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Research Paper

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Haematological Correlates of Work Capacity

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ABSTRACT

Objective: The endeavor of this study is to quantify the work capacity of adolescents in terms of their haemoglobin levels.

Methods: This is a cross-sectional interventional study. Blood haemoglobin levels of 50 first year medical students were estimated. Subjects exercised on bicycle ergometer with incremental loads and their Work capacities were calculated. Their blood lactate and pulse rates were recorded before and after exercise.

Results: There is a positive correlation of blood haemoglobin levels of both male and female subjects with their work capacities. Pulse rate and blood lactate responses to exercise of both sexes with lower ranges of haemoglobin concentrations were comparatively higher than those with higher ranges of haemoglobin concentrations.
Conclusion: Correlation between haemoglobin concentration and work capacity (in both the sexes) was established.

INTRODUCTION: In the pediatric O.P, it was observed that many of the children and adolescents were complaining of easy fatiguability. All of them had anemia of some degree or other. A multiplicity of factors either alone or in combination impose limitations on exercise capability of individuals who therefore differ in this respect. Apart from motivational, Physical and nutritional factors, various physiological endowments play a key role in determining the work capacity, such as

1) Haemodynamic capacity to maintain adequate blood flow
2) Provision of adequate O2 supply
3) Blood glucose levels
4) Preservation of adequate H+ ion concentration etc[7].

With this background the idea of quantifying the work capacity in terms of haemoglobin levels came and in collaboration with departments of physiology and biochemistry, the work was completed. The aim of the study was to quantify the work capacity in terms of haemoglobin concentrations and to study the effect of exercise on pulse rate and blood lactate level[1,3,10,13].

The choice of medical students as test subjects offers the advantages of having a group matched in age, height, weight, nutritional status, training effects. Taking all of them with normal health status minimizes the individual physiological endowments of haemodynamic capacity to maintain adequate blood flow, adequate O2 supply, Blood glucose levels, preservation of adequate H+ ion concentration etc, thus minimizing the other variables.

METHODOLOGY:
The present study was carried out in a group of 50 healthy, first year medical students of both sexes who were not regular athletes[12,17]. They were medically screened at the time of admission. Brief medical histories of all the subjects were enquired, including previous health, smoking, leisure and exercise habits if any. None of the students were reported to be engaged in regular exercise or strenuous physical activities of any kind. Brief clinical examination revealed no disease or disability in any participants.

The subjects were well informed about the experimental purpose and protocol and oral consent obtained. Heights and weights of all subjects were recorded and data compiled separately for both sexes, designated henceforth as Group-A for males and Group –B for females and each group comprising 25 students. Before and after undertaking the exercise regimen, lactate level and pulse rate were determined for all subjects. Blood haemoglobin concentrations were determined for all subjects. Each subject exercised on bicycle ergometer with incremental loads until maximum is reached at exhaustion[4]. Work out put attained is calculated from a record of number of revolutions and loads employed.

PROCEDURES:
1) Hemoglobin estimations were done following Shahils method.

2) Determination of blood lactate:[9] Blood lactate levels were determined by Baker &summer son's method. 1ml samples of blood were drawn from the subjects from a peripheral vein prior to exercise under resting conditions and after exercise. After deproteinization blood lactate estimation was done. The difference between the two values gives an estimate of magnitude of raise induced by exercise.

Prepration of standard calcium lactate:
For the stock standard, 0.342g of pure dry calcium lactate is dissolved in a 1liter volumetric flask. 1ml of concentrated sulfuric acid is added to it. The preparation is diluted up to the mark with water and mixed. This solution contains 1mg of lactic acid in 5ml and is stable indefinitely, if kept in the refrigerator. To prepare the working standard, 5ml of stock solution is diluted to 100ml with water. This solution contains 0.01mg of lactic acid per ml and it is best prepared fresh daily.

