ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

Cardiorespiratory Responses to Exercise and Determination of Aerobic Power

Gouse Bin Mohammad Shaik[1], Vinay Kshirsagar[2], Bhausaheb Vasantrao Jagdale[3]

[1]Assistant Professor, Department of Physiology, Ayaan Institute of Medical Sciences, Teaching Hospital & Research Centre, Hyderabad, Telangana, India.
[2]Assistant Professor, Department of Pharmacology, SMBT Institute of Medical Science & Research Centre, Dhamangaon, Tal. Igatpuri, Nashik, Maharashtra, India.
[3]Assistant Professor, Department of Physiology, SMBT Institute of Medical Science & Research Centre, Dhamangaon, Tal. Igatpuri, Nashik, Maharashtra, India.

Abstract

Background: Cardiovascular and metabolic disorder has become common in individuals leading a sedentary life. Exercise stress tests are carried out as part of the investigations for determining the individual fitness level. Aerobic power or VO2max which involves a full functional support from cardio respiratory and metabolic pathways is an appropriate test to study cardio pulmonary fitness. The main objective of the study is to find out the normal cardiopulmonary responses to exercise and their aerobic power among untrained 1st year medical students by Astrand 6-minute cycle test.**Material and Methods:**This is a prospective and observational study conducted in the Department of Physiology at Tertiary care teaching Hospital over a period of 6 months. The study was undertaken to analyze the cardiorespiratory responses to graded exercise and to determine the aerobic fitness in the untrained male in the age group of 18-21 years. Normal healthy untrained male subjects in the age group of 18-21 years were randomly selected and included in the study. Cardiorespiratory changes associated with exercise were studied using bicycle ergometer. VO2max was determined from the heart rate noted at the end of 6 minutes cycling by using Astrand-Rhyming nomogram.**Results:**Heart rate, systolic blood pressure and respiratory rate increased with exercise, while diastolic pressure recorded a fall. The VO2max is the best physiological indicator of a person's capacity to continue the severe physical work. From this we can set a norm in assessing physical fitness and the test can be used as screening measures before joining in a job or sports training.**Conclusion:**Aerobic power or VO_{2max} or physical work capacity which involves a full functional support from cardiorespiratory and metabolic pathways is an appropriate test to study cardiopulmonary fitness. Implication: Astrand 6 minutes cycle test can be used for screening measures before joining in a job or sports training where physical fitness is needed.

Keywords: Bicycle ergometer, Astrand-Rhyming nomogram, Ergo graph, submaximal load, $V0_2$ max.

Corresponding Author: Dr. Bhausaheb Vasantrao Jagdale, Assistant Professor, Department of Physiology, SMBT Institute of Medical Science & Research Centre, Dhamangaon, Tal. Igatpuri, Nashik, Maharashtra, India.

Introduction

Exercise testing has been a means of finding out the physical capabilities and physiological responses of an individual.[1] Sufficient information is not available on the extent of change observed in different systems in untrained Indian subjects. The present study was therefore undertaken to investigate the cardiovascular and respiratory responses to graded exercise among untrained male medical students (18-19 years). Graded exercise on a mechanically braked bicycle ergo graph was chosen, since progressive workloads can be interspersed with

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

short rest periods, thus giving the subject time to recover before starting next period of exercise.[2]

In the absence of any scientific meaning the term exercise has been quantified by measuring the work done in given time. This gives work rate or power as per following equation.

Power =Work / Time = F x d / t

Where F = force, d = distance, t = time.

Aerobic power or V02 max or physical work capacity which involves a full functional support from cardiorespiratory and metabolic pathways is an appropriate test to study cardiopulmonary fitness.[3]

This study aims to provide a reference data which may serve as a guide for careful monitoring during an exercise procedure.

Material and Methods

This is a prospective and observational study conducted in the Department of Physiology at Tertiary care teaching Hospital over a period of 6 months. The study was undertaken to analyze the cardiorespiratory responses to graded exercise and to determine the aerobic fitness in the untrained male in the age group of 18-21 years.

Normal healthy untrained male subjects in the age group of 18-21 years were randomly selected and included in the study.

Subjects with chronic illness and systemic illness and trained healthy males were excluded from the study so as to minimize the bias. All subjects gave an informed consent after detailed procedure of the non-invasive technique was explained to them.

Physical examination like height in cms and weight in kgs was done. Body Mass Index was derived by Queenlet's index i.e. weight (kg) / height (m2). Body surface area was calculated using Dubois nomogram.

Vital parameters like pulse rate, blood pressure and respiratory rate were recorded. A detailed clinical examination of respiratory system, cardiovascular system and central nervous system was done. Subjects performed graded exercise on a mechanically braked bicycle ergo graph.

