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CARDIAC OUTPUT CHANGES IN SUBMAXIMAL EXERCISE IN YOUNG INDIAN ADULTS

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ABSTRACT

Aims & objectives: Aim of the current study is to measure cardiac output before and after submaximal exercise test on treadmill in physically healthy but untrained young Indian adult males. Study also determine the relative contributions of stroke volume heart rate in the raising cardiac output in such strong group.

Method: This cross sectional study was conducted among 15 adults in the age group of 17-30 years. Heart rate, SBP, DBP, LVET, stroke volume, and cardiac output were measured before and after submaximal exercise test, and the results were correlated.

Results: The mean heart rate was 71.86(57 -91 bpm) at rest, with exercise, it rose to 134.8 bpm, with an increase of 62bpm (87.6%). The difference of heart rate between rest, and exercise was statistically significant ($p<0.0001$).The mean SBP at rest was 74.27mm Hg, with exercise, it rose to 139.67 mm Hg, with a mean rise of 26.14 mmHg ($p<0.0001$). The DBP rose from 74. 26 mmHg at rest to 84. 53mmHg during the exercise ($p<0.0001$).The mean LVET at rest was 253.67 with range of 223-320 msec. This range was correlated with the resting heart rate range of 57-91 bpm. However the ejection time for similar rates were different in some subjects. With exercise, LVET shows a decline of 36.14 msec to 217 msec, a drop of 15.3% and at the rest ejection time for a given heart rate was different for some subjects. The mean stroke volume at the rest was 69.26 ml and at exercise, it shows a decrease by 9.58 of 13.83% ($P<0.0001$). The mean cardiac output at the rest was 4.91 L/min and at exercise, and it was 7.99L/min with a significant increase of 62% ($P<0.0001$). The cardiac index rose to 4.78L/min/m^2 during exercise showing an increase by 1.84L/min/m^2(62.32%). A Positive significant correlation observed between the resting and exercise values of heart rate and cardiac output ($r=+0.73$, $p<0.0001$). A Positive significant correlation observed between the resting and exercise values of LVET and stroke volume($r=+0.99$, $p<0.0001$). A negative significant correlation observed between the resting and exercise values of heart rate and LVET ($r= -0.11$, $p<0.0001$). A negative significant correlation observed between the resting and exercise values of stroke and cardiac output ($r= -0.26$, $p<0.0001$). A negative significant correlation observed between the resting and exercise values of cardiac output and LVET ($r= -0.77$, $p<0.0001$), indicates high significant.

Conclusion: Young physically healthy but untrained group of individuals respondent to Submaximal exercise test with increased cardiac output of 62% predominately due to an increased heart rate and fall in stroke volume. Rise in heart rate compromised the venous return and coupled with a poor contractile reserve due to reduced tolerance to exercise the group showed a reduction in the stroke volume and in the duration of ejection.

Keywords: Submaximal exercise, stroke volume, cardiac output, heart rate.

INTRODUCTION

The cardiovascular system provides link between pulmonary ventilation and oxygen usage at the cellular level. During exercise, efficient delivery of oxygen to working skeletal and cardiac muscles is vital to maintain ATP production by aerobic mechanisms.[1] Cardiac output during exercise increases greatly owing to the relatively high heart rates that are achieved during exercise. Various risk factors such as age, gender, posture, type and duration and intensity of exercise as well as the training status of the individuals.[2]

Heart rate increases proportionately with workload until heart rates close to maximal are attained. It is remarkable that exercise heart rates 6 to 7 times resting values are not associated with a fall in stroke volume, which is maintained by splenic contraction, increased venous return, and increased myocardial contractibility. Despite the great changes in cardiac output, increases in blood pressure during exercise are maintained within relatively smaller limits, as both pulmonary and systemic vascular resistance to blood flow is reduced. Redistribution of blood flow to the working muscles during exercise also contributes greatly to the efficient delivery of oxygen to sites of greatest need. Higher work rates and oxygen uptake at submaximal heart rates after training imply an adaptation due to training that enables more efficient oxygen delivery to working muscle. Such an adaptation could be in either blood flow or arteriovenous oxygen content difference. Cardiac output during submaximal exercise does not increase after training, but studies using high-speed treadmills and measurement of cardiac output at maximal heart rates may reveal improvements in maximal oxygen uptake due to increased stroke volumes, as occurs in humans.[3]

