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Relationship of Heart Rate with Oxygen Consumption of adult male workers from Service and Manufacturing Sectors

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ABSTRACT: The purpose of the present study was to find a relationship between Heart Rate (HR) and Oxygen Consumption of industrial workers. HR and Oxygen Consumption of 135 adult males from service sector and 49 adult male from manufacturing sector in the age group of 40-50 years were measured by direct (breath-by-breath technique using Cortex Metamax 3B) measurement using computerized Bi-cycale ergometer. The correlation coefficients of HR with oxygen consumption of Service and Manufacturing sectors were 0.82 and 0.81 and Mean Square Error were 24.02 and 29.54. These two group were merged (135+49=185) and an Experimental group was formed (Phase I). In Phase II Prediction equation for oxygen consumption was developed from the regression analysis. The correlation coefficient of HR with oxygen consumption was 0.82 and Mean Square Error (MSE) was 24.27. In Phase III 100 new subjects (Validation group) were chosen at random from service and manufacturing sector. There oxygen consumption was determined by using laboratory technique and also by prediction equation developed in phase II. Test-retest correlation values showed high correlation coefficient 0.85 and MSE 16.24. The higher correlation value shows the accuracy of the prediction equation developed in the present study.

Keywords: Heart Rate; Oxygen Consumption; prediction equation; test-retest correlations

INTRODUCTION

The relationship between oxygen consumption and heart rate is important mainly to assess energy expenditure and fitness level [1-4]. ACSM has recommended to use the relationship of VO2 max and HR reserve for improvement of cardio-respiratory fitness.

Oxygen consumption is considered as the standard for measuring the physiological intensity of exercise. Recent studies have shown that heart rate can successfully be used as a proxy for the measurement of rate of oxygen consumption or metabolic rate in free ranging animals [5-6]. The measurement of oxygen consumption which needs technical knowledge, skill

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and sophisticated instrumental setup, it becomes difficult to determine the oxygen consumption of an individual with minimal resources. Therefore, this study aims to develop a relationship of heart rate with oxygen consumption. If heart rate can be reasonably translated into oxygen consumption, then new avenues in monitoring of fitness and energy expenditure would be opened.

1. MATERIALS & METHODS

1.1 Investigation Subjects

The study was conducted on 285 adult male volunteers of which 185 were taken as Experimental group and 100 were taken as Validation group. Volunteers from Experimental group were chosen from Service sector (n=136) and manufacturing sector (n=49). Volunteers were chosen in such a way that a wide variation of Indian population who belong to various regions could be covered. The age group of the volunteers were 40 – 50 years. The age group of 40-50 years was chosen because most of the studies were focused either on the athletes or on college/University students in the lower age groups. Presently a large chunk of workforce in industry is ageing workforce and they become concern of health and fitness generally at the age of 40 years and above to balance their performance level and job demand. The experiment was conducted at least three hours after last meal and 36 hours of limited exertion of the volunteers. The exclusion criteria includes white collar employee and the volunteers with a history of serious clinical, metabolic or cardiac disorders, which was accessed by a questionnaire. All volunteers were briefed in details about the testing procedures and the possible benefit(s) that this study attempted to ascertain. Only those volunteers were considered to participate in the studies who were interested to participate and consequently a signed informed consent was obtained from each one of them. All evaluations/tests were carried out in controlled laboratory condition with the air temp 23°C (±2°C), and relative humidity at 55% (±5%).
The volunteers were divided into two groups.

Group 1: Experimental group includes

1. 136 adult males working in the Service sector
2. 49 adult male working in the Manufacturing sector

Group 2: Validation group includes
100 adult males randomly chosen from a separate set of Service and Manufacturing sectors and considered as Validation group.

