and regular physical exercise boosts the immune system and helps prevent the ''disease of affluence'' such as heart disease,cardiovascular disease, type 2 diabetes , and obesity[1].

Autonomic nervous system and cardiovascular system

Although cardiac muscle has an intrinsic mechanism for HR, neural influences superimpose on the inherent rhythm of the myocardium, the autonomic nervous system provides the innervations for the heart. These influences originate from the cardiovascular centre in the medulla oblongata and flow through the sympathetic and parasympathetic (vagal) components of the autonomic nervous system[4]. The vagal nerves innervate the sinoatrial node, the atrioventricular (AV) conducting pathways and the atrial muscle. Vagal innervation has also proposed to influence on the cardiac ventricular function[2]. The parasympathetic influence is mediated via acetylcholine. In patient with autonomic failure and diabetes mellitus, abnormal parasympathetic control of heart rate is very frequent and can be clinically assessed by studying change during deep breathing or Valsalva Maneuver.

Thus, there is a direct correlation between physical inactivity and cardiovascular morbidity and mortality. In this study, effect of aerobic exercise on parasympathetic function in healthy young adult is shown.

AIMS AND OBJECTIVES

Aim of the study is to evaluate the effect of aerobic exercise (12 week/alternate day) on parasympathetic system in healthy sedentary adult population.Objectives of the study are to record the anthropometric measurements (weight, height, body mass index) of the study and control group and to quantify parasympathetic functions(30^{th}:15^{th} ratio, E:I ratio, Valsalva ratio) in healthy adults before and after 3 months of aerobic exercise.

MATERIAL AND METHODS

The cohort study was conducted in Autonomic function laboratory and Exercise laboratory in the department of Physiology King George Medical University (KGMU) Lucknow, using a battery of standard autonomic function test. The ethical clearance for the study was obtained from the ethics committee of KGMU, Lucknow.

This study included 60 apparently healthy male subjects of age group 18 years - 35 years, with B.M.I >18.5kg/m2-<24.5kg/m2, from K.G.M.U campus, with normal physical activity and were not involved in any exercise training. They were divided into two groups, containing 30 subjects in each group. Of two groups, one group performed aerobic exercise by running on Treadmill (20 minutes ,alternate day) for 3 months and another group continued sedentary life style.All the subjects were

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well informed about the nature of the study and informed consent was obtained for autonomic function test.

Untrained male individual aged - >18 years - <35 years with B.M.I >18.5kg/m2-<24.5kg/m2 with normal daily physical activity, without personal or family history of any disease known to affect autonomic functions, normal baseline clinical examination with no medication for chronic illness, no history of any chronic illness and free from habit of substance abuse were included in the study. Individuals aged<18 years - >35years, or B.M.I, <18.5kg/m2->24.5kg/m^2, or trained, athletes or marathoner or with any history of associated disease that can influence the Autonomic nervous system (Diabetes, Cardiopulmonary disease, Scleroderma, Mitral valve prolapsed, Esophageal, Gastric or Pulmonary surgery, known neuropathy of other etiology) or subjects on meditation that could alter their heart rate or blood pressure during the study period or anyone who during the course of study developed a requirement for such a drug, or subjects involved in substance abuse or having history of substance abuse were excluded from the study.

All the subjects were asked to refrain from drinking alcohol, tea or coffee for at least 12 hrs before performing the test. All the test were carried out in a peaceful environment in room temperature after taking 30 minutes rest .The participants were advised to avoid anything that might modify autonomic responses by inducing fear or anxiety. The subjects were asked to abstain from eating or drinking anything for at least 2 hrs before the commencement of tests.

Tests were carried out in Autonomic function lab with the help of CANWinmachine(Genesis Medical Systems Pvt.Ltd,Hyderabad,India). CANWin is a PC based **Cardiac Autonomic Neuropathy (CAN)** Analysis system with interpretation. It analyses both Sympathetic and Parasympathetic autonomic nervous system response of the patient. It uses TCG (Tacho Cardio Gramme) response to Resting HR, deep breathing, response to standing and Valsalva Maneuver for Parasympathetic function analysis.

