

The association between VO₂max and heart rate of casting industry workers

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Abstract

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Background: To establish a balance between work (physical exercise) and human, the aerobic capacity (VO₂max) could be used as a measure. Assessing the heart rate in association to physiological symptoms is the most commonly used tool for the assessment of fatigue during physical exercise. This study aimed to investigate the association between the aerobic capacity and the heart rate of workers from the casting industry.

Materials and Methods: The subjects were 200 male workers selected from casting industry in Isfahan using random sampling method. The subjects were examined using ergometer in accordance with Astrand 6 minutes cycle test protocol, Then, the VO₂max was estimated using the formula proposed by American College of Sports Medicine (ACSM). The heart rates were monitored and recorded automatically. Finally, the results were analyzed by SPSS 20 statistical software package.

Results: The results illustrated that there was a strong correlation between heart rate (HR) and VO₂max ($r=0.991$, $P<0.001$). The regression analysis of the quadratic equation indicated that there was a significant association between the VO₂max and the heart rate.

Conclusion: As the results indicated there was a strong association between heart rate and VO₂max, indicating the fact that with the increase in heart rate during physical activity, aerobic capacity is reduced, and the heart rate could be used as a prediction measure to estimate VO₂max.

Keywords: Worker, Heart Rate, Castings, Industry.

Introduction

The main purpose of ergonomics is to make equilibrium between man and the environment. To assess the effectiveness of an ergonomic intervention schedule, the particular tools are needed to gather information on the compatibility (1).

One important perspective of the compatibility between man and the environment is the physical perspective. Assessing the physical and physiological characteristics of human, it is possible to assign him to a task based on his physiological tolerance limits. Therefore, by addressing measuring metabolism and

oxygen consumption during work, Marties noted that all physical practices should be done within the human aerobic capacity. Currently, the aerobic capacity has been known as the maximal capacity to accomplish the work (2). VO₂max (also maximal oxygen consumption, maximal oxygen uptake, peak oxygen uptake, or maximal aerobic capacity) is the maximum capacity of an individual's body to transmit through circulatory system and use oxygen in motor muscles (3).

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Aerobic Fitness was our ability to take in and use oxygen (4) to produce energy and we have accepted the aerobic capacity as the maximal capacity during work shifts. Nowadays, scientists believe that the ability to perform physical exercise should be determined using the aerobic capacity (2). There are 2 methods for measuring the aerobic capacity which are divided into two 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) and subjective (e.g., rating of perceived exertion) variables. In fact it is worth noting that the direct methods are more accurate because they are more expensive and need trained technicians for setting up and using equipments which is also time consuming; on the contrary, the indirect methods are useful and effective for assessing aerobic capacity in the industries and have no such limitations (5).

Consequently, we utilized heart Rate (HR) as an indirect method for assessing the aerobic capacity (6). The condition of workers in our country and also other developing countries is important, since in these countries, most industrial processes are performed in the form of semi-mechanized; the workers are forced to do the jobs manually.

To prevent early deterioration of workforce resulting in low efficiency, it is necessary to determine the fitness between the individual and the work. There has been no comprehensive study done on the physical exercise capacity of Iranian workers, as a result, there is no detailed information in this area; (7-9) 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 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 rating of perceived exertion of physical exercise (ergometer) and heart rate measurements to estimate the level of the individual's aerobic capacity and finally to determine the association between aerobic capacity and heart rate measurements.

Materials and Methods

In this descriptive study the subjects were 200 male workers from metal components manufacturers (casting industry) in Isfahan selected using random sampling method. The subjects were tested with a time schedule of maximum 10 subjects per day. The ergometer and Astrand protocol were used to determine the aerobic capacity.

The uses of these devices were to create workload on foreign and domestic studies on workers (10-13).