Cardiac output measurements as introduced by Wiggers based on systolic time interval are relatively simple.[4]

The contributions of heart rate, and stroke volume in raising cardiac output during submaximal exercise are different in the trained and untrained individuals.[5]

Submaximal exercise systolic BP is associated with markers of CV structure in adolescents. Given the clinical relevance of exercise BP in adulthood, such associations may have implications for CV disease screening in young people and risk in later life.[6]

Submaximal exercise testing overcomes many of the limitations of maximal exercise testing, and it is the method of choice for the majority of individuals seen by physical therapists in that these individuals are likely to be limited physically by pain and fatigue or have abnormal gait or impaired balance.[7]

MATERIAL AND METHODS

This cross sectional study was conducted among 15 adults in the age group of 17-30 years. Preliminary clinical examination was done to rule out any cardio respiratory abnormalities of any other disabilities. Anthropometrics, pulse rate and blood pressure were measured. For measuring systolic time intervals, a photoelectric Plethysmograph volume transducer of Nihen Kohen make (model MPP 3-S) was applied over the site of maximum pulsation of the

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right carotid artery and fixed with a light shielding dark black strap wound around the neck. The subjects were given about 15 min time after the application of the transducer to allay anxiety and apprehension, which would have caused a rise in heart rate at rest, and then the pulse tracing was obtained. Transducer was in turn connected to a model 201 polyrite recorder and a graph of the pulse tracing obtained on a sheet of graduated chart paper set to move at a speed of 25 mm/sec. In addition the output from the polyrite was also connected to the cathode ray oscilloscope (D- II- single beam Model 5103 N), calibrated to get 1 cm horizontal distance equivalent to 1 sec. the cathode ray oscilloscope was included to the polyrite and as a stand by in case the recording on the polyrite is affected due to any cause.

The motor driven graduated paper of the polyrite moving at a speed of 25mm/sec gets a recording from the definitions of the pen attached to an ink reservoir and a stylus which moves perpendicular to the paper. The recording of the carotid artery pulse wave is obtained on the polyrite chart paper. The polyrite chart paper speed was calibrated in the paper for 1 min from a previously fixed point in the paper at 25mm/sec speed and the total length of paper which was covered within the minute was confirmed to be 1500mm. to calculate the systolic time intervals from the carotid artery pulse tracing about 10 consecutive and clean recordings with discernible point of beginning of the upstroke and the characteristic notch were chosen. The LVET, the timeinterval between the beginning of upstroke of the carotid pulse wave and the trough of the incisura of the dicrotic notch was calculated in milliseconds.

The heart rate was also obtained from the same recorded pulse trace corresponding to the 10 traces used for calculating the left ventricular ejection time.

Stroke volume (ml) = 0.501 LVET (msec) + 0.13 HR – 67.2

The resting cardiac output (Q) was obtained by multiplying the values of stroke volume and heart rate.After the measuring resting parameters, the subject was made to perform the exercise on a treadmill (Model Venky) set at 0% slope and a speed of 5Km/hr.

The subject exercised for a duration of 9 -15 min within time they attained 70% of his maximum heart rate (submaximal intensity). As the person was exercising, their carotid artery pulse tracing was recorded within the transducer in place. The pulse and blood pressure were measured at every 5 min and the subject was continuously observed for any evidence of discomfort suggestive of cardiorespiratory inadequacy. At the end of the submaximal exercise the subject was asked to hold his breath for a brief moment and the treadmill was also stopped for 10 consecutive pulse traces. The blood pressure and heart rate also were recorded on the digital monitor. The LVET was calculated from the pulse tracing at a rest and stroke volume and cardiac output were calculated as before. The same protocol was followed for all the 15 subjects.

Statistical analysis performed by Student’s t test and correlation coefficient. P value < 0.05 was taken as significant.

RESULTS

The results of the study done are presented in Tables and figures. The mean age of the study subjects was 23.13 years. The heart rate at rest was ranged from 57 – 91 bpm with a mean of 71.86667. These values were within the normal range. With exercise, the heart rate rose to

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mean value of 134.8 bpm, with an increase of 62bpm (87.6%). The difference of heart rate between rest, and exercise was statistically significant ($p<0.0001$).

