ESTIMATION OF AEROBIC CAPACITY (VO_{2max}) OF ADULT MALE POPULATION OF TURKEY

by

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ABSTRACT

ESTIMATION OF AEROBIC CAPACITY (VO_{2max}) OF ADULT MALE POPULATION OF TURKEY

The aerobic capacity (AC or VO_{2max}), also called physical work capacity, is an important parameter to determine the safe work energy expenditure norms to protect the workers. The energy expended during a task performance can be estimated by assuming that most of the energy is produced through aerobic metabolism which is determined by measuring the amount of oxygen consumed by the individual. If the overall workload is too high, aerobic metabolism may not be adequate to provide all the required energy. Then the worker generates the additional energy by anaerobic metabolism resulting lactic acid build up and eventually fatigue. In extreme cases, it may lead to cardiovascular and pulmonary health issues even fatalities. Aerobic capacities may vary among individuals and among populations due to heredity, nutrition, and exercise. Over several decades, a number of researchers have developed aerobic norms for a number of developed countries. However, such norms do not exist for the population of Turkey. This study is the first attempt to develop such baseline values for the male population of Turkey. This study is carried out to estimate the AC of the male population of Turkey and investigate the effects of some personal characteristics on AC. In the study, a modified submaximal cycle ergometer test, called Astrand-Myhre Bike Test, was used. The sample of the study included 260 healthy male volunteers (18 to 54 yrs.) having family origin from different regions of Turkey. Based on the statistical analysis results, the average AC is found to be 2.5 l/min (±0.3) and body weighted adjusted AC is found to be 33.2 ml/kg/min (± 7.7). The mean values of VO_{2max} (in both l/min and in ml/kg/min) decreases by age and body weight groups. Through this study, a first is achieved, and the AC norms of the adult male population of Turkey are established between the ages of 18 and 54 years. These norms can serve as a ‘reference’ in the design for aerobic capacity for the male population of Turkey. The comparisons with the world populations are also made.

ÖZET

TÜRKİYE YETİŞKİN ERKEK MAKSİMUM AEROBIK KAPASİTESİNİN (VO_{2max}) TAHMİNLEMESİ

Fiziksel iş kapasitesi olarak da adlandırılan aerobik kapasite (AK veya VO_{2max}), işçileri korumak için güvenli iş enerji harcaması normlarının belirlenmesinde önemli bir parametredir. Bir görev performansı sırasında harcanan enerjinin çoğunun, birey tarafından tüketilen oksijen miktarının ölçülmesiyle belirlenen aerobik metabolizma yoluyla üretildiği varsayılarak tahmin edilebilir. Genel iş yükü çok yüksekse, aerobik metabolizma gerekli tüm enerjiyi sağlamak için yeterli olmayabilir. Daha sonra, işçi anaerobik metabolizma yoluyla ek enerji üretir ve sonuçta laktik asit oluşur ve en nihayetinde yorgunluk oluşur. Aşırı durumlarda, ölümcül bile olsa kardiyovasküler ve pulmoner sağlık sorunlarına yol açabilir. Aerobik kapasiteler kalıtım, beslenme ve egzersiz nedeniyle toplumlar arasında değişebilir. Birkaç on yıldan beri, bazı araştırmacılar birçok gelişmiş ülke için aerobik normlar geliştirmiştir. Ancak, bu tür normlar Türkiye nüfusu için mevcut değildir. Bu çalışma, Türkiye erkek nüfusu için bu gibi temel değerleri geliştirmeye yönelik ilk girişimdir. Bu çalışma, Türkiye'deki erkek nüfusun aerobik kapasitesini tahmin etmek ve bazı kişisel özelliklerin aerobik kapasite üzerindeki etkilerini araştırmak için yapılmıştır. Çalışmada Astrand-Myhre Bisiklet Testi olarak adlandırılan değiştirilmiş bir submaksimal ergometre testi kullanıldı. Çalışmanın örneklemini, Türkiye'nin farklı bölgelerinden aile kökenli 260 sağlıklı erkek gönüllü (18 ila 54 yaş) oluşturdu. İstatistiksel analiz sonuçlarına göre ortalama aerobik kapasite 2.5 l/dak (± 0.3), vücut ağırlıklı düzeltilmiş aerobik kapasite ise 33.2 ml/ kg/dak (± 7.7) olarak bulunmuştur. Ortalama VO_{2max} değerleri (hem l/dak hem de ml/kg / dak cinsinden) yaş ve vücut ağırlığı gruplarına göre doğrusal olarak azalır. Bu çalışma ile bir ilke ulaşılmış ve 18 ila 54 yaşları arasında Türkiye'nin yetişkin erkek nüfusunun aerobic kapasite normları belirlenmiştir. Bu normlar, Türkiye'nin erkek nüfusu için aerobik kapasite tasarımında 'referans' işlevi görebilir. Aynı zamanda dünya nüfusu ile kıyaslamalar da yapılmıştır.

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LIST OF SYMBOLS

a_i	Effect of i^{th} level of age group factor
$(ab)_{ij}$	Effect of ij^{th} level of age and body mass index interaction factor
H_0	Null hypothesis
H_1	Alternative hypothesis
R^2	Coefficient of determination
R^2_{adj}	Adjusted coefficient of determination
$\bar{x}$	Sample mean
α	The percentage of relative accuracy desired
β_1	Regression coefficient of age
ε_{ijklmn}	Random error component NID $(0,\sigma^2)$
μ	Overall mean

LIST OF ACRONYMS/ABBREVIATIONS

AC	Aerobic Capacity
ACSM	American Collage of Sports Medicine
ANOVA	Analysis of Variance
BMI	Body mass index
bpm	Beats per minute
BSA	Body Surface Area
cm	Centimeter
CRD	Completely Randomized Design
CV	Coefficient of Variation
DoF	Degrees of freedom
GLM	Generalized Linear Model
GXT	Graded Exercise Test
HR	Heart Rate
IPAQ	International Physical Activity Questionnaires
ISCO	International Standard Classification of Occupations
ISO	International Organization for Standardization
lbs	Pound
km	Kilometer
kg	Kilogram
kpm	Kilopondmeter
M	Meter
MAWD	Maximum Acceptable Work Duration
MAWT	Maximum Acceptable Work Time
MHz	Megahertz
mm	Millimeter
MS	Mean of squares
MW	Manual worker

N	Newton
N	Sample size
NID	Normally and independently distributed
NIOSH	National Institute for Occupational Safety and Health
NM	Not Mentioned
NMW	Non manual worker
PA-R	Physical Activity Rating
PASS	Physical Activity Scale Survey
PFA	Perceived Functional ability
RHR	Relative Heart Rate
RPE	Rating of perceived exertion
rpm	Rotation per minute
RTL	Resting Testosterone Level
SD	Standard deviation
SE	Standard error
SS	Sum of squares
TURSTAT	Turkish Statistical Institute
VIF	Variance inflation factor
VO_2	Oxygen uptake
W	Watt
WC	Waist Circumstance
WL	Work Load
yrs	Years
YMCA	Young Men’s Christian Association
3MWD	Three Minute Walk Distance

1. INTRODUCTION

Measuring aerobic capacity (AC) at work has been a field of growing interest in recent decades, and there is a need for reliable, standardized assessment instruments for application in large population studies. AC is the maximal ability to supply oxygen to the working muscles during physical activity (Ekşioğlu, 2010). The level of AC, whose indicator is VO_{2max}, determines the capacity to perform hard or prolonged work, good tolerance and the possibility to eliminate changes due to fatigue. So, the value of VO_{2max}, which determines the potential capacity for hard physical effort, can be a significant element in the subjectively perceived work ability (Bugajska *et al.*, 2005). Thus, the distribution of AC is important for establishing work energy expenditure standards, which protect the majority of workers from overexertion (Kang *et al.*, 2007). Several research results (Michael *et al.*1961, Bink 1962, Ilmarinen 1992) suggested that 33% of the individual's AC should be the acceptable workload for general 8-h physical work. Jørgensen (1985) also proposed that the general upper tolerance limit over an 8-h workday, consisting of mixed physical work including manual-handling operations, was 30-35% of VO_{2max}. In addition, the study of National Institute for Occupational Safety and Health (NIOSH) in the USA in 1978 states 5.0 kcal/min based on the lower 5% of male workers as the maximal permissible limit for energy expenditure during work, and 3.5 kcal/min as the action limit to protect women and older male workers (Kang *et al*., 2007).

There are several studies carried out worldwide aiming to structure a database regarding the AC values of the nations. Generally, the purpose and scope of existing studies (Gökbel et al., 2005, and Güvenç, 2007) in Turkey were to determine AC variations of specific small groups of people differentiated by age, training, region, etc. The other existing local studies in the world are trying to find accurate protocols or methods to estimate valid AC values especially in health issues or sport sciences and the results of them are not applicable for industrial work design. The need of a comprehensive AC study which includes large amounts of people of working age that represents the labor population remains to construct a national standard and database of aerobic capacity and to clarify the reasons of the nationwide variations of it.

Due to the high correlation between VO_2 and Heart Rate (HR), several methods have been designed to predict the VO_{2max} by monitoring and measuring HR while; running on a treadmill, exercising on a cycle ergometer and using a step test. Cycle ergometer methods are useful because they suggest a relatively reasonable way to estimate aerobic capacity. Cycle ergometer is an attractive alternative of testing when it is compared with treadmill and stepping benches tests in that (i) cycle ergometer enables to select precise work rates that can be indicated with appropriate units of power; (ii) cycle ergometers need less space and convenient for transportation; (iii) cycle ergometer exercise is usually applied to individuals with physical limitations and it can be easily adapted with less resistance and (iv) HR, blood pressure and all related data are easily gathered during test protocol (Nielson *et al.*, 2010). The VO_2 estimation obtained through these methods can be either maximal or submaximal. Submaximal tests are more practical to apply. They require the person to perform at less of its maximum capacity, usually at less than 80% and then estimate VO_{2max} using regression. At maximal tests, the subject performs the exercise until he or she reaches exhaustion. Thus, it carries some risk and should only be performed under the supervision of a physician or another qualified clinician.

The Astrand-Rhyming cycle ergometer protocol is designed to determine maximal oxygen consumption by exercising the subject at a submaximal work-load and measuring the steady-state heart rate. The workload, in conjunction with the resultant heart rate, is compared to the predicted relationship, adjusted for age and sex and maximal oxygen consumption is computed. The workload selection is performed manually and the subject is expected to reach an HR of at least 120 beats per minute. Subjects are also should be able to complete the test and reach steady-state conditions which require the variation of HR within 4bpm of previous observations (Manual, Ergomedic 839). In order to eliminate the trial and error exercise of the workload selection, Myhre *et al.* (1998) suggests a validated workload selection methodology which is employed in this study.

Objective of this study is to contribute to the establishment of the aerobic capacity database for the healthy adult male population of Turkey, to carry out statistical analyses to investigate the effects of age, BMI (Body Mass Index), weight, occupation, exercise habits, smoking and alcohol consumption on aerobic capacity and to compare aerobic capacity of the male population of Turkey with the population of several other countries. The Astrand

Bike test is used for the estimation of maximal oxygen uptake of the objectives and Boğaziçi University Ergonomics Laboratory was utilized to conduct the study.

The thesis is organized as follows:

Chapter 2 includes a brief summary of the literature about aerobic capacity studies on various populations all around the world. The rationale behind the study and also the main objectives of the current study are presented in Chapter 3. In Chapter 4, the methodology of experiments that includes the description of subjects, equipment used, procedures while performing the tests and statistical procedure followed to analyze the collected data. In Chapter 5, the results of the statistical analysis of the aerobic capacity are presented. In Chapter 6, the discussions about the results of the current study compared with the results of the previous studies are presented. The final part presents the conclusions of the current study and discussions.

2. LITERATURE REVIEW

In literature, there are many studies related to the measurement of aerobic capacity. The aim of the studies differs from each other at some points. The main purpose of some studies is to generate a valid prediction equation of AC. Besides, the others aim generally to investigate the effects of several anthropometric characteristics and the activities such as exercise or smoking on it.

In a few words, VO_2 is the volume of oxygen (O_2) consumed by the muscle while performing work. Being highly correlated to maximal cardiac output, the assessment of maximal oxygen consumption (VO_{2max}) provides a measure of the maximal energy output during aerobic processes and of the functional capacity of the cardiovascular system (Rodahl, 1989). Furthermore, estimation VO_{2max} is considered the most reliable factor to determine a person’s aerobic capacity, which is useful in the assessment of cardiorespiratory fitness and has been widely used in sportsmen, patients, and workers while performing physical tasks. Prior to the detailed examination of the previous studies about the estimation of the aerobic capacity, the term “VO_{2max}” must be defined and measurement types of it must be investigated in detail.

2.1. Aerobic Capacity (VO_{2max})

Aerobic Capacity (VO_{2max}), is an important parameter because it represents the upper limits aerobic exercise tolerance. Endurance activities are performed at some friction of VO_{2max}. If VO_{2max} is low, then the level of endurance performance is necessarily constrained. The ability to do aerobic exercise is very important for activities of daily living and maintaining a healthy lifestyle. Aerobic capacity can be tested to measure the ability to do exercise specifically by measuring the amount of oxygen required (VO_2). Foss *et al*. (1998) stated that lungs blood, heart, muscles, and other organ systems transport and utilize oxygen and physical fitness of a person is determined by the ability of that transportation and utilization capability.

2.1.1. Maximal Exercise Test Protocols

Maximal exercise tests are generally divided into two groups based on the test period: Continuous and discontinuous. The most widely used testing protocols are continuous and graded. During continuous tests maximum oxygen uptake obtained during a continuous progressively increased workload test using a specific exercise. Ramp test with workload continuously increasing workload or test with specific workload increase at specified time intervals are the examples of continuous maximal tests. On the other hand, the discontinuous tests include both the exercise and resting periods and procedure lasts when the subject reaches his/her tolerance limit. Generally, the continuous procedures are preferred by the subjects due to the long duration of discontinuous tests. The main maximal GXT procedures are The Balke test, Maksus and Coutss treadmill protocol**,** Bruce Protocol**,** Ellestad Protocol.

2.1.2. Submaximal Exercise Test Protocols

Common submaximal test protocols involve walking, jogging, running on indoor/outdoor tracks or treadmill, cycling on ergometers, bench stepping or performing the 20-meter shuttle run (George *et al*., 2009). However, motor-driven treadmills and cycle ergometer are the most popular modes of graded exercise testing. There are studies in literature prove that the maximal oxygen uptake is significantly higher when the test is conducted with a treadmill instead of cycle ergometer. Davis and Kasch (1975) found approximately 10% higher VO_{2max} values when measured during treadmill running compared with cycle ergometer. The well known sub-maximal exercise protocols are Astrand Protocol, YMCA Protocol, Harvard Step Test, ACSM Bike Test.

Among the above protocols Astrand protocol, also known as Astrand-Rhyming test, is the most widely used non-exhaustive test with its well-known nomogram (Appendix A). In this study, the exercise and predictions of VO_{2max} have been carried out according to the Astrand protocol.

Principally, the Astrand-Rhyming test is a six-minute test that is performed on a cycle ergometer and it is designed to predict maximal oxygen consumption by measuring the steady-state heart rate while the subject is exercising at a sub-maximal workload. In the context of protocol, the subjects are evaluated at nine workloads: The workloads for male subjects' span 300 kpm/min to 1500 kpm/min in 150 kpm/min steps. Correspondingly, for the female subject the workload change between 300 kpm/min to 900 kpm/min in 75 kpm/min steps. The workload should be difficult enough to maintain a steady state heart rate of at least 120 beats per minute. Subjects should be able to complete the minimum of six minutes with a steady state heart rate (i.e., until the heart rate varies no more than 4 bpm). At the end of the steady-state HR is recorded and VO_{2max} is estimated from HR and power setting on the ergometer, using the well-known Astrand nomogram (Appendix A). Lastly, this estimate is multiplied by a factor which is related to the age of the subject. The factor is found in the following table according to the predicted maximum heart rate (Manual, Ergomedic 839).

Regarding the VO_{2max} measurement, there are two methods that present the advantages and disadvantages: the direct and indirect methods. The direct measurement of VO_{2max} is performed by submitting the individual to a test with progressive loads and analyses inhaled and exhaled oxygen. On the other hand, with regard to indirect measurement field tests can be used and many subjects can be examined at once. In field tests, calculation of VO_{2max} is performed through equations based on pre-established time or distance. It is known that the direct measurements give more reliable results. However, this method provides a high cost and requires sophisticated equipment. The following part of the study includes detail information about direct and indirect measurement types of VO_{2max}.

2.2. Direct Determination of VO_{2max}

The direct determination of VO_{2max} is basically accomplished by two methods according to the equipment used when measuring the inhaled and exhaled gases during an exercise: Closed or open circuit systems.

2.2.1. Closed and open circuit systems

Closed circuit systems include a gas supply within a system which does not have an interaction with ambient air. On the other hand, open circuit systems enable the subjects to breathe circulating air. The exhaled respiratory gases are penetrated through a settlement consisting of tubes and valves into collapsible bags. Exhaled gases, gathered for particularized periods of time in numbered bags so as to decrease possible error, are conveyed to gas meter thereby verifying volume to be kept.

Open circuit systems have several advantages when they are compared to the closed circuit systems. Firstly, they are more precise and effort far greater comfort to the subjects. Moreover, they allow the collection of important data during work states of any metabolic intensity. One of the first open circuit equipment configurations used to measure VO_{2max} during exercise was the Tissot spirometer-volumetric gas analyzer system. A slight variation of Tissot spirometer-volumetric gas analyzer system was the Douglas bag- volumetric gas analyzer system. In later years, lightweight meteorological balloons replaced the heavy, bulky Douglas bags and a gas meter replaced the Tissot spirometer for measurement of gas volume. Over time, electronic gas analyzers replaced the volumetric gas analyzers. This system is called the meteorological balloon-electronic gas analyzer system (Davis, 1995).

The next development in equipment configuration was the semi-automated system (Wilmore and Costil, 1974). A Further step of the historical development of VO_{2max} measurement was the first automated systems developed by Beckman Instruments called the metabolic measuring card. This system measured ventilation with a turbine volume transducer, had a mixing chamber and measured the mixed expired gas fractions with O_2 and CO_2 electronic gas analyzers (Davis, 1995).

2.2.2. Criteria for VO_{2max}

The most precise way to obtain VO_{2max} is during maximal graded exercise tests (GXT) performed to volitional fatigue on a treadmill or an ergometer. The VO_{2max} is generally considered to be reached if a further increase in work rate results in no further increase in VO_2. This is the most commonly accepted criterion while measuring the maximal oxygen uptake. Figure 2.1 shows the relationship between the work rate and VO_2 during a maximal graded exercise test. Plot of oxygen uptake versus percent grade showing a “true plateau” in oxygen uptake, signifying that maximal oxygen uptake (VO_{2max}) has been achieved.

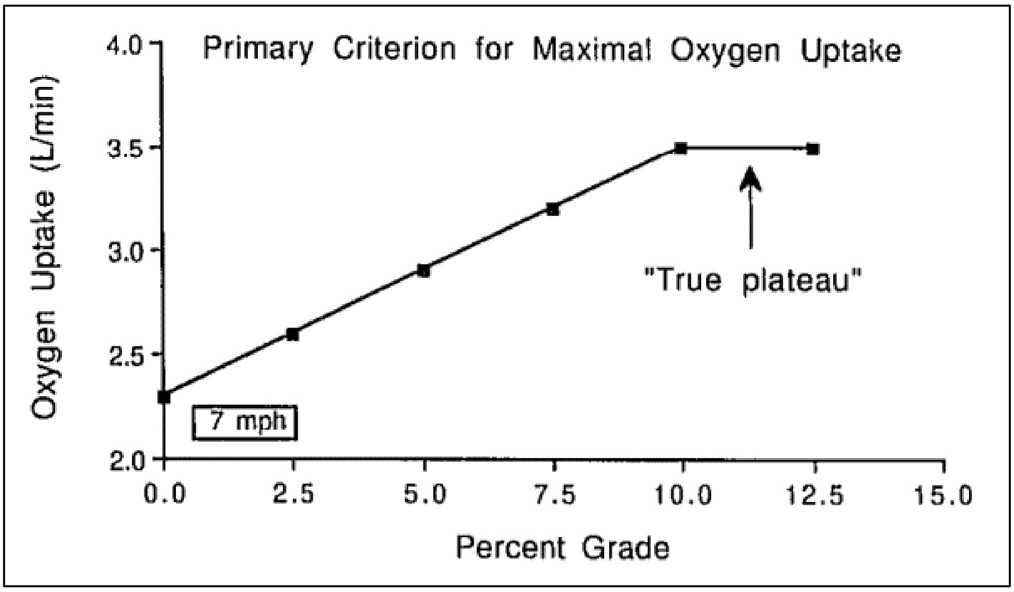

Figure 2.1. The relationship between the work rate and VO_2 (Howley *et al.*, 1995).

While the direct measurement of VO_{2max} during a maximal test is considered the most accurate there are various drawbacks of it:

- Limited to laboratory and clinical settings,
- Requires costly equipment,
- Depends on trained technicians,
- Requires physician supervision in individuals who are strafed in the moderate or high-risk categories based on current exercise testing guidelines (ACSM, 2006).

Besides, previous studies show that people do not always tend to reach a plateau in VO_{2max} as the work rate continues to increase during GXT. Astrand (1952) found that less than %50 of young boys who underwent GXT demonstrated a plateau. Noakes (1988) has demonstrated that the original investigators who developed the plateau criterion failed to find a true plateau in VO_2 as the work rate continued to increase. Many people especially with chronic disease or disability, do not achieve a true VO_{2max}. Instead, they reach a point at which they cannot continue not because of limitations in the supply of oxygen but through some other limiting factor such as mental fatigue, fear, lack of motivation or symptoms such as chest pain, and light-headedness. (Billat and Lopes, 1995)

In spite of the clarity of the concept of the plateau, it is uncommon for subjects to complete a maximal grade exercise test (GXT) on a treadmill or cycle ergometer, and fail to demonstrate a plateau in VO_2. For that reason a variety of secondary criteria have been used by scientists to characterize the oxygen uptake measured in the last minutes of a maximal GXT as the subject's VO_{2max}. These secondary criteria include:

- High levels of lactic acid in the blood in the minutes following the exercise test (Blood lactate concentration in the first 5 min of recovery > 8 mmol/L),
- Elevated Respiratory Exchange Ratio (RER) (at test termination RER > 1.15),
- Achievement of some percentage of an age-adjusted estimate of maximal heart rate (Heart rate at test termination > 90% of theoretical age-predicted maximum (220-age)).

The third criterion is the least accurate because of the well-known large variation in maximal heart rate at any given age (Davis, 1995). Additionally, it is also stated that predicted maximal heart rates should not be used as an absolute endpoint in test termination (ACSM, 2006).

2.3. Indirect Prediction of VO_{2max}

Due to the limitations of maximal exercise testing, several non-exercise prediction models have also been developed to predict VO_{2max}. Nonexercise methods do not require participants to exercise and employ questionnaire data in conjunction with other predictor variables, such as gender, age, height, and body mass, to predict VO_{2max}.

2.3.1. Prediction of VO_{2max} using non-exercise data

The first methods to be carried out for the prediction of VO_{2max} is to employ activity questionnaires and individual physical characteristics. Several regression equations with non-exercise data are existing in literature in order to predict VO_{2max} without the need of exercise test performance for both maximal and sub-maximal. Jackson *et al*. (1990) used an approach to estimate VO_{2max} by identifying various factors including age, gender, BMI and physical activity in which the physical activity rating (PA-R) questionnaire used for the ranking. The regression equation for male is: VO_{2max} (ml/kg/min) = 67.350 + 1.921 (PA-R score) – 0.381 (age) – 0.754 (BMI). In the study of George *et al*. (2009) along with current physical activity rating (PA-R) , the perceived functional ability (PFA) also has been used as a predictor variable in a non-exercise regression model of VO_{2max} in 18-65 years' healthy adults. The regression equation is: VO_{2max} (ml/kg/min) = 30.04 + 6.37 (gender; female=0, male=1) – 0.243 (age) - 0.122 (BMI) + 3.263 (ending self-selected treadmill speed; mph) + 0.391 (PFA) + 0.669 (PA-R).

Currently, the International Physical Activity Questionnaire (IPAQ) is the most widely used and validated a self-report measure of physical activity. The aim of IPAQ is to provide a set of well-developed instruments that can be used internationally to obtain comparable estimates of physical activity. There are two versions of the questionnaire. The short version is suitable for use in national and regional surveillance systems and the long version provide more detailed information often required in research work or for evaluation purposes.

2.3.2. Exercise methods to predict VO_{2max}

There are two fundamental relationships allow indirect predictions of VO_2 during an exercise test (Billat and Lopes, 1995):

- A linear relationship between VO_2 and mechanical power output,
- A linear relationship between VO2 and heart rate according to Fick equation.

Although the existing indirect methods are sophisticated and many are based on Fick principle which was introduced in 1870 by the German physician Adolph Fick (1829-1901). Through the employment of Fick principle which is based on the respiratory exchange, oxygen uptake is equal to the product of blood flow and the difference in the oxygen content of arterial and mixed venous blood.

$$\dot{V}O_2 = Q \times (\text{a-v}O_2 diff) \quad (2.1)$$

Q : The cardiac output

$\dot{V}O_2$: The oxygen uptake

a-v$O_2 diff$: Difference in oxygen content between arterial and venous blood

Thus, cardiac output in ml/min is determined from the amount of the oxygen consumed per minute and the amount of oxygen taken by each milliliter blood within the lungs (Ricci, 1967). Principally, the linear relationship heart rate and VO_2 allow the prediction of VO_{2max} during sub-maximal exercise tests. The main principle of sub-maximal tests is that the greater the work rate or VO_2, the higher the heart rate (HR). Figure 2.2 illustrates heart rate responses to three submaximal work rates for a 40-year old sedentary man. This also shows that there is a linear relationship between the work rate and HR. Since it is known that the work rate and VO_2 have also a linear relationship VO_{2max} can be estimated by the extrapolating the information.

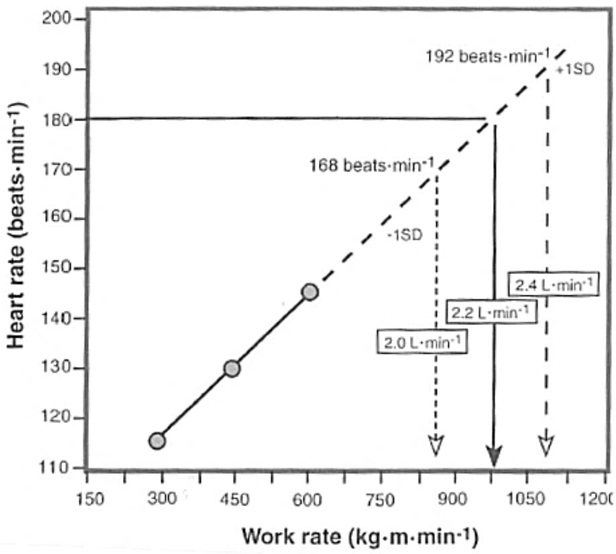

Figure 2.2. The relationship between the work rate (watts) and heart rate (ACSM, 2006).

The validation of sub-maximal tests while determining the VO_{2max} is based on the following principles (Myhre *et al.*, 1998);

- Exercise heart rate increases in direct proportion to increases in workload.
- Heart rate increases during the first minutes of exercise and reaching a plateau between the third and fifth minutes of sub-maximal exercise.

- The maximal work load is indicative of the VO_{2max} .
- The maximal heart rate for a given age is uniform.
- Mechanical efficiency (i.e. VO_2 at a given work rate) is the same for everyone.
- An individual's aerobic capacity can be estimated as a function of relative heart rate during a given peak of sub-maximal work.