Technique:
1ml of blood added to anticoagulant is mixed with 4ml of trichloroacetic acid. This solution is centrifuged and 1ml of supernatant fluid is added to 1ml of 20% copper sulphate solution and made upto 10ml by adding distilled water. 1gm of powdered calcium hydroxide is added to this and shaken vigorously. It is left at room temperature for an hour, shaking occasionally and then centrifuged.

1ml of supernatant fluid is taken into a tube taking care not to include any solid material which may be present in the surface film. About 0.05ml of 4% copper sulfate solution is added and 6ml of concentrated sulfuric acid is added, mixing well while doing so. Then the test tube is placed upright in boiling water and 0.1ml of P-hydroxydiphenyle is poured. The precipitated reagent is quickly removed from the solution and the tube is placed in a water bath at 30^0C for 30min, re-dispersing the precipitated reagent at least once during that time after placing in a boiling wa-

ter bath for 9sec, it is cooled to room temperature, the reading is noted at 560 mμ or by using a yellow-green filter.

Calculation:
Since 1ml portion of the copper lime supernatant used for color development contains 0.005mg of lactic acid in the case of the standard and as this represents 0.02ml of original blood in the unknown (i.e.; a dilution of 50). The calculation in this case is as follows,

$$\left[\frac{\text{Absorbance of unknown} - \text{Absorbance of blank}}{\text{Absorbance of Standard} - \text{Absorbance of blank}}\right] x \frac{0.005x100}{0.02mg/dl}$$
$$= \left[\frac{\text{Absorbance of unknown} - \text{Absorbance of blank}}{\text{Absorbance of standard} - \text{Absorbance of blank}}\right] x \frac{25mg}{100ml}$$

The result is expressed as mg/100ml.

3) Pulse rate: Under resting Conditions radial arterial pulse was recorded. Count was made for 1 full minute. Resting pulse rates were recorded on 3 different occasions and the average of 2 values that closely agreed is taken. Pulse rate was again recorded at the end of exercise sessions. The difference gives the magnitude of pulse rate raise with exercise.

4) Bicycle ergometry: Work capacity of subjects was determined by using bicycle ergometry with incremental loads. Work done is determined by multiplying the distance travelled in unit time with load in kgs. Distance moved is function of number of wheel revolutions (given by a counter) times the wheel circumference.

In order to ensure properly standardized conditions and familiarize the subjects to ergometer and procedure, all the subjects were allowed a 4min unloaded pedaling at least on two occasions. Then they participated in progressive incremental ergometric testing. The incremental exercise test consisted of a 2 minute unloaded pedaling and thereafter against resistance. Each subject exercised on bicycle ergometer in sitting position with an initial load of 2kgs in males and 1kg in females, pedaling at their own rates. The load was increased stepwise every succeeding minute until the maximum exercise tolerance was reached and physical exhaustion was reported or apparent[2].

Work out put or exercise capacity was calculated for individual using the formula W=FS where work is given by the product of force which is equivalent to load and the distance through which it is moved[4,21,22]. The distance moved at any load is given by the product of wheel circumference, which is 176.6cms (0.1766m) and the number of revolutions of flywheel. As the loads were increased stepwise every succeeding minute, the work output is calculated accordingly for each load by the formula shown below and added to derive the total work output in kg.mts for the entire exercise period. This value determined for the time duration of exercise gives the work output per minute.

Work output in kg.m/min = Wheel circumference in meters X number of revolutions/minute X load.

Work output is expressed in watts. The data obtained was tabulated and analysed using spss 16 version.

RESULTS:
The statistical values-arithmetical mean values, values of standard deviation and standard error for all the variables are presented as tables 1&2. For Group-A(male) & Group-B(female) subjects.