The subjects were made comfortable and were explained about the entire procedure before the recording was done. Subject was asked to lie quietly on a bed. First the resting cardio-respiratory parameters (Heart rate, BP and respiratory rate) were recorded in lying down position. The purpose of respiratory recording was two folds, firstly it served as support parameters to confirm whether the tests like deep breathing or Valsalva were correct or not and second to record the base line of the respiratory rhythm.Testsrecorded for Parasympathetic activity:

1. Heart rate response to standing from the supine posture (30:15 ratio),(Weiling et al, 1985)[3]
2. Slow deep breathing test (E:I ratio/Expiration:Inspiration ratio), (Soundkwist et al.,1979)[4], (Weiling 1992)[5]
3. Valsalva maneuver (Levin, 1966)[6], (Korner, *et al.*, 1976)[7]

Training protocol: Subjects were divided into two groups, exercise and control groups, each group containing 30 subjects.Participants of exercise group performed aerobic exercise by running on treadmill, on alternate days for 12 weeks, Sunday being the rest day.HR of the subjects during exercise were maintained between 55% - 69% of maximum HR (moderate exercise).Trainingperiod were of 20 minutes, divided into two equal sets of 10 minutes each , there were 2-3 minutes rest in between two sets.All the parameters were measured at day 1

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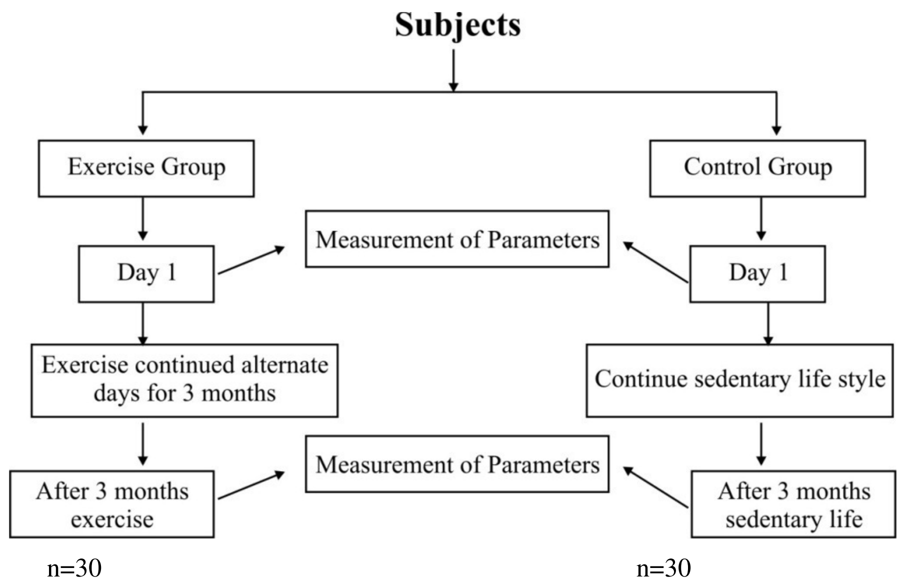
before start of training and after completion of training.All these parameters were also measured in another group of 30 subjects which did not perform any aerobic training, at day 1 and after 12 weeks .



RESULTS

Parasympathetic reactivity in exercise and control group at Day-1

The mean resting heart rate in exercise group was 71.03±8.67 and in the control group was 67.47±7.95. No statistically significant difference was found in the resting heart rate between the exercise group and the control group. (Table-1). To find out the reactivity of parasympathetic system the heart rate response was recorded after different maneuver as these maneuver causes stimulation or withdrawal of the parasympathetic system.

Table-1: Comparison of subjects according to heart rate at baseline

	Exercise group (n=30) (mean±SD)	**Control group (n=30)** (mean±SD)	**p-value[1]**
Heart rate	71.03±8.67	67.47±7.95	0.25

[1]Unpaired t-test

The mean 30^{th}:15^{th} ratio in exercise group was 1.07±0.04, while in control group was 1.04±0.04. The mean E:I ratio in exercise group was 1.31±0.08, while in control group was found to be 1.28±0.11.The mean Valsalva ratio in exercise group was 1.53±0.24, and in control group was found to be 1.59±0.25. No statistically significant difference was found in the 30^{th}:15^{th} ratio, E:I ratio and Valsalva ratio between the exercise group and the control group at baseline. (Table-2).