The mean SBP at rest was 74.27mm Hg. Whereas With exercise, the SBP rose to mean value of 139.67 mm Hg, with a mean rise of 26.14 mmHg ($p<0.0001$).

The DBP rose from 74. 26 mmHg at rest to 84. 53mmHg during the exercise ($p<0.0001$).

The mean LVET at rest was 253.67 with range of 223-320 msec. this range was correlated with the resting heart rate range of 57-91 bpm. However the ejection time for similar rates were different in some subjects. With the exercise, LVET shows a decline of 36.14 msec to 217 msec, a drop of 15.3% and at the rest ejection time for a given heart rate was different for some subjects.

The mean stroke volume at the rest was 69.26 ml with range of 55.04 – 100.5 ml. At exercise, stroke volume shows a decrease by 9.58 of 13.83% ($P<0.0001$).

The mean cardiac output at the rest was 4.91 L/min with range of 4.0 – 5.9 L/min. At exercise, cardiac output went up to 7.99L/min with a significant increase of 3.08L/min of 62% ($P<0.0001$).

The cardiac index rose to 4.78L/min/m^2 during exercise showing an increase by 1.84L/min/m^2(62.32%).

A Positive significant correlation observed between the resting and exercise values of heart rate and cardiac output ($r=+0.73$, $p<0.0001$).

A Positive significant correlation observed between the resting and exercise values of LVETand stroke volume($r=+0.99$, $p<0.0001$).

A negative significant correlation observed between the resting and exercise values of heart rate and LVET ($r= -0.11$, $p<0.0001$), indicates moderate significant.

A negative significant correlation observed between the resting and exercise values of stroke and cardiac output ($r= -0.26$, $p<0.0001$), with just 2 subjects shows an increase in the stroke volume with exercise and the rest showing a fall.

A negative significant correlation observed between the resting and exercise values of cardiac output and LVET ($r= -0.77$, $p<0.0001$), indicates high significant.

TABLE 1. PHYSICAL CHARACTERISTICS OF THE SUBJECTS

Sub NO	Age (Yrs)	Height (cm)	Weight (kg)	BSA (m^2
1	30	169	68	1.78
2	19	173	54	1.64
3	19	178	68	1.85
4	28	164	50	1.53
5	18	176	50	1.61
6	21	164	52	1.59
7	25	176	68	1.74
8	25	169	56	1.64
9	30	167	55	1.61

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10	19	172	62	1.73
11	28	175	60	1.73
12	23	165	65	1.72
13	17	164	48	1.50
14	24	168	62	1.70
15	21	167	58	1.65
Mean	23.13333	169.8	58.4	1.668
SD	4.421807	4.857983	6.946736	0.094203

TABLE 2. CARDIO VASCULAR PARAMETERS AT REST

Sub NO	HR/MIN	SBP	DBP	LVET	SV	Q	BSA	CI
1	68	114	70	250	66.89	4.55	1.78	2.56
2	91	103	66	240	64.87	5.9	1.64	3.6
3	57	114	68	320	100.5	5.73	1.85	3.1
4	78	122	84	250	68.19	5.32	1.53	3.48
5	78	100	70	240	63.18	4.98	1.61	3.06
6	68	110	74	261	72.4	4.92	1.59	3.09
7	64	122	80	270	76.39	4.88	1.74	2.8
8	64	110	80	267	74.99	4.8	1.64	2.93
9	70	124	70	240	62.14	4.35	1.61	2.7
10	60	106	70	280	80.88	4.85	1.73	2.8
11	76	110	70	250	67.93	5.16	1.73	2.98
12	70	118	80	230	57.19	4	1.72	2.33
13	80	100	70	223	53.04	4.4	1.5	2.93
14	80	124	82	232	57.43	4.75	1.7	2.79
15	74	126	80	252	68.67	5.08	1.65	3.08
Mean	71.86667	113.5333	74.26667	253.6667	68.97933	4.911333	1.668	2.948667
SD	8.935217	8.903183	5.993647	24.15032	11.55065	0.499326	0.094203	0.321356