2.4. Comparison of the methods for determining VO_{2max}

In order to determine the aerobic capacity of a person, there are several ways which are basically grouped according to the test protocol or aerobic capacity measurement type. Determination of a person's maximal oxygen uptake can be made by direct or indirect methods and by maximal and sub-maximal test protocols. Obtaining the most precise aerobic capacity values is conducting a graded exercise test while subjects are exposed to volitional exhaustion on a cycle ergometer or treadmill by measuring expired oxygen directly. (George *et al.*, 2009).

Direct methods are basically based on the measurements of an individual's expired gases in order to analyze their pulmonary ventilation, expired oxygen, and their expired carbon dioxide. This breath by breath analysis is the most accurate way to determine an individual's maximum oxygen consumption. Although maximal graded exercise tests accurately assess AC, they are usually limited to laboratory and clinical settings. Besides, maximal graded exercise tests involve costly equipment and require physician supervision in individuals who have health problems. On the other hand, indirect methods, which include field tests, estimate a person's aerobic capacity based on their heart rate, their distance covered, and or their time of trial when using a certain protocol. Submaximal tests have obvious advantages over maximal tests in that specialized lab equipment is unnecessary, test administrators require less training, and the exercise intensity is realistic for most participants. In addition to this, periodic submaximal testing provides an appropriate way to monitor progress throughout an exercise program and educates participants about their potential risk for cardiovascular and other chronic diseases.

Many tests with different types of the protocol such as step test, treadmill running, or using a cycle ergometer have been proposed to predict the VO_{2max} by monitoring and measuring HR since HR and VO_{2max} are highly correlated. It is possible to conduct these tests with both maximal and submaximal methods; however submaximal tests are more applicable. In the sub-maximal tests, the subject is required to perform at less than 80% of their maximum capacity and then VO_{2max} values are measured with the help of regression. Submaximal cycle ergometer protocol was first developed by Astrand and Rhyming (1954). Since then, a number of studies have been conducted in employing a cycle ergometer submaximal test. The utmost advantages of a cycle ergometer are the ease of transportation and the requirement of minimal space. Additionally, several studies proved that cycle ergometer tests provide an accurate prediction of AC values. A correlation of 0.71 is reported to be measured by Astrand and Rhyming (1954) between VO_{2max} measurement and the estimation in the original Astrand cycle ergometer test. The correlation increases to 0.78 when the age-correction factor is taken into account. In the study of Myhre *et al.* (1998) it is also proved that there is no statistically significant difference between the maximal oxygen uptake values collected from maximal tests and estimated from submaximal cycle ergometer tests.

Despite their advantages, there are also some doubts about sub-maximal testing. The main doubt is the absence in the standardization of the procedures. Firstly, informing the subjects about the type and purpose of the test and instructing them to avoid any rigorous activity for 24 hours prior to testing is crucial. Besides, they have to avoid a heavy meal, caffeine, or nicotine within 2 to 3 hours of testing. The subjects have to become familiar with the equipment and test procedures to minimize tension. Calibration of the equipment is one of the most important requirements of testing in order to get accurate test results. In addition, it is stated that there is a potential limitation of submaximal cycle ergometer testing, especially in untrained samples.

Non-exercise methods of estimating aerobic capacity are also useful and convenient, requiring participants to simply answer a few questions and then compute a relatively accurate VO_{2max} score using a multiple linear regression equation. Currently, The International Physical Activity Questionnaire (IPAQ) is the most widely used and validated self-report measure of physical activity. The study of Schembre and Riebe (2011) stated that short IPAQ can be used to successfully estimate VO_{2max} as well as submaximal exercise tests.

Selecting the test method does not only depend on the equipment that the practitioners have but also the subjects' health conditions and physical activity levels. In brief, the maximal tests are much more appropriate when working trained and healthy subjects under the control of experienced physicians. Table 2.1 gives brief information about which test type must be chosen according to the tools available and the population tested:

Table 2.1. Test selection due to the tools required and subjects tested. (Billat and Lopes, 1995)

Tools required	Subjects	Testing method
Pencil	Sedentary	Questionnaires
	Regular exercise	Questionnaires
	Endurance trained	Maximal aerobic speed using critical velocity concept
Stopwatch and tape measure	Sedentary	Walking test for 1.6 km
	Regular exercise	Incremental test form 8 km/h to exhaustion with 1 min long stages and 0.5 km/h speed increment
	Endurance trained	Incremental test form 10 km/h to exhaustion with 2 min long stages and 1 km/h speed increment
		5 min all-out test
Stopwatch and tape measure and HR monitor (cycle ergometer for sedentary subjects)	Sedentary	Astrand nomogram on a cycle ergometer
	Regular exercise	Walking or running test for 1.6 km or 2 km
	Endurance trained	Incremental test form 8 km/h to exhaustion with 1 min long stages and 0.5 km/h speed increment
		Incremental test form 10 km/h to exhaustion with 2 min long stages and 1 km/h speed increment
		5 min all-out test
		Running or walking test in the mountains using Astrand nomogram
Beat by beat HR monitor	Sedentary	Heart rate variability test during a 5 min rest test
	Regular exercise	

2.5. Previous AC Studies

In the literature, there are a great number of studies carried out to estimate and determine aerobic capacity of different samples. In these studies, various measurement and estimation methods have been performed in order to determine aerobic capacity and the factors that affect it. Besides, in some studies, regression models have been determined to find an equation to predict the aerobic capacity. Before conducting the current study, some considerable studies are examined in detail in this part.

Cink and Thomas (1981) carried out research in order to assess the validity of the estimated VO_{2max} from the Astrand-Rhyming nomogram. 40 males with age ranged from 18 to 33 years attended to study and completed both maximal and submaximal tests with cycle ergometer. For the sub-maximal test, Astrand Cycle Ergometer protocol was applied and regarding their habitual physical activity, initial workloads with different work rates are arranged. A 5-minute maximal test was employed with an initial workload for 2 minutes and it was increased by 25 W every minute until the subject was exhausted. According to the data collected during the experiments, results indicated that the VO_{2max} elicited by a maximal cycle ergometer test can be predicted from the Astrand-Rhyming nomogram with a standard error of estimate of approximately 0.42 l/min or 5.6 ml/kg/min standard error. Besides, the study showed that there was no significant difference between the measured VO_{2max} and the predicted mean based on the Astrand age correction factors. Another important output of this study is that if the subjects were being clustered in different exercise groups and/or fitness categories, the Astrand age correction factors should have been applied.

Storer (1990) examined a study so as to validate that cycle ergometer VO_{2max} could be precisely estimated according to its relationship with work rate by developing a new regression equation which considers maximum work rate, body weight, age as independent variables. During the experiments, 116 female and 115 male subjects completed maximal exercise tests using cycle ergometer. The subjects cycled for 4 min without any workload and were exposed to an increase in work rate with 15 W/min increments until they reached their tolerance limits. Results of the experiment indicated that the accurate equations depend on maximum workload, weight and age can be generated in order to predict VO_{2max} from the cycle ergometer graded exercise tests. According to the results of the separate prediction equations of male and female subjects, it was seen that the females had significantly lower levels of absolute VO_{2max} in ml/min. In stepwise regression analysis, a maximum workload which explained %92 of common variance was the first variable chosen. Lastly, it was found that the age was an important factor that decreases the aerobic capacity due to the other probable determinants such as a decrease in body mass and a decline in cardiac output, pulmonary ventilation and pulmonary diffusing capacity in terms of maximal exercise values.

Myhre *et al.* (1998) conducted laboratory research on American Air-force workers aiming to assess the association between estimated maximal oxygen uptake values collected by specifically developed and computer-guided cycle ergometer protocol and values obtained by the maximal treadmill exercise. 58 men and 41 females ranging from 28 to 57 years in age attended the experiments and conducted maximal tests with treadmill and sub-maximal tests with cycle ergometer. In this study, US Air Force Cycle Ergometry Fitness Protocol was developed by the help of tested algorithms that aimed to select initial workload and to guide workload setting in the first three minutes period of test for subjects with different age and weight. In our study, the experiments are also conducted based on this protocol which modified the Astrand Cycle Ergometer protocol in accordance with the subject's weights and ages. The results of the study indicated that the mean difference between the maximal oxygen uptake values collected from maximal treadmill tests and estimated from submaximal cycle ergometer tests remained insignificant. It can be concluded, due to computer-guided specific initial and incremental load selection method, neither the very low fit individuals nor the highly fit were miscalculated by cycle ergometer. However, aerobic capacity values acquired from cycle ergometer were underestimated (more than 10 ml/kg/min) occurred in 5 (%9) of the males and 1 (%2) of the females. Low cycle test scores may attribute to the result of high heart rate regarding energy cost; the most possible explanation for this is a lower than mean stroke volume since during sub-maximal exercise cardiac output is actually alike for both trained and sedentary subjects. It is stated that this deviation in the reaction of human cardiovascular to exercise is needed to be explored.

Another study of George *et al.* (2000) was subject to design a modified sub-maximal cycle ergometer test in order to predict VO_{2max} values collected from treadmill exercises.

156 volunteers with ages from 18 to 39 participated in the study. Participants completed a sub-maximal cycle protocol and a maximal graded exercise test. Precise prediction of treadmill aerobic capacity values in young adults were obtained through a modified cycle ergometer test which only needed a bearable level of hard work and seemed to be an applicable and time-efficient means of predicting cardiorespiratory fitness. In conclusion, a regression model was proposed that included independent variables as gender, age, body mass. But it should be kept in mind that minimal decrease should be executed when proposed regression model is employed to estimate aerobic capacity on the other young, healthy individuals who have similar age, body mass, and fitness level as this sample.

In order to investigate the validity of the use of HR-response in estimating the VO_{2max} during non-steady state exercise Bot and Hollander (2000) conducted a study with 4 experiments including 5 group of subjects in Netherland. The relationship between heart rate and aerobic capacity was examined during dynamic and static non-steady state exercise with large (leg), small muscle (arm) masses and a mixture of different muscle groups (leg + arm). Even though the correlation values were less powerful than under steady-state conditions, it was reported that the prediction of aerobic capacity by monitoring heart rate values was not restricted to steady-state exercise. It was also concluded that aerobic capacity can be estimated from a single heart rate and aerobic capacity regression line during changing nonsteady-state exercises. But it was also noted that one should evaluate carefully required reliability when the aerobic capacity was predicted based on group regression equations.

To assess the workload in an industrial workplace, instructions about decent workload duration for particular job types are crucial. For that purpose, Wu and Wang (2001) examined a study on 15 males and 15 females who were untrained adults to evaluate the maximum acceptable work duration (MAWD) for high-intensity work which was valid for job types such as construction, mining. Since high-intensity work was more appropriate for young workers which were also in good condition, the subjects' age group was determined specifically at 20-30 years. In the study, cycle ergometer was designed to simulate high-intensity work in two levels (%60 and %70 maximum work rate) since more than %60 of the aerobic capacity was required for high-intensity work. Including gender, subject, and relative work rate as independent predictors, a balanced nested design was applied which had also taking into account workload response variables regarding relative heart rate (RHR) that was defined as ($HR_{work} – HR_{rest}$) / ($HR_{max} – HR_{rest}$) x 100% and relative oxygen uptake (R$\dot{V}O_2$) that was defined as ($\dot{V}O_{2work} – \dot{V}O_{2rest}$) / ($\dot{V}O_{2max} – \dot{V}O_{2rest}$) x 100%. According to the results of the study, it was reported that all physical responses due to exertion under 70% maximum work rate (MWR) were statistically greater than those under 60 %MWR. Another critical finding of the study was that MAWD and both (R$\dot{V}O_2$) and RHR were significantly inversely correlated. Due to acquired MAWD values, it was proposed that a worker should have taken a break after 18.8 minutes of work when he/she was exposed to an average workload of 65% (R$\dot{V}O_2$). When the average workload is increased to 80% of (R$\dot{V}O_2$), then it is recommended that brake should be taken after 6.5 minutes of work. All these suggestions were based on the assumption that any workload with an average HR over 150 beats per minute was too high to be valid for a sedentary worker. At last but not least it was also stated that the proposed MAWD estimation models can be individually used in job tasks containing lower limb muscle effort such as climbing stairs or rapid walking.

Another study of Wu and Wang (2002) was aiming to determine an equation which was displaying the relationship between the maximum acceptable work time (MAWT) and given workload. In the study, 12 healthy adults (6 male and 6 female) performed cycling tests at six different work rates (20, 30, 40, 60 and 70% W_{max}) relative to their individual maximum work capacity. During the tests, VO_{2max}, RHR, and R$\dot{V}O_2$ of the subjects were gathered. In the study it was concluded that dependent predictors (MAWT, % VO_{2max}, RHR, R$\dot{V}O_2$) were not significantly different from each other in terms of male and female subjects which was also interpreted as if the subjects from each gender executed the cycling tests at the same ratio of their maximal work rates, relative exertion were very close to each other. Therefore, the suggested results of the study were considered applicable to both genders. Additionally, due to the exponentially decreasing relationship between MAWT and relative efforts, three estimation equation was proposed with $R^2 > 0.80$. According to the model for % VO_{2max}, the recommended upper limits of % VO_{2max} for active work completed in 12, 10, 8 and 4 hours were 28.5, 31, 34 and 43.5% respectively. Another notable finding of the study was the fact that the relationship between MAWT and %VO_{2max} for Taiwanese populations was nearly the same as that for Western populations.

Regarding aerobic capacity reference values on the cycle ergometer, Farazdaghi and Wohlfart (2003) investigated research aiming to make a comparison between male subjects' values that were obtained in this study and female subjects' values that had been collected previously in another study by the same authors in Sweden. Another consideration of the study was commonly used aerobic capacity values were too low. For this purpose, 81 healthy men were employed to the test within the age range of 20 to 80 years. The results of the comparison showed that the men reached higher maximal workload then the women. Moreover, maximal workload decreased with age in both men and women. It can also be said that the effects of age on maximal HR and maximal workload were less pronounced in women. It was also stated that aerobic capacity values presented in the study are higher than commonly existing in Sweden.

The primary objective of the study carried out by Bugajska *et al*. (2005) was determining the level of the aerobic capacity and work ability in men and women in working age. The secondary purpose was to evaluate what kind of effects aerobic capacity has on work ability. 524 occupationally active women and 664 occupationally active men from different working groups that were classified into 5 category (mental work, light physical work, physical work of moderate intensity, and hard physical work) due to the intensity level of work were volunteered to the study. In order to estimate VO_{2max}, the subjects performed 2-4 sub-maximal exercise tests on a bicycle ergometer. Work ability of subjects was determined with the Work Ability Index, which possessed a survey that tried to cover dimensions of workers by asking their current work ability in comparison with their lifetime best, their work ability in relation to the demands of the job, limiting conditions or illnesses they suffer from, the number of days they were out of work last year due to sickness, categorized work ability in the range of 7–49 points such as bad (7-27 points), moderate (28-36 points), good (37-43 points), very good (44-49 points). The result of the study related to age indicated that the VO_{2max} was significantly inversely correlated with age (decrease in men by 0.40 ml/kg/min a year and in women by 0.44 ml/kg/min a year). Another outcome of the study was a positive correlation between aerobic capacity and work ability index, specifically for the male subjects who were under hard physical workgroup.

In order to investigate the ethnics differences between measured and estimated values of maximal oxygen uptake, Vehrs and Fellingham (2006) conducted a study with sixteen White and sixteen African men. The participants completed sub-maximal exercise tests according to Astrand cycle ergometer and Young Men's Christian Association (YMCA) protocols. The important finding of the study was that in comparison with White men, being in similar age and having close weight, BMI had similar aerobic capacity values, whereas significantly lower heart rate results to the absolute sub-maximal workloads.

The primary objective of the study carried out by Kang *et al.* (2007) was to establish the distribution of aerobic capacity of Korean male metal workers. Secondly, it was aimed to conclude the effects of aerobic capacity. Male metal employees with a sample size of 507 and having an age variation between 20 and 60 in years from different metal industries were recruited in the study. The aerobic capacity values were measured and collected with a sub-maximal ramp test employing a bicycle ergometer. Aerobic capacity values were evaluated both as absolute (absolute VO_{2max} in l/min) and as a relative value to body weight (relative VO_{2max} in ml/kg/min). Maximal physical work capacity (kcal/min) was measured by multiplying absolute aerobic capacity with 4.8 kcal. Then energy expenditure per unit heart rate (kcal) was found by dividing maximal physical work capacity (kcal/min) by maximum heart rate. The results of the study indicated that the aerobic capacity was influenced by the age, body mass index and work index. Relative aerobic capacity values were diminished as age increases, whereas they were increased where BMI values were decreased. Workload index which was also strong determinant was negatively correlated with relative aerobic capacity. Based on the results of the study, 97.8% of the employees were found to be overloaded which concluded that highly populated group of workers in the metal industry in South Korea were working in extremely physically demanding jobs. Lastly, no other variables including marital status, education and exercise level, alcohol drinking or smoking had a significant relationship with the relative aerobic capacity.

Vehrs *et al.* (2007) aimed to assess the precision of estimation of an existing regression equation used to estimate aerobic capacity by conducting treadmill jogging test in 3 different locations among a subject sample (250 men and 150 women) with an age range varying from 18 to 40 in years. The main objective was to evaluate the effect of variability in different test locations and to find out the reliability of generalization of treadmill jogging test for different geographical locations. In the study, it was concluded that proposed regression equation including gender, age, body mass, self-selected jogging speed, and steady-state HR as independent variables to predict aerobic capacity had a lower constant error, a lower standard error of estimate and lower total error values. Therefore, it was suggested that it could directly be used for both laboratory and nonlaboratory settings.

Mou and Fu (2007) conducted a study to investigate the effect of the post-exercise HR parameters on the estimation of aerobic capacity by collecting 3-minute step test with 3 different step heights varying 30, 35 and 40 cm. A sample with 31 college males having age distribution with 19.77 years in mean and 1.20 years in standard deviation attended to the study and completed the Bruce treadmill test. It was stated that physical fitness index, which was a measure of recovery in heartbeat counts after exercise, was found to be an appropriate independent variable for predicting aerobic capacity. Additionally, it was reported that the step test employing 40 cm platform was relatively highly correlated with aerobic capacity than the others.

Smolander *et al.* (2008) conducted a study so as to eliminate the use of laboratory test in the prediction of aerobic capacity employing heart rate by developing a new neural network method based on heart rate variability. This method was developed to analyze physical workload from rest and recreation interval by monitored data during work without any need of additional calibration with a laboratory test such as cycle ergometer or treadmill. Additionally this new method was aimed to enable to prevent difficulties according to an increase in heart rate that was not related to metabolic changes and discrepancies in the relationship between heart rate and aerobic capacity during varying work intensities. Therefore data related to respiratory frequency and on/off dynamics were gathered. For this purpose, 13 men and 9 women working as postal workers which had varying daily work activities were recruited. In the study, it was concluded that when an evaluation was done for different heart rate categories, the highest correlations between new method and traditional laboratory tests and smallest differences were detected at higher heart rate levels. Moreover, aerobic capacity values obtained by the traditional method were higher than those gathered by the new methodology. The higher differences and lower correlation occurred at a heart rate level of 80-100 beats per min, which was the typical heart rate zone for most daily activities. These differences were attributed to additional thermal stress (heat, cold), prevention of metabolic changes with the effect of medicine consumption, psychological factors during low-activity physical work.

Another study with a primary goal which was to predict aerobic capacity values with a regression model due to results collected from sub-maximal treadmill exercise and according to non-exercise data that was gathered via questionnaires was carried out by George *et al*. (2009). For that purpose, 116 participants whose ages were varying from 18 to 65 in years were recruited. In this study, it was concluded that a regression model including a combination of both exercise variables such as ending treadmill speed and non-exercise variables were introduced to the literature. It was reported that 80.4 % variation in aerobic capacity values were attributed to age, gender, body mass and ending self-selected treadmill, whereas remaining 8.1% variation was due to non-exercise variables that were based on perceived functional ability and physical activity information. In the study, exercise heart rate which was also an exercise data was dropped from the regression model since it was not found to be statistically significant.

George *et al.* (2010) intended to reconsider the submaximal cycle ergometer test protocol established by George et al. (2000) and to create a precise estimation model that mixed valid exercise data such as heart rate and work rate gathered during test and non-exercise data based on perceived functional ability score, and physical activity rating. In this purpose, 53 male and 52 females with a mean (±SD) equaled 23.5 ± 2.8 ages were volunteered to perform submaximal cycle ergometer test and a maximal graded exercise test on a motorized treadmill. The results of the study indicated that the contribution (10.1% increase in explanation of model variation, change in R^2 from 0.732 to 0.833) of the perceived functional ability score in the estimation of aerobic capacity using a multiple linear regression model involving cycle ergometer was statistically significant whereas physical activity rating was found statistically insignificant.

Balderrama *et al.* (2010) aimed to consider the aerobic capacity values of a group of subjects from different ages and genders as long as conducting different physical activity levels employing three different aerobic capacity prediction methodologies so as to discover and evaluate probable variations between methodologies, age, and gender. In the experiments 33 subjects whose ages were varying from 18 to 65 in years were tested with three different methods; i) direct measurement, ii) employing heart rate results of the submaximal step test and calculating maximal oxygen uptake predefined charts, iii) prediction by heart rate which were monitored and collected from real-time HR signals.

According to the statistical analysis of the results of the study, it was found that there were significant differences between the three studied VO_{2max} estimation methods. However, when paired-t tests were applied, it was found that the direct measurement method and heart rate prediction method did not statistically differ from each other. It was also stated that age and gender were the main determinants that made the study applicable, while other factors such as weight, height, exercise level, smoking were also taken into consideration in order to decrease error in experimental design.

Ahmadian *et al.* (2013) conducted a study in order to investigate the differences in predicted maximal oxygen uptake values that were separately determined by actual body weight and ideal body weight with a regression equation. The test group was consisting of 230 subjects (%62 male and %38 female) with a mean (±SD) equaled 37 ± 15 in ages, completed a graded exercise test with 25 watts of increments until exhaustion. In the study it was stated that employing ideal body weight instead of actual body weight, less overestimation occurred when it is compared with the results of previous regression models in the literature.

The experimental study that carried out by Sloan *et al.* (2013), was stem from the absence in precise non-exercise fitness assessment equation among the Asian population. Therefore, the first goal of the study was to develop a new non-exercise fitness assessment equation without HR_{rest} as an independent variable and making cross-validation with the one that was constructed by Jurca *et al*. (2005) among Singaporean population. In the experiments, 57 men and 43 women that were aged between 18 and 65 years were completed a treadmill exercise with Bruce protocol and their maximal oxygen consumption was collected by indirect calorimetry. The study indicated a high correlation between the aerobic capacity values estimated from non-exercise fitness assessment equation which involved gender, age, physical activity score and laboratory-measured aerobic capacity values ($r = 0.83$). In general, it was stated that the accuracy of the non-exercise fitness assessment equation became better when it was adjusted specifically gender-based. The findings of the study were also in line with the outcomes of the study conducted by Jurca *et al*. (2005).

The objective of the study examined by Afolabi & Akanbi (2013) was to evaluate the effect of body mass index (BMI) on aerobic capacity and energy expenditure during performing a manual task which was lifting loads from ground level into the inlet stationary. For this purpose, the biometric and physical features of thirteen subjects were collected. In the study, it was indicated that amount of loads lifted and body mass index are directly corresponding to the heights and energy expenditure respectively and inversely correlated to the weights and aerobic capacity of the subject, respectively.

Cao *et al.* (2013) examined a study in order to propose a new aerobic capacity estimation models employing a intuitively modified three minute walk distance (3MWD) test among a sample of subjects consisting of two hundred and eighty-three Japanese adults (143 men, 140 women) that were aged 20–69 years without chronic diseases. The proposed method in the study was based on a test in which subjects were requested to walk in a twenty-meter long hallway for three minutes at a self-adjusted intensity “considerably hard” according to ratings of perceived exertion. At the end of 3 minutes, the total distance walked was listed. To validate the results of the suggested protocol and methodology, a maximal graded exercise test (GXT) with bicycle ergometers was conducted and VO_{2max} results were measured. The correlation between measured VO_{2max} values and results from 3 meter walk distance test (in meter) were statistically significant for both men ($r = 0.56$, p-value < 0.001) and women ($r = 0.55$, p-value < 0.001). In the study three prediction models which were investigated the effect of body mass index (BMI), body fat percentage (%Fat) and waist circumstance (WC) individually in multiple regression with other independent variables such as gender, age were examined so as to predict aerobic capacity. The same three models were then conducted by including 3MWD values as independent variables. Among the prediction models in the current study, the %Fat model with 3MWD values included demonstrated the highest $R^2 =0.62$ values with the lowest standard deviation. With a contribution of %8 in R^2 values, 3-minute walk distance was found significantly related to aerobic values.

Another study specifically focused on rescue workers executed by Prieto *et al.* (2013) in Spain concerning the effect of age and other variables such as body mass index and body mass percentage on aerobic capacity. The secondary objective of the study was also to analyze the effect of differentiation in training methods and the subjective perception of physical on aerobic capacity values. Male subjects were recruited to complete a Bruce treadmill test from a group of 358 firefighters, 281 lifeguards and 421 mine rescue workers that were aged 18-50 years. The results of the study indicated that there was a significant decline in VO_{2max} of the older participants which affected the effectiveness of rescue work. Besides, the results presented satisfactory aerobic capacity levels among the lifeguards and the firefighters which were acceptable values for three rescue groups to perform effectively rescue activities. On the other hand, the mine rescue workers presented quite low maximal aerobic capacity levels. Another critical finding of the study was the statistically significant correlation between the number of hours spent on endurance training and aerobic capacity values (p-value < 0.001).

Myers *et al.* (2017) aimed to develop regression model for determinants of aerobic capacity to improve previous regression formula in literature with the help of Exercise: A National Database (FRIEND) registry initiative which has an objective of enhancing the importance of aerobic capacity and cardiorespiratory fitness across different units of society consisting not only clinical setting and workplaces but also the public so as to inform national regulation efforts on physical fitness, activity and health. The study sample consists of 7759 participants (4601 men, 3158 women with age ranged from 20 to 80 years) from different geographic regions such as Indiana, Louisiana, North Carolina, Oregon, Pennsylvania, Tennessee, and Texas in the USA. It was reported that age, gender, and body weight were the only statistically significant independent variables of aerobic capacity ($R^2 = 0.62$ and p-value < 0.001). It was also stated in the study that regression equation based on the FRIEND data was relatively stable among the range of age, BMI and gender when it is compared to equation models which had been previously determined and mentioned in the study.

Hosick *et al.* (2018) examined a study to investigate the effect of aerobic capacity on the correlation between body mass index and resting testosterone level (RTL) in males. A subset of male subjects from 2003-2004 National Health Nutrition Examination Survey of USA was gathered and analyzed by weight status as normal, overweight, obese. The subset of participants was determined and restricted to young adults (18-35 years of age) since sex steroid hormones may be influenced by age. The findings of the study indicate that there was a negative correlation between % Fat and RTL and a positive correlation between AC and RTL. Additionally, based on the results of the study it was suggested that a loss in weight or an increase in aerobic capacity led to an increase in RTL.

Ando *et al.* (2018) aimed to investigate whether there was an association between directly measured aerobic capacity values and weight change since it is known that energy expenditure measured under living conditions estimated weight change. 80 American Indian males from southwestern heritage aged 18 to 45 years participated to graded exercise test with discontinuous work bouts on a treadmill. In the study, a regression model (R^2=0.73 and R^2_{adj} = 0.727) was developed which was including independent variables such as fat-free mass that had an incremental effect and also predictors like age and fat mass that had negative contributions on predicted aerobic capacity. In the study, it was concluded that aerobic capacity was not a predictor of weight change although it was positively associated with energy expenditure. In the study, this was attributed to the mediating effect of exercise. An increased fitness level which was affected by regular physical activity and resulting in higher aerobic values might have increased energy intake that opposed any positive influence on daily energy expenditure.