The study was conducted in three different phases-

1.2 PHASE I: Measurement of Cardio-Respiratory Fitness

Measurements of oxygen consumption (breath-by-breath technique) and heart rate were done by Cortex - Metamax 3B (Germany) and computerized Bi-cycle ergometer. Heart rate monitoring was done by Polar Heart Rate Monitor (S810i Finland)

Stages of Experiment

Initial Stage: In this stage heart rate and oxygen consumption were recorded for two minutes while the subject was sitting on cycle before started cycling.

Exercise Stage: Ramp protocol (ACSM, 1991) was used. Initial load on bicycle ergometer was 20 watt. The experiment was divided into four phases; rest, reference, test and recovery. First three minutes was the rest phase. During this period subject remained sitting on the bicycle; the duration of reference phase was three minutes, the load was 20 watt with 50-60 rpm paddle speed. The test phase started at 6th minute of the experiment; in this phase starting load was 40 watt with an increment of 20 watt each minute till the subjects get exhausted and indicate to stop. Also there was no further increase in oxygen consumption with increase in workload. At the end of the test phase, subjects were put on recovery phase which was continued for three minutes with 20 watt load. Cardio-respiratory parameters like heart rate and oxygen consumption were recorded throughout the experiment.

Recovery Phage: Recovery phase was without any load and all the above physiological variables were monitored till oxygen consumption returned to the pre-exercise level.

1.3 PHASE II: Development of Prediction Equations

In this phase prediction equation for oxygen consumption was developed from the data of Experimental group.

1.4 PHASE III: Test Re-Test Correlations

In this phase 100 new subjects (Validation group) were chosen at random from Service and Manufacturing sector. Their cardio-respiratory fitness was determined by using the laboratory technique and also by using the prediction equations developed in phase II. Observed and predicted cardio-respiratory parameters were compared separately to prove the validity of the prediction equations which were developed from Experimental group.

1.5 Statistical analysis

The following statistical treatments were applied for the present study:

Oxygen consumption and heart wee correlated and linear regression equation was developed from the Experimental group for prediction of oxygen consumption from the heart rate.

The prediction equation was validated by using the Validation group.

All the statistical analysis was done by NCSS (2007) software package.

ISSN: 2277: 5447 | Vol.3.No.3 | September'2014

2. RESULTS AND DISCUSSION

2.1 Physical Characteristics of the Subjects

All the physiological characteristics of the subjects depend on some physical parameters like age, height, weight. Therefore, measurements of these physical factors are essential before administration of any physiological evaluation. Physical characteristics of the subjects have been presented in Table 1.

Table 1: Corporal Data of Service and Manufacturing sector

Parameters	Service sector (n =136) Mean (±SD)	Manufacturing sector (n = 49) Mean (±SD)	Experimental group (Service sector + Manufacturing sector) (n =185) Mean (±SD)	Validation group (n =100) Mean (±SD)
Age (yrs)	46.7 (±8.10)	44.4 (±10.88)	46.1 (±8.95)	49.4 (±9.74)
Height (cms)	164.4 (±6.36)	165.6 (±4.78)	164.7 (±5.99)	165.0 (±5.3)
Weight (kgs)	63.1 (±11.54)	66.1 (±10.72)	66.1 (±10.72)	66.1 (±10.40)

The values do not differ much between Service and Manufacturing sector, even the mean corporal data of the Validation group are similar to those of the Experimental group.
The resting and maximum values of heart rate (HR) and oxygen consumption are presented in Table 2 for experimental group and validation group.

Table 2: Pre-work and maximum values of heart rate and oxygen consumption

Parameters	Service sector Mean (±SD)	Manufacturing sector Mean (±SD)	Experimental group Mean (±SD)	Validation group Mean (±SD)
Resting HR (beats.min-1)	72.2 (±16.29)	71.0 (±7.96)	72.3 (±16.69)	71.5 (±16.49)
Resting VO2 (ml.kg-1.min-1)	5.5 (±1.30)	5.0 (±2.26)	5.6 (±1.27)	5.3 (±1.27)
HR max (beats.min-1)	154.0 (±17.00)	166.0 (±15.99)	158 (±21.84)	159 (±21.11)
VO2 max (ml.kg-1.min-1)	27.3 (±4.15)	34.8 (±5.99)	33.0 (±5.61)	31.5 (±5.99)