Table I: Data of statistical values for group A (male subjects)

Statistic	Ht (cms)	Wt (kgs)	Hb gm/dl	Work capacity Watts	Pulse rate (bpm)			Blood lactate (mg/dl)		
					Resting	Post exercise	Raise	resting	Post exercise	Raise
Mean	170.7	60.6	10.57	114.32	78.6	151	76	12.96	48.4	35.44
±S.D	±7.9	±6	±1.95	±19.18	±4.8	±9	±6	±2.8	±6.74	±6.4 4
S.E	1.6	1.2	0.39	3.88	0.96	1.8	1.2	0.56	1.35	1.29

Table II: Data of statistical values for groupB (female subjects)

Statistic	Ht (cms)	Wt (kgs)	Hb gm/dl	Work capacity Watts	Pulse rate (bpm)			Blood lactate (mg/dl)		
					resting	Post exercise	raise	resting	Post exercise	Raise
Mean	160.36	51.56	8.82	87.24	76.44	118.36	41.92	12.48	54.72	41.56
±S.D	±6.78	±8.58	±0.92	±7.81	±4.41	±9.4	±4.81	±2.35	±7.84	±5.94
S.E	1.35	1.72	0.18	1.56	0.88	0.89	0.96	0.47	1.49	1.18

TABLE III: Correlation between hemoglobin concentrations and work capacities and levels of significance.

PARAMETER	SEX	Correlation coefficient (r)	Coefficient of determination (r2 %)	T	P
HEMOGLOBIN CONCENTRATION	M	+0.7	49	4.6	<0.001
	F	+0.87	75.7	8.46	<0.001

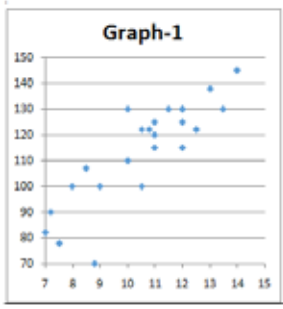
Table-IV: Table showing relation between different parameters and ranges of work capacities.

S.No	PARAMETER	Work capacity < 100 watts			Work capacity 100- 120 watts		Work capacity > 120 watts	
		M	F(<80wt)	F(81-100)	M	F	M	F
	No. of subjects	n=4(16%)	n=6(32%)	n=12(48%)	n=8(32%)	n=7(28%)	n=13(52%)	n=6(24%)
1	WORK CAPACITY (WATTS)	83±8.33 SE= 4.16	66.75±7.66 SE= 2.74	90.25±5.13 SE= 1.48	108.13±8.52 SE= 3.07	106.4±3.64 SE= 1.62	128.53±5.32 SE= 1.41	-
2	HAEMOGLOBIN (gm/dl)	7.82±0.82 SE= 0.4	7.33±0.84 SE= 0.33	9.62±0.93 SE= 0.29	9.82±1.43 SE= 0.41	10.28±0.8 SE= 0.28	11.83±0.22 SE= 1.28	-
3	HEIGHT (cms)	153.7±5.95 SE= 1.43	160.88±3.88 SE= 2.08	160.13±6.45 SE= 1.87	167.5±11.29 SE= 4.08	159.8±6.9 SE= 3.09	172.84±8.01 SE= 3.62	-
4	WEIGHT (kgs)	39.3±1.92 SE= 0.96	45±4.69 SE= 1.85	53.58±7.2 SE= 2.08	58.75±6.2 SE= 2.2	57.6±10.71 SE= 4.78	63.23±11.27 SE= 3.13	-
5	RAISE OF PULSE RATE (beats/min)	83.5±4.3 SE= 1.55	87±5.32 SE= 1.82	83.58±7.04 SE= 2.03	78.13±5.69 SE= 2.45	77.8±5.49 SE= 2.45	72.46±8.32 SE= 3.39	-
6	RAISE OF BLOOD LACTATE (mg/dl)	43±3.67 SE= 2.73	47±4.47 SE= 1.58	39.58±7.2 SE= 2.37	33.37±6.69 SE= 2.37	37.1±4.58 SE= 2.46	33.15±6.99 SE= 1.58	-

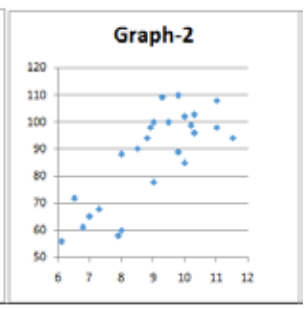
Table-V : Showing variations in work capacities with different Hemoglobin ranges and corresponding rise in the pulse rates & blood lactate levels in group- A & group- B subjects.