Apart from the studies discussed above, two studies were also investigated that were conducted in Turkey with subjects from population of Turkey.

One of the main studies conducted in Turkey was the study of Gökbel *et al.* (2005) which had the main purpose of evaluating the validity of Astrand-Rhyming nomogram and Fox equation. Secondly, it aimed to determine if these methods could be used when predicting the subject’s anaerobic thresholds. In the extent of the study, 15 sedentary and 7 trained men (18-24 years) performed a maximal cycle ergometer test following the protocol which required initial workload 60-100 W, and increment in 10W/min until exhaustion. The results of the study showed that both in sedentary and trained groups, directly determinated aerobic capacity values were found to be significantly higher than the estimated ones by Fox equation. In trained groups, directly determinated aerobic capacity values were found to be significantly higher than the estimated ones by Astrand-Rhyming nomogram. The relationship between the anaerobic thresholds and VO_{2max} was found more significant when the estimated values of aerobic capacity by Fox equation were used. For trained groups, it could not be found any relationship between the measured and estimated values of physical work capacity. Therefore, the study suggested that VO_{2max} should be measured directly in athletes.

Another experimental study from Turkey was conducted by Güvenç (2007) in order to investigate aerobic, anaerobic power and capacity differences as a function of age, maturation, training, and physical activity among normal untrained and trained boys 11 to 15 years' age. This study was carried on 75 untrained and 75 trained boys who were handball, soccer and volleyball players and trained regularly three times a week at least one year. The results of the study showed that the trained boys have higher aerobic, anaerobic power and capacity values and relatively steeper increase with growth compared to untrained counterparts. On the other hand, physical activity level was related to aerobic fitness in the untrained group whereas it was not in the trained group. The relationship between physical activity level and aerobic fitness was low but significant and somewhat better with higher intensity activity. In contrast, daily activity level was not related to anaerobic power and capacity in both groups.

2.5.1. Summary and Critics of Findings

Past studies in the literature are summarized and displayed in Table 2.2. Because of difficulties and complexity of maximal tests such as not being applicable for all the subjects and requiring experienced and qualified technicians, most of the studies in the literature were interested in the validity and verification of the non-exercise or sub-maximal methods to obtain accurate aerobic capacity. Table 2.3 illustrates the classification of the studies according to VO_2 measure type. Besides, the classification of the studies based on the exercise type and equipment used is shown in Table 2.4.

A great number of studies focused on the correlation between HR and oxygen consumption and used HR_{max} as an indicator of the VO_{2max}. Apart from submaximal test protocols that were taken into account HR values for estimating aerobic capacity, Bot (2000) stated that prediction from HR-response during non-steady state exercise in daily tasks is also valid. Mou and Fu (2007) investigated the effect of the post-exercise HR parameters on the estimation of aerobic capacity and physical fitness index, which was a measure of recovery in heartbeat counts after exercise, was found to be appropriate independent variable for predicting aerobic capacity.

In many studies, the effects of gender and age on VO_{2max} were investigated. The gender and age effects on VO_{2max} were the most conspicuous findings in literature rather than other effects such as BMI, weight, exercise or occupation, etc. It is generally stated that there is a strongly inversely correlation between the VO_{2max} and age. Moreover, aerobic capacity of males is higher than females. Apart from age and gender, authors also focused on other exercise or non-exercise independent predictors and tried to develop equations to estimate VO_{2max} accurately. The effect of body biometrics such as weight, height, body mass index, body surface area, fat-free mass, body fat percentage, and waist circumstances were investigated. Addition to body biometrics, the influence of physical fitness level on aerobic capacity were tried to be evaluated through non-exercise data that were obtained by surveys or questionnaires.

To assess the workload in an industrial workplace, instructions about decent workload duration for particular job types are crucial. For that purpose, to determine a bearable upper limit of work, the relationship between maximum acceptable work duration, maximum acceptable work time, work ability index, energy expenditure, and aerobic capacity were also examined in the literature.

Results of the studies in the literature related to aerobic capacity can be summarized as follows:

- Most of the studies focused on to investigate the validity of the use of HR-response in estimating the VO_2 and the results of the studies stated that HR values of both and males and females increase with increments in workload.
- Heart rate increases rapidly during the first minutes of the exercise and reaching a steady state between the fourth and fifth minutes of constant submaximal exercise.
- The aerobic capacity of an individual can be estimated as a function of relative heart rate during sub-maximal work.
- In many studies (Astrand *et al.*, Nielson *et al.*, Duque and Parra, Bugajska *et al.*, Bugajska *et al.*, Singh *et al.*), the effect of age on aerobic capacity has been investigated. It is generally stated that there is a strong inverse correlation between VO_{2max} and age.
- Gender has a significant effect on aerobic capacity. In general, primarily due to physiology women have a lower VO_{2max} than men. Since men have generally

physically larger than women, they have larger hearts that pump more blood and larger lungs to take in more oxygen.

- The body mass index, or BMI, is a commonly used indicator of weight status. High BMI measurements have been correlated with reduced levels of physical fitness, including lowered VO_{2max}.
- In general HR at any given level of sub-maximal exercise generally decreases with fitness level of a person. On the other hand, there were studies that could not find any significant training effect on VO_{2max}.
- Lastly, there was not enough evidence to conclude that alcohol drinking or smoking had a direct relationship with the relative VO_{2max}. One of the most comprehensive studies about the effect of smoking on maximal aerobic capacity was conducted by Suminski *et al.* (2009) and concluded that measured VO_{2max} was significantly lower in the heavy smoking group compared with the other groups. On the other hand, in the study of Kang *et al.* (2007) conducted by 570 male metal workers, no variables including exercise level, alcohol drinking or smoking had a significant relationship with the relative VO_{2max} .

Table 2.2. Summary of studies in literature.

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Cink and Thomas (1981)	USA	NM	40 M	(18-33)	Indirect	Maximal	Cycle Ergometer	The work load was 25 W for the first 2 minutes. increased by 25 W every minute thereafter until the subject was exhausted.
						Sub-maximal	Cycle Ergometer	Astrand Cycle Ergometer
Storer *et al.* (1990)	USA	NM	116 F	(20-70)	Direct	Maximal	Cycle Ergometer	Cycle for 4 min at 0 W, increase work rate in 15 W/min increments until the subject reached his/ her limit of tolerance
			115 M					
Myhre *et al.* (1998)	USA	American Air Force Workers	41 F	(20-59)	Direct	Maximal	Treadmill	Constant speed and increased treadmill grade until exhaustion.
			58 M		Indirect	Sub-maximal	Cycle Ergometer	US Air Force Cycle Ergometry Fitness Protocol (modified)

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
George *et al*. (2000)	USA	College students	80 F	27.6 ± 7.1	Direct	Maximal	Treadmill	Brigham Young University Cycle Ergometer Protocol
			76 M	28.6 ± 6.3		Sub-maximal	Cycle ergometer	NM
Bot and Hollander (2000)	Netherlands	Healthy Adults	8 F, 8 M	25 ± 5	Direct Indirect	Submaximal Maximal	Cycle Ergometer	Astrand Cycle Ergometer Interval Cycle Ergometer Test
			4 F, 8 M	33± 10		Submaximal	Field test	In three 20-min periods various leg exercises
			5 M, 10 F	32± 8		Submaximal	Cycle Ergometer	Astrand Cycle Ergometer Protocol
			2 M, 3 F	22± 1		Submaximal	Field test	Two rounds of six low-strain activities
			14 M	23± 3		Maximal	Wheelchair	Interval Wheelchair Ergometer Test

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Wu and Wang (2001)	Taiwan	Taiwanese Healthy Adults	15 F	23.5± 2.1	Direct	Maximal	Cycle ergometer	NM
			15 M	23.3± 3.6				
Farazdaghi and Wohlfart (2001)	Sweden	Swedish Adult Women	87 F	n= 18 (20-29) n= 12 (30-39) n= 13 (40-49) n=17 (50-59) n=16 (60-69) n=11 (70-79)	Indirect	Maximal	Cycle ergometer	Start with workload 30W and increase in 5W/30s until exhaustion
Wu and Wang (2002)	Taiwan	Taiwanese Young Adults	6 F	25.3± 1.0	Direct	Maximal	Cycle ergometer	Astrand Cycle Ergometer Protocol
			6 M	27.2± 2.4				

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Farazdaghi and Wohlfart (2003)	Sweden	Swedish Adult Men	81 M	n= 14 (20-29) n= 16 (30-39) n= 18 (40-49) n=12 (50-59) n=11 (60-69) n=10 (70-79)	Indirect	Maximal	Cycle ergometer	Start with workload 30W and increase in 5W/30s until exhaustion
Bradshaw *et al.* (2005)	USA	Adults	50 F	37.24± 13.8	Direct	Maximal	Treadmill	Arizona State University Maximal GXT protocol
			50 M	37.76 ± 12.76				

Table 2.2. Summary of studies in literature (cont.).

Source	**Location**	**Population**	**Sample size (N)**	**Sample Age (yrs)**	**VO_2 Measure type**	**Exercise method**	**Exercise Equipment**	**Exercise protocol**
Bradshaw *et al.* (2005)	USA	NM	50 F	37.24± 13.8	Direct	Maximal	Treadmill	Arizona State University Maximal GXT protocol
			50 M	37.76 ± 12.76				
Bugajska *et al.* (2005)	Poland	Polish workers	524 F	43.7 ± 10.1	Indirect	Sub- maximal	Cycle ergometer	NM
			664 M	42.7 ± 10.4				
Gökbel *et al.* (2005)	Turkey	Turkish healthy men	15 M Sedantary	18-24	Direct	Maximal	Cycle Ergometer	Initial workload 60-100W, increase in 10W/min until exhaustion
			7 M Trained					

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Pennathur *et al.* (2005)	USA	Mexican-American Graduate Students	5 F	22.60± 0.89	Direct	Sub- maximal	Treadmill	Bruce Protocol
			16 M	23.94 ± 2.38				
Pulkkinen *et al.* (2005)	Finland	Healthy untrained adults	16 M	36 ± 8	Direct	Maximal	Cycle Ergometer	5 minutes prior to, during and 15 minutes after 10-min exercises at 40% and 70% VO2max and maximal stepwise test
			16 F	39 ± 10				
Vehrs and Fellingham (2006)	USA	White and African American Men	16 M White	21.10 ± 1.0	Direct	Sub-maximal	Cycle ergometer	Astrand Cycle Ergometer Protocol
			16 M African					

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Garatachea *et al.* (2007)	Spain	Sedentary or moderately active adults	28 F	43.6 ± 6.1	Direct	Maximal	Cycle Ergometer	YMCA Cycle Ergometer Protocol
			28 M	43.5 ± 5.9	Indirect	Sub-maximal		
Smolander *et al.* (2008)	Finland	Postal workers	9 F	42 ± 8	Indirect	Sub-maximal	Cycle Ergometer	NM
			13 M	41 ± 8				
Kang *et al.* (2007)	Korea	Korean Metal Workers	507 M	39.3± 7.7	Indirect	Sub-maximal	Cycle Ergometer	NM

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Vehrs *et al.* (2007)	USA	College Students	150 F	(18-40)	Direct	Sub-maximal	Treadmill	Single-stage Submaximal Treadmill Jogging Protocol
			250 M					
Güvenç (2007)	Turkey	Turkish young boys	75 M untrained	(11-15)	Direct	Sub-maximal	NA	3 minutes running, 1 minute recovery
			75 M trained					
Yoon *et al.* (2007)	USA	Healthy Adults	8 F	26.0 ± 8.9	Direct	Maximal	Cycle ergometer	Computer-controlled ramp function on the basis of maximal power output from the familiarization trial
			8 M	23.8 ± 3.2				
Mou and Fu (2007)	Taiwan	College male students	31 M	19.77±1.20	Direct	Maximal	Treadmill	Bruce protocol

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Crocetta and Loperfido (2008)	Italy	Italian Patients	NM	NM	NM	Sub-maximal	NM	6 minutes walk test
Singh *et al.* (2008)	India	Indian farm women	15 F	n= 9 (25-35)	Direct	Sub-maximal	Treadmill	Naughton protocol
				n= 6 (36-45)				
George *et al.* (2009)	USA	NM	50 F	n= 57 (18-39)	Direct	Maximal	NM	Arizona State University
			50 M	n= 43 (40-65)		Sub-maximal		Maximal GXT protocol
Duque and Parra (2009)	Colombia	Adult patients with chronic low back pain	33 F	39.7 ± 6.8	Direct	Maximal	Cycle Ergometer	An incremental test until exhaustion with an initial stage at 30 watts, followed by a 30 watt increase at each 3 min stage.
			37 M	38.9 ± 7.5				

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
George *et al.* (2010)	USA	%90 Caucasian	52 F	22.4 ± 3.1	Direct	Maximal	Treadmill	Arizona State University Maximal GXT protocol
			53 M	24.6 ± 1.87		Sub-maximal	Cycle Ergometer	Modified Brigham Young University Cycle Ergometer Protocol
Balderrama *et al.* (2010)	Mexico	Mexican	19 F	(20-71)	Direct	Maximal	NM	Manero Step Test Protocol
			14 M		Indirect	Sub-Maximal		
Levin (2012)	Australia	Australian Soccer and Football Players	17 M	(18-24)	Indirect	Sub-Maximal	Cycle Ergometer	Astrand Cycle Ergometer Protocol
Nes *et al.* (2013)	Norway	Norwegian Healthy Adults	1594 F	45.3 ± 12.7	Direct	Maximal	Treadmill	Individualized protocol with different initial workload levels
			1726 M	46.9 ± 12.8				

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Ahmadian *et al.* (2013)	USA	Patients with complaints of dyspnea or exercise tolerance	88 F 142 M	37±15	Direct	Maximal	Cycle Ergometer	Graded exercise test using a standard protocol within increases 25 watts every minute exercising until exhaustion
Sloan *et al.* (2013)	Singapore	Singaporean adults	43 F 57 M	18-65	Indirect	Maximal	Treadmill	The Bruce Treadmill Ramp Protocol
Afolabi & Akanbi (2013)	Nigeria	Students	2 F 11 M	21-30	Direct	Sub-maximal	Lifitng	Three iterative manual lifting of loads through the vertical distance of 0.92m.

Table 2.2. Summary of studies in literature (cont.).

Source	Location	Population	Sample size (N)	Sample Age (yrs)	VO_2 Measure type	Exercise method	Exercise Equipment	Exercise protocol
Das (2013)	India	Urban and Rural female students	30 F (Urban)	16-21	Indirect	Sub-maximal	Running	Cooper 12-min run test
			30 F (Rural)					
Cao *et al.* (2013)	Japan	Healthy adults	140F	44.1 ± 13.9	Direct	Maximal	Cycle Ergometer	Graded exercise test with initial work load of 30–60 W and increments of 15 W/min.
			143M	44.1 ± 13.9	Indirect	Sub- maximal	NM	3-minute walk test
Prieto *et al.* (2013)	Spain	Rescue Groups	358 Firefighters	29.0 ± 3.6	Direct	Maximal	Treadmill	Bruce Treadmill test
			281 Lifeguards	21.4 ± 3.2				
			421 Mine rescue workers	35.9 ± 4.8				

Table 2.3. Summary of studies classified according to VO_2 measure type.

Direct Measurement	**Indirect measurement**
• Storer *et al.* (1990) • Myhre *et al.* (1998) • George *et al.* (2000) • Wu and Wang (2001) • Bot and Hollander (2001) • Wu and Wang (2002) • Bradshaw *et al.* (2005) • Gökbel *et al.* (2005) • Pennathur *et al.* (2005) • Pulkkinen *et al.* (2005) • Vehrs and Fellingham (2006) • Garatachea *et al.* (2007) • Yoon *et al.* (2007) • Güvenç (2007) • George *et al.* (2007) • Mou and Fu (2007) • Singh *et al.* (2008) • George *et al.* (2009) • Nielson *et al.* (2010) • Duque and Parra (2009) • Balderrama *et al.* (2010) • Nes *et al.* (2013) • Ahmadian *et al.* (2013) • Afolabi & Akanbi (2013) • Cao *et al.* (2013) • Prieto *et al*. (2013)	• Cink and Thomas (1981) • Myhre *et al.* (1998) • Bot and Hollander (2001) • Farazdaghi and Wohlfart (2001) • Farazdaghi and Wohlfart (2003) • Bugajska *et al.* (2005) • Garatachea *et al.* (2007) • Smolander *et al.* (2008) • Kang *et al.* (2007) • Balderrama *et al.* (2010) • Levin (2012) • Das (2013) • Cao *et al.* (2013) • Sloan *et al.* (2013)

Table 2.4. Summary of studies classified according to Exersice type & Equipment.

Maximal Test	***Sub-maximal Test***	***Treadmill***	***Cycle Ergometer***	***Other / NM***
• Storer *et al.* (1990) • Myhre *et al.* (1998) • George *et al.* (2000) • Wu and Wang (2001) • Bot and Hollander (2001) • Farazdaghi and Wohlfart (2001) • Wu and Wang (2002) • Farazdaghi and Wohlfart (2003) • Bradshaw *et al.* (2005) • Gökbel *et al.* (2005) • Pulkkinen *et al.* (2005) • Garatachea *et al.* (2007) • Yoon *et al.* (2007) • Mou and Fu (2007) • George *et al.* (2009) • Nielson *et al.* (2010) • Duque and Parra (2009) • Balderrama *et al.* (2010) • Nes *et al.* (2013) • Ahmadian *et al.* (2013) • Sloan *et al.* (2013) • Cao *et al.* (2013) • Prieto *et al.* (2013)	• Cink and Thomas (1981) • Myhre *et al.* (1998) • George *et al.* (2000) • Bot and Hollander (2001) • Bugajska *et al.* (2005) • Pennathur *et al.* (2005) • Vehrs and Fellingham (2006) • Garatachea *et al.* (2007) • Smolander *et al.* (200) • Kang *et al.* (2007) • George *et al.* (2007) • Güvenç (2007) • Crocetta and Loperfido (2008) • Singh *et al.* (2008) • George *et al.* (2009) • Nielson *et al.* (2010) • Levin (2012) • Afolabi & Akanbi (2013) • Das (2013) • Cao *et al.* (2013)	• Myhre *et al.* (1998) • George *et al.* (2000) • Bradshaw *et al.* (2005) • Pennathur *et al.* (2005) • Mou and Fu (2007) • Singh *et al.* (2008) • George *et al.* (2010) • Nes *et al.* (2013) • Sloan *et al.* (2013) • Prieto *et al.* (2013)	• Cink and Thomas (1981) • Storer *et al.* (1990) • Myhre *et al.* (1998) • George *et al.* (2000) • Wu and Wang (2001) • Farazdaghi and Wohlfart (2001) • Bot and Hollander (2001) • Wu and Wang (2002) • Farazdaghi and Wohlfart (2003) • Bugajska *et al.* (2005) • Gökbel *et al.* (2005) • Pulkkinen *et al.* (2005) • Vehrs and Fellingham (2006) • Garatachea *et al.* (2007) • Yoon *et al.* (2007) • Smolander *et al.* (2008) • Kang *et al.* (2007) • George *et al.* (2009) • Duque and Parra (2009) • Levin (2012) • Ahmadian *et al.* (2013) • Cao *et al.* (2013)	• Bot and Hollander (2001) • Güvenç (2007) • George *et al.* (2009) • Balderrama *et al.* (2010) • Afolabi & Akanbi (2013) • Das (2013) • Cao *et al.* (2013)

Table 2.5. Summary result table of AC studies in the literature.

Author	**Year**	**Gender**	**Sample Size**	**Age (yrs)**				**AC (l/min)**	**AC (ml/kg/min)**	**Max HR (beats/min)**	**Nationality**	**Population Type**
				Min	**Max**	**Mean**	**SD**	**Mean - SD**	**Mean - SD**	**Mean**		
MacNab *et al.*	1969	M	24	-	-	-	-	3.92 ± 0.58	51.70 ± 5.10		Canadian	College Students
		F	24	-	-	-	-	2.32 ± 0.41	39.10 ± 5.10			
McArdle *et al.*	1970	M	23	-	-	-	-	3.27 ± 0.51	42.70 ± 4.90		American	College Students
Astrand *et al.*	1973	M	31	-	-	26.9	-	4.08 ± 0.07	58.70 ± 0.70		Swedish	Physical Education College Students
		F	35	-	-	21.9	-	2.83 ± 0.05	47.60 ± 0.70			
Higgs	1973	F	20	-	-	-	-	-	41.30 ± NR		American	Physical Education College Students
Maksud *et al.*	1976	M	NR	-	-	-	-	2.71 ± 0.48	44.10 ± 3.90		Colombian	Laborers
Cink and Thomas	1981	M	40	18	33	23.8	3.8	Predicted: 3.94 ±0.81	Predicted: 52.9 ± 13.35	-	American	Adults
								Measured: 4.08 ±0.64	Measured: 54.6 ± 10.21	-		
Vogel *et al.*	1986	M	210	-	-	-	-	3.61 ± 0.50	51.10 ± 5.10		American	New Army Recruits
		F	212	-	-	-	-	2.18 ± 0.32	37.40 ± 3.70			

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Storer *et al.*	1990	F	116	20	70	42.5	14.8	1.61 ± 0.39	-	168.6 ± 17.4	American	Adults
		M	115	20	70	44.3	14.3	2.77 ± 0.60	-	174.7 ± 18		
Founooni and Mital	1993	M	10	19	35	-	-	3.51 ± 0.77	-	-	-	Adult male students
Vitalis *et al.*	1994	M	14	-	-	43.0	11.2	2.44 ± 0.55	33.90 ± 8.90	-	Greek	Steelworkers
Jackson *et al.*	1995	M	145	25	34			3.57 ± 0.67	45.80 ± 7.70	-	American	College Educated White Collars
Lee *et al.*	1995	M	12	-	-	21.2	1.9	3.10 ± 0.41	47.20 ± 3.67	-	Chinese	College Students
Mamansari and Salokhe	1996	M	10	20	52	-	-	2.07 ± 0.52	36.84 ± 9.09	-	Thai	Agricultural Laborers
		F	10	25	55	-	-	1.38 ± 0.23	25.52 ± 4.19	-		

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Myhre *et al.*	1998	F	41	21	50	33.2	7.3	-	Treadmill: 35.58 ± 7.17	-	American	American Air Force Workers
									Cycle: 36.91 ± 11.48			
		M	58	20	57	33.5	9.7	-	Treadmill: 46.11 ± 10.02	-		
									Cycle: 44.76 ± 12.25			
George *et al.*	2000	F	80	-	-	27.6	7.1	-	40.70 ± 4.70	189.4 ± 7.4	American	College Students
		M	76	-	-	28.6	6.3	-	48.70 ± 5.60	191.2 ± 6.9		

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Bot and Hollander	2000	F	8	-	-	25.0	5.0	-	3.97 ± 1.12	187 ± 8	Dutch	Healthy Adults
		M	8	-	-	25.0	5.0					
		F	8	-	-	33.0	10.0	-	3.98 ± 0.92	186 ± 9		
		M	4	-	-	33.0	10.0					
		10	F	-	-	32.0	8.0	-	2.58 ± 1.04	186 ± 12		
		5	M	-	-	32.0	8.0					
		3	F	-	-	22.0	1.0	-	2.45 ± 0.35	195 ± 3		
		2	M	-	-	22.0	1.0					
		14	M	-	-	23.0	2.0	-	2.39 ± 0.42	179 ± 12		
Bhambhani and Maikala	2000	M	11	-	-	25.1	3.0	4.41 ± 0.69	56.90± 7.10		Canadian	College Students
		F	11	-	-	23.7	2.8	2.86 ± 0.33	44.60 ± 7.60			

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Llyod and Cooke	2000	M	4	-	-	26.5	4.5	-	53.70 ± 10.00		English	Adults
		F	5	-	-	23.3	4.0	-	45.50 ± 4.50		English	Adults
Kirk and Sullman	2001	M	4	-	-	-	-	4.21 ± 0.82	56.50 ± 11.82		New Zealander	Cable Hauler Choker Setters in the Logging Industry
Woo *et al.*	2001	M	11	-	-	25.0	1.2	2.87 ± 0.33	42.31 ± 4.04		Korean	College Students
		M	11	-	-	25.0	1.2	2.61 ± 0.29	38.48 ± 4.55			
		F	13	-	-	20.0	1.0	2.05 ± 0.31	37.01± 6.64			
		F	13	-	-	20.0	1.0	1.85 ± 0.22	33.54 ± 4.37			
Wu and Wang	2001	F	15	20	27	23.5	2.1	2.08 ± 0.34	-	186.4 ± 5.1	Taiwanese	Healthy Adults
		M	15	20	30	23.3	3.6	3.31 ± 0.49	-	189.1 ± 6.2		

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Farazdaghi and Wohlfart	2001	F	18	21	28	24.1	2.2	-	-	186 ± 8	Swedish	Municipal population
		F	12	31	39	34.7	3.1	-	-	184 ± 8		
		F	13	42	49	45.3	2.4	-	-	179 ±10		
		F	17	50	59	54.3	3.5	-	-	174±10		
		F	16	60	69	64.1	3.3	-	-	167±10		
		F	11	71	79	75.0	3.3	-	-	155±14		
Wu and Wang	2002	F	6	20	30	25.3	1.0	1.86 ± 0.21	-	183.8± 11.5	Taiwanese	Taiwanese Healthy Adults
		M	6	20	30	27.2	2.4	2.80 ± 0.23	-	187.5 ± 10.6		

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Farazdaghi and Wohlfart	2001	M	14	23	29	26.3	2.9	-	-	186 ± 8	Swedish	Swedish Adult Men
		M	16	30	38	34.5	2.5	-	-	184 ± 8		
		M	18	40	49	45.8	2.9	-	-	179 ±10		
		M	12	50	60	57.3	3.1	-	-	174±10		
		M	11	62	69	65.8	2.8	-	-	167±10		
		M	10	70	79	74.0	2.5	-	-	155±14		
Bradshaw *et al.*	2005	F	50	18	65	37.2	13.8	2.35 ± 0.49	36.32 ± 8.91	181.9 ± 13.6	American	Adults
		M	50	18	65	37.8	12.8	3.56 ± 0.63	43.59 ± 8.80	186.8 ± 10.3		

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Bugajska *et al.*	2005	F	524	19	24	43.7	10.1	-	44.1 ±10.6		Polish	Polish workers
				25	30			-	42.3 ± 7.7	-		
				31	40			-	36.0 ± 7.6	-		
				41	50			-	32.9 ± 9.4	-		
				51	60			-	28.9 ± 8.8	-		
				61	70			-	26.0 ± 7.1	-		
		M	664	18	24	42.7	10.4	-	42.8 ±9.8	-		
				25	30			-	44.1 ±10.4	-		
				31	40			-	43.5 ±10.9	-		
				41	50			-	38.5 ±10.9	-		
				51	60			-	33.4 ±10.6	-		
				61	68			-	29.9 ± 9.5	-		