Bicycle ergo graph:

The use of bicycle in testing has several advantages. It is chosen to perform graded exercise since progressive workloads can be changed with short rest periods, thus giving the subject, time to recover before starting next period of exercise.

The subject's body weight does not influence exercise capacity appreciably and sitting on a bicycle often produces less anxiety than walking on a mechanically driven treadmill. In addition bicycle requires less space in the laboratory and less expensive than a treadmill.

A brake band is applied to the rear wheel which has a circumference of about 1.68 m and the work done calculated from the tension difference between the two sides of the bands and the linear velocity of the circumference of the wheel. With a standardized tension difference, the work done depends on the rate of pedaling which is determined by the revolution counter attached to the rear wheel.

Pedaling the cycle at a rate of 60 times per minute is equivalent to 156 revolutions per minute at the wheel. Peddling rate – wheel rate.

Calculation of work done:

Kilopond meter (Kpm) is the unit of work, whereas power is the rate at which work is done. Therefore Kpm may be converted to power output (watts) by multiplying with a factor of 0.1635. (1 watt = 0.135 x Kpm / min).

Work done in Kpm/min = distance x force (breaking resistance)

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

Distance = wheel circumference (meters) x revolution per minute Wheel circumference = 1.68m.
In this study pedaling rate is 60/minute = 156 revolutions per min at the wheel
Breaking resistance is 1.75 kg and 3.5 kg respectively
For 1.75 kg breaking resistance (tension load),
Work done = 1.68 x 156 x 1.75
= 450 Kpm/min
For 3.5 kg work done = 900 Kpm/min.

Collection of data:
Subjects were explained the whole procedure in detail and were motivated prior to the start of exercise. They were told to report immediately if they felt any discomfort, fatigue or dizziness. Subjects rested in supine position for 15 min before the start of exercise.

Choice of load:
Subjects were called to the department and the maximal load at which they would cycle on the bicycle ergo graph was determined. In most of the subjects under study, maximal load was found out to be 4.5kg with a heart rate of about 198 beats/min.
The submaximal load should be within 85-90% of the maximal heart rate at maximal load i.e in between 164-178 beats / min was found to be 3.5 kg after repetitive testing.
For two sessions of graded exercise the recommended load is 1.75 kg and 3.5 kg respectively, corresponding to heart rates in between 130 and 178 beats/min.

Results
The present study, entitled "Cardiorespiratory responses to graded exercise and determination of aerobic fitness in untrained males" was conducted. 70 male untrained subjects were analyzed for the results. The results obtained are expressed as mean standard deviation. The age of subjects ranged from 18-21 years.

Table 1: Age -Wise Distribution

Age Groups (Yrs)	No. of Cases	Percentage
18	30	45
19	18	25
20	12	16
21	10	14
Total	70	100

Table 2: Physical Characteristics

Parameters	Range	Mean	S.D.
Height (cm)	150-192	180	9.0
Weight (kg)	45-91	58.4	8.7
Body Mass Index (BMI)-kg/m^2	14.54 – 28.67	22.37	3.14
Body Surface Area (BSA)-m^2	1.67 – 1.97	1.8	0.3

Out of the hundred subjects, 27 subjects were in the age group of 18 years and 15 subjects were in the age group of 19 years [Table 1, Figure 1]. On analysis of the physical characteristics of the 70 subjects, the mean height in cm is 165 8.0; the mean weight in kg is 55.1 7.5; the mean BMI (kg/m^2) is 20.06 2.89; and the mean BSA (m^2) is 1.5 0.1[Table 2].

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

Heart rate:

The mean resting heart rate in beats/min was 74.2±6.9. During the session I of exercise (i.e.) submaximal exercise at 450 kpm/min, there was statistically significant increase in the heart rate to 128.4±8.5 ($p < 0.001$) [Table 3].