Table-2: Comparison of subjects according to ratios at baseline

Ratios	**Exercise group (n=30)** (mean±SD)	**Control group (n=30)** (mean±SD)	**p-value**[1]
30:15	1.07±0.04	1.04±0.04	0.07
E:I	1.31±0.08	1.28±0.11	0.20
VALSALVA	1.53±0.24	1.59±0.25	0.39

[1]Unpaired t-test

Parasympathetic reactivity in exercise and control groups at 3 months

The mean resting heart rate in exercise group was 67.23±6.12 and in the control group was 64.57±2.01. Statistically significant difference was found in the resting heart rate between the exercise group and the control group (Table-3).

Table-3: Comparison of resting heart rate at 3 month between exercise and control groups

	Exercise group (n=30) (mean±SD)	**Control group (n=30)** (mean±SD)	**p-value**[1]
Heart rate	67.23±6.12	64.57±2.01	0.02*

[1]Unpaired t-test, *Significant

The mean 30^{th}:15^{th} ratio in exercise group was 1.15±0.07, while in control group was 1.10±0.08. The mean E:I ratio in exercise group was 1.40±0.15, while in control group was found to be 1.31±0.16. The mean Valsalva ratio in exercise group was 1.83±0.43, and in control group was found to be 1.62±0.28. Statistically significant difference was found in the 30^{th}:15^{th} ratio, E:I ratio and Valsalva ratio between the exercise group and the control group (Table-4).

Table-4: Comparison of ratios at 3 month between exercise and control groups

Ratios	**Exercise group (n=30)** (mean±SD)	**Control group (n=30)** (mean±SD)	**p-value[1]**
30:15	1.15±0.07	1.10±0.08	0.02*
E:I	1.40±0.15	1.31±0.16	0.03*
VALSALVA	1.83±0.43	1.62±0.28	0.02*

[1]Unpaired t-test, *Significant

A significant ($p<0.05$) change was observed in the resting heart rate among the exercise group but no such change was seen in the control group.A significant ($p<0.05$) change was also observed in the 30 :15 ratio, E:I ratio and Valsalva ratio among the exercise group. However, no significant change was observed in the control group. (Table-5)

Table-5: Comparison of mean change in the study parameters from baseline to 3 months within groups

Study parameters	**Exercise group**		**Control group**	
	Mean change±SD	**p-value[1]**	**Mean change**±SD	**p-value[1]**
Resting heart rate	-3.76±9.11	0.03*	-2.90±11.60	0.07
30:15	0.08±0.08	0.04*	0.06±0.06	0.81
EI	0.08±0.11	0.03*	0.03±0.10	0.42
VAL	0.30±0.41	0.02*	0.03±0.32	0.47

[1]Paired t-test, *Significant

DISCUSSION

The present study has demonstrated that exercise group has definite improvement in parasympathetic function. All the test were done for ANS function, namely- E:I ratio, Valsalva ratio , 30:15 ratio.

When the parasympathetic system is stimulated by various maneuver there is an increased parasympathetic response in exercise groupfollowing exercise as compared to control group. Test for parasympathetic functions, E:I ratio, Valsalva ratio , 30:15 ratio, were found to be significantly different in exercise group as compared to control groups after 3 months. A significant increase was also found within the exercise group from the baseline parameters but not in the control group.

These test are totally vagally mediated, though sympathetic activity may play a small role in the Valsalva response **(Ewing, *et al* 1974)**[8],and the

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increased magnitude of heart rate variation in exercise group as compared to control group may suggest enhanced parasympathetic activity.