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	**Max**	**Mean**	**SD**	**Mean - SD**	**Mean - SD**	**Mean**		
Gökbel *et al.*	2005	M	15	18	24	-	-	2.88 ± 0.46	-	-	Turkish	Sedentary Men
		M	7	18	24	-	-	3.01 ± 1.55	-	-		Trained Men
Pennathur *et al.*	2005	F	5	22	24	22.6	0.9	2.81 ± 0.73	44.69 ± 6.72	197.8 ± 0.45	Mexican American	Young Adults
		M	16	20	28	23.9	2.4	4.81 ± 1.75	56.32 ± 12.16	197.1 ± 1.75		
Pulkinken *et al.*	2005	F	16	25	54	36.0	8.0	-	40± 7	-	NM	Healthy Untrained Adults
		M	16	24	50	39.0	10.0	-	49 ± 8	-		
Vehrs and Fellingham	2006	M	16	18	24	21.1	1.1	Astrand: 3.51 ± 0.1	-	185.8 ± 4.9	American	White men
								YMCA: 3.86 ± 0.5	-			
		M	16	18	24	20.8	1.0	Astrand: 3.99 ± 0.2	-	186.7 ± 9.1		African Men
								YMCA: 4.52 ± 0.8	-			
Garatachea *et al.*	2007	M	28	-	-	43.5	5.9	Maximal: 3.31± 0.86	-		Spainish	Adults
		F	28	-	-	43.6	6.1	Maximal: 1.81± 0.43	-			
		M	28	-	-	43.5	5.9	Sub-maximal: 3.34± 0.88	-			
		F	28	-	-	43.6	6.1	Sub-maximal 2.02± 0.47	-			

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Kang *et al.*	2007	M	507	20	29	39.3	7.7	2.5 ± 0.5	-	-	Korean	Metal Workers
		M		30	39			2.5 ± 0.4	-	-		
		M		40	49			2.4 ± 0.4	-	-		
		M		50	59			2.2 ± 0.4	-	-		
Vehrs *et al.*	2007	M	250	-	-	25.5	5.5	-	33.20 ± 3.90	154.6 ± 13.8	American	College Students
		F	150	-	-			-	30.40 ± 3.60	160.6 ± 11.9		
Güvenç	2007	M	150	11	11	-	-	1.85 ± 0.20	50.00±4.21	-	Turkish	Young boys
		M		12	12	-	-	2.04 ± 0.27	50.16±3.30	-		
		M		13	13	-	-	2.44 ± 0.36	50.02±4.84	-		
		M		14	14	-	-	2.81 ± 0.38	50.64±4.09	-		
		M		15	15	-	-	3.10 ± 0.34	51.50±3.41	-		
Yoon *et al.*	2007	F	8	-	-	26.0	8.9	2.87 ± 0.36	-	-	American	Healthy Adults
		M	8	-	-	23.8	3.2	4.44 ± 0.39	-	-		

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Mou and Fu	2007	M	31	-	-	19.77	1.2	-	47.08 ± 3.39	-	Taiwan	College male students
Singh *et al.*	2008	F	9	25	35	31.3	3.5	1.70 ± 0.33	33.54 ± 4.86	-	Indian	Farm women
		F	6	36	45	42.7	2.7	1.45 ± 0.40	32.65 ± 5.77	-		
Duque and Parra	2009	F	33	-	-	39.7	6.8	-	27.2 ± 7.30		Colombian	Adult patients with chronic low back pain
		M	37	-	-	38.9	7.5	-	33.9 ± 6.80			
Nielson *et al.*	2010	M	53	-	-	24.6	1.9	-	49.7 ± 7.42	193.7±7.8	Causian	College Students
		F	52	-	-	22.4	3.1	-	39.96 ± 5.78	190.0±8.0		
Nes *et al.*	2012	F	1594			45.3	12.7	2.55 ± 0.48	37.3 ± 7.5	182 ± 13.0	Norwegian	Healthy Adults
		M	1726			46.9	12.8	3.88 ± 0.71	45.9 ± 8.9	182±14.1		
Sloan *et al.*	2013	F	43	18	65	41.4	14.8		26.9 ± 4.6	173.4 ± 15.9	Singaporean	Adults
		M	57	18	65	43.9	12.5		35.2 ± 5.0	173.3 ± 16.2		
Afolabi & Akanbi	2013	F	2	21	22	-	-	-	41.5 ± 6.9	195.8 ± 3.0	Nigerian	Students
		M	11	21	30	-	-	-				

Table 2.5. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age (yrs)				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Das	2013	F	30	16	21	18.4	1.5	-	41.3 ± 4.37	-	Indian	Urban female students
		F	30	16	21	18.5	1.5	-	50.2 ± 5.75	-		Rural female students
Cao *et al.*	2013	F	140	20	69	44.1	13.9	-	31.2 ± 6.5	-	Japanese	Healthy Adults
		M	143	20	69	44.1	13.9	-	37.3 ± 8.7	-		
Prieto *et al.*	2013	M	-	-	-	29.0	3.6		43.8 ± 9.40		NM	Firefighters
		M	-	-	-	21.4	3.2		50.0 ± 11.3			Lifeguards
		M	-	-	-	35.9	4.8		36.0 ± 9.10			Mine rescue workers

3.

3. RATIONALE AND OBJECTIVES OF THE STUDY

3.1. Rationale of the Study

The knowledge of the aerobic capacity (AC or VO_{2max}), also called physical work capacity, is an important parameter to determine the safe work energy expenditure limits to protect the workforce. The high energy demanding jobs designed without considering AC capacities of the workforce may lead to quick lactic acid buildup and fatigue resulting in low work performance and employee complaints. Additionally, in extreme cases, high energy demanding tasks may lead to cardiovascular and pulmonary health issues even fatalities. Furthermore, aerobic capacity has numerous clinical applications, including risk stratification, evaluation of the efficacy of therapy in patients with cardiovascular or pulmonary diseases and the assessment of disability. The AC is the gold standard expression of cardiorespiratory fitness. Therefore, it is important to establish AC databases for world populations.

AC may vary among world populations, in general, due to heredity, nutrition and fitness. So it may be a need for differing populations of the world to develop AC norms. Over several decades, a number of researchers have developed aerobic norms for a number of developed countries. However, such norms do not exist for the population of Turkey. The purpose and scope of existing studies in Turkey were to determine AC variations of specific small groups of people differentiated by age, training, region, etc. Still, some other studies considered health issues or sportive activities and the results of them are not suitable for the use in industrial work design. The need for a comprehensive AC study which includes a representative sample of the working population of Turkey still remains. This study is the first attempt to develop such comprehensive baseline values for the male population of Turkey.

3.2. Objectives of the Study

Based on the rationale, the objectives of the study are as follows:

(i) Estimating aerobic capacity of the healthy (normal) adult male population of Turkey

(ii) Investigating the effects of age, BMI and job-group on aerobic capacity; and

(iii) Comparing aerobic capacity data of the male population of Turkey with the aerobic capacity data of the male population of other world populations.

4. METHODOLOGY

4.1. Sampling

The sample of the study included 260 male volunteers from population of Turkey. Nearly all subjects were recruited from İstanbul, a metropolitan city of Turkey. İstanbul is a city whose population is composed of people from all regions of Turkey. Therefore, it is assumed that the population of İstanbul approximately represents the general population of Turkey.

A stratified sample of volunteer male subjects between the ages of 18 and 54 years are recruited for the experiment. The subjects are divided into four age groups as following (in years): (18-24), (25-34), (35-44) and (45-54). Before the experiment implementation, selection of age groups, levels, and group stratification is referred to TURKSTAT Health Survey study which is important with to be the first study that reflects the country as a whole and international and national needs allowing comparisons. (TURKSTAT, 2012) . Table 4.1 depicts the distribution of the whole Turkey male population (TURKSTAT, 2012) and defined sample sizes for each group for the experiment.

Table 4.1. Distribution of age groups of the subjects

Age Group	**Male Population of Turkey**	**Ratio (%)**	**Sample Size**	**Sample Size Ratio (%)**
18-24	6,438,117	28.3%	77	29.6%
25-34	6,492,756	28.5%	69	26.5%
35-44	5,455,669	23.9%	64	24.6%
45-54	4,397,558	19.3%	50	19.2%
Total	22,784,100	100%	260	100%

The subjects were requested to declare their family origin city, father and mother’s birthplace, and their birthplace so as to assure nearly balanced distribution among different regions of Turkey. The distribution of family origins of the subjects is shown in Table 4.2.

Table 4.2. Distribution of family origin regions of the subjects.

Regions	Number of Subjects	Ratio (%)
Marmara	56	22%
Black Sea	49	19%
Central Anatolia	34	13%
Mediterranean	33	13%
Aegean	31	12%
Southeastern Anatolia	29	11%
Eastern Anatolia	28	11%
Total	260	100%

It is known that BMI is an important factor that affects aerobic capacity according to the results of previous studies (Bradshaw *et al*., 2005; Vehrs and Fellingham, 2006; Kang e*t al*., 2007; George *et al*., 2007; Suminski *et al*., 2009; George *et al*., 2009; Nielson *et al*., 2010; Das, 2013; Prieto *et al*., 2013; Afolabi & Akanbi, 2013). Taking into consideration the BMI effect on AC, subjects were divided into four BMI groups. Literally, the body mass index (BMI) is a statistical measure of the weight of a person scaled according to height. It is defined as the individual's body weight divided by the square of their height (kg/m^2) (ACSM, 2006). The categorization was based on the formula stated below. Besides, BMI categories and the number of subjects of each category can be seen in Table 4.3.

$$BMI\ (kg / m^2) = Weight\ (kg) / Height^2\ (m^2) \quad (4.1)$$

Table 4.3. BMI categories.

Category	BMI Range (kg/m^2)	Subjects	Ratio (%)
Underweight	< 18.5	12	5%
Normal	$18.5 \leq x < 25$	113	43%
Overweight	$25 \leq x < 30$	97	37%
Obese	> 30	38	15%
Total		260	100%

A great number of subjects, approximately half of them were normal-weighted. %37 of the subjects consists of over-weighted people. Underweight was the smallest group, the number of under-weight people was only 12.

In order to investigate the occupation effect on the aerobic capacity, subjects were seperated into two job groups; manual workers and non-manual workers according to power demand levels of their jobs (ISCO-08; Crawley and *et al.*, 2009). This categorization was made by the contribution of "Regulation of Heavy and Dangerous Labors" which was published in the "Turkish Official Newspaper" on 16 June 2004. There were 100 manual workers whereas 160 of the subjects were non-manual workers in the study. The detailed classification of the groups according to occupation can be seen in detail in Table 4.4.

Table 4.4. Occupation Classification.

Manual workers (100)	**Non-manual workers (160)**
Boring & drilling machine setters (2)	Production, works & maintenance managers (2)
Grinding machine setters & setter-operators (2)	Purchasing managers (3)
Milling machine setters & setter-operators (2)	Organisation & methods & work study managers (2)
Press setters & setter-operators (2)	Computer systems & data processing managers (5)
Tool makers, tool fitters & markers-out (7)	Managers in warehousing & materials handling (2)
Metal production & maintenance fitters (7)	Hotel & accommodation managers (1)
Precision instrument makers & repairers (1)	Design & development engineers (26)
Electricians, electrical maintenance fitters (8)	Process & production engineers (14)
Cable jointers, lines repairers (6)	Planning & quality control engineers (8)
Moulders, core makers, die casters (9)	Management consultants, business analysts (10)
Sheet metal workers (7)	Architects (5)
Security guards & related occupations (4)	Psychologists (7)
Chefs, cooks (1)	Laboratory technicians (16)
Waiters, waitresses (1)	Engineering technicians (17)
Hairdressers, barbers (1)	Telephone operators (14)
Assemblers/lineworkers (14)	Undergraduate and Graduate Students (28)
Inspectors, viewers & testers (7)	
Routine laboratory testers (10)	
Forklift & mechanical truck drivers (9)	

In summary, a stratified random sampling method was employed to distribute the population into strata (age group, occupation group and seven geographical regions of

Turkey) based on family roots and birthplace. Table 4.5. shows the number of subjects categorized by age, occupation groups and BMI.

Table 4.5. The number of subjects categorized by age, job groups and BMI.

Occupation Group	BMI Category	Age Group				Total
		18-24	25-34	35-44	45-54	
Manual	Under-weight	2	2	1	1	6
	Normal-weight	11	19	13	5	48
	Over-weight	6	10	12	6	34
	Obese	3	2	5	2	12
	Subtotal	**22**	**33**	**31**	**14**	**100**
Non-Manual	Under-weight	1	1	2	2	6
	Normal-weight	26	18	13	8	65
	Over-weight	22	12	13	8	63
	Obese	8	5	5	8	26
	Subtotal	**55**	**36**	**33**	**36**	**160**
Total		**77**	**69**	**64**	**50**	**260**

In this study, smoking, exercise, and alcohol consumption data of the subjects were also collected. The subjects are asked about their physical activity. The subjects run about 1 mile per week or walk about 1.3 miles per week or spend about 30 minutes per week in comparable physical activity or doing more are classified as having “Regular” physical activity and the remaining subjects are clustered as “Irregular or No”. The classification is made by the experiment instructor during collecting the personal data forms according to NASA Physical Activity Scale Survey (PASS). The smoking level is determined based on the smoking habit of subjects that are varying in numbers of cigarettes smoked per day and years of smoking. In detail, if a subject never smoked before or smoked more than 100 cigarettes in a lifetime is classified as “Non or Ex-Smoker” and the remaining subjects who are smoking regularly are clustered in “Smoker” group. Lastly, subjects who do not consume or who consume 3-4 drinks per day or 14 and less per week are included in the “Non-Drinking” group and remaining subjects are listed in the “Drinking” group. Table 4.6 illustrates the distribution of subjects based on smoking habit, alcohol consumption, and physical activity.

Table 4.6. The number of subjects categorized by smoking habit, alcohol consumption, and physical activity.

Smoking Habit	**Alcohol Consumption**	**Physical Activity**		**Total**
		Irregular or no	**Regular**	
Non or ex-smoker	Drinker	41	8	49
	Non-Drinker	62	10	72
	Subtotal	**103**	**18**	**121**
Smoker	Drinker	5	0	5
	Non-Drinker	105	29	134
	Subtotal	**110**	**29**	**139**
Total		**213**	**47**	**260**

4.2. Equipment

In this part of the study, the information about the tools used in the aerobic capacity experiments and anthropometric measurements are provided.

4.2.1. Monark 839 E Cycle Ergometer

Cycle ergometer is a fixed cycling machine used in physical performance testing in order to estimate the power output from the resistance to pedaling, which can be adjusted to vary the intensity. In the experiments of this study, the submaximal AC tests are conducted by Monark 839 E cycle ergometer. It is one of the world's most accurate cycle ergometers and computerized with a removable control unit and programmed with Astrand, Bruce, Naughton, protocols. Heart rate is monitored with chest belt of telemetry type. Figure 4.1 shows the cycle ergometer used in this study.

Figure 4.1. Monark 839 E Cycle Ergometer.

The computer system consists of one main unit and one terminal. The main unit reads in the pedal speed, the applied force and determines the subjects heart rate by a chest transmitter. Additionally, the base controller activates motor to adjust the tension of the belt, thereby regulating the applied braking force. The force may be automatically varied in response to changes in pedal speed to maintain a constant power workload. The computer features of the ergometry are as follows:

- Computer system 8MHz
- Backlit display
- Multi-colour RPM pacing bar graph display
- Visual metronome or heart rate
- Heart rate maximum limit alarm
- Preprogrammed protocols: Astrand, YMCA, Bruce, Naughton
- HR-training

4.2.2. The calibration check of Cycle Ergometer

Since Monark 839 E is a mechanically weighted and braked ergometer, making performance validation is a simple procedure. The work performed on the ergometer is the product of the weight lifted times the number of revolutions. Validations included both mechanical and electronic procedures. Calibration is regularly performed according to the procedures described in Monark 839 E cycle ergometer Manual. Basically, it consists of: (Figure 4.2)

- Removing the cover from the flywheel.
- Loosen the brake belt at the balancing spring.
- Waiting until the flywheel is not moving any longer.
- The pendulum weight index should be aligned with "0" on the scale.
- Attaching the calibration weight to the point at which the spring was attached.
- The known weight should match the value on the scale.
- Reattaching the tension belt.
- Reassembling the cover.

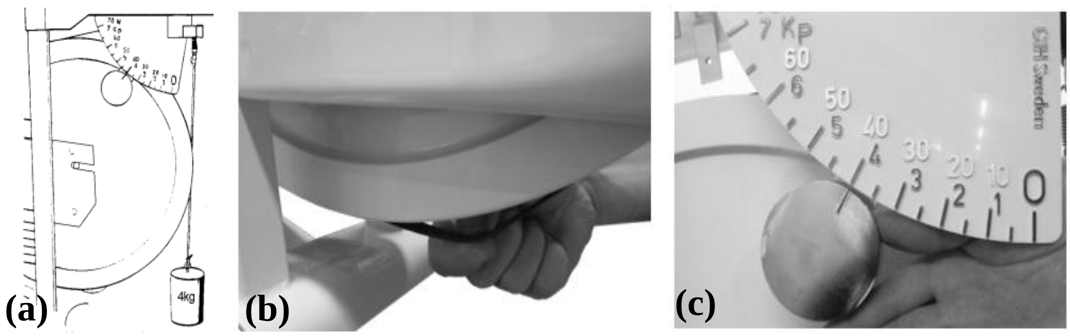

Figure 4.2. Calibration check of Monark 839 E Cycle Ergometer. (a) Calibration Weight (b) Control loose brake belt (c) 4kp position

4.2.3. Polar T-31 Heart Rate Monitor

During the AC measurements, heart rates of the subjects are measured by the Polar T-31 heart rate monitor and transmitted to the computer in order to adjust work rate of the subjects according to the HR and lastly to estimate AC from measured maximal HR values. This wireless heart rate monitor used in the experiments can be shown in Figure 4.3.

Figure 4.3. Polar T-31 HR Monitor

4.3. Testing Procedure

People of different age and job groups were recruited for the aerobic capacity measurement experiments. Subjects were introduced to drink plenty of water and avoid vigorous exercise on the day of testing and to avoid large meals, caffeine, alcohol, and tobacco products within at least three hours of their appointment (ACSM, 2006). They were also introduced to dress in lightweight clothing and comfortable exercise shoes, and to avoid any fatiguing exercise on the day of the test. Prior to experiments, all the candidate subjects filled “Medical History Form” and the ones who were free from diseases such as musculoskeletal or cardiovascular disorders according to predefined guidelines of American College of Sports Medicine were accepted to participate in the study (ACSM, 2006). The participants then signed the “Personal Consent Form”, which includes a detailed description of the aim and procedures of the study, to show that he was voluntarily participating in the study. The “Personal Consent Form” and “Medical History Form” were prepared both in English and Turkish (Appendix B). All the subjects filled the Turkish version of the forms. Before performing the tests, the subjects filled also “Personal Data Form” (Appendix B), that provided information including birth date, birthplace, occupation, family origin, and mother and father’s birthplace. Afterwards, the subjects were introduced with the testing equipment and test procedures before the test is done for real. All tests were to be conducted in a quiet, private environment maintained at normal room temperature (22-24° C).

4.3.1. Anthropometric measurements

The height (cm) and body mass (kg) of each person (wearing no shoes) were measured using a stadiometer and weighing scale.

(i) *Measurement of Height:* Stature (body height) was measured by wall-mounted meter while the subject stood fully erect with feet together and the head was oriented in the Frankfurt plane (ISO 7250).

(ii) *Measurement of Weight:* In order to measure weight a mechanical scale was used. This mechanical scale had been checked for accuracy with known weights before the tests. The subjects wore light clothes and did not wear any accessories which cause extra weight. In addition, the participant was not very hungry or full.

4.3.2. Heart rate measurements

After collection of the anthropometric data the subjects, each participant was fitted with an HR monitor to measure HR during the submaximal cycle ergometer protocol. The HR monitor was placed around the chest and over the heart, and it was checked if the pulse signal was being picked up by the computer. After having a 20 min rest, resting HR values of the subjects were measured and age predicted HR_{max} values were calculated using the common (220-age) formula. HR was continuously being recorded during the experiments.

4.3.3. Submaximal Cycle Ergometer Test

(i) *Preparation for the test:* The seat of the bike was adjusted as the knee of the subjects was not fully stretched but a little bent. The subjects were asked if they were comfortable and begin cycling. The workload that the subjects had to begin with, was entered and subjects practiced cycling in predefined pedal rate of 60 rotations per minute (RPM).

(ii) *Test protocol:* Since submaximal testing is commonly used in practical settings and across different subject groups, and does not require medically qualified staff, the estimation of VO_{2max} was held during submaximal cycle ergometer tests. During the submaximal test, following a structured protocol is very important to get accurate results. The Astrand Bike Test (also known as the Astrand-Rhyming test) was applied to the subjects since it is the most recognized way of submaximal cycle ergometer testing and the validity of it proved by previous studies. Astrand and Rhyming (1954) recommended that (a) the exercise load imposed on a given individual should be high enough to elicit a heart rate response in excess of 125 bpm while not exceeding about 150 bpm, (b) the exercise should be limited in six minutes in duration, (c) the steady-state heart rate achieved during the last minutes of exercise should be used in entering the nomogram for estimating VO_{2max}. The protocol defines nine workloads at which the subject may be evaluated. The workloads for male subjects span 300 kpm/min to 1500 kpm/min in 150 kpm/min steps. The workloads for males cover 300 kpm/min to 900 kpm/min in 75 kpm/min steps. In order to eliminate the trial and error exercise of the workload selection Myhre *et al.* (1998) developed a procedure that allowed early selection of the most appropriate test workload based on the rate of rise during first 3 minute of exercise. Subscribing to well-established principles describing normal heart rate responses to exercise, this protocol establishes most appropriate workload early in the test and then maintains that workload for six minutes to assure that the heart rate reached a steady state. In the experiments of this study, workload selection part of the Astrand Bike test was conducted according to this protocol. The methodology used in the current study regarding Astrand Rhyming Test (1954) as suggested by Myhre *et al.* (1998) is basically described below:

- *Step 1:* Initial workload is selected according to the subject's age and weight. Table 4.7 shows initial workload selection criteria. For instance, a 25 years old male subject whose weight is above 78 kg is exposed to 600 kpm/min initial workload.

Table 4.7. Initial workload selection criteria (Myhre *et al.*, 1998).

		Initial workload (kpm/min)	
Subject Weight (Ibs)	**Subject Weight (kg)**	**18 to 35 yrs.**	**36 to 55 yrs.**
<100	<45	300	300
100-140	45-64	450	450
141-170	65-77	600	600
>170	>78	600	600

- *Step 2:* The workload of the test is adjusted according to the subject's age and HR at the end of the 1st minute. Table 4.8 shows workload adjustment criteria at the end of the 1st minute. Continuing with male subject mentioned in Step 1, if his HR value is between 105-114 bpm at the end of 1st minute of the test, workload is increased by 150 kpm/min from 600 kpm/min to 750 kpm/min.

Table 4.8. The workload (kpm/min) adjustments at the end of the 1st minute (Myhre *et al.*, 1998).

18 to 29 yrs.		**30 to 39 yrs.**		**40 to 49 yrs.**		**50 to 62 yrs.**	
HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)
<105	300	<100	300	<95	300	<90	300
105-114	+150	100-109	+150	95-104	+150	90-99	+150
115-130	0	110-125	0	105-125	0	100-120	0
131-150	-150	126-145	-150	126-140	-150	121-135	-150
>150	**Stop test**	**>145**	**Stop test**	**>140**	**Stop test**	**>135**	**Stop test**

- *Step 3:* The workload of the test is adjusted according to the subject's age and HR at the end of the 2nd minute. Table 4.9 shows workload adjustment criteria at the end of the 2nd minute. If HR value of the selected subject mentioned in Step 1 and Step 2 is between 120-135 bpm, workload is sustained with existing workload that is 750 kpm/min.

Table 4.9. The workload (kpm/min) adjustments at the end of the 2nd minute (Myhre *et al.*, 1998).

18 to 29 yrs.		**30 to 39 yrs.**		**40 to 49 yrs.**		**50 to 62 yrs.**	
HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)
<110	300	<105	300	<100	300	<100	300
110-119	+150	105-114	+150	100-109	+150	100-109	+150
120-135	0	115-130	0	110-130	0	110-130	0
136-155	-150	131-150	-150	131-145	-150	131-140	-150
>155	**Stop test**	**>150**	**Stop test**	**>145**	**Stop test**	**>140**	**Stop test**

- *Step 4:* The workload of the test is adjusted according to the subject's age and HR at the end of the 3rd minute in order to reach a steady state heart rate. Table 4.10 shows workload adjustment criteria at the end of the 3rd minute. If HR value of the selected subject is between 146-155 bpm, the workload is decreased by 150 kpm/min from 750 kpm/min to 600 kpm/min which is the steady-state heart rate level for related subject.

Table 4.10. The workload (kpm/min) adjustments at the end of the 3rd minute (Myhre *et al.*, 1998)

18 to 29 yrs.		**30 to 39 yrs.**		**40 to 49 yrs.**		**50 to 62 yrs.**	
HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)	HR (bpm)	WL (kpm/min)
<120	300	<110	300	<110	300	<105	300
120-129	+150	110-124	+150	110-119	+150	105-117	+150
130-145	0	125-140	0	120-135	0	118-130	0
146-155	-150	141-150	-150	136-145	-150	131-145	-150
>155	**Stop test**	**>150**	**Stop test**	**>145**	**Stop test**	**>145**	**Stop test**

- *Step 5:* The subject is observed throughout the rest of the test (remaining 3 minutes) for any indications such as exhaustion in legs or related body muscles, and any outstanding increase in steady-state HR that leads to exceeding %85 of age-predicted maximum HR. If there is no indication then subjects are motivated to perform the test at a given workload and reach the end of the test. Otherwise, test is failed. (Figure 4.4)
- *Step 6:* The heart rate is recorded at the end of the fifth minute. If, by the end of the next minute (6th minute) the heart rate is within 4 bpm of the previous observation (at the 5th minute), the protocol is finished. If not, the test continues until the pulse rate is within 4 beats for one minute or more.
- *Step 7:* The accepted HR, test workload and $\%HR_{max}$ data are recorded.
    - Accepted HR is the stabilized HR value at the end of the test.
    - Test workload is the work rate that subject finished the test.
    - $\%HR_{max}$ is the ratio of accepted HR to theoretical age-predicted maximum HR (220-age).
- *Step 8:* The subject is asked to continue to cycle, at a lower intensity with workload lower than 300 kpm/min until recovery HR is lower than 120 bpm and stopping the test. The purpose of this is to bring the subject in resting condition slowly and safely.
- *Step 9:* VO_{2max} value obtained from the computer report of test is recorded. (Figure 4.5 and Figure 4.6) That is making calculations based on Astrand nomogram (Appendix A) and age correction factor (Table 4.11). For example at the end of the Step 7, Accepted HR is found as 152 bpm and test workload is as 900 kpm/min.

Then, using the Astrand nomogram (Appendix A) and the correction factor (Table 4.11), we can estimate the subject’s VO_{2max} as follows;

$VO_{2max} \approx 3.1$ l/min (from the nomogram for 152 bpm and 900 kpm/min)

Assuming the subject is 25 years old, the age correction factor is found as 1.

$VO_{2max} = 3.1$ l/min x 1 = 3.1 l/min

Flow chart of the experimental procedure is also illustrated in detail in Figure 4.8.

Table 4.11. Age correction factor of Astrand Protocol.