GROUP	RANGE OF HEMOGLOBIN CONCENTRATION (g/dl)	POST EXERCISE RAISE IN PULSE RATE (bpm)	POST EXERCISE RAISE IN BLOOD LACTATE LEVEL (mg/dl)	WORK CAPACITY (watts)
A (males)				
	7-8 (a)	88	45	92
	8-9 (b)	82	38	94
	9-10 (c)	80	40	118
	10-11 (d)	74	36	119
	11-12 (e)	72	38	132
	12-13 (f)	68	32	131
B (females)				
	6-7 (a)	92	45	62
	7-8 (b)	92	45	68
	8-9 (c)	78	38	90
	9-10 (d)	76	36	96
	10-11 (e)	70	35	97

Scatter diagram showing relation between hemoglobin concentrations and work capacities in group A Subjects.



Scatter diagram showing relation between hemoglobin concentration and work capacities in group B



The overall degree of correlation between haemoglobin concentration and the work capacity as well as levels of significance in Groups A&B are shown in the table-III. The extent to which haemoglobin concentrations correlate with work capacities is expressed in percentage, referred to as "***coefficient of determination***." In the same table "t" values and statistical levels of significance (p-value) for the correlation established are shown. For group A(male) subjects the correlation coefficient being +0.7 and p value being<0.001, the relationship is said to be statistically highly significant and similarly with correlation coefficient +0.87 and "p" value 0.001 the group B(female) subjects also had statistically significant values.

Table-IV segregates individuals in to 3 broad categories on the basis of work levels attained, in ranges of 20 watts. In the first category, subjects whose work output was less than 100W were grouped. The second subgroup consists of individuals who attained a work output in the range of 100W-120W and the third, those with work capacities above 120W. The number of individuals (n) falling under each sub-group is also represented in actual numbers and also as percentage of total with in a group A or B. Among Group-A subjects tested, 16% belonged to category of less than 100W, 32% to100-120W range and 52% to a higher range of 120W.

Mean values, S.D's and S.E's of work capacity and all other variables are presented in the table for each of the above categories or sub-groups to facilitate comparative analysis. None of the female subjects tested could attain a work capacity exceeding 120W and hence this column is left blank. 80% of them could achieve levels of work output of only less than100W and 20% between 100-120W. Further look at the<100W categories, reveals the proportion performing low at<80W and at 80-100W range. Again group specific mean values, S.D's and S.E's of work capacities and all other corresponding variables are noted in the tables. Therefore from table-IV, it is possible to undertake a comparative study of both intergroup (Groups A&B) and intra group differences in the exercise capacities and the variables which might account for, or be consequence of them such as pulse rate and blood lactate.

Table-V further analyzed work capacities, post exercise rise in pulse rates and rise in blood lactate levels with hemoglobin levels by splitting hemoglobin levels in 'one' g/dl ranges.

The relationship between haemoglobin concentration and work capacity is shown graphically by means of scatter diagrams also.

The correlation between the haemoglobin concentration and the work capacities of Groups A and B subjects is shown in graph-1 and 2 respectively.

DISCUSSION: There are extensive studies dealing with both the short term responses to a single bout ofoccasional exercise (acute exercise) and long term adaptations to a regular exercise (chronic exercise)[4]. While the literature is abundant on the effect of exercise on body's physiology, few studies are devoted to endogenous factors that limit exercise capacities among individuals5,6. In this study, attention is paid to one of the endogenous systems, which is haemoglobin concentration and its effect on work capacity. Individuals differ widely in their exertional abilities which are determined by a large number of variables such as nutritional status, age, haemodynamic capacities, muscular strength, environmental factors, skill, motivation etc[5,6,28]. In the light of these complexities, what can be accomplished is to interpret the work capacities against one of the chosen variables while freezing others to barest minimum possible.