(a) Heart rate:

In comparison to control group the exercise group was having lower basal heart rate after 3 month of aerobic training. A significant decrease was also found within the exercise group from the base line parameters but not in the control group. The findings are in accordance to **Craft** and **Schwartz (1995)**[9] and **Robinson *et al.* (1966)**[10]. This decrease in basal heart rate in exercise group may be due to increase in parasympathetic tone. The lowering of resting and submaximal HR is mediated by alterations in the autonomic nervous system and by changes in the intrinsic mechanism of the sinus node and right atrial myocytes **(Ekblom*et al.* 1973)**[11] **(Lewis *et al.* 1980)**[12]. During exercise, in a trained subject, a given increase in cardiac output requires less increase in HR due to the maintenance of a larger stroke volume. Studies focusing on autonomic responses to training indicate that HR is reduced during submaximal exercise due to a lower intrinsic HR, a reduction in sympathetic activity and circulating catecholamines and a greater parasympathetic influence **(Ekblom*et al.* 1973)**[11], **(Lewis *et al.* 1980)**[12]**(Tulppo*et al.* 1998b)**[13]. The lower sympathetic activation of the heart at submaximal working levels derives in part from the diminished reflex signals originating from skeletal muscle due to less abundant metabolite accumulation and attenuated discharge of metaboreceptors **(Mostoufi-Moab *et al.* 1998)**[14].

The mechanisms underlying the training induced increase in vagal activity are thought to consist of greater activation of the cardiac baroreceptors in response to the enlargement of blood volume and ventricular filling **(Spinelli*et al.* 1999)**[15] as well as changes in the opioid **(Angelopoulos *et al.* 1995)**[16] and dopaminergic modulation of parasympathetic tone **(Slavik and LaPointe 1993)**[17]. Lower intrinsic HR due to enlarged heart may be one adaptation mechanism after aerobic training **(Bonaduce*et al.* 1998)**[18]. Another possible mechanism for reduced intrinsic HR is that, atrial enlargement reduces the stretch-depolarization stimulus altering the resting regulation of heart muscle.

(b) 30:15 ratio

In normal subjects there is a characteristic immediately shortening of R-R interval i.e, minimal around the 15th beat after standing followed by a relative lengthening that reaches a maximum around the 30th beat after standing. The immediate heart response to standing is reproducible and initiated by instantaneous cardiac vagal withdrawal followed by vagal reactivating over the first 25-30 beat. Following aerobic training there is increased response presumably due to increased tone of the reflex pathways mediating the response. A statistically significant difference was found in the 30:15 ratio between the exercise group and the control group. A significant increase was also found within the exercise group from the baseline 30:15 ratio but there was no such significant change among the control group.

(c) E:I Ratio:

The variation of R-R interval is larger in exercise group than in control group. This study demonstrates a significant difference in the E:I ratio between the exercise group and the control group after 3 months. A significant increase was also found within the exercise group from the baseline parameters but not in the control group. The findings are similar to **Tulpoo MP et al (1998)**[13].R-R interval variation during the breathing has shown to be under vagal control **(Wheeler T et al, 1973)**[19].This change may be due to increase vagal tone in the exercise group following aerobic training.

(d) Valsalva Maneuver:

The Valsalva maneuver tests the integrity of baroreceptor reflex heart rate control mechanism in normal individual **(Sarnoff et al., 1966**)[20].The study found a significant difference in Valsalva ratio between the exercise group and the control group after 3 months. A significant increase was also found within the exercise group from the baseline parameter but there was no such significant change among the control group. This is in accordance to the findings reported by **Eckberg*et al.*, (1971)**[21].

CONCLUSION

The present study was designed to examine the difference in Autonomic functions between exercise and control group and within the groups, after three month of aerobic exercise.At day-1 of the study, no statistically significant difference was found in parasympathetic parameters between exercise and control group.At day-90 of the study, exercise group had significantly lower resting heart rate than the control group. Also, exercise group had significantly higher 30^{th}:15^{th} ratio, E:I ratio and Valsalva ratio as compare to control group.A significant difference was observed in the resting heart rate(decreased)among the exercise group but no such change was seen in the control group.Significantly higher, 30 : 15 ratio, E:I ratio and Valsalva ratio was observed among the exercise group. No significant change was observed in the control group.

This study has suggested that parasympathetic functions shows favorable changes with aerobic exercise, this could be translated into practice of stress management which emphasize predominance of parasympathetic function for better stress management. Aerobic exercise can not only improve parasympathetic functions but also act as an alternative stress management method.

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