Maximum HR (220-age)	**Age (in yrs.)**	**Correction factor**
Over 200	<20	1.12
191-200	20-29	1.00
181-190	30-39	0.93
171-180	40-49	0.83
161-170	50-59	0.75
151-160	60-69	0.69
Less than 151	>69	0.64

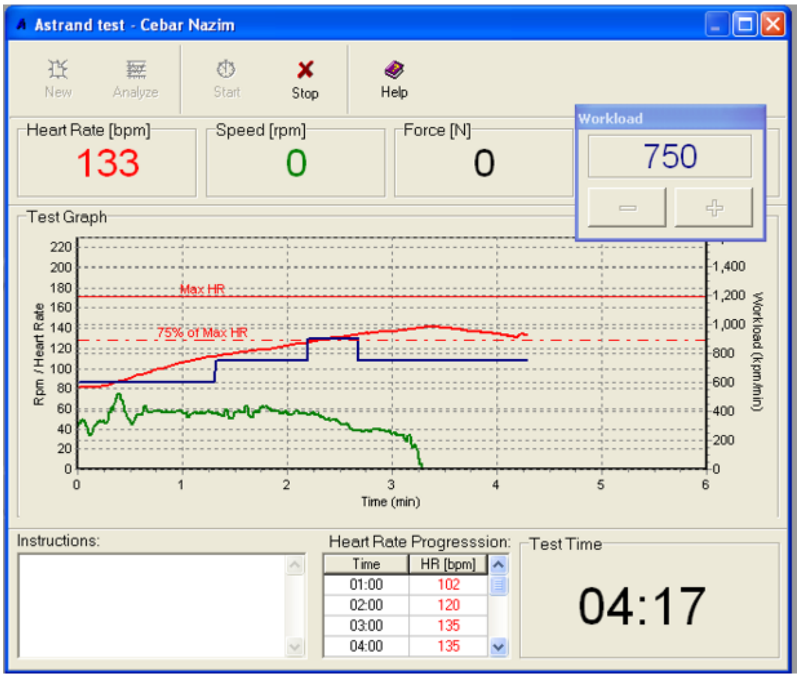

Figure 4.4. Failed Test Example in Monark 839 E with modified protocol in study.

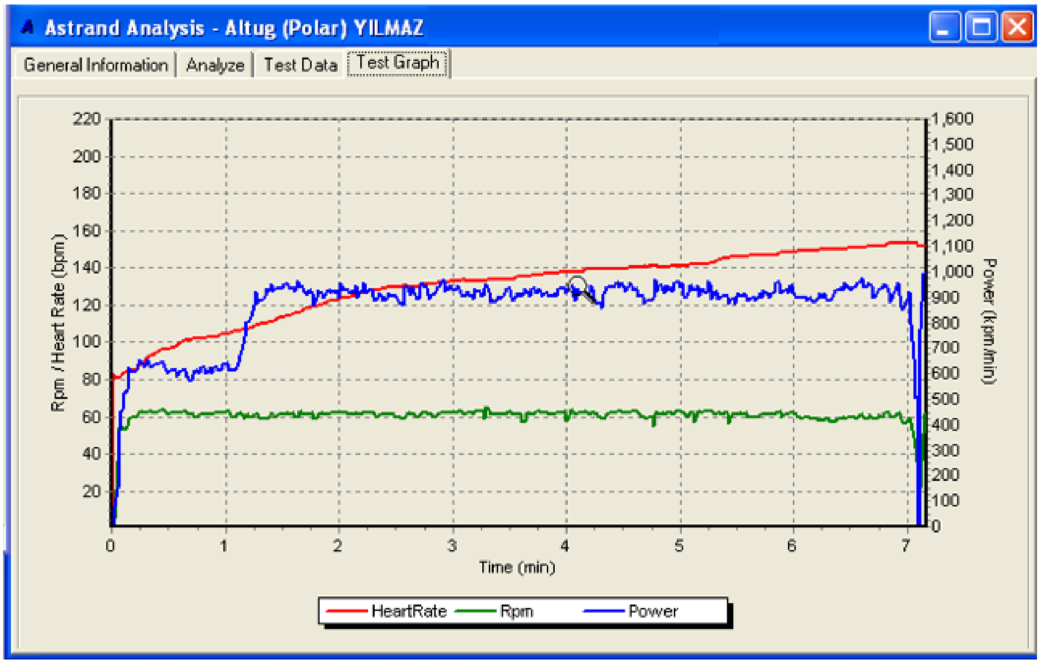

Figure 4.5. Successful Test Example in Monark 839 E with modified protocol in study.

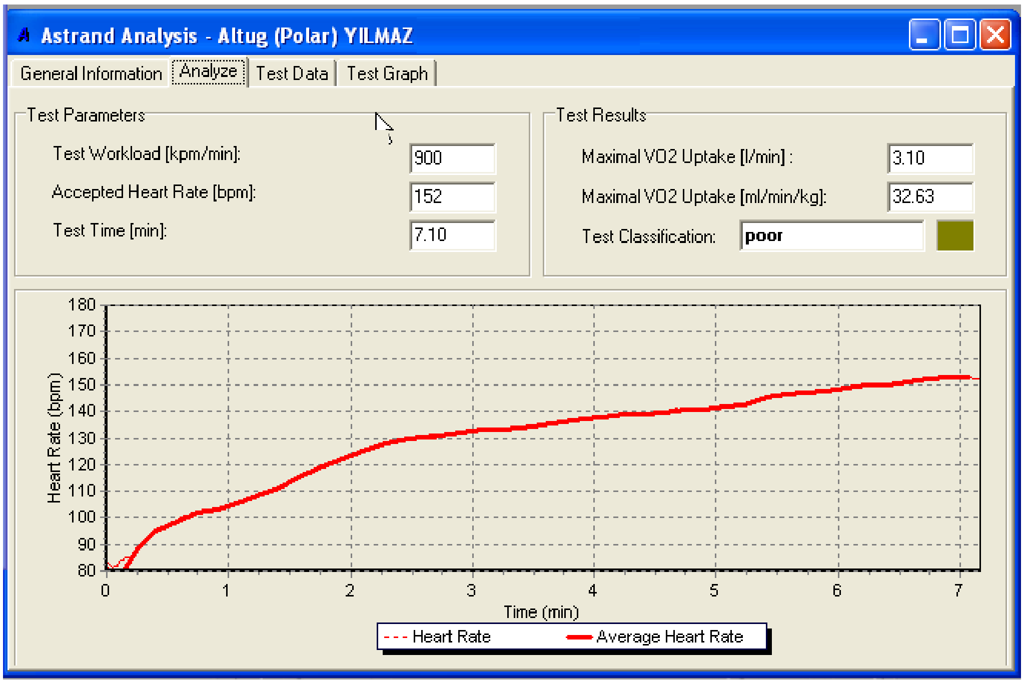

Figure 4.6. Results of Successful Test Example in Monark 839 E with modified protocol in study.

Figure 4.7. A Test Example in Monark 839 E with a subject.

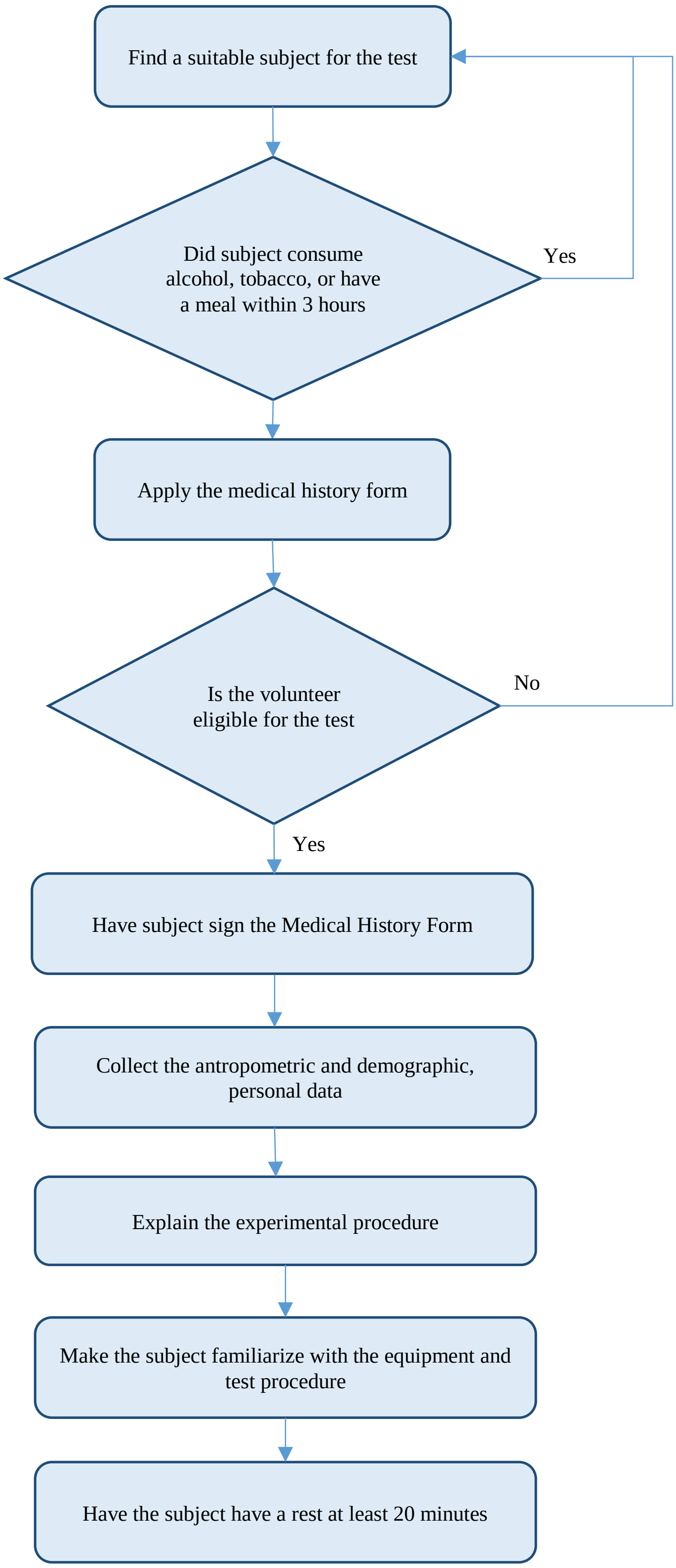

Figure 4.8. Flow chart of the experimental procedure.

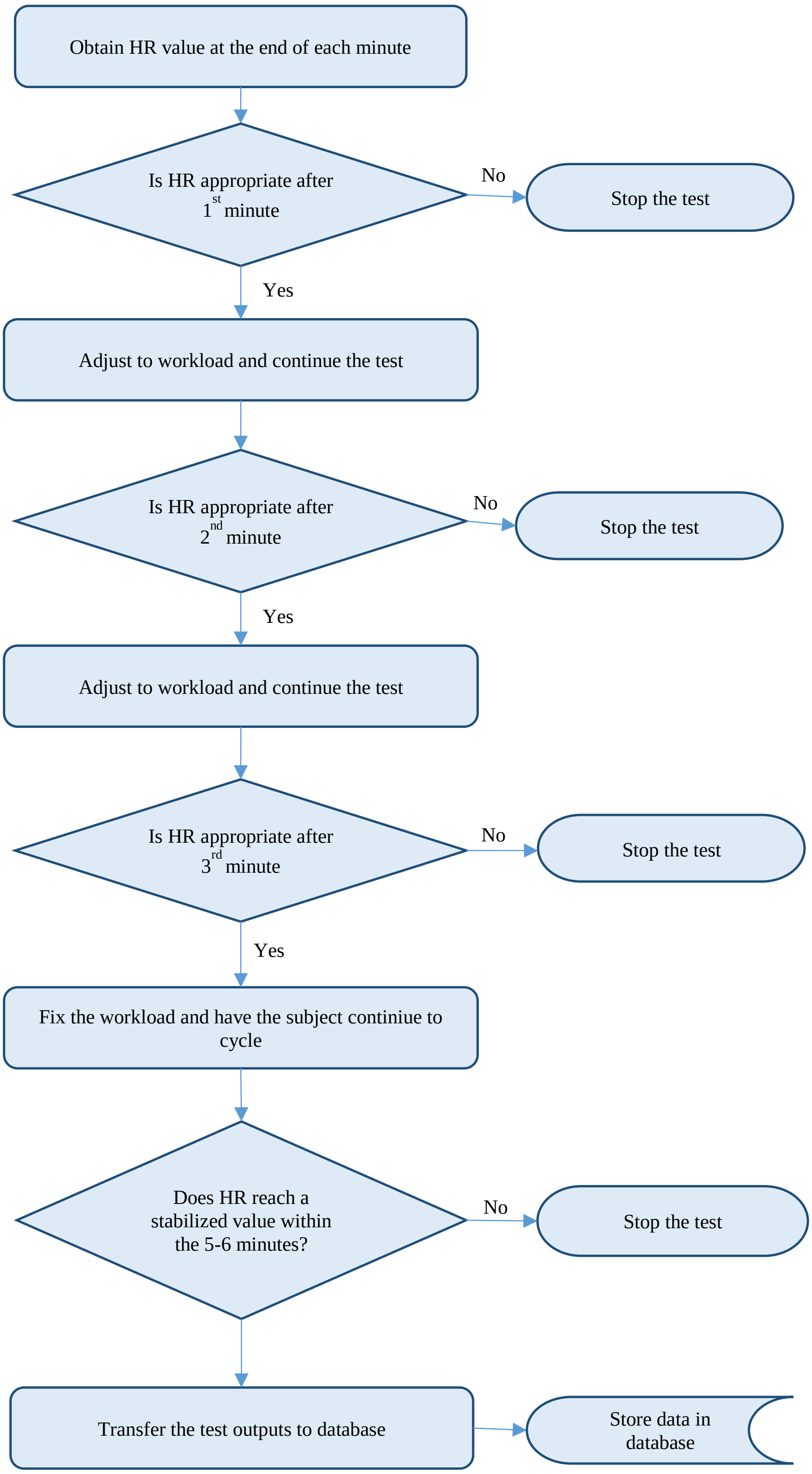

Figure 4.8. Flow chart of the experimental procedure (cont.)

4.4. Experimental Design and Statistical Analysis

4.4.1. Experimental Variables

The dependent (response) variables for the current study are absolute aerobic capacity (VO_{2max} in l/min) and relative aerobic capacity (VO_{2max} in ml/kg/min). There are six design factors (independent variables) in this study. These factors are age group, body mass index (BMI) group, occupation group, exercise group, smoking group, alcohol consumption group of the subjects. Levels of the factors can be seen in Table 4.12.

Table 4.12. Design factors and levels of these factors.

Design Factors	Number of Levels	Levels
Age Group	4	(1) 18-24 yrs (2) 25-34 yrs (3) 35-44 yrs (4) 45-54 yrs
BMI Group	4	(1) Under-weight (2) Normal -weight (3) Over-weight (4) Obese
Occupation Group	2	(1) Manual worker (2) Non-manual worker
Exercise Group	2	(1) Regular (2) Irregular or no
Smoking Group	2	(1) Smoker (2) Non or ex-smoker
Alcohol Consumption Group	2	(1) Drinking (2) Non-drinking

4.4.2. Experimental Model

Completely randomized design (CRD) with multi factors was conducted in the study where subjects were randomly selected including different levels in each factor group. CRD is an experimental design where observations are taken in random order and that the environment (often called the experimental units) in which the treatments are used is as uniform as possible. An ANOVA was conducted so as to determine the factor effects on aerobic capacity. In the ANOVA analysis, the interactions between independent variables were also investigated.

Therefore, the model for complete randomized design was determined as following:

$$y_{ijklmn} = \mu + a_i + b_j + c_k + d_l + e_m + f_n + (ab)_{ij} + \cdots + (ef)_{mn} + \varepsilon_{ijklmn} \quad (4.2)$$

where,

y_{ijklmn}	: $ijklmn^{th}$ response (VO_{2max} in l/min and ml/kg/min)
μ	: The overall response mean
a_i	: Effect of i^{th} level of age group factor
b_j	: Effect of j^{th} level of body mass index (BMI) group factor
c_k	: Effect of k^{th} level of occupation group factor
d_l	: Effect of l^{th} level of exercise group factor
e_m	: Effect of m^{th} level of smoking group factor
f_n	: Effect of n^{th} level of alcohol consumption factor
$(ab)_{ij}$	: Effect of ij^{th} level of age and body mass index interaction factor
⋮	⋮
$(ef)_{mn}$	: Effect of mn^{th} level of smoking and alcohol consumption interaction factor
ε_{ijklmn}	: Random error component NID $(0,\sigma^2)$

for

$i = 1, 2, 3,4$	(1: 18-24 years)
	(2: 25-34 years)
	(3: 35-44 years)
	(4: 45-54 years)
$j = 1, 2, 3,4$	(1: Under-weight)
	(2: Normal -weight)
	(3: Over-weight)
	(4: Obese)

$k = 1, 2$ (1: Manual worker)
(2: Non-manual worker)

$l = 1, 2$ (1: Regular)
(2: Irregular or no)

$m = 1, 2$ (1: Smoker)
(2: Non- or ex-smoker)

$n = 1, 2$ (1: Drinking)
(2: Non-drinking)

The hypotheses of interest are:

$H_0: \mu_1 = \mu_2 = \ldots\ldots = \mu_{256}$
H_1 *: At least one* μ_{ijklmn} *is dif.*

4.4.3. Pilot Study

In the current study, VO_{2max} was the main response and it was expressed in absolute (l/min) and relative (ml/kg/min) forms. Prior to main experiments, a pilot study with randomly selected 56 male subjects (7 subjects from each age-occupation category) was conducted in order to:

(i) To have subjects adapt to the equipment and experimental procedures,
(ii) To gather the statistical parameter values (mean, standard deviation) that are required to conclude the necessary minimum sample size for the experiment.

The results of the pilot study can be seen in Table 4.13.

Table 4.13. Sample Statistics.

Responses	$\bar{x}$	SD	CV
VO_{2max} (l/min)	2.5	0.4	14.4
VO_{2max} (ml/kg/min)	32.6	7.1	21.6

4.4.4. Sample Size Determination

Sample size refers to the number of participants or observations included in a study. The size of a sample influences two statistical properties: i) the precision of estimates and ii) the power of the study to draw conclusions. In this study, the goal was to make an inference regarding aerobic capacity values about male population of Turkey by studying a sample of that population. Therefore, that sample has to be representative of the target population, and the number of subjects must be appropriate. It should be large enough for the probability of finding differences between groups accurately, whereas a very large sample size is also not recommended since it is a waste of time when an answer can be accurately found from a smaller sample. (Montgomery and Runger, 2011).

Sample size calculation formula for normative data studies is given in the ISO standards for establishing anthropometric databases as the following (ISO 15535:2006):

$$N = \left(\frac{1.96 \times CV}{a}\right)^2 \times 1.534^2 \tag{4.3}$$

where 1.96 is the critical Z value from a standard normal distribution for a 95% confidence interval, CV is the coefficient of variation, a is the percentage of relative accuracy desired (CI is to be no larger than ± some percentage of the mean).

CV is defined as the following:

$$CV = \frac{SD}{\bar{x}} \times 100 \tag{4.4}$$

where, $\bar{x}$ is the sample mean and SD is the sample standard deviation.

In the study, since true mean and standard deviation of the population are unknown, these values are estimated by using the results of the pilot study. Relative accuracy is decided to be at least 5%. Therefore, sample size for males for 95%CI is calculated as :

$$N = \left(\frac{1.96 \times CV}{5}\right)^2 \times 1.534^2 \tag{4.5}$$

In the study, there was only one response in two different expressions subject to same experiments. Aerobic capacity (VO_{2max}) was expressed either as an absolute rate in liters of oxygen per minute (l/min) or as a relative rate in milliliters of oxygen per kilogram of body mass per minute (ml/kg/min). Since CV values of aerobic capacity varies for each type of expressions, the calculation of required minimum sample sizes vary accordingly. The largest of the calculated sample size, which is related to absolute maximal aerobic capacity is taken as the minimum required sample size. This is at least 170 subjects are needed for conduct a reliable statistical analysis.

As can be seen in Table 4.14 by obtaining aerobic capacity of 170 male subjects, it can be assured that the required levels of relative accuracy and confidence are accomplished for all the variables. However, in order to improve power of test, the total 256 subjects were recruited for the study.

Table 4.14. Minimum sample size for 95 % confidence and 5 % relative accuracy.

VO_{2max} (l/min)	$N = \left(\frac{1.96 \times 14.4}{5}\right)^2 \times 1.534^2 = 74.94 \approx 75$
VO_{2max} (ml/kg/min)	$N = \left(\frac{1.96 \times 21.6}{5}\right)^2 \times 1.534^2 = 169.2 \approx 170$

4.4.5. Repeatability Study

When running experiments, accuracy is the topic that is most often discussed. But in fact, there is something equally important which is repeatability. There are many factors that come into play that affect the ability to repeat experiments including equipments out of calibration, inadequate methods of data collection. Therefore, 32 subjects from different age and job groups performed the aerobic capacity once more at least a week later from the first trail to examine the repeatability of the measurements. For repeatability test, it was investigated whether the means of first and second are equal to each other or not. The result of the t-test indicated that the difference between the means of first and second trails does not differ significantly from each other (Table 4.15).

Table 4.15. Result of t-test for repeatability study.

	N	Mean	St Dev.	SE Mean	T-value	P-value
1. Trails	32	2.43	0.36	0.06	-1.45	0.158
2. Trails	32	2.49	0.46	0.08		
Difference	32	-0.06	0.14	0.02		

The hypothesis was: H_0: Difference = 0, H_1: Difference $\neq$ 0

Since the p value is greater than 0.05, the null hypothesis was not rejected. This result confirmed that there is no significant difference between the means of two trails.

4.4.6. Statistical Analysis Methods and Assumptions

Minitab 17.0 was employed for statistical analysis. For hypothesis testing and all statistical analysis, α significance level were accepted as significant and $0.05 < \text{p-values} \leq 0.1$ were accepted as marginal. For descriptive statistics: mean, standard deviation, range, confidence intervals, percentages and correlation coefficients were calculated. For inferential statistics: Analysis of variance (ANOVA) and second degree polynomial multiple regression were used to investigate the effects of age, BMI (or height and weight), job . Also the effects of exercise or fitness level, alcohol consumption and smoking factors on aerobic capacity are investigated. However, in order to employ ANOVA and regression, the following three assumptions must be satisfied:

4.4.6.1. ANOVA Assumptions. Three assumptions should be checked and verified.

(i) *Normality assumption:* The errors must (to a reasonable approximation) be independently and identically distributed according to a normal distribution with mean zero and unknown but fixed variance σ^2. Normality assumptions should be checked by diagnostic plot of the residuals, which are the differences between the observations. Checking of normality can be made by plotting a histogram of the residuals. The plots are meant to diagnose any major discrepancies between the assumptions and reality in the situation being studied. A normal probability plot (or equivalent, such as a dot diagram or stem-and-leaf display) of all the residuals should look like a sample from a normal distribution centered at zero. If normality is not reasonably symmetrical and consistent with a normal distribution, some change of variable should be considered. If normality plot shows one or more outliers, the corresponding numbers should be checked to see if some obvious mistake (such as an error of recording an observation) is present. However, in the absence of any obvious error the outlier should not be discarded, although the assumption of an underlying normal distribution should be questioned. Careful examination of remaining outliers will often give useful information, clues to desirable changes to the assumed relationship (Montgomery and Runger, 2011). Additionally, in order to assure normality assumption quantitatively, Anderson Darling normality test should be used. The hypotheses for the Anderson Darling test are:

$$\begin{aligned} &H_0 : \textit{The data follow normal distribution} \\ &H_1 : \textit{The data do not follow normal distribution} \end{aligned} \tag{4.6}$$

If the p-value for the Anderson Darling test is lower than the significance level (0.05), it is concluded that the data do not follow the normal distribution. Normality of the residuals of aerobic capacity data of male subjects was tested by using Anderson-Darling normality test. With p value greater than 0.05 normal probability plot of the residuals for males is found following approximately normal distribution (Appendix D).

(ii) *Equal variances assumption:* To check the assumption of equal variances at each factor level, plotting the residuals against the factor levels and compare the spread in the residuals is essential. It is also useful to plot the residuals against the fitted values of the model; the variability in the residuals should not depend in any way on the fitted values. When a pattern appears in these plots, it usually suggested that the need for a transformation, that is, analyzing the data in a different metric. Additionally, Bartlett’s test was used to check whether the variances were statistically equal or not. According to the plots and the result of Bartlett's test this assumption is also satisfied. (Appendix D).

(iii) *Independence assumption:* The independence assumption can be checked by plotting the residuals against the time or run order in which the experiment was performed. A pattern in this plot, such as sequences of positive and negative residuals, may indicate that the observations are not independent (Montgomery, 2009). The plot of the residuals versus observation order for males is investigated to determine whether there is any correlation between residuals. According to the plots, there is no correlation between residuals.

Since the three assumptions of ANOVA are approximately achieved, it was assured that model can be employed to examine whether the independent variables have an effect on aerobic capacity of males.

4.4.6.2. Multiple Comparisons. When there are more than two groups in an experiment, it is inappropriate to simply compare each pair using a t-test because of the problem of multiple testing. The correct way to do the analysis is to use analysis of variance (ANOVA) to evaluate whether there is any evidence that the means of the populations differ. If the ANOVA leads to a conclusion that there is evidence that the group means differ, then it is needed to be interested in investigating which of the means are different. This is where the Tukey multiple comparison test is used. The test compares the difference between each pair of means with appropriate adjustment for the multiple testing. To extend, Tukey's test is used in ANOVA to create confidence intervals for all pairwise differences between factor level means while controlling the family error rate to a level that is specified. It is important to consider the family error rate when making multiple comparisons because chances of making a type I error for a series of comparisons is greater than the error rate for any one comparison alone. To counter this higher error rate, Tukey's method adjusts the confidence level for each individual interval so that the resulting simultaneous confidence level is equal to the value that is specified (Tukey, 1970). Additionally, Tukey's test was designed for a situation with equal sample sizes per group, but can be adapted to unequal sample sizes as well. In brief, procedure of Tukey' test accurately maintains alpha levels at their intended values as long as statistical model assumptions are met (i.e., normality, homogeneity, independence). Then, since ANOVA model in the current study did not violate any model assumptions and it had unequal sample sizes, Tukey's test was appropriate to be used for post-hoc analysis.

The hypotheses of this test are (Montgomery, 2009):

$$H_0: \mu_i = \mu_j$$
$$H_1: \mu_i \neq \mu_j \qquad (4.7)$$

where i and j are treatment levels ($i \neq j$). Tukey's procedure makes use of the distribution of the studentized range statistic which is equal to (Montgomery, 2009):

$$q = \frac{\bar{y}_{max} - \bar{y}_{min}}{\sqrt{MS_E/n}} \qquad (4.8)$$

where $\bar{y}_{max}$ and $\bar{y}_{min}$ are the largest and the smallest sample means, MS_E is mean squares due to error and n is the sample size. Due to q value, T value of Tukey's test for unequal sample sizes can be calculated as (Montgomery, 2009):

$$T_\alpha = \frac{q_\alpha(a,f)}{\sqrt{2}} \sqrt{MS_E\left(\frac{1}{n_i} + \frac{1}{n_j}\right)} \qquad (4.9)$$

where $q_\alpha(a,f)$ is the upper α percentage points of studentized range statistics (q), f is the number of degrees of freedom associated with the MS_E, α is the number of groups will be compared, n_i and n_j are the sample sizes of the groups.

Apart from multiple comparisons in Anova, to make comparisons between the results of the current study and the results of the studies done before, two sample t-test was also employed.

<u>4.4.6.3. Regression Analysis and Model Adequacy Checking.</u> After the ANOVA and multiple comparison tests, multiple linear regression analysis was also conducted to develop prediction equations for aerobic capacity of males. In the ANOVA analysis, the interactions between independent variables were found significant, however contribution of interaction

effects on R^2_{adj} was relatively low. The R^2_{adj} statistic essentially penalizes the analyst for adding terms to the model. It is an easy way to guard against overfitting, that is, including regressors that are not really useful. Because of that, a no-interaction multiple linear regression model was determined as a suitable model for the analysis. Additionally, quadratic terms are also investigated in regression analysis. Stepwise approach was adopted for model selection. The procedure iteratively constructs a sequence of regression models by adding or removing variables at each step. For each step, 0.05 was selected for the level of significance. Moreover, Best Subsets approach was used as a second check of the model developed by stepwise regression. In the Best subsets approach, it gives many different alternative sub-models with Mallow's Cp statistics to compare them. It is usually recommended using the minimum S and Cp evaluation criteria in conjunction with this procedure. Models that are more complex in structure like Equation 4.10 (i.e considering the second degree polynomial in two regressor variables.) may often still be analyzed by multiple linear regression techniques. Polynomial regression models are widely used when the response is curvilinear, because the general principles of multiple regression can be applied. In general, any regression model that is linear in parameters (the β's) is a linear regression model, regardless of the shape of the surface that it generates (Montgomery and Runger, 2011).