TABLE 3. CARDIO VASCULAR PARAMETERS DURING EXERCISES

Sub No	HR/MIN	SBP	DBP	LVET	SV	Q	BSA	CI
1	160	140	90	230	68.83	11.01	1.78	6.19
2	162	147	84	210	59.07	9.56	1.64	5.83
3	130	148	70	268	83.97	10.92	1.85	5.90
4	130	140	90	205	52.2	6.78	1.53	4.43
5	128	130	80	210	53.95	6.9	1.61	4.29
6	130	142	84	205	52.66	6.85	1.59	4.31
7	130	130	86	220	59.92	7.78	1.74	4.47
8	124	140	94	230	64.15	7.96	1.64	4.85
9	132	150	86	210	55.17	7.28	1.61	4.52
10	120	138	78	240	68.64	8.24	1.73	4.76
11	128	150	80	210	54.65	7	1.73	4.05
12	132	142	90	203	51.66	6.82	1.72	3.97
13	136	124	80	210	55.69	7.57	1.5	5.05
14	140	130	86	200	51.2	7.17	1.7	4.22
15	140	144	90	212	57.21	8.01	1.65	4.85

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Mean	134.8	139.6667	84.533	217.533	59.2646	7.99	1.668	4.7793
SD	11.8514	7.9970	6.1628	17.959	8.9194	1.412	0.094	0.690

TABLE 4. COMPARISON OF RESTING AND EXERCISE VALUES OF CARDIOVASCULAR PARAMETERS

Sub No	HEART RATE			STROKE VOL(ML)			CARDIAC INDEX(L/M2)		
	RESTING	EXERCISE	DIFFERENCE	RESTING	EXERCISE	DIFFERENCE	RESTING	EXERCISE	DIFFERENCE
1	68	160	92	66.89	68.83	1.94	2.56	6.9	3.63
2	91	162	71	64.89	59.07	-5.82	3.60	5.83	2.23
3	57	130	73	100.5	83.97	-16.53	3.10	5.90	2.81
4	78	130	52	68.19	52.20	-15.99	3.48	4.43	0.95
5	78	128	50	63.18	53.95	-9.23	3.06	4.28	1.22
6	68	130	62	72.4	52.66	-19.74	3.09	4.31	1.21
7	64	130	66	76.39	59.92	-16.47	2.80	4.47	1.67
8	64	124	60	74.99	64.15	-10.84	2.93	4.85	1.93
9	70	132	62	62.14	55.17	-6.97	2.70	4.52	1.82
10	60	120	60	80.88	68.64	-12.24	2.80	4.76	1.96
11	76	128	52	67.93	54.65	-13.28	2.98	4.05	1.06
12	70	132	62	57.13	51.66	-5.47	2.33	3.97	1.64
13	80	136	56	55.04	55.69	0.65	2.93	5.05	2.11
14	80	140	60	59.43	57.20	-2.23	2.79	4.22	1.42
15	74	140	66	68.67	57.21	-11.46	3.08	4.85	1.78
Mean	71.86	134.8	62.93	69.24	59.66	-9.5786	2.948	4.826	1.829
SD	8.935	11.851	10.39	11.23	8.662	6.5209	0.321	0.808	0.698