Table 3: Cardiorespiratory Changes during Session I and During Recovery

Parameters	At rest R	Session I S1	Difference S1-R	P-value	Post exercise 5 minutes S5	Difference S5 R	P value	Post exercise 15 minutes S15	Difference S15-R	P-Value
Heart rate (beats/ min)	74.2±6.9 (62-96)	128.4 ±8.5 (96-144)	54.2±8.4	<0.001 HS (t=60.9)	98.2±13.0 (76-140)	24.0 13.4	<0.001 HS (t=17.9	81.3± 6.9 (69-96)	5 7.19	<0.001 HS (t=12.0)
S.B.P. (mm of Hg)	109.9±9.2 (90-134)	127.4±7.8 (110-144)	17.5±6.6	<0.001 HS (t=26.5)	115.7±6.2 (94-138)	5.8 4.9	<0.001 HS (t=11.8)	110.1±8.1 (90-134)	0.2 3.9	<0.61 NS (t=0.51
D.B.P. (mm of Hg)	71.9±6.4 (60-84)	68.7±7.4 (58-82)	-3.2±2.7	<0.001 HS (t=11.8)	70.4±6.5 (60-82)	-1.4 1.7	<0.001 HS (t=8.2)	71.4±6.3 (60-84)	-0.5 1.4	<0.20 NS (t=1.31)
Respiratory rate/min	13.6±1.4 (11-16)	22.7±2.2 (16-29)	9.1±2.2	<0.001 HS (t=41.4)	17.1±1.9 (14-24)	3.5 1.8	<0.001 HS(t=19.4)	14.0±1.4 (12-18)	1 0.40	<0.001 HS (t=4)

The reduction in the heart rate during the recovery period, after 5 minutes and 15 minutes was also analyzed. After 5 minutes the heart rate was reduced to 98.2±13.0. Statistical analysis was done to compare recovery heart rate to the resting heart rate. At the end of 5 minutes, the heart rate showed a statistically significant increase than the resting heart rate. After 15 minutes, the heart rate was 81.3±6.9; this showed a statistically significant increase from the resting heart rate [Table 3]. During the session II of exercise the heart rate was 164.5 8.8.

After 5 minutes post exercise the heart was reduced to 116.2±16.0 and this value showed a statistically significant increase from the resting value ($p < 0.001$).

After 15 minutes post exercise the heart rate was 94.7±15.5 and this value was analyzed statistically to compare it with the resting value. This also showed statistically a highly significant increase ($p < 0.001$). Statistical analysis was done by paired 't' test.

Systolic blood pressure:

The mean resting systolic blood pressure in mm Hg was 109.9±9.2. During the session I of exercise, there was statistically significant increase to 127.4±7.8 ($p < 0.001$).

The reduction in the systolic blood pressure during recovery period, after 5 minutes and 15 minutes was also analyzed. After 5 minutes the systolic blood pressure was reduced to 115.7±6.2. Statistical analysis was done to compare it with the resting SBP. At the end of 5 minutes the systolic blood pressure showed a statistically significant increase from the resting SBP ($p < 0.001$). After 15 minutes the systolic blood pressure was 110.1±8.1. Statistical analysis was done to compare it with the resting value; the difference is 0.2±3.9 and it is not statistically significant ($p < 0.61$).

During session II of exercise the systolic blood pressure was 144.8 ±6.2. This showed a highly significant value than the resting value ($p < 0.001$). Recovery Systolic blood pressure after 5 minutes was 121.7 statistically 11.9. This was compared with the resting SBP and showed a high significant increase.

After 15 minutes the systolic blood pressure was 110.8±8.2. Statistical analysis was done to compare it with the resting value and it is significant, but clinically the increase is not very much.

The same was also analyzed statistically with the resting systolic blood pressure at the beginning of exercise and it is not significant.

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

The increase in systolic blood pressure during session I and session II was also analyzed and it is significant ($p < 0.001$). Statistical analysis was done by paired 't' test.

Diastolic blood pressure:

The mean resting diastolic blood pressure in mm Hg was 71.9±6.4. During the session I, the diastolic blood pressure was 68.7±7.4. Statistical analysis was done to compare it with the resting value and it is highly significant.

During the recovery period the diastolic pressure at 5th and 15th minutes were 70.4±6.5 and 71.4±6.3 respectively. The decrease is compared with the resting value statistically. Recovery diastolic pressure at end of 5th minute showed a highly significant decrease ($p < 0.001$). But at the 15th minute, it is not significant ($p < 0.20$).

During the session II the diastolic blood pressure was 65.8±7.7. Statistical analysis was done to compare it with the resting value and showed a highly significant decrease ($p < 0.001$).

Recovery diastolic pressure at the end of 5th and 15th minute were 69.3±6.5 and 71.3±5.9 respectively. Statistical analysis was done to compare the decrease from the resting value. The value at the end of 5th minute showed a highly significant decrease ($p < 0.001$) but the decrease at the end of 15th minute is not significant ($p < 0.55$).

The decrease in diastolic blood pressure between two session of exercised was compared statistically and the decrease is highly significant ($p < 0.001$). When the reduction in diastolic blood pressure was compared between the post exercise 15 minutes after session II and resting value at the beginning of session I, it is significant ($p < 0.01$) but clinically no difference was seen. Statistical analysis was done by paired 't' test.