The general form of the multiple regression equation with no interaction effect is as the following:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_3^2 + \beta_5 x_4 + \beta_6 x_4^2 + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3 + \gamma_4 D_4 + \gamma_5 D_5 + \varepsilon \quad (4.10)$$

where, y is the response (aerobic capacity), β_0 is constant, $\beta_1, \ldots, \beta_6, \gamma_1, \ldots \gamma_5$ are the regression coefficients for independent variables, $x_1, x_2, \ldots$, are the regression variables, $D_1, \ldots D_5$ are dummy variables, and ε is the error term (normally and independently distributed, $\approx$NID $(0,\sigma^2)$). The usual method of accounting for the different levels of a qualitative, or categorical, variable is to use indicator variables. Indicator variables are also referred to as dummy variables (Montgomery and Runger, 2011).

The final model obtained from any model-building procedure should be subjected to the usual adequacy checks (Montgomery, 2009). Normality, equal variances and autocorrelation assumptions, which are discussed and mentioned in Anova assumptions section, are also valid for regression models. Apart from these assumptions, other model diagnostics like multicollinearity should also be checked for model validity and reliability. In most regression problems there may be dependencies among the regressor variables. In situations where these dependencies are strong, it may be concluded that multicollinearity exists. Multicollinearity can have serious effects on the estimates of the regression coefficients and on the general applicability of the estimated model. The presence of multicollinearity can be detected in several ways. The variance inflation factors (VIF), are very useful measures of multicollinearity. The larger the variance inflation factor, the more severe the multicollinearity. It is suggested that VIF should not exceed 4 or 5 (Montgomery and Runger, 2011).

After regression models were concluded, to check the goodness of model a test for significance of regression was examined. The test for significance of regression is a test to determine whether a linear relationship exists between the response variable and a subset of the regressor variables. The appropriate hypotheses are:

$$\begin{aligned} &H_0: \beta_1 = \beta_2 = \cdots = \beta_n = 0 \\ &H_1: \beta_j \neq 0 \; for\; at\; least\; one\; j \; (j = 1, \ldots, n) \end{aligned} \tag{4.11}$$

Rejection of H_0 in Equation 4.11 implies that at least one of the regressor variable contributes significantly to the model. Additionally, just as in Anova for CRD, R^2 is a measure of the amount of reduction in the variability of responses obtained by using the regressor variables in the model. However, a large value of R^2 does not necessarily imply that the regression model is a good one. Adding a variable to the model will always increase R^2, regardless of whether the additional variable is statistically significant or not. Because R^2 always increase as terms are added to the model, adjusted R^2 is preferred to be used. In general the R^2_{adj} will not always increase as variables are added to the model. In fact, if unnecessary terms are added, the value of R^2_{adj} will often decrease. Therefore, for best regression model selection not only significance of regressor variables tested, but also higher R^2_{adj} and smaller Cp and S are tried to be satisfied.

5. RESULTS

5.1. Overview

In this section collected data were analyzed and documented. Respectively, descriptive statistics of subjects, descriptive statistics of aerobic capacity (VO_{2max} in l/min and VO_{2max} in ml/kg/min), correlation analysis, analysis of variance results and multiple comparisons, and regression analysis were covered in detail.

5.2. Descriptive Statistics

5.2.1. Summary Statistics

The demographic profile and anthropometric characteristics of male subjects are summarized in Table 5.1.

Table 5.2 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by age and BMI groups.

Table 5.3 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of VO_{2max} results (in both l/min and ml/kg/min) by age and BMI groups.

Table 5.4 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by occupation and age.

Table 5.5 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by occupation and BMI.

Table 5.6 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of VO_{2max} results (in both l/min and in ml/kg/min) by occupation age.

Table 5.7 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of VO_{2max} results (in both l/min and in ml/kg/min) by occupation and BMI.

Table 5.8 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by BMI and age groups.

Table 5.9 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of VO_{2max} results (in both l/min and ml/kg/min) by BMI and age.

Table 5.10 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of VO_{2max} results (in both l/min and ml/kg/min) by exercise and smoking.

Table 5.11 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of VO_{2max} results (in both l/min and ml/kg/min) by exercise and alcohol consumption.

Table 5.12 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of Test Workload (in kpm/min), Accepted HR (in bpm) and %HRmax by exercise and smoking.

Table 5.13 represents descriptive statistics (mean, standard deviation (SD) and range (min-max)) of males of Test Workload (in kpm/min), Accepted HR (in bpm) and %HRmax by exercise and alcohol consumption.

According to tables from Table 5.2 to Table 5.13 some statistical inferences are summarized as below:

- The mean values of Test Workload (in kpm/min) and Accepted HR (in bpm) are decreasing from 18-24 years group to 45-54 years' group and from under-weight group to obese group.
- It seems that there is no significant difference between any groups based on mean values of $\%HR_{max}$.

- There is only a slight difference between manual and non-manual groups due to mean values of Test Workload (in kpm/min) and insignificant difference according to mean values of Accepted HR (in bpm), VO_{2max} results (in l/min and in ml/kg/min).
- The mean values of VO_{2max} results (in l/min and in ml/kg/min) are decreasing from 18-24 years group to 45-54 years' group and from under-weight group to obese group.

Figure 5.1 and Figure 5.2 show aerobic capacity distributions (VO_{2max} in l/min and VO_{2max} in ml/kg/min). As can be seen, both of them are fairly symmetrical.

Table 5.1. Anthropometric characteristics of male participants.

		Age (in years)			Height (in cm)			Weight (in kg)			BMI (in kg/m^2)		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	260	**32.7 ± 10.6**	**18**	**54**	**175.6 ± 5.2**	**164**	**197**	**76.9 ± 11.4**	**54**	**106**	**24.9 ± 3.6**	**18.2**	**33.2**
18-24 yrs	77	**20.7 ± 1.8**	**18**	**24**	**176.4 ± 5.7**	**166**	**197**	**74.9 ± 12.8**	**55**	**104**	**24 ± 3.6**	**18.2**	**31.0**
Under-weight	3	18.3 ± 0.6	18	19	177.7 ± 3.5	174	181	57.7 ± 2.5	55	60	18.3 ± 0.1	18.2	18.3
Normal-weight	37	20.8 ± 1.8	18	24	176 ± 6.9	166	197	66.2 ± 7.8	55	89	21.3 ± 1.3	19.0	24.9
Over-weight	26	20.8 ± 1.7	18	24	176.2 ± 4.3	171	186	80.2 ± 3.8	75	89	25.8 ± 0.8	25.1	28.1
Obese	11	20.7 ± 2	18	24	178.2 ± 4.5	171	186	96.6 ± 4.7	89	104	30.4 ± 0.3	30.1	31.0
25-34 yrs	69	**28 ± 1.9**	**25**	**34**	**178.3 ± 3.9**	**169**	**193**	**77.5 ± 10.9**	**57**	**106**	**24.4 ± 3.5**	**18.3**	**33.2**
Under-weight	3	26.7 ± 1.5	25	28	177.7 ± 1.5	176	179	58 ± 1	57	59	18.4 ± 0.1	18.3	18.4
Normal-weight	37	28.2 ± 1.9	25	34	178.7 ± 4.6	171	193	70.9 ± 4.7	62	80	22.2 ± 1.5	19.0	24.9
Over-weight	22	27.6 ± 2	25	32	178.1 ± 2.7	174	184	85 ± 4.1	78	93	26.8 ± 1.4	25.0	29.4
Obese	7	28.7 ± 1.6	26	31	176.7 ± 4.2	169	183	96.9 ± 6.8	86	106	31 ± 1.2	30.0	33.2
35-44 yrs	64	**39.7 ± 1.8**	**35**	**44**	**174.3 ± 5.5**	**164**	**190**	**77.7 ± 10.6**	**55**	**97**	**25.6 ± 3.4**	**18.2**	**32.4**
Under-weight	3	39.7 ± 1.5	38	41	174 ± 1	173	175	55.3 ± 0.6	55	56	18.3 ± 0.1	18.2	18.4
Normal-weight	26	40.1 ± 1.8	36	43	174.9 ± 6.5	164	190	71.2 ± 5.3	56	82	23.3 ± 1.4	19.1	24.9
Over-weight	25	39.6 ± 2	35	44	174 ± 5.5	165	185	80.7 ± 6	68	89	26.6 ± 1.4	25.0	29.8
Obese	10	39.2 ± 1.4	38	42	173.9 ± 3.3	168	179	93.8 ± 3.6	87	97	31 ± 0.7	30.0	32.4
45-54 yrs	50	**48.4 ± 2.1**	**45**	**54**	**172.3 ± 2.6**	**164**	**178**	**78.1 ± 10.9**	**54**	**97**	**26.3 ± 3.8**	**18.2**	**32.5**
Under-weight	3	47 ± 2	45	49	175 ± 2.6	172	177	56 ± 1.7	54	57	18.3 ± 0.1	18.2	18.4
Normal-weight	13	48.1 ± 1.6	46	51	173 ± 2.2	170	177	68.5 ± 4.4	59	74	22.9 ± 1.5	19.9	24.6
Over-weight	24	48.5 ± 2.4	45	54	171.6 ± 2.8	164	178	79.9 ± 5.5	68	89	27.1 ± 1.6	25.0	29.8
Obese	10	49.1 ± 2	46	53	172.1 ± 2.2	170	175	92.6 ± 2.7	89	97	31.3 ± 0.7	30.4	32.5

Table 5.2. Descriptive statistics of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by age and BMI groups.

		Test Workload (in kpm/min)			**Accepted HR (in bpm)**			**$\%HR_{max}$**		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**616.7 ± 144.3**	**300**	**1050**	**141.9 ± 12.1**	**119**	**170**	**76% ± 5%**	**62%**	**88%**
18-24 yrs	**77**	**689.6 ± 131.6**	**300**	**900**	**150 ± 10.7**	**123**	**170**	**75% ± 5%**	**62%**	**85%**
Under-weight	3	800 ± 86.6	750	900	154.7 ± 5.5	149	160	77% ± 3%	74%	79%
Normal-weight	37	721.6 ± 126.7	450	900	152.2 ± 10.3	132	170	76% ± 5%	66%	85%
Over-weight	26	698.1 ± 94.3	600	900	150.2 ± 8.9	131	168	75% ± 4%	66%	85%
Obese	11	531.8 ± 123	300	750	140.9 ± 12.9	123	166	71% ± 6%	62%	84%
25-34 yrs	**69**	**673.9 ± 125**	**450**	**1050**	**147.3 ± 9.1**	**124**	**168**	**77% ± 5%**	**64%**	**86%**
Under-weight	3	650 ± 86.6	600	750	138.3 ± 7.8	132	147	72% ± 4%	68%	76%
Normal-weight	37	697.3 ± 123.6	600	1050	148.1 ± 8.2	131	168	77% ± 4%	68%	86%
Over-weight	22	688.6 ± 110.1	600	900	149.8 ± 8.8	133	163	78% ± 4%	69%	85%
Obese	7	514.3 ± 80.2	450	600	139.1 ± 10.5	124	156	73% ± 6%	64%	82%
35-44 yrs	**64**	**548.4 ± 120.2**	**300**	**750**	**133.4 ± 8.1**	**120**	**153**	**74% ± 5%**	**67%**	**85%**
Under-weight	3	650 ± 173.2	450	750	131.3 ± 4	127	135	73% ± 2%	71%	75%
Normal-weight	26	576.9 ± 81.5	450	750	134.5 ± 8.5	122	153	75% ± 4%	68%	85%
Over-weight	25	546 ± 121.6	300	750	133.6 ± 8.3	122	150	74% ± 5%	67%	85%
Obese	10	450 ± 141.4	300	750	130.8 ± 7.9	120	148	72% ± 5%	67%	82%
45-54 yrs	**50**	**513 ± 113.8**	**300**	**900**	**132.6 ± 8.2**	**119**	**152**	**77% ± 5%**	**69%**	**88%**
Under-weight	3	500 ± 86.6	450	600	127.7 ± 1.5	126	129	74% ± 1%	73%	75%
Normal-weight	13	530.8 ± 99	450	750	136.2 ± 6.8	123	146	79% ± 4%	72%	85%
Over-weight	24	531.3 ± 124.9	300	900	133.5 ± 9	121	152	78% ± 5%	70%	88%
Obese	10	450 ± 100	300	600	127.3 ± 5.6	119	134	75% ± 4%	69%	80%

Table 5.3. Descriptive statistics of VO_{2max} results by age and BMI groups.

	N	VO_2max (in l/min)			VO_2max (in ml/kg/min)		
		Mean ± St.Dev	Min	Max	Mean ± St.Dev	Min	Max
All	**260**	**2.5 ± 0.3**	**1.7**	**3.4**	**33.2 ± 7.7**	**19.5**	**61.5**
18-24 yrs	**77**	**2.7 ± 0.3**	**2.1**	**3.4**	**37.1 ± 8.1**	**20.4**	**61.5**
Under-weight	3	3.1 ± 0.3	2.8	3.4	54.2 ± 7.4	46.7	61.5
Normal-weight	37	2.7 ± 0.3	2.3	3.3	41.4 ± 6.1	29.0	54.8
Over-weight	26	2.7 ± 0.3	2.3	3.3	33.8 ± 3.6	27.5	41.6
Obese	11	2.5 ± 0.2	2.1	2.9	26 ± 2.6	20.4	29.7
25-34 yrs	**69**	**2.6 ± 0.3**	**2.0**	**3.4**	**34.6 ± 7**	**20.4**	**50.8**
Under-weight	3	2.9 ± 0.1	2.8	2.9	49.3 ± 1.9	47.1	50.8
Normal-weight	37	2.7 ± 0.3	2.1	3.4	37.6 ± 4.8	29.3	46.6
Over-weight	22	2.6 ± 0.3	2.1	3.1	30.6 ± 4.1	23.8	38.6
Obese	7	2.4 ± 0.3	2.0	2.8	24.8 ± 4.6	20.4	31.7
35-44 yrs	**64**	**2.4 ± 0.2**	**1.9**	**3.1**	**31.2 ± 6.3**	**19.6**	**55.7**
Under-weight	3	2.7 ± 0.4	2.3	3.1	49.3 ± 7.2	41.4	55.7
Normal-weight	26	2.4 ± 0.2	2.1	2.7	33.9 ± 3.4	28.5	44.2
Over-weight	25	2.4 ± 0.2	1.9	2.7	29.4 ± 3.3	24.1	36.8
Obese	10	2.2 ± 0.3	1.9	2.6	23.5 ± 2.6	19.6	28.1
45-54 yrs	**50**	**2.1 ± 0.2**	**1.7**	**2.7**	**27.8 ± 5.5**	**19.5**	**45.3**
Under-weight	3	2.3 ± 0.2	2.1	2.6	41.1 ± 3.7	38.5	45.3
Normal-weight	13	2.1 ± 0.2	1.7	2.4	30.5 ± 2.6	26.5	34.4
Over-weight	24	2.1 ± 0.3	1.7	2.7	27 ± 4.2	19.5	34.9
Obese	10	2.1 ± 0.1	1.8	2.3	22.3 ± 1.5	20.6	25.0

Table 5.4. Descriptive statistics of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by occupation and age groups.

		Test Workload (in kpm/min)			Accepted HR (in bpm)			%HRmax		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**616.7 ± 144.3**	**300**	**1050**	**141.9 ± 12.1**	**119**	**170**	**76% ± 5%**	**62%**	**88%**
Manual	**100**	**622.5 ± 132.1**	**300**	**900**	**142 ± 11.7**	**119**	**170**	**76% ± 5%**	**66%**	**85%**
18-24 yrs	22	715.9 ± 112.7	450	900	148.1 ± 10.5	131	170	74% ± 5%	66%	85%
25-34 yrs	33	668.2 ± 99.9	450	900	149.5 ± 9	131	163	78% ± 5%	68%	85%
35-44 yrs	31	551.6 ± 112.2	300	750	133 ± 8	122	153	74% ± 4%	67%	85%
45-54 yrs	14	525 ± 128.2	300	750	134.9 ± 7.6	119	144	78% ± 4%	69%	83%
Non-manual	**160**	**613.1 ± 151.8**	**300**	**1050**	**141.8 ± 12.4**	**119**	**168**	**76% ± 5%**	**62%**	**88%**
18-24 yrs	55	679.1 ± 138	300	900	150.8 ± 10.8	123	168	76% ± 5%	62%	85%
25-34 yrs	36	679.2 ± 145.6	450	1050	145.3 ± 8.9	124	168	76% ± 4%	64%	86%
35-44 yrs	33	545.5 ± 128.9	300	750	133.8 ± 8.3	120	152	74% ± 5%	67%	85%
45-54 yrs	36	508.3 ± 109.2	300	900	131.8 ± 8.3	119	152	77% ± 5%	70%	88%

Table 5.5. Descriptive statistics of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by occupation and BMI groups.

		Test Workload (in kpm/min)			Accepted HR (in bpm)			%HRmax		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**616.7 ± 144.3**	**300**	**1050**	**141.9 ± 12.1**	**119**	**170**	**76% ± 5%**	**62%**	**88%**
Manual	**100**	**622.5 ± 132.1**	**300**	**900**	**142 ± 11.7**	**119**	**170**	**76% ± 5%**	**66%**	**85%**
Under-weight	6	675 ± 82.2	600	750	138.7 ± 13.1	127	160	73% ± 4%	68%	79%
Normal-weight	48	653.1 ± 125.6	450	900	143.5 ± 11.2	122	170	76% ± 5%	66%	85%
Over-weight	34	613.2 ± 124.5	300	900	143.1 ± 12.2	122	163	77% ± 5%	66%	85%
Obese	12	500 ± 133.1	300	750	134.4 ± 9	119	148	72% ± 4%	68%	82%
Nonmanual	**160**	**613.1 ± 151.8**	**300**	**1050**	**141.8 ± 12.4**	**119**	**168**	**76% ± 5%**	**62%**	**88%**
Under-weight	6	625 ± 199.4	450	900	137.3 ± 11.3	126	155	75% ± 2%	73%	77%
Normal-weight	65	662.3 ± 140	450	1050	146 ± 11.6	123	168	77% ± 4%	67%	86%
Over-weight	63	616.7 ± 142.8	300	900	140.9 ± 11.9	121	168	76% ± 5%	68%	88%
Obese	26	478.8 ± 112.4	300	750	134.3 ± 11.9	119	166	73% ± 6%	62%	84%

Table 5.6. Descriptive statistics of VO_{2max} results by occupation and age groups.

		VO_2max (in l/min)			VO_2max (in ml/kg/min)		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**2.5 ± 0.3**	**1.7**	**3.4**	**33.2 ± 7.7**	**19.5**	**61.5**
Manual	**100**	**2.5 ± 0.3**	**1.7**	**3.3**	**33.7 ± 8**	**20.6**	**55.7**
18-24 yrs	22	2.8 ± 0.2	2.4	3.3	39.7 ± 8.7	25.9	54.3
25-34 yrs	33	2.6 ± 0.3	2.0	3.1	34.4 ± 7.1	21.2	50.8
35-44 yrs	31	2.4 ± 0.2	2.0	3.1	31.3 ± 6.3	22.3	55.7
45-54 yrs	14	2.1 ± 0.3	1.7	2.6	28.2 ± 6.7	20.6	45.3
Non-manual	**160**	**2.5 ± 0.4**	**1.7**	**3.4**	**32.9 ± 7.5**	**19.5**	**61.5**
18-24 yrs	55	2.7 ± 0.3	2.1	3.4	36.1 ± 7.7	20.4	61.5
25-34 yrs	36	2.7 ± 0.3	2.0	3.4	34.8 ± 7	20.4	50.0
35-44 yrs	33	2.3 ± 0.2	1.9	2.8	31.2 ± 6.5	19.6	50.8
45-54 yrs	36	2.1 ± 0.2	1.7	2.7	27.7 ± 5	19.5	39.5

Table 5.7. Descriptive statistics of VO_{2max} results by occupation and BMI groups.

		VO_2max (l/min)			VO_2max (ml/kg/min)		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**2.5 ± 0.3**	**1.7**	**3.4**	**33.2 ± 7.7**	**19.5**	**61.5**
Manual	**100**	**2.5 ± 0.3**	**1.7**	**3.3**	**33.7 ± 8**	**20.6**	**55.7**
Under-weight	6	2.9 ± 0.2	2.6	3.2	50 ± 4.3	45.3	55.7
Normal-weight	48	2.6 ± 0.3	1.7	3.3	37.2 ± 6.3	26.5	53.8
Over-weight	34	2.4 ± 0.3	1.7	3.0	29.3 ± 4	21.2	38.9
Obese	12	2.3 ± 0.3	1.8	2.9	24.5 ± 3	20.6	29.7
Nonmanual	**160**	**2.5 ± 0.4**	**1.7**	**3.4**	**32.9 ± 7.5**	**19.5**	**61.5**
Under-weight	6	2.6 ± 0.5	2.1	3.4	47 ± 8.9	38.5	61.5
Normal-weight	65	2.5 ± 0.3	1.7	3.4	37.2 ± 5.9	27.8	54.8
Over-weight	63	2.5 ± 0.4	1.7	3.3	30.8 ± 4.7	19.5	41.6
Obese	26	2.3 ± 0.3	1.9	2.8	24 ± 3.1	19.6	31.7

Table 5.8. Descriptive statistics of Test Workload (kpm/min), Accepted HR (bpm) and $\%HR_{max}$ by BMI and age groups.

		Test Workload (kpm/min)			Accepted HR (bpm)			%HRmax		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**616.7 ± 144.3**	**300**	**1050**	**141.9 ± 12.1**	**119**	**170**	**76% ± 5%**	**62%**	**88%**
Under-weight	**12**	**650 ± 147.7**	**450**	**900**	**138 ± 11.7**	**126**	**160**	**74% ± 3%**	**68%**	**79%**
18-24 yrs	3	800 ± 86.6	750	900	154.7 ± 5.5	149	160	77% ± 3%	74%	79%
25-34 yrs	3	650 ± 86.6	600	750	138.3 ± 7.8	132	147	72% ± 4%	68%	76%
35-44 yrs	3	650 ± 173.2	450	750	131.3 ± 4	127	135	73% ± 2%	71%	75%
45-54 yrs	3	500 ± 86.6	450	600	127.7 ± 1.5	126	129	74% ± 1%	73%	75%
Normal-weight	**113**	**658.4 ± 133.6**	**450**	**1050**	**145 ± 11.5**	**122**	**170**	**77% ± 5%**	**66%**	**86%**
18-24 yrs	37	721.6 ± 126.7	450	900	152.2 ± 10.3	132	170	76% ± 5%	66%	85%
25-34 yrs	37	697.3 ± 123.6	600	1050	148.1 ± 8.2	131	168	77% ± 4%	68%	86%
35-44 yrs	26	576.9 ± 81.5	450	750	134.5 ± 8.5	122	153	75% ± 4%	68%	85%
45-54 yrs	13	530.8 ± 99	450	750	136.2 ± 6.8	123	146	79% ± 4%	72%	85%
Over-weight	**97**	**615.5 ± 136**	**300**	**900**	**141.7 ± 12**	**121**	**168**	**76% ± 5%**	**66%**	**88%**
18-24 yrs	26	698.1 ± 94.3	600	900	150.2 ± 8.9	131	168	75% ± 4%	66%	85%
25-34 yrs	22	688.6 ± 110.1	600	900	149.8 ± 8.8	133	163	78% ± 4%	69%	85%
35-44 yrs	25	546 ± 121.6	300	750	133.6 ± 8.3	122	150	74% ± 5%	67%	85%
45-54 yrs	24	531.3 ± 124.9	300	900	133.5 ± 9	121	152	78% ± 5%	70%	88%
Obese	**38**	**485.5 ± 117.9**	**300**	**750**	**134.3 ± 10.9**	**119**	**166**	**73% ± 5%**	**62%**	**84%**
18-24 yrs	11	531.8 ± 123	300	750	140.9 ± 12.9	123	166	71% ± 6%	62%	84%
25-34 yrs	7	514.3 ± 80.2	450	600	139.1 ± 10.5	124	156	73% ± 6%	64%	82%
35-44 yrs	10	450 ± 141.4	300	750	130.8 ± 7.9	120	148	72% ± 5%	67%	82%
45-54 yrs	10	450 ± 100	300	600	127.3 ± 5.6	119	134	75% ± 4%	69%	80%

Table 5.9. Descriptive statistics of VO_{2max} results by BMI and age groups.

		VO_2max (l/min)			VO_2max (ml/kg/min)		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**2.5 ± 0.3**	**1.7**	**3.4**	**33.2 ± 7.7**	**19.5**	**61.5**
Under-weight	**12**	**2.8 ± 0.4**	**2.1**	**3.4**	**48.5 ± 6.8**	**38.5**	**61.5**
18-24 yrs	3	3.1 ± 0.3	2.8	3.4	54.2 ± 7.4	46.7	61.5
25-34 yrs	3	2.9 ± 0.1	2.8	2.9	49.3 ± 1.9	47.1	50.8
35-44 yrs	3	2.7 ± 0.4	2.3	3.1	49.3 ± 7.2	41.4	55.7
45-54 yrs	3	2.3 ± 0.2	2.1	2.6	41.1 ± 3.7	38.5	45.3
Normal-weight	**113**	**2.6 ± 0.3**	**1.7**	**3.4**	**37.2 ± 6**	**26.5**	**54.8**
18-24 yrs	37	2.7 ± 0.3	2.3	3.3	41.4 ± 6.1	29.0	54.8
25-34 yrs	37	2.7 ± 0.3	2.1	3.4	37.6 ± 4.8	29.3	46.6
35-44 yrs	26	2.4 ± 0.2	2.1	2.7	33.9 ± 3.4	28.5	44.2
45-54 yrs	13	2.1 ± 0.2	1.7	2.4	30.5 ± 2.6	26.5	34.4
Over-weight	**97**	**2.5 ± 0.3**	**1.7**	**3.3**	**30.3 ± 4.5**	**19.5**	**41.6**
18-24 yrs	26	2.7 ± 0.3	2.3	3.3	33.8 ± 3.6	27.5	41.6
25-34 yrs	22	2.6 ± 0.3	2.1	3.1	30.6 ± 4.1	23.8	38.6
35-44 yrs	25	2.4 ± 0.2	1.9	2.7	29.4 ± 3.3	24.1	36.8
45-54 yrs	24	2.1 ± 0.3	1.7	2.7	27 ± 4.2	19.5	34.9
Obese	**38**	**2.3 ± 0.3**	**1.8**	**2.9**	**24.2 ± 3.1**	**19.6**	**31.7**
18-24 yrs	11	2.5 ± 0.2	2.1	2.9	26 ± 2.6	20.4	29.7
25-34 yrs	7	2.4 ± 0.3	2.0	2.8	24.8 ± 4.6	20.4	31.7
35-44 yrs	10	2.2 ± 0.3	1.9	2.6	23.5 ± 2.6	19.6	28.1
45-54 yrs	10	2.1 ± 0.1	1.8	2.3	22.3 ± 1.5	20.6	25.0

Table 5.10. Descriptive statistics of VO_{2max} results by exercise and smoking groups.