To perform the test based on the Astrand protocol (14-16), on the worker with light clothing (17) then, 25 watt per minute was added to the workload (heaviness of pedal) (18); and at the end of each stage, the heart rate using the sports tester was measured during the last 15 seconds (19,20). Next, VO₂max will be calculated in ml.kg⁻¹.min.⁻¹ using ACSM formula (21).

$$VO_2 \text{ max (ml/kg/min)} \\ = VO_2 \frac{(220 - \text{age} - 73 - (\text{sex}(10)))}{HR - 73 - (\text{sex}(10))}$$

Vo₂= submaximal VO₂ (ml/kg/min) from final stage

>> VO₂ (ml/kg/min) = ((1.8 (workrate))/BW) + 7

Sex =0 for women and 1 for men

HR= steady state HR from final stage

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

To undertake the test: First, by coordinating and corresponding metal industries (casting industry) several manufacturers were invited to participate in the study. Second, some of the workers were removed from the

population due to the following reasons: Absence, not willing to participate in the study, cardiovascular diseases and respiratory diseases) (22). Finally, the results were analyzed by SPSS 20 statistical software package.

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

| Item | Mean (SD) | Min – Max |
|-------------------------|---------------|-------------|
| Age (years) | 33.17 (7.76) | 17-50 |
| Weight (Kg) | 72 (10.07) | 52-100 |
| Height (cm) | 174.15 (6.24) | 158.5 – 188 |
| BMI | 23.87 (2.95) | 16.9 – 31.4 |
| Work experience (years) | 6.67 (5.23) | 0.49 – 25 |
| Join the Club | Yes | 39 (19.5%) |
| | No | 161 (80.5%) |
| Marital Status | Married | 163 (81.5%) |
| | 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 | 122 (61%) |

Results

The average dry bulb temperature of the test environment and wet bulb temperature were 26° C and 21° C respectively. All the subjects were male, comprising of 67.5% (n = 135) 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 aerobic capacity and heart rate ($r = -0.904$, $P < 0.005$).

Table 1 shows several studied demographic and individual characteristics. The measurements of heart rate, aerobic capacity at the end of each minute are presented in Table 2.

Table 2: Means and Standard Deviations of HR, VO2max, during resting and the end of each minute (n = 200)

| Variable | HR | VO2max |
|---------------------|--------------|--------------|
| Time of measurement | Mean (SD) | Mean (SD) |
| Resting | 80.14(8.48) | - |
| End of min. 1 | 100.87(8.33) | 60.29(33.85) |
| End of min. 2 | 111.96(8.61) | 34.93(12.90) |
| End of min. 3 | 122.74(7.64) | 25.88(5.99) |
| End of min. 4 | 129.73(6.17) | 23.17(2.68) |
| End of min. 5 | 132.50(4.33) | 22.96(1.27) |
| End of min. 6 | 131.5(4.93) | 23.84(0.51) |

As tables 2 indicates there is a stronger significant relationship between heart beat and the aerobic capacity. However, simple linear regression analysis illustrated that there is significantly a linear relationship ($VO_{2max}=404.56-0.648(hr)$) between the aerobic capacity and heart beat ($R^2 = 0.72, P < 0.0001$). Further, the quadratic equation

$$(VO_{2max} = 404.56 - 5.62 (hr) + 0.021(hr)^2)$$

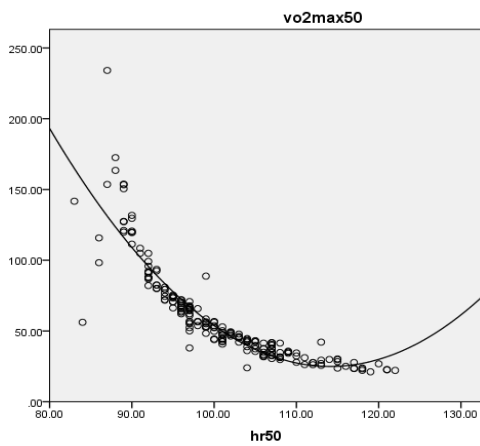


Figure 1: The association between HR and VO2max at the end of min. 2 (n = 200)

$$VO_{2max} = 404.56 - 5.62 (hr) + 0.021(hr)^2$$

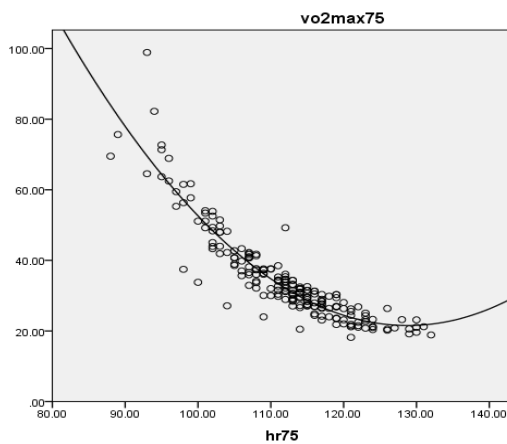


Figure 2: The association between HR and VO2max at the end of min. 3 (n = 200)

$$R^2 = 0.818, P < 0.0001$$

With ($R^2=0.802, P<0.0001$) is more accurate in relation to the degree, indicating that with the increase in the heart rate during physical activity, aerobic capacity is reduced.