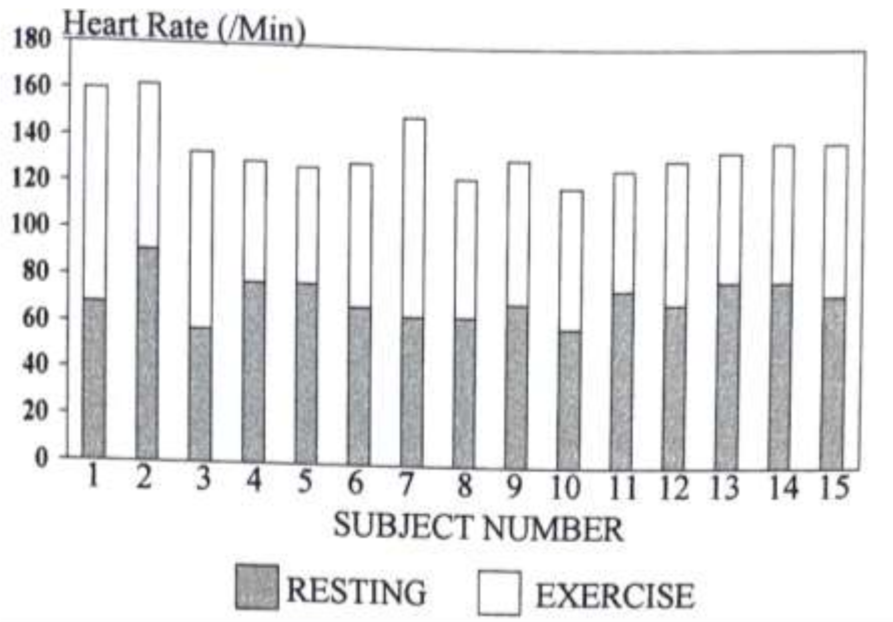

FIGURE 1. RESTING AND EXERCISE HEART RATE

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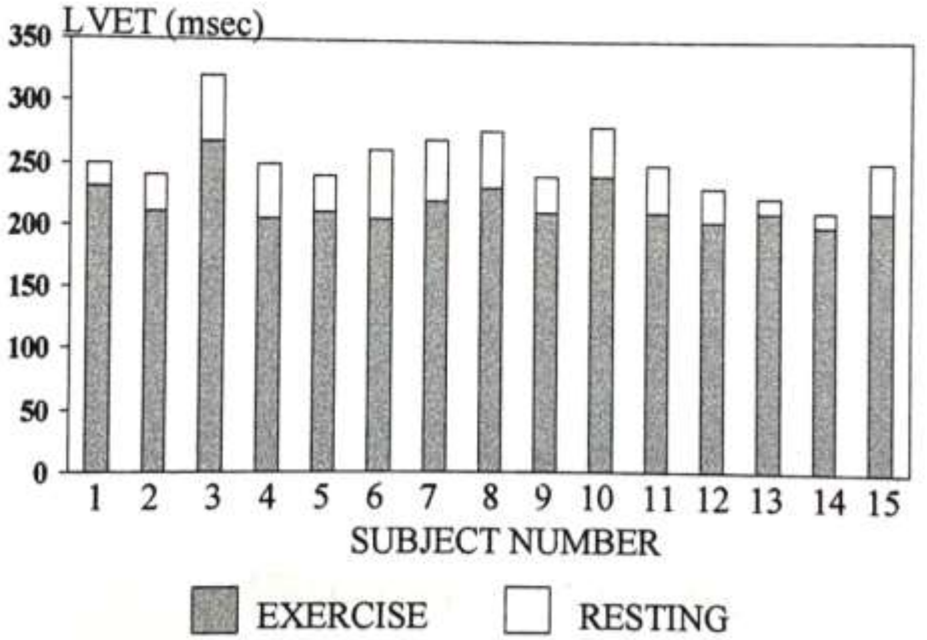

