Original Article

Study of the relationship between the aerobic capacity (VO2 max) and the rating of perceived exertion based on the measurement of heart beat in the metal industries Esfahan

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ABSTRACT

Background and Objective: To establish a balance between work (physical exercise) and human beings, the aerobic capacity (VO2 max) could be used as a measure. Additionally, the subjective and physiological assessment could be applied as one of the methods for assessing physical exercise. The most commonly used tools for the assessment of fatigue during physical exercise include the Borg scale Rating of perceived Exertion (RPE) in relation to subjective symptoms and heart rate (HR) in relation to physiological symptoms. The study is aimed to investigate the relationship between the aerobic capacity and the RPE based on the measurement of heat rate (HR) of workers from the Metal Industries of Isfahan. **Materials and Methods:** The subjects were 200 male workers from metal components manufacturers in Isfahan selected by using random sampling based on statistic method. The subjects were examined by using ergometer in accordance with A strand 6 minutes cycle test protocol. Furthermore, the subjects were asked to rate their status based on the Borg rating scale at the end of each minute. Additionally, their heat rates were monitored and recorded automatically at the end of each minutes. **Results:** Statistical analysis showed that there was a significant relationship between the RPE and the aerobic capacity (VO2 max) ($r = -0.904$, $P < 0.05$). The results illustrated that there was a stronger correlation between HR and VO2 max ($r = 0.991$, $P < 0.001$). The regression analysis of the quadratic equation also indicated that there was also a significant relationship between the VO2 max and HR. **Conclusions:** The results indicated that there was a strong relationship between the RPE and VO2 max, as well as a greater correlation between HR and VO2 max. Therefore, the HR could be used as a Prediction measure to estimate VO2 max.

Key words: Heart rate, metal industries, rating of perceived exertion, VO2 max

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INTRODUCTION

The main objective of ergonomics is to create a balance between human beings and the environment. To assess the effectiveness of an ergonomic intervention program, the special tools are needed to gather information on the fitness.[1]

One important aspect of the fitness between human beings and the environment is the physical aspect. By assessing the physical and physiological characteristics of human beings, it is possible to assign him to a task on the basis of his physiological tolerance limits.[2] Therefore, by addressing measuring metabolism and oxygen consumption during work, Martines

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noted that all physical exercises should be done within the aerobic human capacity. Currently, the aerobic capacity has been as the maximal capacity to perform the work.[2]

VO2 max (also maximal oxygen consumption, maximal oxygen uptake, peak oxygen uptake, or maximal aerobic capacity) is the maximum capacity of an individual's body to transport through circulatory system and use oxygen in motor muscles.[3] Now, we have accepted the aerobic capacity as the maximal capacity during work shifts. Today, scientists believe that the ability to perform physical exercise should be determined using the aerobic capacity.[2] There are various methods to measure the aerobic capacity which are divided into groups: Direct methods and indirect methods. The direct methods include using the treadmill, ergometer, and step tests, while the indirect methods include charts and formulas of Astrand and physiological (e.g., heart rate [HR]) and subjective (e.g., rating of perceived exertion [RPE]) variables. It is worth noting that the direct methods are more accurate but more expensive which need training technicians for setting up and using equipments while time consuming; on the contrary, the indirect methods are useful and effective for assessing aerobic capacity in the industries as to have no such limitations.[4] Consequently, we utilized heart beat (HR) as an indirect method for assessing the aerobic capacity.[5] Additionally, although the aerobic capacity varies at different workloads, there are several methods to evaluate and estimate the workload (work intensity), such as subjective assessment. In order to measure the level of subjective physical workload, the RPE scale proposed by Borg is very useful,[6] which is a rating scale as to rating scales are important supplemental measures of psycho - physical performance and work capacity. Furthermore, this scale also has several applications in the field of medicine and ergonomics.[7,8] Most of researchers have found that understanding subjective symptoms and how to interrelate them with objective findings is of most importance.[7] In general, the resultant information could be used for assessing individual's features, such as the aerobic capacity, metabolism rate, and so on; hence, the histories of workers in our countries and also other developing countries is important, since in these countries, most industrial processes are performed in the form of semi-mechanized work resulting in more pressure on the shoulders of the workers.