	N	VO_2max (l/min) Mean ± St.Dev	Min	Max	VO_2max (ml/kg/min) Mean ± St.Dev	Min	Max
All	**260**	**2.5 ± 0.3**	**1.7**	**3.4**	**33.2 ± 7.7**	**19.5**	**61.5**
Irregular or no	**213**	**2.4 ± 0.3**	**1.7**	**3.3**	**33.7 ± 8**	**20.6**	**55.7**
Smoker	103	2.4 ± 0.3	1.8	3.3	32.6 ± 7.4	20.6	55.7
Non- or ex-smoker	110	2.4 ± 0.4	1.7	3.2	34.6 ± 8.5	21.2	54.3
Regular	**47**	**2.7 ± 0.4**	**1.7**	**3.4**	**32.9 ± 7.5**	**19.5**	**61.5**
Smoker	18	2.7 ± 0.4	2.2	3.4	33.1 ± 7.3	20.4	61.5
Non- or ex-smoker	29	2.7 ± 0.4	1.7	3.2	32.7 ± 7.7	19.5	50.8

Table 5.11. Descriptive statistics of VO_{2max} results by exercise and drinking groups.

	N	VO_2max (l/min) Mean ± St.Dev	Min	Max	VO_2max (ml/kg/min) Mean ± St.Dev	Min	Max
All	**260**	**2.5 ± 0.3**	**1.7**	**3.4**	**33.2 ± 7.7**	**19.5**	**61.5**
Irregular or no	**213**	**2.4 ± 0.3**	**1.7**	**3.3**	**33.7 ± 8**	**20.6**	**55.7**
Drinking	46	2.4 ± 0.3	1.7	3.1	33.2 ± 8	21.2	55.7
Non-Drinking	167	2.4 ± 0.3	1.7	3.3	33.9 ± 8.1	20.6	54.3
Regular	**47**	**2.7 ± 0.4**	**1.7**	**3.4**	**32.9 ± 7.5**	**19.5**	**61.5**
Drinking	8	2.6 ± 0.4	2.2	3.4	31.9 ± 6.7	19.5	44.3
Non-Drinking	39	2.7 ± 0.4	1.7	3.4	33.2 ± 7.7	19.6	61.5

Table 5.12. Descriptive statistics of Test Workload (kpm/min), Accepted HR (bpm) and $\%HR_{max}$ by exercise and smoking groups.

		Test Workload (kpm)			Accepted HR (bpm)			%HRmax		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**616.7 ± 144.3**	**300**	**1050**	**141.9 ± 12.1**	**119**	**170**	**76% ± 5%**	**62%**	**88%**
Irregular or no	**213**	**622.5 ± 132.1**	**300**	**900**	**142 ± 11.7**	**119**	**170**	**76% ± 5%**	**66%**	**85%**
Smoker	103	600 ± 125.3	300	900	140.2 ± 11.1	119	162	75% ± 5%	66%	83%
Non- or ex-smoker	110	640.2 ± 135.7	300	900	143.4 ± 12	122	170	76% ± 5%	67%	85%
Regular	**47**	**613.1 ± 151.8**	**300**	**1050**	**141.8 ± 12.4**	**119**	**168**	**76% ± 5%**	**62%**	**88%**
Smoker	18	598.1 ± 140.8	300	1050	138 ± 10.1	119	167	74% ± 5%	62%	88%
Non- or ex-smoker	29	627.1 ± 160.8	300	1050	145.3 ± 13.3	120	168	77% ± 5%	67%	88%

Table 5.13. Descriptive statistics of Test Workload (kpm/min), Accepted HR (bpm) and $\%HR_{max}$ by exercise and drinking groups.

		Test Workload (kpm)			Accepted HR (bpm)			%HRmax		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**260**	**616.7 ± 144.3**	**300**	**1050**	**141.9 ± 12.1**	**119**	**170**	**76% ± 5%**	**62%**	**88%**
Irregular or no	**213**	**622.5 ± 132.1**	**300**	**900**	**142 ± 11.7**	**119**	**170**	**76% ± 5%**	**66%**	**85%**
Drinking	46	600 ± 108.8	450	750	138.3 ± 9.8	126	162	75% ± 5%	66%	83%
Non-Drinking	167	628.1 ± 137.3	300	900	142.9 ± 12	119	170	76% ± 5%	66%	85%
Regular	**47**	**613.1 ± 151.8**	**300**	**1050**	**141.8 ± 12.4**	**119**	**168**	**76% ± 5%**	**62%**	**88%**
Drinking	8	577.9 ± 152.8	300	1050	135.7 ± 9.9	119	153	74% ± 5%	62%	88%
Non-Drinking	39	622.6 ± 150.7	300	1050	143.4 ± 12.5	120	168	76% ± 5%	62%	88%

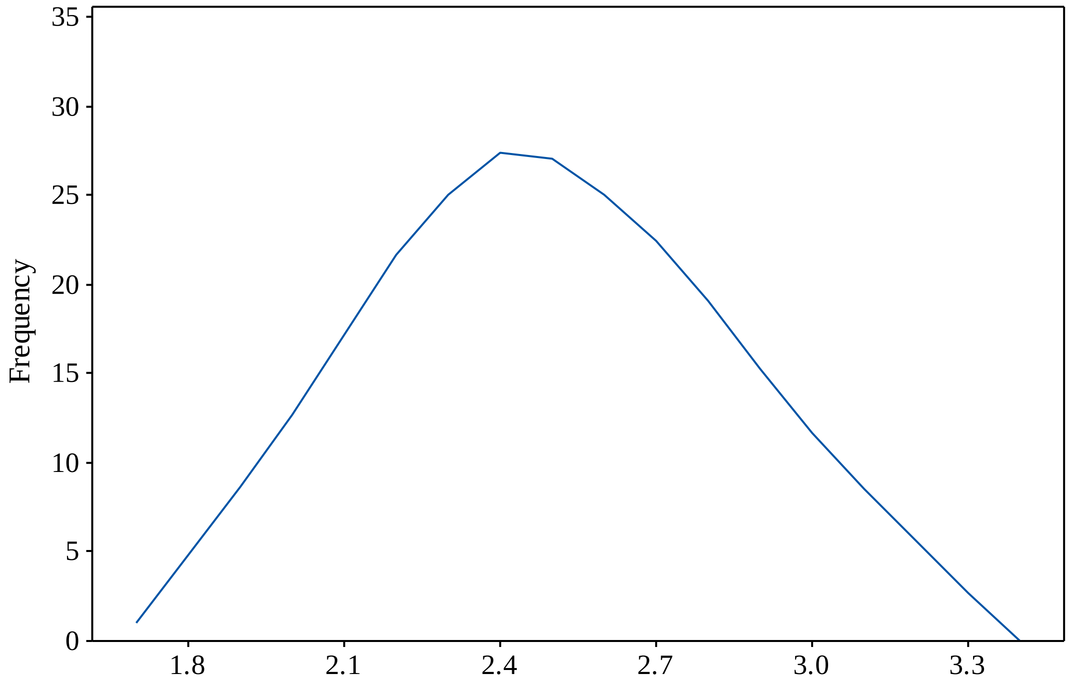

Figure 5.1. Distribution of aerobic capacity (VO_{2max} in l/min)

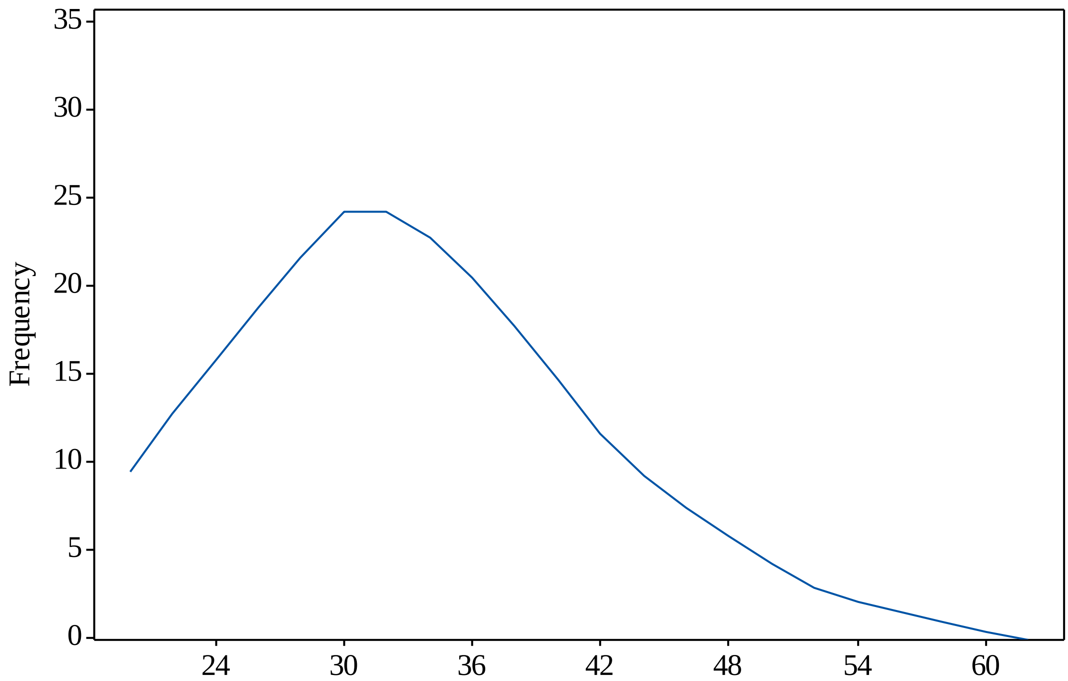

Figure 5.2. Distribution of aerobic capacity (VO_{2max} in ml/kg/min)

Graphical summary of results for different levels of independent variables are shown by boxplots in Figure 5.3 – 5.8.

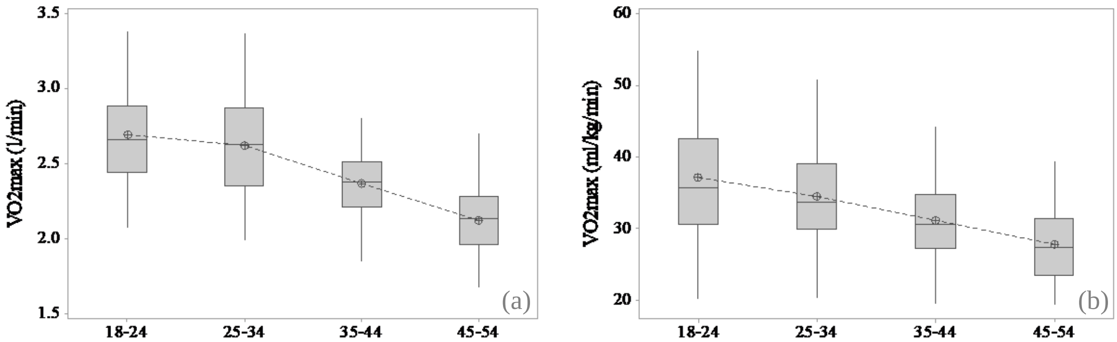

Figure 5.3. Box plot of aerobic capacity for different age groups.

(a) VO_{2max} in l/min (b) VO_{2max} in ml/kg/min

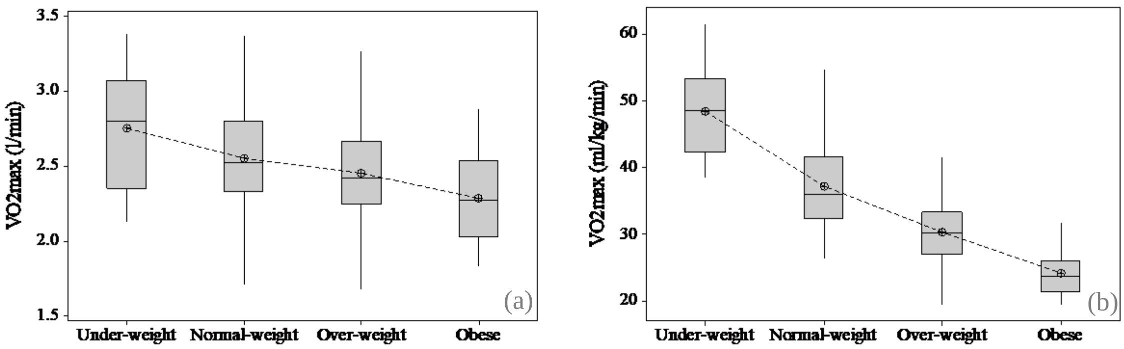

Figure 5.4. Box plot of aerobic capacity for different BMI groups.

(a) VO_{2max} in l/min (b) VO_{2max} in ml/kg/min

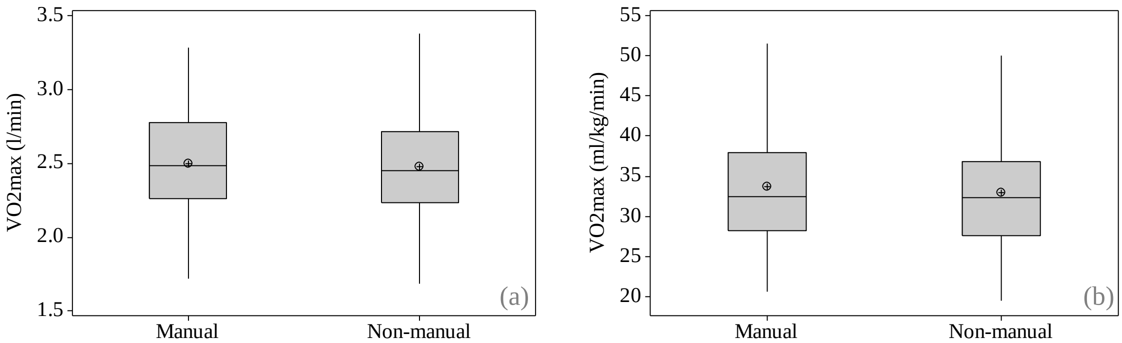

Figure 5.5. Box plot of aerobic capacity for different occupation groups.

(a) VO_{2max} in l/min (b) VO_{2max} in ml/kg/min

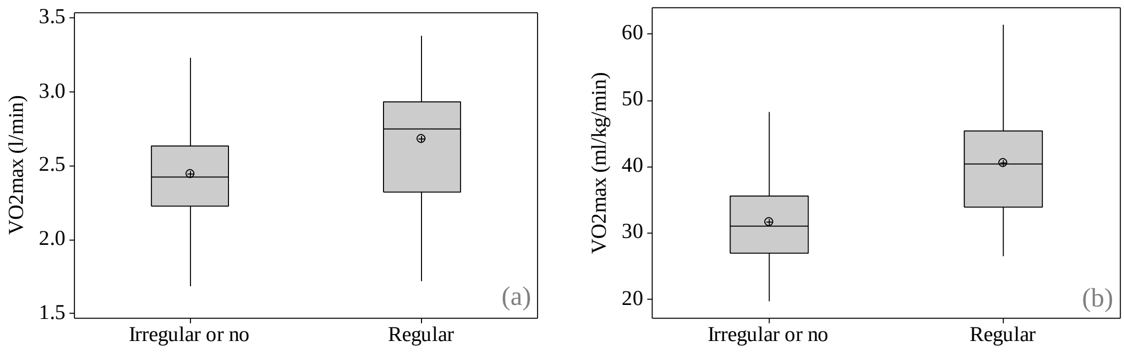

Figure 5.6. Box plot of aerobic capacity for different exercise groups.

(a) VO_{2max} in l/min (b) VO_{2max} in ml/kg/min

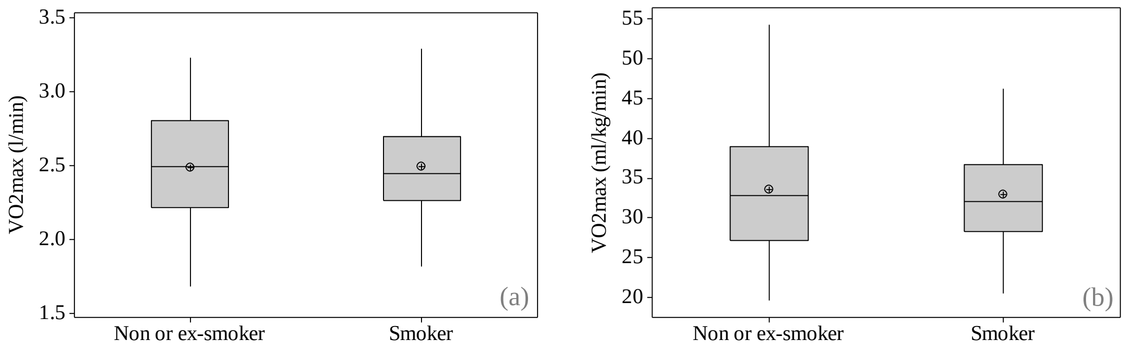

Figure 5.7. Box plot of aerobic capacity for different smoking groups.

(a) VO_{2max} in l/min (b) VO_{2max} in ml/kg/min

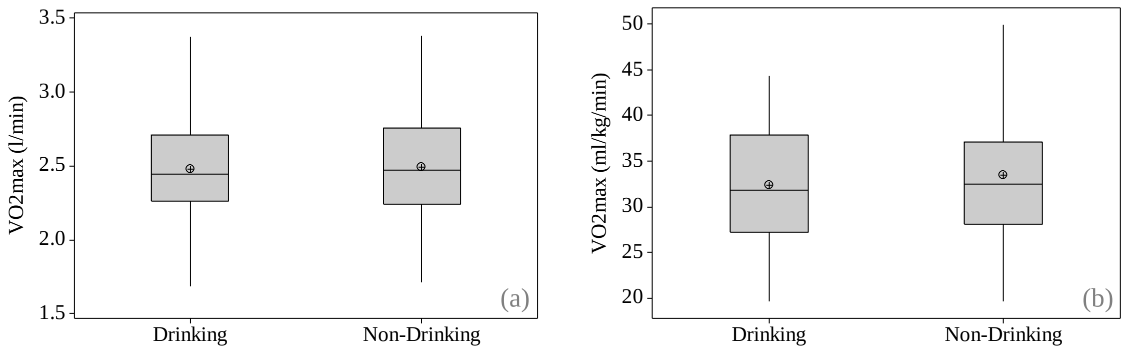

Figure 5.8. Box plot of aerobic capacity for different alcohol drinking groups

(a) VO_{2max} in l/min (b) VO_{2max} in ml/kg/min

5.2.2. Percentiles

In this part, the percentiles of the measured values were calculated for different age, BMI, occupation groups (Table 5.14 – Table 5.21).

Table 5.14. Percentiles of Test Workload (kpm/min), Accepted HR (bpm) and %HR$_{max}$ by age and BMI groups.

		Test Workload			Accepted HR			%HRmax		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	**260**	**450**	**600**	**900**	**123**	**141**	**162**	**68%**	**76%**	**84%**
18-24 yrs	**77**	**450**	**750**	**900**	**133**	**150**	**166**	**67%**	**76%**	**84%**
Under-weight	3	750	750	885	150	155	160	74%	77%	79%
Normal-weight	37	570	750	900	135	150	167	68%	76%	84%
Over-weight	26	600	750	863	137	150	163	70%	75%	82%
Obese	11	375	600	675	124	140	161	62%	70%	80%
25-34 yrs	**69**	**510**	**600**	**900**	**131**	**148**	**160**	**69%**	**77%**	**83%**
Under-weight	3	600	600	735	132	136	146	68%	71%	76%
Normal-weight	37	600	600	930	134	149	158	70%	78%	82%
Over-weight	22	600	600	900	135	149	162	70%	78%	83%
Obese	7	450	450	600	126	140	153	66%	74%	80%
35-44 yrs	**64**	**323**	**600**	**750**	**122**	**132**	**150**	**68%**	**74%**	**83%**
Under-weight	3	480	750	750	128	132	135	71%	73%	75%
Normal-weight	26	450	600	713	126	132	152	69%	74%	83%
Over-weight	25	450	600	750	122	134	148	68%	74%	82%
Obese	10	300	450	683	122	130	144	67%	72%	80%
45-54 yrs	**50**	**368**	**450**	**683**	**121**	**132**	**146**	**70%**	**77%**	**85%**
Under-weight	3	450	450	585	126	128	129	73%	73%	75%
Normal-weight	13	450	450	660	127	135	145	74%	79%	85%
Over-weight	24	450	450	728	122	134	149	71%	78%	87%
Obese	10	300	450	600	119	130	133	70%	76%	79%

Table 5.15. Percentiles of VO_{2max} results by age and BMI groups.

		VO_2max (l/min)			VO_2max (ml/kg/min)		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	**260**	**1.9**	**2.5**	**3.1**	**22.2**	**32.4**	**46.6**
18-24 yrs	**77**	**2.3**	**2.7**	**3.2**	**25.9**	**35.8**	**53.0**
Under-weight	3	2.8	3.2	3.4	47.4	54.3	60.8
Normal-weight	37	2.3	2.6	3.2	33.0	41.1	53.0
Over-weight	26	2.4	2.7	3.2	28.9	34.0	40.5
Obese	11	2.2	2.5	2.8	21.6	26.0	29.2
25-34 yrs	**69**	**2.1**	**2.6**	**3.1**	**24.0**	**33.7**	**46.3**
Under-weight	3	2.8	2.9	2.9	47.4	50.0	50.7
Normal-weight	37	2.2	2.7	3.1	31.3	38.0	44.7
Over-weight	22	2.2	2.5	3.0	25.4	30.4	36.4
Obese	7	2.0	2.3	2.8	20.5	24.3	31.2
35-44 yrs	**64**	**2.0**	**2.4**	**2.7**	**23.0**	**30.7**	**40.9**
Under-weight	3	2.3	2.8	3.1	42.3	50.8	55.2
Normal-weight	26	2.1	2.5	2.6	29.6	33.8	37.6
Over-weight	25	2.0	2.4	2.6	26.0	28.5	35.2
Obese	10	1.9	2.2	2.6	19.7	23.8	27.2
45-54 yrs	**50**	**1.7**	**2.1**	**2.6**	**20.7**	**27.5**	**36.9**
Under-weight	3	2.1	2.2	2.5	38.6	39.5	44.8
Normal-weight	13	1.7	2.1	2.4	26.9	30.7	34.2
Over-weight	24	1.7	2.2	2.6	21.4	26.7	33.2
Obese	10	1.9	2.1	2.3	20.6	22.4	24.4

Table 5.16. Percentiles of Test Workload (kpm/min), Accepted HR (bpm) and $\%HR_{max}$ by occupation and age groups.

		Test Workload			Accepted HR			%HRmax		
	N	5th	50th	95th	5th	50th	95th	5th	50th	95th
All	**260**	**450**	**600**	**900**	**123**	**141**	**162**	**68%**	**76%**	**84%**
Manual	**100**	**450**	**600**	**758**	**122**	**141**	**160**	**68%**	**76%**	**83%**
18-24 yrs	22	600	750	900	132	147	167	66%	74%	83%
25-34 yrs	33	600	600	810	132	152	161	68%	79%	83%
35-44 yrs	31	450	600	750	122	132	146	68%	73%	81%
45-54 yrs	14	300	600	653	121	137	143	70%	79%	83%
Non-manual	**160**	**450**	**600**	**900**	**123**	**141**	**164**	**69%**	**75%**	**84%**
18-24 yrs	55	450	750	900	135	150	166	68%	76%	83%
25-34 yrs	36	450	600	938	133	145	159	69%	76%	82%
35-44 yrs	33	300	600	750	124	132	150	68%	74%	83%
45-54 yrs	36	450	450	638	122	131	147	70%	77%	86%

Table 5.17. Percentiles of VO_{2max} results by occupation and age groups.

		VO_2max (l/min)			VO_2max (ml/kg/min)		
	N	5th	50th	95th	5th	50th	95th
All	**260**	**1.9**	**2.5**	**3.1**	**22.2**	**32.4**	**46.6**
Manual	**100**	**2.0**	**2.5**	**3.0**	**22.4**	**32.4**	**50.8**
18-24 yrs	22	2.4	2.8	3.1	28.1	39.6	53.8
25-34 yrs	33	2.1	2.6	3.0	24.7	33.4	46.8
35-44 yrs	31	2.1	2.4	2.7	23.8	30.2	37.4
45-54 yrs	14	1.7	2.1	2.5	20.7	27.1	38.0
Non-manual	**160**	**1.9**	**2.5**	**3.1**	**22.0**	**32.3**	**44.8**
18-24 yrs	55	2.3	2.6	3.2	25.6	35.6	46.2
25-34 yrs	36	2.2	2.7	3.1	23.4	34.2	44.8
35-44 yrs	33	1.9	2.4	2.7	21.7	30.9	42.5
45-54 yrs	36	1.7	2.1	2.5	21.2	27.8	35.8

Table 5.18. Percentiles of Test Workload (kpm/min), Accepted HR (bpm) and $\%HR_{max}$ by occupation and BMI groups.

		Test Workload			**Accepted HR**			**%HRmax**		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	**260**	**450**	**600**	**900**	**123**	**141**	**162**	**68%**	**76%**	**84%**
Manual	**100**	**450**	**600**	**758**	**123**	**141**	**162**	**68%**	**76%**	**83%**
Under-weight	6	600	675	750	127	134	157	68%	72%	78%
Normal-weight	48	450	600	900	127	144	158	68%	77%	83%
Over-weight	34	450	600	750	122	143	161	67%	78%	83%
Obese	12	300	450	668	121	134	147	68%	72%	79%
Non-manual	**160**	**450**	**600**	**900**	**123**	**141**	**162**	**69%**	**75%**	**84%**
Under-weight	6	450	600	863	127	134	153	73%	75%	77%
Normal-weight	65	450	600	900	129	146	166	69%	76%	84%
Over-weight	63	450	600	900	123	140	160	70%	75%	85%
Obese	26	300	450	600	121	132	156	63%	72%	81%

Table 5.19. Percentiles of VO_{2max} results by occupation and BMI groups.

		VO_2max (l/min)			**VO_2max (ml/kg/min)**		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	**260**	**1.9**	**2.5**	**3.1**	**22.2**	**32.4**	**46.6**
Manual	**100**	**2.0**	**2.5**	**3.0**	**22.4**	**32.4**	**50.8**
Under-weight	6	2.6	2.9	3.1	45.7	48.9	55.3
Normal-weight	48	2.1	2.6	3.0	29.4	36.1	49.8
Over-weight	34	2.0	2.4	2.9	23.3	29.6	36.0
Obese	12	1.9	2.3	2.8	20.7	24.4	28.8
Non-manual	**160**	**1.9**	**2.5**	**3.1**	**22.0**	**32.3**	**44.8**
Under-weight	6	2.1	2.5	3.2	38.7	45.7	58.9
Normal-weight	65	2.0	2.5	3.1	29.0	36.1	45.3
Over-weight	63	1.8	2.5	3.1	23.6	30.5	37.9
Obese	26	1.9	2.2	2.7	20.0	23.6	29.8

Table 5.20. Percentiles of Test Workload (kpm/min), Accepted HR (bpm) and %HR_{max} by BMI and age groups.