FIGURE 2. RESTING AND EXERCISE LVET

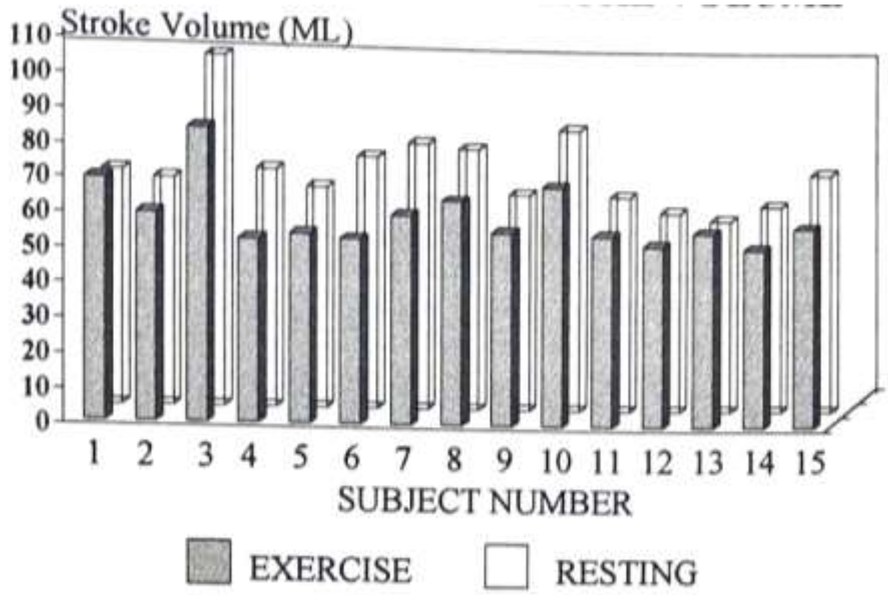

FIGURE 3. RESTING AND EXERCISE STROKE VOLUME

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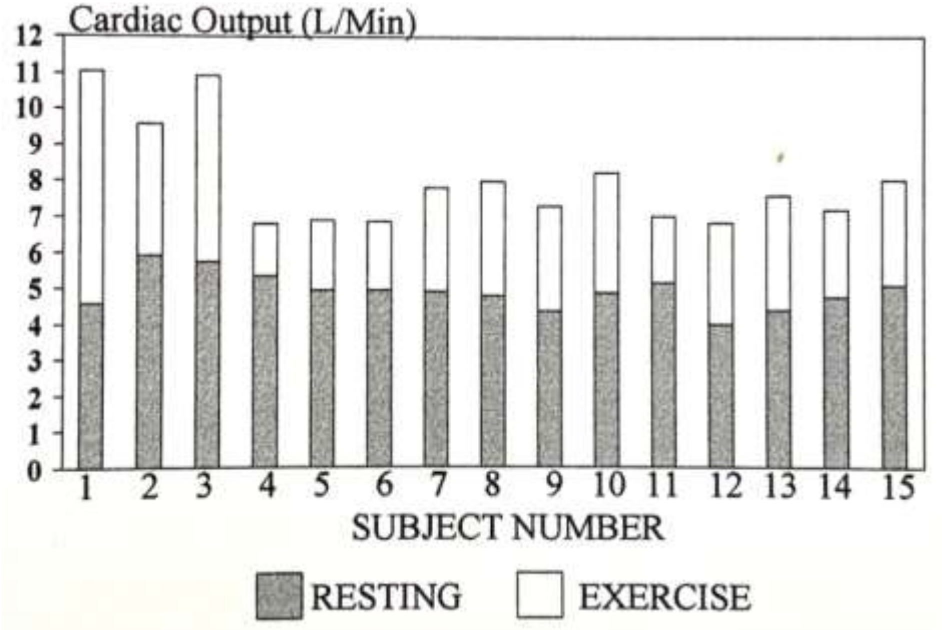

FIGURE 4. RESTING AND EXERCISE CARDIAC OUTPUT

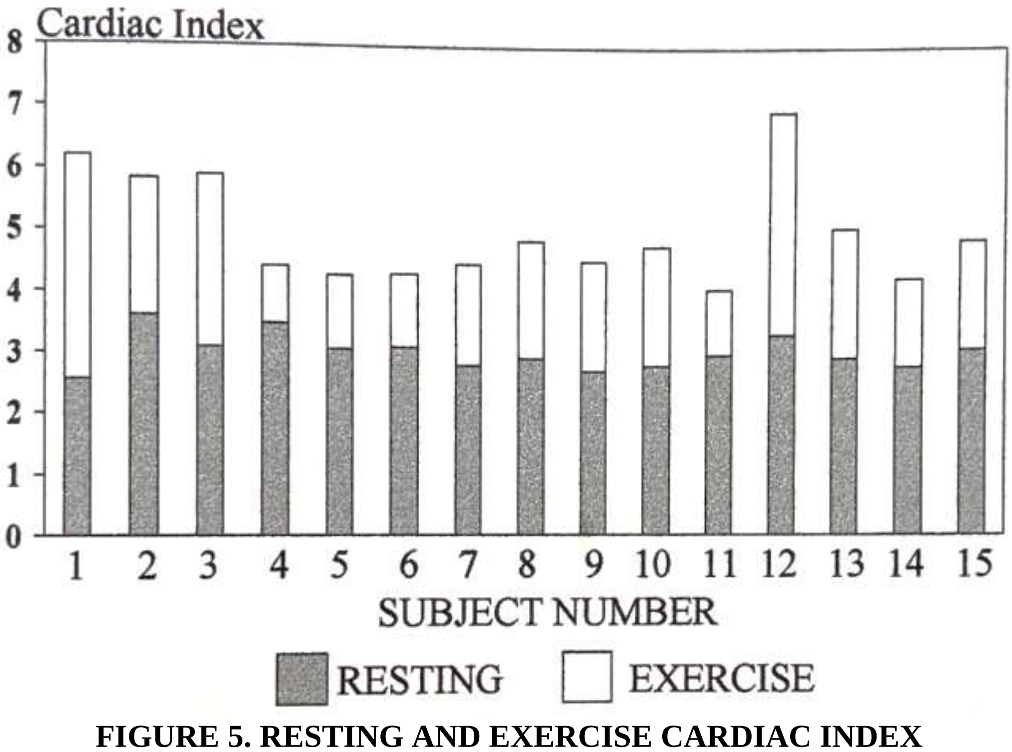

FIGURE 5. RESTING AND EXERCISE CARDIAC INDEX

DISCUSSION

In this study, the heart rate showed a significant and consistent increase about 86% with submaximal exercise. This response is similar to the observations of Astrand wherein a higher heart rate during submaximal exercise for a given cardiac output in the younger age groups had been a very consistent finding.[5]