Therefore, to prevent early deterioration of workforce resulting in low efficiency, it is needed to determine the fitness between the individual and the work. However, yet there has been no comprehensive study done on the physical exercise capacity of Iranian workers and, as a result, there is no detailed information in this area;[9-11] perhaps because of the high cost of technician training to operate the special equipments of direct methods such as ergometer, which isn't cost-effective and affordable for the industry. Nevertheless, a few studies have been done abroad on the worker populations by using physiological and subjective methods to assess the oxygen consumption of the workers in physical exercises. These studies were aimed to assign individuals to the tasks on the basis of their physiological tolerance limits in accordance with ergonomics principles. Therefore, the current study intends to use the results of the RPE of physical exercise (ergometer) and HR measurements to estimate the level of the individual's aerobic capacity and finally to determine the association between aerobic capacity and HR measurements.

MATERIALS AND METHODS

The current study is a cross-sectional analysis with no direction. The subjects were 200 male workers from metal components manufacturers in Isfahan selected by using random sampling based on statistic method, so that they were tested with a time schedule of maximum 10 subjects per day.

The ergometer and Astrand protocol were used to determine the aerobic capacity. To perform the test based on the Astrand protocol based on the,[12-15] worker with light clothing[7] pedals the ergometer for 6 minutes to reach his HR over 120 beats per minute;[12,13,16] then, 25 watt per minute is added to the workload (heaviness of pedal)[17,18] as well as, at the end of each stage, the HR using the sports tester and the RPE (according to the Borg scale) are measured during the ending 15 seconds.[19,20] The scale starts from number 6 to 20, and each is labeled with its own individual's RPE and physical activity.[21] Additionally, the scale has been validated by domestic studies.[22] Finally, HR and the Borg scale relative to 6-20 RPE will be determined for each subject. Next, VO2 max will be calculated in $ml.kg^{-1}.min^{-1}$ using ACSM formula.[23]

$$VO2\max\ (ml/kg/min) = VO2\frac{(220 - age - 73 - (sex \times 10)}{HR - 73 - (sex \times 10)}$$

Vo2 (ml/kg/min) = (1.8 * work heart rate)/body weight Sex= 0 for women and 1 for men HR=Heart rate at final stage.

The ergometer TUNTURI model (Finland) was used for Astrand Cycle Test.

To undertake the test: First, by coordinating and corresponding metal industries in isfahan, several manufacturers have invited to participate in the study. Second, some of the workers were removed from the population due to following reasons: Absence, not wanting to participate in the study, cardiovascular diseases and respiratory diseases).[24] Finally, the results were analyzed by SPSS 20 statistical software package.

RESULTS

Average dry bulb temperature of the test environment and wet bulb temperature were 26°C and 21°C respectively.

All the subjects were male, Which 67.5% (n = 135) are the workers; 13.5% (n = 27) official personnel; 7% (n = 14) personnel of engineering division; 3% (n = 6) personnel of procurement division; 2.5% (n = 5) personnel of quality control unit; 3% (n = 6) personnel of security and guarding; and 3.5% (n = 7) related to storage division.

Pearson correlation test showed that there is a strong significant relationship between the RPE and HR ($r = 0.991$, $P < 0.005$). Moreover, the results indicated that there is a significant relationship between the RPE and the aerobic capacity ($r = –0.904$, $P < 0.005$), as well as a stronger significant relationship between the aerobic capacity and HR ($r = –0938$, $P < 0.005$) [Figures 1-4].

Table 1 Shows several studied demographic and individual characteristics.

The measurements of HR, aerobic capacity and Borg rating scale at the end of each minute are presented in Table 2.

