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Estimation of Aerobic Capacity and Determination of Its Associated Factors Among Male Workers of Industrial Sector of Iran

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Introduction. *The aim of this study was to estimate maximal aerobic capacity ($V_{O2\,max}$), to determine its associated factors among workers of industrial sector of Iran and to develop a regression equation for subjects' $V_{O2\,max}$.* ***Methods****. In this study, 500 healthy male workers employed in Shiraz industries participated voluntarily. The subjects' $V_{O2\,max}$ was assessed with the ergocycle test according to the Åstrand protocol. Required data was collected with a questionnaire covering demographic details (i.e., age, job tenure, marital status, education, nature of work, shift work, smoking and weekly exercises).* ***Results****. The subject's mean $V_{O2\,max}$ was 2.69 ± 0.263 L/min. The results showed that there was an association between $V_{O2\,max}$ and age, BMI, hours of exercise and smoking, but there was no association between $V_{O2\,max}$ and height, weight, nature of work and working schedule. On the basis of the results, regression equations were developed to estimate $V_{O2\,max}$.* ***Conclusion****. Final regression equation developed in this study may be used to estimate $V_{O2\,max}$ reliably without the need to use other laboratory instruments for aerobic measurement.*

ergocycle test Åstrand protocol aerobic capacity $V_{O2\,max}$

1. INTRODUCTION

Heavy and dynamic physical work is still common in many industrial activities such as mining, building and agriculture [1, 2]. In the developed countries, 10–20% of workers are engaged in muscular demanding jobs, while in the developing countries all kinds of intensive work are common [3]. Unbalanced relationship between physical demands and workers' capacities caused adverse health outcomes [1, 4, 5]. In physically demanding jobs, the aerobic capacity (V_{O2}) of workers determines man's power productivity [6]. Assessing V_{O2} is essential to fit the job to the worker's physiological capacity and to prevent over strain and negative consequences of demanding muscular exertion of daily tasks. Knowledge about the level of physical work capacity is inevitable to ensure physiologically safe working conditions.

The capacity of performing prolonged dynamic work is determined with V_{O2}, which is assessed by $V_{O2\,max}$ [7, 8]. According to some studies, general health status and physical exercise have positive influence on the physical capacity [7, 8, 9], whereas age has negative effects [1, 8, 10, 11, 12, 13].

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The best method to measure $V_{O2\,max}$ is a direct measurement of V_{O2} in the maximal exercise test, which is frequently used by athletes [14]. For industrial workers, much more suitable is indirect method estimating $V_{O2\,max}$, which puts less physiological pressure on the subject [15].

There have been few studies in Iran on estimating physical capacity of different population groups, especially workers of industrial sector, but there is no national data on physiological characteristics. Therefore, this study was conducted to a) establish the level of V_{O2}, b) determine its associated factors among industrial workers of Shiraz and c) to develop regression equation to estimate the subjects' V_{O2}. The findings of this study can help to fit the job to the workers' characteristics and to select personnel during the process of employment.

2. MATERIAL AND METHODS

2.1. Study Subjects

Subjects of this cross-sectional study were 500 healthy, occupationally active, blue-collar male workers of industrial sectors of Shiraz. The study was conducted from October 2010 to February 2011. The subjects were randomly selected from those referred to a governmental clinic for periodic medical examinations. Each day, researchers randomly selected 10 workers out of 40 from 50 different factories, who came to the clinic. All subjects participated in the study voluntarily and received information on the aims and protocol of the study. The study was conducted in accordance with the Helsinki Declaration of 1964 as revised in 1984. All subjects signed a consent form before the study. The study was reviewed and approved by Shiraz University of Medical Sciences ethics committee.

2.2. Measurements

2.2.1. Demographic characteristics

The subjects filled a self-administered questionnaire with questions on demographics and job related variables (i.e., age, job title, job tenure, marital status, education, static or dynamic nature of work, shift work, smoking and weekly exercise hours).

2.2.2. $V_{O2\,max}$

The subjects performed a 6-min sub-maximal exercise test on a cycle-ergometer (Monark, Sweden) based on the Åstrand protocol to calculate V_{O2} [16]. During the test, heart rate was monitored and a wireless transmitter transmitted the heart beat data to the base unit. The subjects' $V_{O2\,max}$ (expressed both in L/min and ml/min/kg) was calculated with obtained data and a special software. The tests were performed in the laboratory, between 8 am and 2 pm. The average temperature was 20.5 °C, relative humidity 41% and barometric pressure 857 hPa.