The increased sensitivity to catecholamines in the younger age group as a cause for increased heart rate was shown by Sugimoto and Brunwald.[8,9] A raise in heart rate on assuming upright

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posture could have further added onto the exercise induced increase. This may be due to the inadequate venous return from exercising muscles of the untrained even in the erect posture and a consequent increase in heart rate. This was similar to Astrand and Ekekund studies.[5,10]

Various studies shows that they had in their works found a higher rates at submaximal exercise in the untrained.[5,11]

As the subjects in this study were also untrained increase in the cardiac output was caused by a rise in heart rate rather than in the stroke volume.

Ejection was measured showed a mean fall of 36.24 msecs during exercise. This is similar to other study.[12]

The rise in heart rate decreased the diastolic filling and the stroke volume and this caused the ejection duration to the reduced as was reported other study. Stronger correlation of ejection time with the stroke volume both at rest and exercise. This correlation was depicted in the form of different left ventricular time for a given heart rate in different subjects as observed in other study. A decrease in the contractility in the untrained and an increase in contractility in the trained had been seen by several reports. This increased contractility could cause a rise in stroke volume despite a fall in ejection time in the trained subjects.

The mean stroke volume during the exercise was 9.58 ml/beat lesser than at rest. The cause of reduction of stroke volume could be due to increase in heart rate.

The increased in the heart rate caused by reduction in the venous return by encroaching in to the diastolic period. This caused in the decline in the stroke volume by 13.83% or 9.85ml/bt. This was similar to other studies.[5,13,14]

In the trained subjects the increase in contractility could increase stroke volume even if the end diastolic volume is reduced as shown by other study.[14] Whereas in our study, our untrained subjects shows decline in stroke volume occurred due to a decreased contractility not able to compromise a reduced venous return.

But in our study both the stroke volume and ejection time dropped thereby providing that the subjects has poor contractile reserve.

The increase cardiac output is due to increase heart rate than the increasing the stroke volume as reported by other studies.[5,15] This is also more at the submaximal levels of exercise in which heart reports to just 2 of the 3 basic mechanisms ie, increase in heart rate and increase in end diastolic volume as reported by others. Some studies shows that there was a drop in stroke volume due to decreased contractility in the untrained.[16,17]

Another possible reason for finding a drop in stroke volume and a rather smaller rise in cardiac output in exercise in this study would be the following. The recording of the carotid pulse tracing at the end of the 15 min of exercise was with the subject virtually standstill and holding his breath. In this situation the heart rate would have remained higher due to the residual effect of sympathetic discharge. The venous return could have dropped due to the breathe holding as well vasodilation when the exercise was terminated. These two factors led to a reduction in stroke volume and concomitant fall in ejection duration. This is similar to other study.[18,19]

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The cardiac output in the untrained group were shown to increase during submaximal exercise by Hermansen et al to be about 2 -3 times the resting values.[20] Our results the increase was just about 1.6 times the resting values. The smaller change in our study was due to the reduced stroke volume at submaximal exercise. The cardiac output should have showed a higher value had the recording been obtained with the person continuing to exercise on the treadmill.

Various studies had also showed a rise in cardiac output to about 8 -10 L/min at submaximal exercise in the healthy untrained subjects and to a value of 17- 24 L/min in the subjects at heart rate range of 200 bpm.[15,20,21,22]

Our results in the untrained subjects are I conformity with these findings.

CONCLUSION

Young physically healthy but untrained group of individuals respondent to Submaximal exercise test with increased cardiac output of 62% predominately due to an increased heart rate and fall in stroke volume. Rise in heart rate compromised the venous return and coupled with a poor contractile reserve due to reduced tolerance to exercise the group showed a reduction in the stroke volume and in the duration of ejection.

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