Tables 3 and 4 indicated that there is stronger significant relationship between heart beat and the aerobic capacity than the RPE. However, simple linear regression analysis illustrated that there is significantly a linear relationship (vo2 max=404.56-0.648(hr)) between the aerobic capacity and heart beat (R2 = 0.72, $P < 0.0001$). Further, the quadratic equation (vo2 max= 404.56-5.62 (hr) + 0.021 $(hr)^2$)with (R2=0.802, $P < 0.0001$) is more accurate in relation to the degree, indicating that with the increase in HR during physical activity, aerobic capacity is reduced [Figures 1-4].

vo2 max= 404.56-5.62 (hr) + 0.021 $(hr)^2$

DISCUSSION

The current study is aimed to investigate the relationship between the aerobic capacity and the RPE based on the measurements of heat rates (HRs) of the 200 male workers from metal components manufacturers in isfahan selected by using random sampling based on statistic method ($n = 200$). The results indicated that there is a significant strong relationship between the aerobic capacity and HR.

The relationship between the rating of perceived exertion and heart beat

In this study, the mean increase in HR was significantly associated with mean RPE during each stage [Table 2] ($r = 0.991$, $P < 0.001$), which was approved by the previous

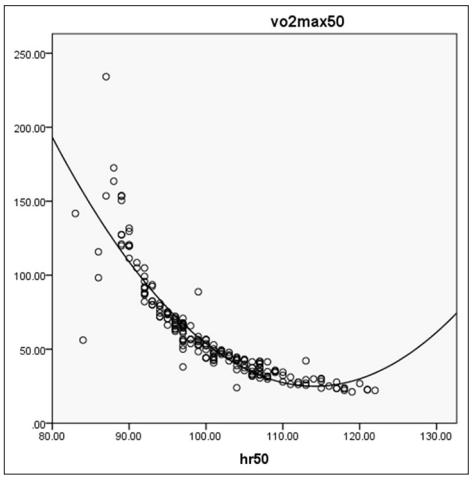

Figure 1: The relationship between heart rates and VO2 max at the end of min. 2 ($n = 200$) R2=0.818, $P < 0.0001$

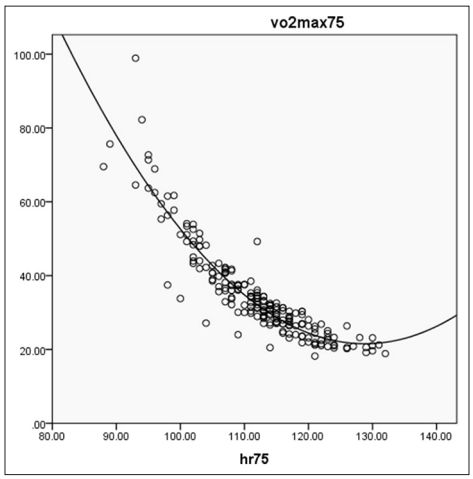

Figure 2: The relationship between heart rates and VO2 max at the end of min. 3 ($n = 200$) R2 = 0.866, $P < 0.0001$

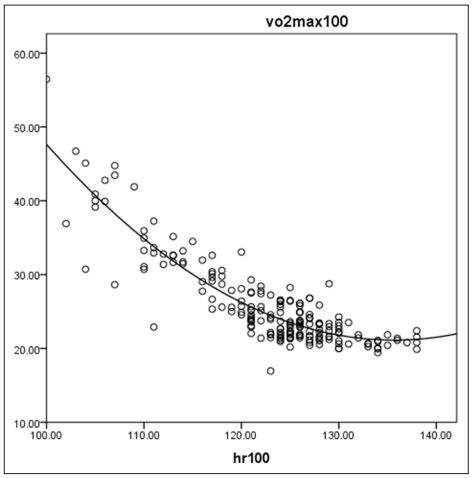

Figure 3: The relationship between heart rates and VO2 max at the end of min. 3 ($n = 196$) R2=0.802, $P < 0.0001$