2.2.3. Height and weight

The subjects' height was measured with a tape in the standard position (Pakhsh Abzar, Iran) [16]. The subjects' weight was measured with a digital scales (Beurer, Germany). During the measurements, the subjects wore light clothing only. Body mass index (BMI) was calculated for each subject.

2.3. Data Analysis and Statistical Procedures

SPSS version 16 was used for statistical analyses. Nonparametric analyses were applied because the data was not normally distributed. Kruskal–Wallis and Mann–Whitney *U* tests were used to compare the mean values of $V_{O2\,max}$ in age, weight, height and BMI groups. A linear regression analysis examined relationship between $V_{O2\,max}$ and different variables separately, and a multiple regression analysis developed the overall regression equation for $V_{O2\,max}$ estimation in the study population; $p < .05$ was significant.

3. RESULTS

Table 1 presents demographic characteristics of the subjects. Table 2 presents mean (*M*), standard deviation (*SD*), minimum and maximum V_{O2}.

TABLE 1. Characteristics of Subjects (*N* = 500)

Variable	*M* (*SD*)	Range
Age (years)	32.01 (7.66)	20–59
Weight (kg)	77.10 (12.41)	50–110.2
Height (cm)	176.10 (5.93)	159–190
BMI	24.82 (3.58)	15.90–33.57
Job tenure (years)	8.50 (6.27)	0.17–30
Exercise per week (h)	2.95 (3.49)	0–12

Variable	*n* (%)
Marital status	
single	104 (20.8)
married	396 (79.2)
Education	
primary	134 (26.8)
secondary	258 (51.6)
tertiary	108 (21.6)
Nature of work	
static	255 (51)
dynamic	245 (49)
Type of industry	
chemical	177 (35.4)
food	167 (33.4)
other[1]	156 (31.2)
Work shift	
rotating	234 (46.8)
fixed day	266 (53.2)
Cigarette smoking	
smoker	60 (12)
nonsmoker	440 (88)

Notes. 1 = including metal structure manufacturing, construction, textile and wood industries. BMI = body mass index.

TABLE 2. Aerobic capacity (V_{O2}) of Subjects (*N* = 500)

V_{O2}	*M*	*SD*	Range
L/min	2.69	0.263	1.71–3.50
ml/min/kg	35.95	7.390	19.50–58.04

Table 3 presents V_{O2} of the subjects by age groups. The results show that V_{O2} decreases with age. Kruskal–Wallis analysis reveales that mean values of $V_{O2\,max}$ in the age groups are significantly different ($p < .001$). Moreover, Mann–Whitney *U* test shows that mean values of $V_{O2\,max}$ of each pair of the age groups are significantly different ($p < .001$).

Linear regression analysis reveals a reverse relationship between V_{O2max} and age ($r = –.796$). It is defined with Equation 1 (Figure 1):

$$V_{O2\,max}\text{ (L/min)} = (–0.027 \times \text{age}) + 3.572. \quad (1)$$

Table 4 presents V_{O2} by BMI [17]. The subject with normal BMI (18.5–24.9) has the highest value of $V_{O2\,max}$. Statistical analysis shows that mean $V_{O2\,max}$ values in the BMI groups are significantly different ($p < .001$). Mann–Whitney *U* test also shows significant differences in V_{O2} between normal and overweight groups ($p < .001$), and normal and obese groups ($p = .005$).

The linear regression analysis reveals relationship between $V_{O2\,max}$ and BMI ($r = –.158$). It is defined with Equation 2 (Figure 2):

$$V_{O2\,max}\text{ (L/min)} = (–0.012 \times \text{BMI}) + 2.982. \quad (2)$$

According to Equation 2, V_{O2} declines when BMI increases. The linear regression analysis also shows a direct relationship between $V_{O2\,max}$ and weekly exercise hours ($r = .37$) (Figure 3).

The multiple regression analysis reveals that there is a strong relationship between $V_{O2\,max}$, age, BMI and weekly exercises ($r = .818$). It is defined with Equation 3:

$$V_{O2\,max}\text{ (L/min)} = (–0.026 \times \text{age}) – (0.002 \times \text{BMI}) + (0.014 \times \text{exercise}) + 3.516. \quad (3)$$

TABLE 3. Aerobic Capacity (V_{O2}) by Age (*N* = 500)

	$V_{O2\,max}$ (ml/min/kg)			$V_{O2\,max}$ (L/min)		
Age (years)	*M*	*SD*	Range	*M*	*SD*	Range
20–29 (*n* = 227)	38.82	7.30	23.91–58.04	2.84	0.165	2.45–3.50
30–39 (*n* = 198)	34.78	6.59	22.22–57.40	2.66	0.183	2.00–2.97
40–49 (*n* = 55)	31.14	5.21	22.26–45.50	2.38	0.241	1.78–2.73
50–59 (*n* = 20)	27.97	5.10	19.50–35.74	2.13	0.27	1.71–2.56

Notes. $V_{O2\,max}$ = maximal aerobic capacity.