The choice of medical students as test subjects offers the advantage of having a group matched in age, heights, weights, nutritional status, training effects etc. As seen from table-I, Group-A subjects had mean height of 170.7±7.9cms and mean weight of 60.6±6kgs. The mean height Of Group-B subjects was 160.36±6.78cms and mean weight was 51.36±8.58kgs, as shown in the table-II. Stress is not laid on anthropometric data, which obviously closely matched and did not constitute the objective of this study. However studies indicate that wide variations in anthropometric measures among individuals account for variations in work capacities[14].

A good test to evaluate exercise capacity or physical fitness should confirm to the following criteria,

1) It must place the cardiovascular system under considerable stress.
2) It should be so intense that at least one third of all the subjects will stop from exhaustion within 5min, but the work intensity should not be so high as to make motivation play a dominant role.
3) It should not demand unusual type of skill for successful performance.
4) The work load must be carefully determined, reproducible and fairly easy, so that mechanical efficacy is kept relatively constant[2,4,19,20,21,22.]

The bicycle ergometry fulfills the requirements of a good test.

Subjects, so tested on bicycle ergometer depicted under table-I and II showed a distinct sex difference in work capacities with females having lower capacities than their male counterparts in the same age group.

A significant correlation between work capacity and haemoglobin was found for both the sexes.

The observations from table-V were, in group A (male) subjects, the increase in work capacity with hemoglobin ranges "a" and "b" i.e. up to a hemoglobin level of 9g/dl is slight, but above the range "c" i.e. above a hemoglobin level 9g/dl there is a sudden spurt of work capacity from 94 watts to 118 watts and there occurred a stabilization after the hemoglobin range " e" i.e., above 12 g/dl i.e., after attaining a work capacity of 132 watts. The same thing happened in group-B also. In the hemoglobin ranges "a' and "b" i.e., up to a hemoglobin level of 8g/dl the rise in work capacity is slight and above that range in the sub group "c" i.e. above 8g/dl there is a sudden spurt in work capacity from 68 watts to 90 watts and a stabilization phase reached from the hemoglobin range "d' i.e., from above 9g/dl i.e., after attaining a work capacity of 96 watts.

However neither a significant correlation coefficient nor a 'p' value of<0.001 would mean a cause effect relationship, from purely statistical point of view. This calls for interpretation of the observed relationship, as to how haemoglobin concentration can

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affect exercise capacity.

The oxygen carrying capacity of the blood is in particular due to haemoglobin. Each gram of haemoglobin is capable of combining with 1.34ml of oxygen at S.T.P. At a given rate of flow through a group of hard working muscles, the O2 supply is determined by the O2 transporting capacity of blood in terms of the quantity of haemoglobin. Apart from Haemoglobin, other factors also influence and limit O2 consumption by the muscles. These are:

1) Exercise R.Q (respiratory coefficient).
2) The degree of dissociation of oxy-Hb in the tissues.
3) The volume output of the heart.
4) The rate of haemoglobin flowing through the muscles and
5) Pulmonary ventilation[8,26,28.]

No single factor can be said to be a dominating factor, since during severe work, it is possible that each has its effect. Notwithstanding individual differences in haemoglobin concentration, the other variables mentioned are not, deemed to be pathologically changed in the present study group who are all proclaimed to be healthy. But it is expected that physiological adjustments do take place in the above factors to ensure greater supply of O_2 to working muscles, at a given level of haemoglobin concentration. During extremely heavy work states, the coefficient of oxygen utilization may increase to over 75%. With increase in muscle blood flow, increase in muscle O_2 consumption to well over 15 times the resting state is to be expected. In superbly conditioned individuals possessing excellent cardiovascular and pulmonary response, the muscle O_2 uptake may be increased up to 24 times that of resting state[11,18.] It is therefore logical that the total body O_2 consumption (VO_2) at peak dynamic exercise is good correlation of work capacity[11,18.] An increase in VO2 may result from increased cardiac output (central) or from increased O2 extraction (peripheral) or both.