Respiratory rate:

The resting respiratory rate before the start of exercise was 13.6±1.4 and during the session I it was increased to 22.7±2.2, a statistically significant increase ($p < 0.001$).

During the recovery period respiratory rates at the end of 5th and 15th minutes of session I were 17.1±1.9 and 14.0±1.4 respectively. When the two values were analyzed with the resting respiratory rate, both showed a statistically significant increase ($p < 0.001$).

During the session II the respiratory rate was 30.9±3.7. When the increase in respiratory rate was compared to the resting value, it showed a statistically significant increase ($p < 0.001$).

Recovery respiratory rate at the end of 5th and 15th minute of session II were 20.5±2.4 and 15. ± 2.7 respectively. Statistical analysis was done to compare it with the resting value (i.e.) at the beginning of session II and it showed a statistically significant increase ($p < 0.001$). But clinically negligible increase is seen after 15 minute.

When the increase in respiratory rate was compared between two sessions of exercise it was found to be from 22.7±2.2 to 30.9±3.7. The increase is statistically significant ($p < 0.001$). When the increase was compared between resting value at the beginning of session I and 15th minutes after the session II, it was found to be from 13.6 ±1.4 to 15.4±2.7. Even though the increase is statistically significant, clinically less change is seen. Statistical analysis was done by paired 't' test.

Mean arterial pressure:

The resting mean arterial pressure before the start of exercise was 84.5±7.1 mm of Hg and during the session I of exercise it was increased to 88.0±7.2. When the increase in mean arterial pressure was compared with the resting M.A.P, it showed a statistically significant increase ($p < 0.001$).

During the recovery period, mean arterial pressure at the end of 5th and 15th minute of session I were 85.6±0.1 and 84.3±7.0 respectively. When the two values were analyzed with the resting mean arterial pressure, the value at the end of 5th minute did not show statistically

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

significant increase, and the value at the end of 15th minute was also not significant. Clinically also no difference were seen.

During the session II the mean arterial pressure was 94.5±9.7. When the increase in mean arterial pressure was compared to the resting value, it showed a statistically significant increase ($p < 0.001$). Recovery mean arterial pressure at the end of 5th and 15th minute of session II were 86.3±6.9 and 84.5±6.9 respectively. Statistical analysis was done to compare it with the resting value at the beginning of session II. Statistically significant increase was observed at the end of 5th minute but not at the end of 15th minute.

When the increase in mean arterial pressure was compared between two sessions of exercise it was found to be from 88.0±7.2 to 91.5±9.7 . Statistical analysis was done by paired 't' test.

Table 4: Comparison of Age Related Vo_2max

Age	**Vo_2max (L/min)**		**P value**	**Vo_2max (ml/kg/min)**		**P value**
(yrs)	**Range**	**Mean SD**		**Range**	**Mean SD**	
18	3.4 – 4.3	3.24 0.41	< 0.67 NS	39.97 – 72.0	52.97 7.94	< 0.21 NS
19	3.7-4.3	3.87 0.37	(t = 0.6)	32.71 – 69.0	50.24 8.76	(t = 1.47)

Discussion

There was statistically significant increase in heart rate immediately after the exercise over the pre exercise value ($p<0.001$). Also, there was persistent tachycardia 15 minutes after exercises. Tachycardia in exercise occurs due to following mechanisms: Increased sympathetic discharge, muscle heart reflex, increased release of catecholamine's and thermogenic stimulation.[2-4] There was statistically significant increase in systolic blood pressure immediately after the exercise over the pre exercise value ($p<0.001$).

Chapman CB et al conducted a study regarding stroke volume and cardiac output have shown that the stroke volume continue to increase at higher levels of exercise.[5] Other investigators found that the stroke volume after increasing promptly with low level of exertion reaches a plateau and does not increase progressively as exertion becomes more intense for untrained subjects.[6,7] Other researchers found that plateau in stroke volume may not occur for trained subjects.[8-10] The result discussed earlier regarding blood pressure states that the systolic blood pressure always increases in exercise proportionate to increase in cardiac output.[11] This occurs due to sympathetic induced cardio-acceleration.

There was statistically significant decrease in diastolic blood pressure immediately after exercise over the pre exercise value ($p<0.001$). The diastolic blood pressure decreases with moderate exercise, which could be due to sympathetic cholinergic vasodilatation of skeletal blood vessels, metabolic vasodilatation and thermogenic vasodilatation leads to decreased peripheral resistance.[11]

There was statistically significant increases in respiratory rate immediately after the exercise over the pre-exercise value ($p<0.001$). The respiratory rate increases with exercise, which could be due to neural mechanism, chemical mechanism and thermogenic mechanism.[12-16]

VO_{2max} can be a limiting factor for individual capacity to do prolonged muscular work.[17] So the determination of aerobic power or VO_2 max gives an idea of the capacity and regulation of O_2 transporting system.