ISSN: 2277: 5447 | Vol.3.No.3 | September'2014

2.2 Correlation of Heart Rate (HR) With Oxygen Consumption (VO2)

2.2.1 Correlation of Heart Rate (HR) With Oxygen Consumption (VO2) In Service Sector

The obtained oxygen consumption of 135 employees from service sector was correlated with HR and presented graphically (Fig 1). The correlation coefficient (r) was 0.82 and the mean square error was 24.02 (Table 3).

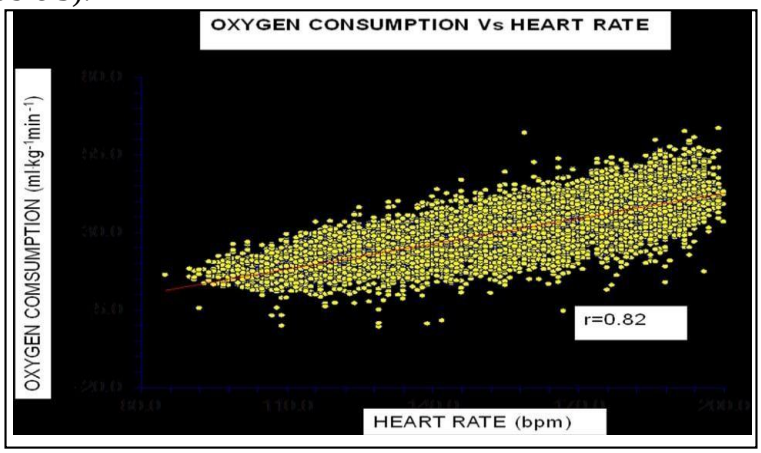

Fig 1: Relationship between oxygen consumption (breath-by-breath data) and HR in Service sector

2.2.2 Correlation of Heart Rate (HR) With Oxygen Consumption (VO2) In Manufacturing Sector

In the next stage, the obtained oxygen consumption of 49 employees from Manufacturing sector was correlated with HR (Fig 2). The correlation coefficient (r) was 0.81 and the mean square error was 29.54 (Table 3).

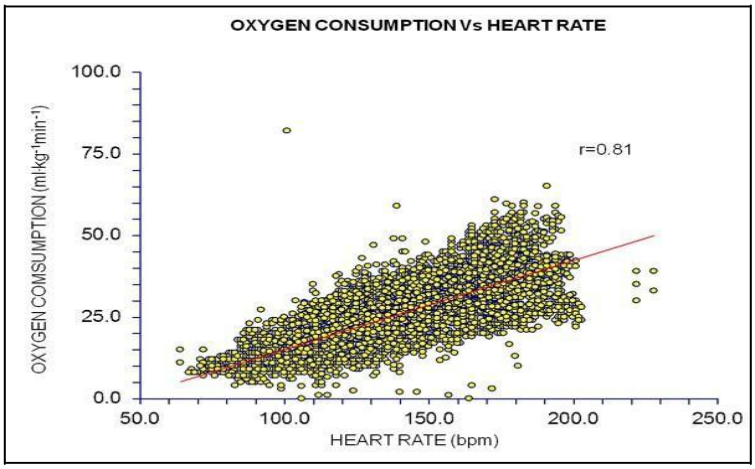

Fig 2: Relationship between oxygen consumption (breath-by-breath data) and HR in manufacturing sector

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The regression analysis of HR reveals high correlation coefficient with oxygen consumption. In both the sectors viz., Service sector and Manufacturing sector the correlation coefficient values are 0.82 and 0.81 respectively. All the correlations are significant at $p<0.001$ level.

Table 3: Statistical parameters calculated from the oxygen consumption and heart rate of Service sector, Manufacturing sector and Experimental group.