In the present study to a symptom limited point of exhaustion, the magnitude of heart rate (H.R) raise, as reflected in pulse rate raise is also used as an objective criterion. The raise in pulse rate is a well known accompaniment of exercise. Pulse rate is often used in the evaluation of the cardiac response to exercise, since increased heart rate contributes to increased cardiac output of exercise. Bergger and Christensen (1950) used pulse rate as an index of metabolic rate for work periods of short duration. A linear relationship is found between pulse rate and O2 consumption[13]. Leblanc(1957) feels that pulse rate can be used as an index of work output as well as indicator of level of fatigue[23]. The maximum permissible H.R at exhaustion known as target heart rate is often used, to terminate the exercise by the observer.

Age specific target heart rates are listed in literature along with simple formulas such as; 195-age, to arrive at it. As a group male subjects in this study showed a mean raise of 76±6 beats/min. While females showed a mean raise of 81.92±9 beats/min. In table-V, it is observed that in both group-A and group-B along with their sub groups according to their hemoglobin ranges, the rise in pulse rates and blood lactate levels are high with low hemoglobin levels. From these it can be generalized that those individuals under lower ranges of haemoglobin concentration, demonstrated a higher pulse rate rise for work outputs attained by them, although their work capacities are comparatively lower than those at higher haemoglobin concentration. The intergroup difference in pulse rate observed, corroborate with reports that women show a significantly greater rate of raise at identical workloads than men. Greater pulse rate responses at lower ranges of haemoglobin concentration within a given group is in agreement with higher rates observed in anemic subjects[5,6].

The onset of fatigue in heavy exercise is often associated with increase in blood lactate concentration. When exercise load is increased progressively, energy supply from aerobic metabolism (oxidative phosphorylation) may not be adequate and therefore anaerobic metabolism (anaerobic glycolysis) must be utilized to supplement energy[4,16,25.]

As a result blood lactate concentration begins to increase and eventually intracellular acidification takes place. The mechanism by which lactic acid contributes to fatigue is primarily by lowering pH. At low pH the affinity of Ca++ ions for troponin is reduced. Further fall in pH inhibits some key glycolytic enzymes ex: glycogen phosphorylase and phosphofructokinase. Thus, lactic acid may effect both the contractile mechanism and energy supply adversely. Thus raise in blood lactate concentration which heralds the transition from aerobic muscle metabolism and triggers fatigue, is a valuable indicator of severity of exertion[15,24.]

Although accumulation of lactate is a consequence of exercise, it is also an important limiting factor as well[27.] A tendency for greater degrees of raise in individuals with lower haemoglobin concentrations than those with higher ranges, regardless of the absolute amount of work turned out. Thus it would appear that individuals with lower levels of haemoglobin and lower O2 transporting capacity reach anaerobic levels of work output sooner and show signs of fatigue sooner. Accumulated data in literature supports this view, corroborating the role of lactic acid as a limiting factor of exercise capacity[15.]

The magnitude of raise in pulse rate and lactate levels was higher in low performers, successively decreased in groups turning out greater work outputs. Thus the raise in pulse rate and lactate seem to correlate with characteristics of other parameters such as haemoglobin level rather with absolute level of work capacity.