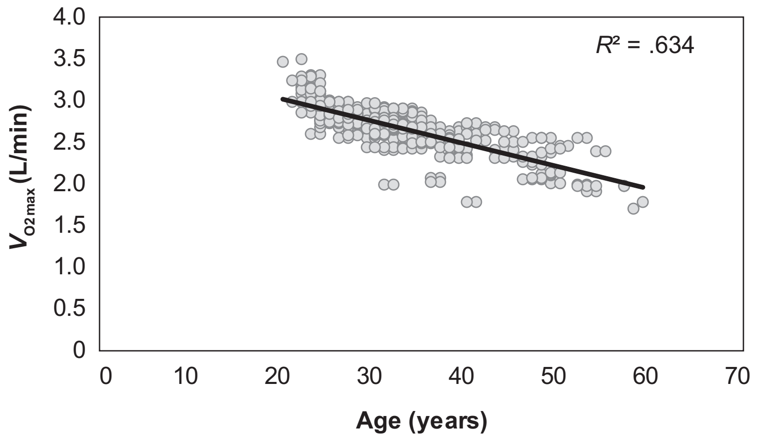

Figure 1. Relationship between aerobic capacity (V_{O2}) and age of subjects (N = 500).

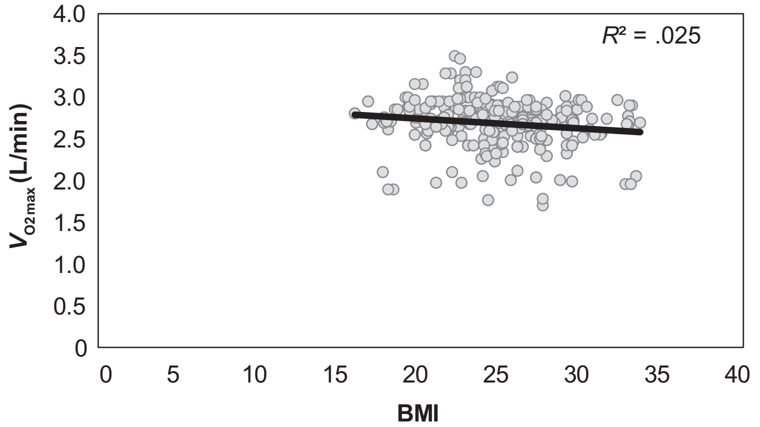

Figure 2. Relationship between aerobic capacity (V_{O2}) and body mass index (BMI) of subjects (N = 500).

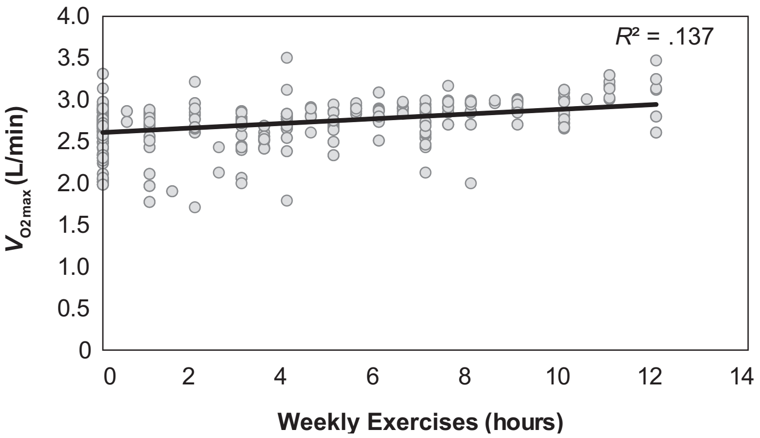

Figure 3. Relationship between aerobic capacity (V_{O2}) and weekly exercise of subjects (N = 500).