Statistical Parameters	**Service sector (N=135)**	**Manufacturing sector (N=49)**	**Experimental group (185) (Service sector+ Manufacturing sector)**
Correlation (r)	0.82	0.81	0.82
Probability (p)	0.001	0.001	0.001
Mean Square Error	24.02	29.54	24.27
Slope (m)	0.27	0.27	0.28
Intercept (i)	-11.85	-12.26	-12.4

Regression coefficients of HR in both the sectors i.e Service sector and Manufacturing sector exhibit high correlations with oxygen consumption and there is no significant difference of the correlation coefficients between each other. Since, the correlation coefficients of the two groups do not differ significantly; it was thought that both the two groups can be marged together to form a single Experimental group. Therefore, the Experimental group was formed and oxygen consumption of the Experimental group was correlated with their respective heart rate scores.

The Experimental group also exhibits a high correlation coefficient (r) of 0.82 (Table 3) between HR and oxygen consumption relationship.

2.2.3 Development of Prediction Equation for Oxygen Consumption from Experimental Group by using HR

The correlation coefficient of the oxygen consumption with HR score is 0.82 (Fig 3), which is also highly significant ($p<0.001$). The mean square error is 24.27. The slope and intercept are 0.28 and -12.4 respectively (Table 3).

ISSN: 2277: 5447 | Vol.3.No.3 | September'2014

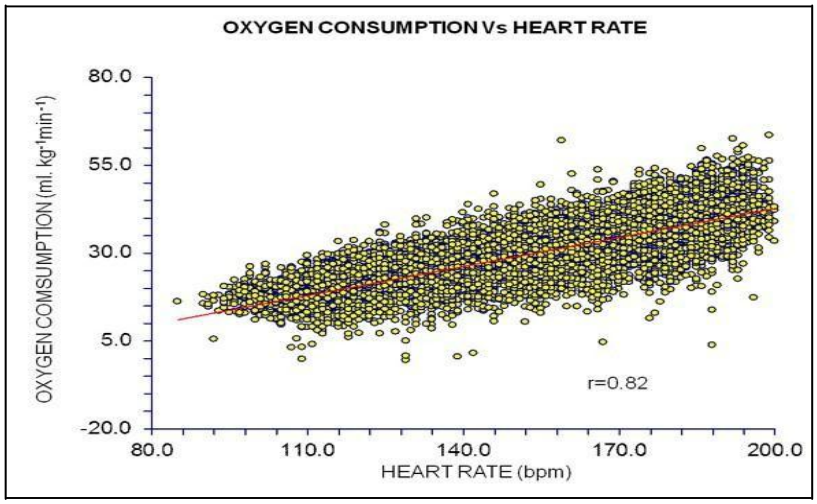

Fig 3: Relationship between oxygen consumption and HR in Experimental group

From the slope and intercept point of the regression analysis of the Experimental group (Table 3), an equation for the prediction of Oxygen consumption of Indian industrial population was developed, as under:

Oxygen Consumption ($ml.kg^{-1}.min^{-1}$) = (-12.4) + (0.28) * (Heart Rate)

2.2.4 Validation Group: Directly Measured Oxygen Consumption Vs Predicted Oxygen Consumption

100 new industrial workers belonging to Service as well as Manufacturing sectors were selected and treated as Validation group at phase III. Oxygen consumption of this group was estimated by i) direct graded exercise protocol by using a bicycle ergometer as well as by ii) using the prediction equation developed on the Experimental group. The reliability of the oxygen consumption from prediction equation was examined by this duplicate measurement on the Validation group. The means of the oxygen consumption obtained by direct method and by using modified equation are 26.4 $ml.kg^{-1}min^{-1}$ and 25.5 $ml.kg^{-1}min^{-1}$ respectively. The observed and predicted oxygen consumption ware correlated to examine the accuracy of the prediction equation. Graphical representation of the observed Vs predicted oxygen consumption has been shown in Fig 4. The test – retest correlation shows high correlation coefficient (r = 0.85). The mean square error is 16.24 (Table 4).