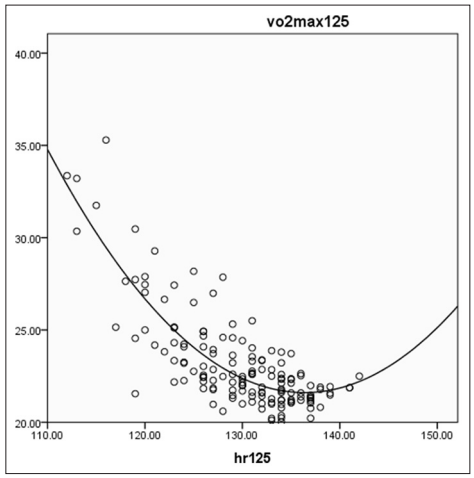

Figure 4: The relationship between heart rate and VO2 max at the end of min. 4 ($n = 150$) R2 = 0.677, $P < 0.0001$

studies. For instance, the results are consistent with the study by McKinun who investigated the relationship between HR and RPE using treadmill test (r = 0.7).[25] Additionally, The results also are compatible with the study on athletes by Youda and Karo Kava (r = 0.999)[20] However, The study results in The relationship between HR and RPE Compared tointernal studies of Daneshmandi *et al.*, on the workers and Parvari *et al.*, on the students is greater (Respectively 0.874, 0.89).[22,26] This The study has a low correlation Compared study of the Capodaglio that was conducted in 2001 year (r = 0.993).[27]

Table 1: Individual characteristics of the subjects (n=200)

Item	Mean (SD)	Min-Max
Age (years)	(7.76) 33.17	17-50
Weight (Kg)	(10.07) 72	52-100
Height (cm)	174.15 (6.24)	188-158.5
BMI	23.87 (2.95)	31.4-16.9
Work experience (years)	(5.23) 6.67	25-0.49
Join the club		
Yes	39 (19.5%)	
No	161 (80.5%)	
Marital status		
Married	163 (181.5%)	
Single	37 (18.5%)	
Education		
Under diploma	151 (75.5%)	
Under B.S.	41 (20.5%)	
Under M.S.	8 (4%)	
Drug abuse		
Yes	78 (39%)	
No	(1%)	

SD = Standard deviation

The relationship between heat rates and VO2 max

Pearson correlation between the aerobic capacity and HR during the different moments of the test was significant [Table 3] as to the Pearson correlation between mean HR and the aerobic capacity equal to r = -0.938, illustrating that there is a significant strong relationship between these two variables. Furthermore, the results are in agreement with the study by Artes *et al.*, using ergometer, and also results of Esposito *et al.*, based on the study on the athletes using the HR as a measure for assessing the aerobic capacity.[28] Results of this study with the internal investigation Eizadi *et al.*, on the 25 Adolescent corresponds.[29] While the study of Foster *et al.*, found a nonlinear relationship between VO2 and HR averaged over the subjects.[30]

The relationship between RPE and the aerobic capacity based on the measurement of HR

This study is aimed to investigate the association between RPE and the aerobic capacity based on the measurement of HR. According to the results, Pearson correlation between

Table 2: Means and Standard Deviations of HR, VO2 max, and Rating Scale of RPE 6-20 during resting and the end of each minute (n=200)

Variable Time of measurement	HR Mean (SD)	RPE Mean (SD)	VO2 max Mean (SD)
Resting	80.14 (8.48)	-	-
End of min. 1	100.87 (8.33)	9.61 (2.59)	60.29 (33.85)
End of min. 2	111.96 (8.61)	11.66 (2.71)	34.93 (12.90)
End of min. 3	122.74 (7.64)	13.69 (2.65)	25.88 (5.99)
End of min. 4	129.73 (6.17)	15.16 (2.39)	23.17 (2.68)
End of min. 5	132.50 (4.33)	16.04 (2.57)	22.96 (1.27)
End of min. 6	131.5 (4.93)	16.50 (1.91)	23.84 (0.51)