REFERENCE

1) Jones, AM, Wilkerson, DP, DiMenna, F, Fulford, J, and Poole, DC. Muscle metabolic responses to exercise above and below the "critical power" assessed using 31P-MRS. Am J Physiol Regul Integr Comp Physiol 294: R585–R593, 2008 | 2) Brickley, G, Doust, J, and Williams, CA. Physiological responses during exercise to exhaustion at critical power. Eur J Appl Physiol 88:46–151, 2002 | 3) A Comparison of Blood Lactate Level and Heart Rate Following a Peak Anaerobic Power Test in Different Exercise Loads Ercan GürPelagia Research Libra European Journal of Experimental Biology, 2012, 2 (5):1854-1861 | 4) HALEY C. BERGSTROM, A NEW SINGLE WORK BOUT TEST TO ESTIMATE CRITICAL POWER AND ANAEROBIC WORK CAPACITY, National Strength and Conditioning Association 26(3)/656–663 Journal of Strength and Conditioning Research 2012 | 5) Haas JD, Brownlie TT, 2001. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. J Nutr131: 676S–688S. | 6) S Swaminathan, B S Edward and A V Kurpad, Micronutrient deficiency and cognitive and physical performance in Indian childrenEuropean Journal of Clinical Nutrition 67, 467-474 (May 2013) | doi:10.1038/ejcn.2013.14 | 7) ASMUSSEN E and NIELSON M: Cardiac output during muscular work and its regulation, Physiol. REV, 35:778-800, 1955. | 8) ASTRAND P.O, RODAHL K. Textbook of work physiology, network, MEROAVO HILL 1970&669. | 9) BARKER S and SUMMERSON W. The colorimetric determination of lactic acid in biological material J.Biol Chem 138: 535, 1941. | 10) BOCK A.V, DILL D.B and EDWARDS H.T. Lactic acid in the blood of resting man, J.CLIN INVES 11:775-778, 1922. | 11) BRAUNWALD E. and others. An analysis of the cardiac response to exercise circulat Res 20, suppl 1: 1-44, 1967. | 12) BROTHERGHOOD J.B, BROZOVAC B et al Hematological studies of middle and long distance runners, clinic SCI MOL Med 48:139-145, 1975. | 13) BEGRRREN G and CHRISTENSEN E.H. Heart rate and body temperature as indices of metabolic rate during work AR.BEITS physiologic 14: 255-260, 1955. | 14) BENZJAMIN RICCI- Physiological basis of human performance LEA and FEBIGER 1967. | 15) CRECITELLI F and TAYLOR C. The lactate response to exercise and its relationship to physical fitness AMERJ PHYSIOL 141: 630-640, 1944. | 16) DAVIS J.A: VODAK P, WILMORE J.H. et al. Anaerobic threshold and maximal aerobic power for three modes of exercise. J.APPL. PHYSIOL 41:544-550, 1979. | 17) EDWARD P. EICHNER. Physician sports Med. 14: 122-130, 1986. | 18) HERMANSEN L, EKBLOM et al, Cardiac output during submaximal and maximal treadmill and bicycle exercise J.APPL. PHYSIOL 26: 31, 1969. | 19) JHONSON R.E, BRONHA.L. Et al. A test for physical fitness for strenuous exertion REV. Cand. Bion. 1: 491-503, 1942. | 20) JONES N L, CAMPBELL EJM- Clinical exercise testing second ed.PHILASDELPHIA W.B SAUNDERS CO 1981. | 21) LAWRENCE E. MOREHAUGE Laboratory manual for physiology of exercise C.V.Mosby co 1972. | 22) LAWRENCE E.MOREHAUGE & AUGSTIES T.MILLER Jr. Physiology of exercise 7th cd. C.V.Mosby co 1971. | 23) LE BLANC J.A. Use of heart rate as an index of work output J.Appl.phys. Vol 10: 275-290, 1957. | 24) MADER A, HECK H, HOLL MAN Evaluation of lactic acid anaerobic energy contribution by determination of post exercise lactic acid and contraction of ear capillary blood in middle distant runner and swimmers. Exercise physiology. 1stEd symposia specialists, Miami 187-204, 1978. | 25) MAC DONGALL J.D. The anaerobicthreshold: its significance for the endurance athletes. Cand.J.Appl. Sports Sci. 2: 137-40, 1997. | 26) ROSSIER P.H, BHULMAN A.AA & WESSINGER Respiration: physiologic principles and clinical applications C.V Mosby Co 1960. | 27) WELLS J.G, BLAKE B et al Lactic acid accumulation as a factor in determining work capacity. J.Appl. Physiol. 10: 51-55, 1957. | 28) WILLIAM F. GANONG. Review of medical Physiology 17th ed. 1995. | |