Jackson AS et al suggests that VO_{2max} or aerobic power increases during childhood and reaches a peak during early adulthood, after that a gradual and steady decline take place with the increasing age.[18,19]

VO_{2max} varies greatly between individual, genetics play a major role.[20,21] Training in aerobic exercise may improve VO_{2max}. Resistance training alone does not increases VO_{2max}.[22,23]

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

Conclusion

Aerobic power or VO2max or physical work capacity which involves a full functional support from cardiorespiratory and metabolic pathways is an appropriate test to study cardiopulmonary fitness. Implication: Astrand 6 minutes cycle test can be used for screening measures before joining in a job or sports training where physical fitness is needed.

References

1. Fortuin NJ, Weiss JL. Exercise stress testing. Circulation 1977; 56(5): 699-711.
2. WHO meeting on Exercise tests in relation to cardiovascular function. Wld Hlth Org Techn Rep Ser 1968; 388: 5-29.
3. Astrand PO, Kaare Rodahal. Text book of Work Physiology. 1st ed. KogaKusha McGraw Hill; 1996.
4. Lars Hermansen, Lange Anderson K. Aerobic work capacity in young Norwegian men and women. J Appl Physiol 1965; 20(3): 425-431.
5. Chaudhuri SK. Concise Medical Physiology. 4thed. Calcutta: New Central Book Agency; 2002: 404-410.
6. Ellestad EH. Stress Testing: Principles and Practice. 4th Ed. New Delhi: Jaypee Brothers; 1996:1-41.
7. Jain AK. Manual of Practical Physiology for M.B.B.S. 1sted. New Delhi: Arya Publications; 2003: 161-162.
8. Berne RM, Levy MN. Physiology. 3rded. USA: International Edition; 1993:532-537.
9. Sembulingam K, Prema Sembulingam. Essentials of Medical Physiology 3rded. New Delhi: Jaypee Brothers Medical Publishers (P) LTD; 2004.
10. Ganong WF. Review of Medical Physiology. 21sted. USA: McGraw Hill; 2003.
11. Green JH. An introduction to human physiology. 1sted. Great Britain: Oxford Medical Publications; 1963: 72.
12. Chakrabarti BK, Ghosh HN, Sahana SN. Human Physiology. 2nded. Calcutta: The New Book stall; 1984.
13. Smith DE, Paterson Colin R, Scratcherd Thomas, Read NW. Textbook of Physiology. 11thed. UK: Churchill Livingstone, ELBS; 1988.
14. Shepherd JT. Circulatory changes in the lungs during exercise. Pediatrics 1963 October, part II; supplement 683-686.
15. Mcllroy MB. The respiratory response to exercise. Pediatrics 1963; part II: 680-682.
16. Phatak MS, Kurhade GA, Karore SB, Pradhan GC. Effect of exercise on acid – base status and ventilatory kineties. Indian J Physiol Pharmacol 1998; 42(3): 417-420.
17. Chatterjee CC. Human Physiology. 11thed. New Mudran: Ashutosh Lithographic Company; 1985.
18. Bijlani RL. Understanding Medical Physiology. 3rd Ed. New Delhi: Jaypee Brothers; 2004: 636-649.
19. Thompson WR. ACSM’S Guideline’s for exercise Testing and Prescription. 8th edition. 2010.
20. Jackson AS, Wier LT, Ayers GW, Beard EF, Stutevile JE, Blair SN. Changes in aerobic power of women, ages 20-64 yrs. Med Sci Sports Exercise. 1996; 2 8(7):884-91.
21. Green HJ, Jones S, Balt Burnett M, Farrance B, Ranney D. Adaptations in muscle metabolism to prolonged voluntary exercise and training. J Appl Physiol. 1995; 78(1):138-45.
22. Kraemer WJ, Duncan ND, Volek JS. Resistance training and elite athletes: adaptations and program considerations. J Orthop Sports Phys Ther. 1998; 28(2); 110-9.

ISSN: 0975-3583,0976-2833 VOL13, ISSUE 02, 2022

23. Kraemer WJ, Patton JF, Gordon SE, Harman EA, Deschenes MR, Reynolds K, et al. Compatibility of high intensity strength and endurance training on hormonal and skeletal muscle adaptation. J Appl Physiol. 1995; 78(3):976-89.