HR = Heart beat, RPE = Rating of perceived exertion, SD = Standard deviation

Table 3: Pearson correlation coefficient of HR and VO2 max during various times

Time	Min. 2	Min. 3	Min. 4	Min. 5	Min. 6	Min. 7
	Vo2 max	Vo2 max	Vo2 max	Vo2 max	Vo2 max	Vo2 max
r: HR (*P*)	−0.381 ,(0.0001)	−0.724, (0.0001)	−0.610, (0.0001)	−0.467, (0.0001)	−0.253, (0.083)	0.406, (0.498)
r: HR (*P*)	−0.739 ,(0.0001)	−0.883, (0.0001)	−0.724, (0.0001)	−0.555, (0.0001)	−0.252, (0.084)	0.722, (0.169)
r: HR (*P*)	−0.632, (0.0001)	−0.717, (0.0001)	−0.849, (0.0001)	−0.662, (0.0001)	−0.264, (0.070)	0.490, (0.402)
r: HR (*P*)	−0.510, (0.0001)	−0.510, (0.0001)	−0.626, (0.0001)	−0.748, (0.0001)	−0.375, (0.009)	0.074, (0.0906)
r: HR (*P*)	−0.298, (0.036)	−0.420, (0.002)	−0.546, (0.0001)	−0.387, (0.006)	−0.542, (0.0001)	0.479, (0.415)
r: HR (*P*)	0.881, (0.119)	−0.573, (0.427)	0.131, (0.698)	0.343, (0.657)	0.096, (0.904)	0.176 (0.824)

Table 4: Pearson correlation coefficient of RPE and VO2 max during various times

Time	Min. 2	Min. 3	Min. 4	Min. 5	Min. 6	Min. 7
	Vo2 max	Vo2 max	Vo2 max	Vo2 max	Vo2 max	Vo2 max
r: RPE (*P*)	−0.115, (0.105)	−0.176, (0.012)	−0.205, (0.004)	−0.111, (0.171)	−0.138, (0.340)	−0.372 (0.628)
r: RPE (*P*)	−0.074, (0.297)	−0.123, (0.083)	−0.160, (0.025)	−0.030, (0.714)	0.029, (0.842)	0.754, (0.246)
r: RPE (*P*)	−0.054, (0.452)	−0.076, (0.287)	−0.114, (0.111)	−0.017, (0.832)	0.083, (0.569)	0.595, (0.405)
r: RPE (*P*)	−0.05, (0.546)	−0.132, (0.107)	−0.132, (0.108)	−0.155, (0.059)	0.003, (0.985)	−0.260, (0.740)
r: RPE (*P*)	−0.084, (0.568)	−0.144, (0.328)	−0.049, (0.740)	−0.073, (0.623)	−0.039, (0.795)	0.281, (0.719)
r: RPE (*P*)	−0.429, (0.471)	0.012, (0.985)	−0.192, (0.757)	−0.0432, (0.628)	−0.395, (0.510)	−0.956, (0.44)

aerobic capacity and RPE was significant which indicates a strong relationship between them ($r = -0.904$, $P < 0.05$), and also is compatible with the results of study on football players by Karling *et al.*,[31] However, there is a relationship between the aerobic capacity and RPE which is in agreement with the study on the patients with physical issues by Satounka *et al.*, ($r = 0.74$, $P < 0.02$).[32] in the study of Men and women were treated. There was a direct correlation between RPE and VO2 max So that the results of this study are consistent.[33-42]

CONCLUSIONS

Determination of aerobic capacity is important in the discussion of health promotion and the prevention of occupational physical problems. Further, estimation of the aerobic capacity requires expensive and sophisticated laboratory equipment that is not affordable for the industry.

The results indicates a significant relationship between the RPE and the aerobic capacity (VO2 max), and also a stronger significant relationship between heat rate (HR) and the aerobic capacity. Therefore, using the extended regression equation, it is possible to readily assess the aerobic capacity with no expensive laboratory equipments. Finally, prevention of HR as a factor used to estimate aerobic capacity of individuals

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