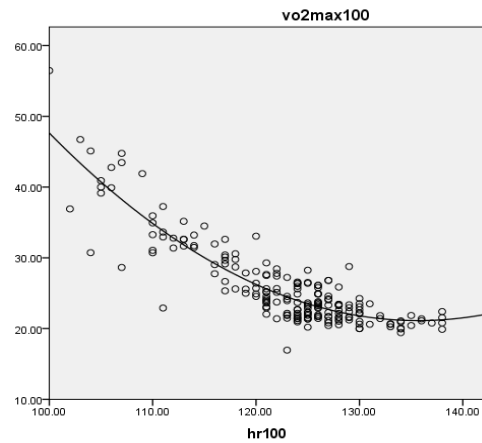


Figure 3: The association between HR and VO2max at the end of min. 3 (n = 196)

$$R^2 = 0.802, P < 0.0001$$

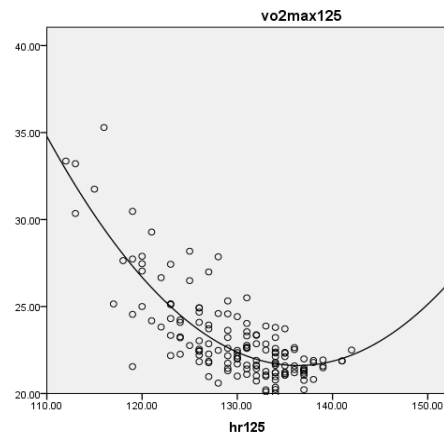


Figure 4: The association between HR and VO2max at the end of min. 4 (n = 150)

$$R^2 = 0.677, P < 0.0001$$

Discussion

The current study aimed to investigate the relationship between the aerobic capacity and

the heart rate (HR) of the 200 male workers from metal components manufacturers (industry workers) in Isfahan. The participants were selected by using random sampling based on statistic method ($n = 200$). The results indicated that there is a strong significant relationship between the aerobic capacity and the heart beat.

In this study VO₂max was predicted by equation based on heart rate recovery. Heart rate has been used in many articles for Assessment of physical workload (23), mental workload (24), fatigue (25), rating of perceived exertion (26) and etc which Indicates the accuracy of heart rate as a physiological factor. In our study, Pearson correlation showed a significant association between the aerobic capacity and heart rate during the different moments of the test (Table 2). Pearson correlation between mean heart rate and the aerobic capacity was equal to -0.938 , illustrating a significant association between these two variables. Furthermore, the results were in agreement with the study of Artes et al (27) using ergometer, and also results of Esposito et al which was done on the athletes using the HR as a measure for assessing the aerobic capacity (28). Results of this study with the internal investigation of Eizadi et al on 25 Adolescent corresponds (6) in the other study found a nonlinear relationship between VO₂ and HR averaged over the subjects (29). On the other hand, in a study conducted on children, the heart rate was a factor used to estimate aerobic capacity (30). Even in UK, according to a study on men, heart rate with age is a determining factor to estimate aerobic capacity (31) In the study of vema et al to estimates the aerobic capacity, several different techniques were used in which the heart rate was measured during the work activity and it has been one appropriate technique for estimating aerobic capacity (32). So that a study in 2012, conducted by

Malek Mohamed et al on the patients, the significant correlation between two factors has not been observed. Perhaps, it is due to Brady Arrhythmia (33).

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 which is not affordable for the industry.

The results indicate a significant relationship between the heart 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, the measured VO₂max is used to monitor the changes in the physical ability of workforce, plan for preventative actions, the required periodic examinations and, etc.

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Conflict of interest: Non declared

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