TABLE 4. Aerobic Capacity (V_{O2}) by BMI (N = 500)

	$V_{O2\,max}$ (L/min)			$V_{O2\,max}$ (ml/min/kg)		
BMI [17]	***M***	***SD***	**Range**	***M***	***SD***	**Range**
Underweight (n = 23)	2.62	0.30	1.91–2.96	48.73	6.57	34.11–58.04
Normal (n = 245)	2.74	0.26	1.78–3.50	49.17	6.18	33.12–58.09
Overweight (n = 196)	2.65	0.24	1.71–3.24	31.64	3.57	22.22–42.16
Obese (n = 36)	2.61	0.27	1.97–2.97	26.21	3.29	19.50–30.90

Notes. BMI = body mass index; underweight = BMI <18.5, normal = BMI 18.5–24.9, overweight = BMI 25–29.9, obese = BMI ≥30; $V_{O2\,max}$ = maximal aerobic capacity.

TABLE 5. Aerobic capacity (V_{O2}) by Work Properties and Smoking Habit (N = 500)

	$V_{O2\,max}$ (L/min)		$V_{O2\,max}$ (ml/min/kg)		
Variable	***M***	***SD***	***M***	***SD***	***p******
Nature of work					
static (n = 255)	2.68	0.29	35.67	7.75	.668
dynamic (n = 245)	2.70	0.23	36.23	7.00	
Work shift					
rotating (n = 234)	2.69	0.23	35.69	6.87	.552
fixed day (n = 266)	2.69	0.28	36.17	7.82	
Cigarette smoking					
smoker (n = 60)	2.57	0.28	36.94	7.28	< .001
nonsmoker (n = 440)	2.70	0.25	37.81	7.40	

Notes. * = Independent Mann–Whitney *U* test between two groups.

Table 5 presents the result of V_{O2} on the basis of the nature of work, working schedule and smoking habit. Independent Mann–Whitney *U* test shows that only smoking has influence on V_{O2}. The mean value of $V_{O2\,max}$ is significantly lower among smokers than nonsmokers ($p < .001$).

Further experiments were conducted to check to what extent the final regression equation could estimate V_{O2}. The value of V_{O2} of 10 workers (selected from the subjects of this study) was estimated with developed regression equation. The value of $V_{O2\,max}$ of 10 workers was measured with the Åstrand protocol [16]. Compared results of statistical analysis indicates that the mean values of $V_{O2\,max}$ obtained with the two methods are not significantly different ($p > .05$) (Table 6).

TABLE 6. V_{O2} Measured with Final Regression Equation and Åstrand Protocol (n = 10)

	$V_{O2\,max}$ (L/min)		
Method	***M***	***SD***	***p******
Åstrand protocol	2.49	0.41	.348
Regression equation	2.58	0.14	

Notes. * = paired-sample *t* test.

4. DISCUSSION

The subjects of the study were young (32.01 ± 7.66 years) and tall (176.10 ± 5.93 cm). The subjects were male workers with BMI within the normal range (24.82 ± 3.58). Mean value of $V_{O2\,max}$ was 2.69 ± 0.263 L/min (35.95 ± 7.39 ml/min/kg).

The value of V_{O2} measured in this study was close to the findings of Tuxworth and Shahnavaz. In their study, $V_{O2\,max}$ of 45 Iranian male workers of a steel corporation was measured with the step test and it was 2.65 L/min [18]. In contrast, V_{O2} of the present study subjects was lower than V_{O2} of the trained men who's $V_{O2\,max}$ was 4.451 ± 0.629 L/min [19], and of the Netherlands male nonsmokers who's $V_{O2\,max}$ was 3.89 ± 0.92 L/min [20].

Additionally, the linear regression analysis showed significant relationship between $V_{O2\,max}$ and age, BMI and weekly exercises. These findings are similar to the findings of other studies [10, 11, 12, 13, 21, 22, 23, 24]. The developed final regression equation showed these relationships and made it possible to estimate V_{O2} of any individual with the smaller number of measurements.

Similarly to the results of Betik and Hepple's study, smoking reduced V_{O2} among workers as compared with their nonsmoker colleagues [24]. Moreover, $V_{O2\,max}$ among workers with exercise habit was significantly higher than among those who did not exercise. This finding is in line with the previous study [25]. The findings of the present study revealed that work schedule had no association with V_{O2} and confirmed the results of the previous study [26].

Estimation of V_{O2} with the final regression equation and the Åstrand protocol yielded similar results. This indicated that the regression equation developed in this study might be used to measure $V_{O2\,max}$.

5. CONCLUSION

There is a relationship between $V_{O2\,max}$ and age, BMI, hours of exercise and smoking habit, but weight, height, nature of work and working schedule have no influence on V_{O2}. The final regression equation developed in this study shows relationship between $V_{O2\,max}$ and age, BMI and exercise, and may be used to estimate V_{O2} without using additional laboratory instruments for cardiorespiratory capacity measurement.

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