ISSN: 2277: 5447 | Vol.3.No.3 | September'2014

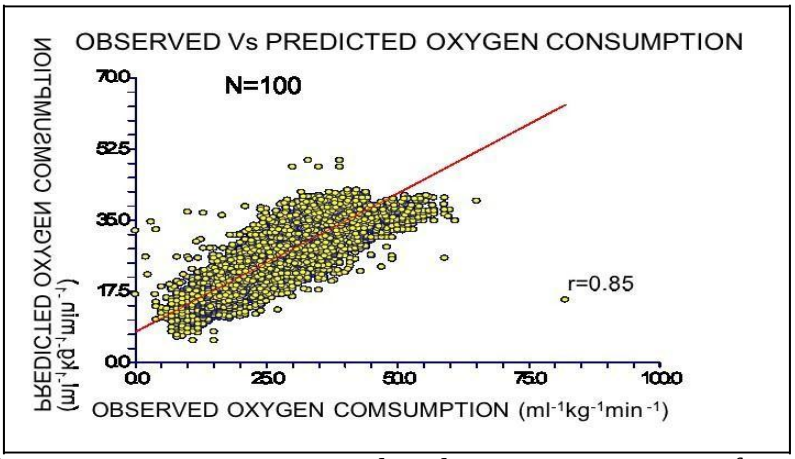

Fig 4: Observed oxygen consumption Vs predicted oxygen consumption for Validation group (N=100) from the prediction equation (Equation Number 1)

Table 4: Test-retest correlation of Oxygen Consumption

Parameter	**Oxygen Consumption by direct method (Cortex Metamax3B)**	**Predicted Oxygen Consumption (Present study)**
Values ($ml.kg^{-1}.min^{-1}$)	26.4	25.5
r	---	0.85
Mean Square Error	---	16.24
Standard Error	---	0.11

3. CONCLUSION

There are a number of highly sophisticated and expensive methods that may be used to measure oxygen consumption. All of these methods are subject to technical knowledge and skill of the user and also require very sophisticated and expensive laboratory setup that needs regular calibration and proper maintenance of the equipment. Because of the limited availability of such equipments, various indirect methods have been developed for determination of oxygen consumption. Since heart rate highly correlated with oxygen consumption (present study), it's playing a significant role in the assessment of oxygen consumption of an individual.

Therefore, the equation developed in the present study can be suitably used to determine the oxygen consumption of the adult males working in the service as well as in the manufacturing sectors.

4. ACKNOWLEDGEMENT

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ISSN: 2277: 5447 | Vol.3.No.3 | September'2014

5. REFERENCES

1. G. A. Meijer, K. R. Westerterp, H. Koper, F. Ten Hoor, Assessment of energy expenditure by recording heart rate and body acceleration, *Medicine & Science in Sports & Exercise*, 21 (1989) 343–347.
2. S. Schulz, K. R. Westerterp, K. Brück, Comparison of energy expenditure by the doubly labeled technique with energy intake, heart rate, and activity recording in man, *The American Journal of Clinical Nutrition*, 49 (1989) 1146–54.
3. W. C. Miller, J. P. Wallace, K. E. Eggert, Predicting max HR and the HR – V O2 relationship for exercise prescription in obesity, *Medicine & Science in Sports & Exercise*, 25 (1993) 1077–81.
4. M. B. Gilman, The use of heart rate to monitor the intensity of endurance training, *Sports Medicine*, 21 (1996) 73–79.
5. P. J. Butler, J. A. Green, I. L. Boyd, J. R. Speakman, Measuring metabolic rate in the field: the pros and cons of the doubly-labelled water and heart rate methods, *Functional Ecology*, 18 (2004)168–183.
6. J. A. Green, P. J. Butler, A. J. Woakes, I. L. Boyd, R. L. Holder, Heart rate and rate of oxygen consumption of exercising macaroni penguins, *The Journal of Experimental Biology*, 204 (2001) 673–684.