		Test Workload			**Accepted HR**			**%HRmax**		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	**260**	**450**	**600**	**900**	**123**	**141**	**162**	**68%**	**76%**	**84%**
Under-weight	**12**	**450**	**675**	**818**	**127**	**134**	**157**	**69%**	**74%**	**78%**
18-24 yrs	3	750	750	885	150	155	160	74%	77%	79%
25-34 yrs	3	600	600	735	132	136	146	68%	71%	76%
35-44 yrs	3	480	750	750	128	132	135	71%	73%	75%
45-54 yrs	3	450	450	585	126	128	129	73%	73%	75%
Normal-weight	**113**	**450**	**600**	**900**	**128**	**145**	**166**	**69%**	**77%**	**84%**
18-24 yrs	37	570	750	900	135	150	167	68%	76%	84%
25-34 yrs	37	600	600	930	134	149	158	70%	78%	82%
35-44 yrs	26	450	600	713	126	132	152	69%	74%	83%
45-54 yrs	13	450	450	660	127	135	145	74%	79%	85%
Over-weight	**97**	**450**	**600**	**900**	**122**	**141**	**160**	**68%**	**76%**	**84%**
18-24 yrs	26	600	750	863	137	150	163	70%	75%	82%
25-34 yrs	22	600	600	900	135	149	162	70%	78%	83%
35-44 yrs	25	450	600	750	122	134	148	68%	74%	82%
45-54 yrs	24	450	450	728	122	134	149	71%	78%	87%
Obese	**38**	**300**	**450**	**623**	**120**	**132**	**155**	**64%**	**72%**	**82%**
18-24 yrs	11	375	600	675	124	140	161	62%	70%	80%
25-34 yrs	7	450	450	600	126	140	153	66%	74%	80%
35-44 yrs	10	300	450	683	122	130	144	67%	72%	80%
45-54 yrs	10	300	450	600	119	130	133	70%	76%	79%

Table 5.21. Percentiles of VO_{2max} by BMI and age groups.

		VO_2max (l/min)			VO_2max (ml/kg/min)		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	**260**	**1.9**	**2,5**	**3,1**	**22.2**	**32.4**	**46.6**
Under-weight	**12**	**2.2**	**2.8**	**3.3**	**39.0**	**48.6**	**58.3**
18-24 yrs	3	2.8	3.2	3.4	47.4	54.3	60.8
25-34 yrs	3	2.8	2.9	2.9	47.4	50.0	50.7
35-44 yrs	3	2.3	2.8	3.1	42.3	50.8	55.2
45-54 yrs	3	2.1	2.2	2.5	38.6	39.5	44.8
Normal-weight	**113**	**2.1**	**2.5**	**3.1**	**29.0**	**36.1**	**46.4**
18-24 yrs	37	2.3	2.6	3.2	33.0	41.1	53.0
25-34 yrs	37	2.2	2.7	3.1	31.3	38.0	44.7
35-44 yrs	26	2.1	2.5	2.6	29.6	33.8	37.6
45-54 yrs	13	1.7	2.1	2.4	26.9	30.7	34.2
Over-weight	**97**	**1.9**	**2.4**	**3.0**	**23.5**	**30.2**	**37.0**
18-24 yrs	26	2.4	2.7	3.2	28.9	34.0	40.5
25-34 yrs	22	2.2	2.5	3.0	25.4	30.4	36.4
35-44 yrs	25	2.0	2.4	2.6	26.0	28.5	35.2
45-54 yrs	24	1.7	2.2	2.6	21.4	26.7	33.2
Obese	**38**	**1.9**	**2.3**	**2.8**	**20.3**	**23.8**	**29.7**
18-24 yrs	11	2.2	2.5	2.8	21.6	26.0	29.2
25-34 yrs	7	2.0	2.3	2.8	20.5	24.3	31.2
35-44 yrs	10	1.9	2.2	2.6	19.7	23.8	27.2
45-54 yrs	10	1.9	2.1	2.3	20.6	22.4	24.4

5.3. Correlation Analysis

Correlation analyses (Pearson) were performed to understand the degree of linearity between continuous independent variables and response (absolute and relative aerobic capacity) variables. The correlation analysis involves the following hypotheses:

$$H_0: \rho = 0$$
$$H_1: \rho \neq 0 \tag{5.1}$$

Table 5.22 displays the Pearson correlation matrix between anthropometric data, test results in the final stage (Test Workload (in kpm/min), Accepted HR (in bpm)) and responses (VO_{2max} in l/min and in ml/kg/min). According to the comparison of anthropometric data of each other, except weight vs. age relationship, with moderate and high correlation coefficients and with p-values < 0.001, it is obvious that there is a significant correlation between them. Due to the relationship among test results in the final stage and anthropometric data, it can be said that there is a strong correlation between them. Besides, there is a highly positive correlation between Test Workload and Accepted HR. Test Workload and Accepted HR are negatively correlated with age, weight, and BMI and positively correlated with height. Test responses (VO_{2max} in l/min and in ml/kg/min) have also a correlation with anthropometric data and test results. Absolute aerobic capacity (VO_{2max} in l/min) is positively correlated with height, test workload and accepted HR and negatively correlated with age, weight, BMI with p-values < 0.001. Relative aerobic capacity (VO_{2max} in ml/kg/min) has the same correlation pattern as well as absolute aerobic capacity (VO_{2max} in l/min) except with a negative correlation with height. Moreover, relative aerobic capacity (VO_{2max} in ml/kg/min) has strong relationships rather than absolute aerobic capacity (VO_{2max} in l/min) in terms of correlation coefficients.

Table 5.22. Pearson correlations between test results and anthropometric data.

	Age	Height	Weight	BMI	Test Workload	Accepted HR	Predicted HR_{max}	% HR_{max}	VO_{2max} (l/min)
Height	-0,341* <0.001**								
Weight	0,103 0,099	0,236 <0.001							
BMI	0,25 <0.001	-0,155 0,012	0,922 <0.001						
Test Workload	-0,48 <0.001	0,28 <0.001	-0,285 <0.001	-0,403 <0.001					
Accepted HR	-0,644 <0.001	0,281 <0.001	-0,178 0,004	-0,297 <0.001	0,701 <0.001				
Predicted HR_{max}	-1 0	0,341 <0.001	-0,103 0,099	-0,25 <0.001	0,48 <0.001	0,644 <0.001			
% HR_{max}	0,033 0,602	0,065 0,299	-0,143 0,021	-0,169 0,006	0,496 <0.001	0,743 <0.001	-0,033 0,602		
VO_{2max} (l/min)	-0,591 <0.001	0,263 <0.001	-0,234 <0.001	-0,346 <0.001	0,756 <0.001	0,279 <0.001	0,591 <0.001	-0,152 0.014	
VO_{2max} (ml/kg/min)	-0,436 <0.001	-0,005 0,933	-0,786 <0.001	-0,801 <0.001	0,623 <0.001	0,268 <0.001	0,436 <0.001	-0,032 0,612	0,761 <0.001

*Pearson correlation coefficient; **p-value

5.4. Factor Effects: ANOVA and Post-hoc Analyses

5.4.1. Effects of Classification Variables on Aerobic Capacity

In this study complete randomized design (CRD) model was used for independent variables. In order to investigate the main and interaction effects of age-group, job-group and BMI group, smoking group, alcohol drinking group, exercise group and occupation group on aerobic capacity, General Linear Model (GLM) models are used. ANOVA results are further investigated by post-hoc analysis using Tukey tests. The details of the analyses' results are covered in the following sections.

Before conducting each ANOVA, ANOVA assumptions were checked carefully and the details about the ANOVA assumptions are shown in Appendix D.

Table 5.23 and Table 5.24 depict the summary of ANOVA of CRD for absolute and relative aerobic capacity (VO_{2max} in l/min and in ml/kg/min). The results indicate that except occupation group, smoking group and alcohol drinking group; age-group, BMI group, and exercise group have a significant main effect on aerobic capacity (VO_{2max} in l/min and ml/kg/min). Even the contribution of age-occupation and age-exercise interaction effects to the model are relatively low since p-value of age-occupation is smaller than 0.05 and age-exercise is between 0.05 and 0.10 (marginally), they are included in the reduced model for VO_{2max} in l/min. 2-way interaction effects of occupation, exercise, smoking with age and BMI, exercise with occupation were found significant in the reduced model of VO_{2max} in ml/kg/min.

Table 5.23. ANOVA of Aerobic Capacity (VO_{2max} in l/min).

Source	DoF	Sequential SS	Contribution	Adjusted SS	Adjusted MS	F	P
Age Factor	3	11.9314	38.58%	8.0594	2.68647	42.620	0.001
BMI Factor	3	2.0531	6.64%	1.3751	0.45836	7.270	0.001
Occupation Factor	1	0.0	0.00%	0.0000	0.00004	0.000	0.981
Exercise Factor	1	0.5259	1.70%	0.2328	0.23283	3.690	0.056
Age Factor*Occupation Factor	3	0.5445	1.76%	0.5211	0.17372	2.760	0.043
Age Factor*Exercise Factor	3	0.4297	1.39%	0.4297	0.14324	2.270	0.081
Error	245	15.4421	49.93%	15.4421	0.06303		
Total	259	30.9267	100.00%				

Table 5.24. ANOVA of Aerobic Capacity (VO_{2max} in ml/kg/min).

Source	DoF	Sequential SS	Contribution	Adjusted SS	Adjusted MS	F	P
Age Factor	3	3024.2	19.64%	1889.3	629.760	38.140	<0.001
BMI Factor	3	7665.0	49.77%	5193.9	1731.300	104.850	<0.001
Occupation Factor	1	0.1	0.00%	19.5	19.520	1.180	0.278
Exercise Factor	1	146.1	0.95%	10.1	10.070	0.610	0.436
Smoking Factor	1	13.1	0.09%	19.7	19.700	1.190	0.276
Age*Occupation Factor	3	132.5	0.86%	142.3	47.430	2.870	0.037
Age*Exercise Factor	3	237.8	1.54%	195.1	65.0300	3.9400	0.009
Age*Smoking Factor	3	111.5	0.72%	134.5600	44.8500	2.7200	0.045
BMI*Occupation Factor	3	72.0	0.47%	130.8	43.610	2.640	0.050
Occupation*Exercise Factor	1	84.0	0.55%	84.0	84.010	5.090	0.025
Error	237	3913.5	25.41%	3913.5	16.510		
Total	259	15399.8	100.00%				

5.4.2. Age Effect on Aerobic Capacity

Table 5.25 and Table 5.26 depict the results of Tukey's test in absolute AC (VO_{2max} in l/min) for different age groups. All pairwise differences between factor level means are significantly different from each other except 18-24 and 25-34 age groups, which are significantly not different. Mean values of AC (VO_{2max} in l/min) decreases as age increases. Table 5.27 and Table 5.28 results show somehow relevant behavior as absolute AC values (VO_{2max} in l/min) where relative AC (VO_{2max} in ml/kg/min) also decreases as age increases. On the contrary to the results in absolute AC (VO_{2max} in l/min), 35-44 and 45-54 age groups are not significantly different from each other where all other group means are significantly different.

Table 5.25. Tukey Test Results of AC (VO_{2max} in l/min) for different age groups.

Age Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group 2 - Group 1	-0.082	0.0518	-1.58	0.389
Group 3 - Group 1	-0.3953	0.0599	-6.6	<0.001
Group 4 - Group 1	-0.6473	0.0645	-10.03	<0.001
Group 3 - Group 2	-0.3133	0.06	-5.22	<0.001
Group 4 - Group 2	-0.5653	0.0648	-8.73	<0.001
Group 4 - Group 3	-0.252	0.0713	-3.53	0.002

Group 1: 18-24; Group 2: 25-34; Group 3: 35-44; Group 4: 45-54

Table 5.26. Grouping information of AC (VO_{2max} in l/min) for age groups using Tukey Method.

Age Factor	N	Mean	Grouping
18-24	77	2.79	A
25-34	69	2.71	A
35-44	64	2.39	B
45-54	50	2.14	C

Table 5.27. Tukey Test Results of AC (VO_{2max} in ml/kg/min) for different age groups.

Age Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group 2 - Group 1	-3.949	0.853	-4.63	<0.001
Group 3 - Group 1	-7.634	0.993	-7.68	<0.001
Group 4 - Group 1	-10.34	1.07	-9.64	<0.001
Group 3 - Group 2	-3.685	0.991	-3.72	<0.001
Group 4 - Group 2	-6.39	1.07	-5.95	<0.001
Group 4 - Group 3	-2.71	1.18	-2.3	0.101

Group 1: 18-24; Group 2: 25-34; Group 3: 35-44; Group 4: 45-54

Table 5.28. Grouping information of AC (VO_{2max} in ml/kg/min) for age groups using Tukey Method.

Age Factor	N	Mean	Grouping
18-24	77	40.33	A
25-34	69	36.38	B
35-44	64	32.69	C
45-54	50	29.99	C

5.4.3. BMI Effect on Aerobic Capacity

Table 5.29 and Table 5.30 display the results of Tukey's test in AC (VO_{2max} in l/min) for different BMI groups. Factor levels within a group are significantly different from each other. Normal-weight and Over-weight groups are not statistically different since they share the same letter and adjusted p-value of Tukey Test is 0.983. According to Table 5.31 and Table 5.32, Tukey's test result show that AC values (VO_{2max} in ml/kg/min) regarding BMI are statistically different for all groups. On the contrary to Tukey's test of AC (VO_{2max} in l/min), every group has a different letter, does not form a group with each other.

Table 5.29. Tukey Test Results of AC (VO_{2max} in l/min) for different BMI groups.

BMI Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group 2 - Group 1	-0.1499	0.0502	-2.99	0.015
Group 3 - Group 1	0.0141	0.0381	0.37	0.983
Group 4 - Group 1	0.2342	0.0788	2.97	0.016
Group 3 - Group 2	0.164	0.0481	3.41	0.004
Group 4 - Group 2	0.3841	0.0897	4.28	<0.001
Group 4 - Group 3	0.2201	0.0834	2.64	0.041

Group 1: Normal-weight; Group 2: Obese ; Group 3: Over-weight; Group 4: Under-weight

Table 5.30. Grouping information of AC (VO_{2max} in l/min) for BMI groups using Tukey Method.

BMI Factor	N	Mean	Grouping
Under-weight	12	2.72	A
Normal-weight	113	2.48	B
Over-weight	97	2.50	B
Obese	38	2.33	C

Table 5.31. Tukey Test Results of AC (VO_{2max} in ml/kg/min) for different BMI groups.

BMI Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group 2 - Group 1	-11.880	0.861	-13.8	<0.001
Group 3 - Group 1	-5.964	0.639	-9.33	<0.001
Group 4 - Group 1	11.53	1.3	8.84	<0.001
Group 3 - Group 2	5.915	0.839	7.05	<0.001
Group 4 - Group 2	23.41	1.5	15.57	<0.001
Group 4 - Group 3	17.49	1.39	12.6	<0.001

Group 1: Normal-weight; Group 2: Obese ; Group 3: Over-weight; Group 4: Under-weight

Table 5.32. Grouping information of AC (VO_{2max} in ml/kg/min) for BMI groups using Tukey Method

BMI Factor	N	Mean	Grouping
Under-weight	12	47.95	A
Normal-weight	113	36.43	B
Over-weight	97	30.46	C
Obese	38	24.55	D

5.4.4. Exercise Effect on Aerobic Capacity

Table 5.33 and Table 5.34 show the results of Tukey's test in AC (VO_{2max} in l/min) for different exercise groups. Factor levels within a group are significantly different from each other. It is seen that the mean values of (VO_{2max} in l/min) are decreasing from regular exercise to irregular or no exercise group.

Table 5.33. Tukey Test Results of AC (VO_{2max} in l//min) for different Exercise groups

Exercise Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group2-Group1	0.0938	0.0488	1.92	0.045

Group 1: Irregular or no, Group 2: Regular

Table 5.34. Grouping information of AC (VO_{2max} in l/min) for Exercise groups using Tukey Method

Exercise Factor	N	Mean	Grouping	
Regular	47	2.55	A	
Irregular or no	213	2.46		B

5.4.5. Interaction Effects on Aerobic Capacity

Figure 5.9 and Figure 5.10 shows the interaction plot of aerobic capacity fitted mean values for reduced models. According to graphs, it may be concluded that having regular exercise has an incremental impact on absolute AC (VO_{2max} in l/min) when age group drops from 18-24 to 25-34. In the reduced model, occupation factor has also an interaction effect in which absolute AC values of non-manual working group increase as age group shifts from 18-24 to 25-34. In different factor groups, there are also interaction effects on relative AC (VO_{2max} in ml/kg/min) which cause minor changes in fitted means of reduced model. This may stem from a bias of samples' declaration to questions in which classification factor conditions are determined.

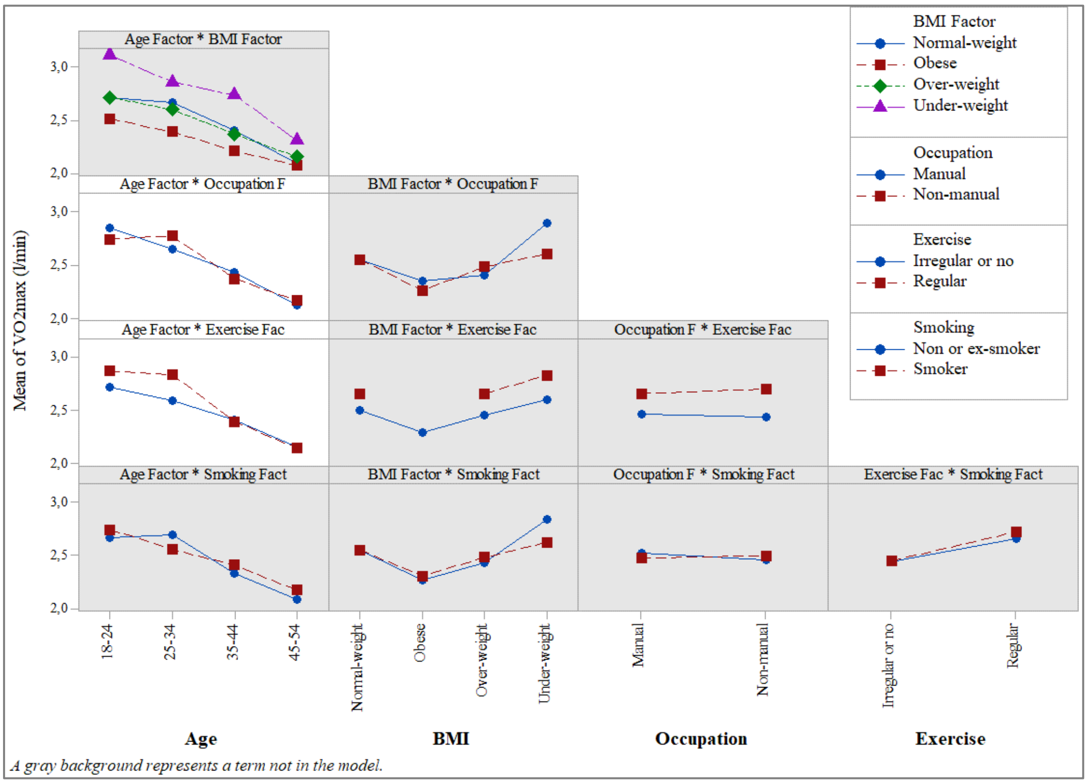

Figure 5.9. Interaction Plot for absolute aerobic capacity values (VO_{2max} in l/min)

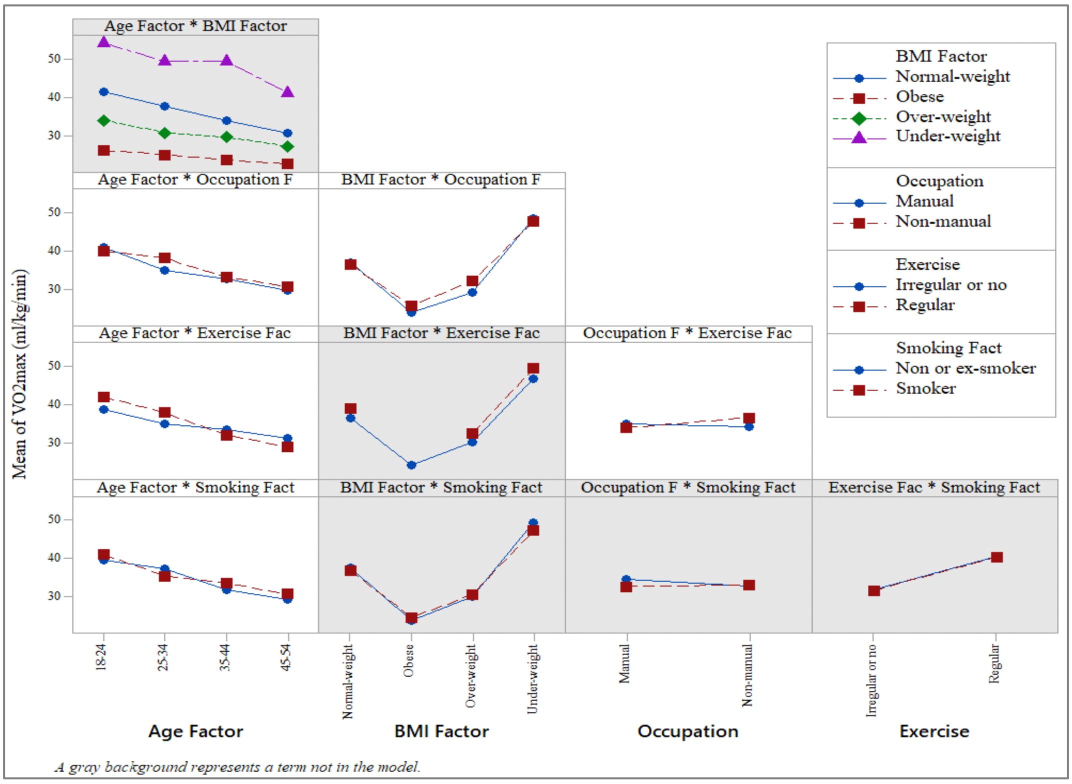

Figure 5.10. Interaction Plot for relative aerobic capacity values (VO_{2max} in ml/kg/min)

5.5. Regression Analysis of Aerobic Capacity Values

The significant independent variables which were determined by ANOVA and correlation analysis were used in building the regression models to predict aerobic capacity of males. After the diagnostics analysis, a no-interaction multiple linear regression model was determined as a suitable model for male aerobic capacity. According to Figure 5.11. quadratic terms of weight and BMI are also investigated in regression model of VO_{2max} in ml/kg/min.

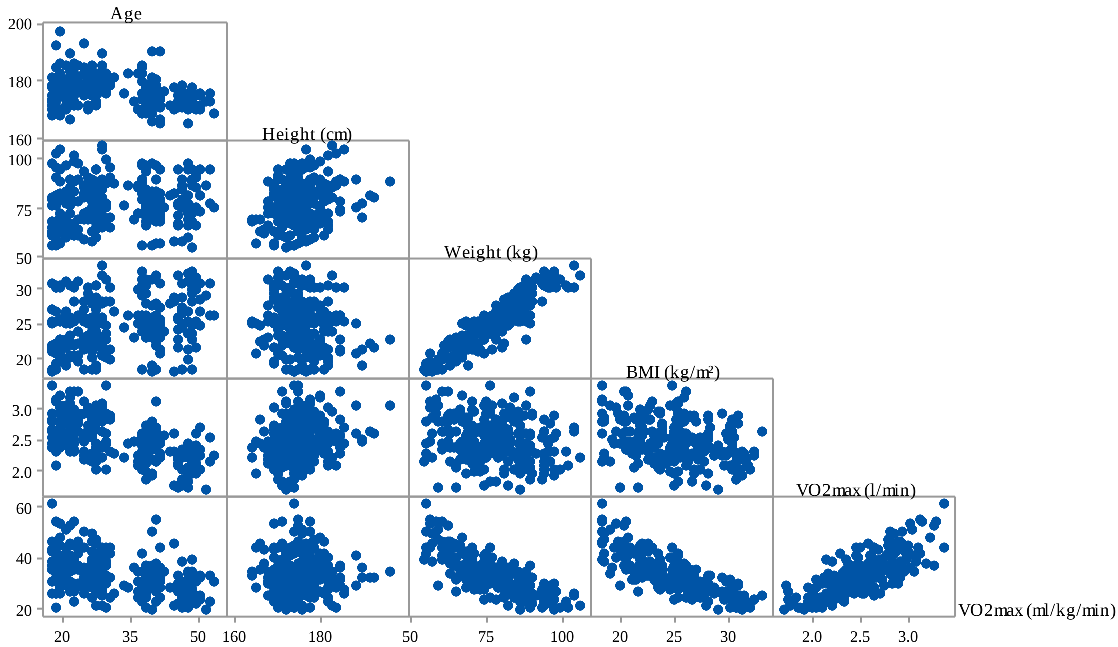

Figure 5.11. Matrix plot of continuous variables and aerobic capacity values

For developing the best regression equation, Stepwise Regression Analysis technique (backward elimination and forward selection) was used. Moreover, Best Subsets Regression analysis method was used to verify the results by comparing alternative models. Interaction effects were neglected and only the main and quadratic effects were taken into consideration. The general form of the male aerobic capacity model is as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_3^2 + \beta_5 x_4 + \beta_6 x_4^2 + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3 + \gamma_4 D_4 + \gamma_5 D_5 + \varepsilon \qquad (5.2)$$

where, β_0 is constant, β_1 is the regression coefficient of age, β_2 is the regression coefficient of height, β_3 is the regression coefficient of weight, β_4 is the regression coefficient of quadratic terms of weight, β_5 is the regression coefficient of BMI, β_6 is the regression coefficient of quadratic terms of BMI, γ_1 is the regression coefficient of occupation, γ_2 is the regression coefficient of exercise, γ_3 is the regression coefficient of smoking, γ_4 is the regression coefficient of alcohol drinking, ε is the error term, x_1 is the regressor variable of age, x_2 is the regressor variable of height, x_3 is the regressor variable of weight , x_4 is the regressor variable of BMI, D_1 is the dummy variable for occupation, D_2 is the dummy variable for exercise, D_3 is the dummy variable for smoking and D_4 is the dummy variable for alcohol drinking.

Occupation	D_1
Manual	1
Non-manual	0

Exercise	D_2
Regular	1
Irregular or no	0

Smoking	D_3
Smoker	1
Non or ex smoker	0

Alcohol Drinking	D_4
Drinking	1
Non-drinking	0

In Table 5.35, for absolute aerobic capacity and in Table 5.39, for relative aerobic capacity values 12 and 16 different alternative models are represented, respectively. All models regression equations are listed in Appendix C.

Table 5.35. Different regression model alternatives of AC (VO_{2max} in l/min) for males

Regression Models	Predictors	S	R^2 (%)	R^2 adj. (%)	Cp
Model 1	Age, Height, Weight, BMI, Alcohol Drinking, Smoking, Exercise, Occupation	0.2632	43.3	41.5	9
Model 2	Age, Height, Weight, BMI, Alcohol Drinking, Smoking, Exercise	0.2627	43.3	41.7	7
Model 3	Age, Height, Weight, BMI, Smoking, Exercise	0.2625	43.1	41.8	6
Model 4	Age, Height, Weight, Exercise	0.2629	42.5	41.6	5
Model 5	**Age, BMI, Exercise**	**0.2634**	**42**	**41.4**	**4**
Model 6	Age, Weight, Exercise	0.2648	41.4	40.7	8
Model 7	Age, Height, Exercise	0.2651	41.3	40.6	8
Model 8	Age, Exercise	0.2658	40.7	40.3	9
Model 9	Age, BMI	0.2680	39.8	39.3	12
Model 10	Age, Weight	0.2703	38.7	38.2	18
Model 11	Age, Height	0.2749	36.6	36.1	27
Model 12	Age	0.2753	36.2	35.9	26

When all of the models are checked, Model 4 and Model 5 seem as the most appropriate model due to their higher R^2_{adj} values, relatively small S values and valid C_p values.

$$H_0 : \beta_I = 0 \qquad H_1 : \text{Not all } \beta_I \text{ are zero} \tag{5.3}$$

Table 5.36 and Table 5.37 present analysis of variance table of regression models regarding Model 4 and Model 5. Since p value < 0.05, it is clear that at least one of the regressor variables contributes significantly to the model. Since BMI is also an indicator of weight and height, Model 5 was selected in order to provide a simple model by avoiding adding more predictors. The regression equation absolute aerobic capacity (for males) can be seen in Table 5.38.

Table 5.36. Analysis of variance table of regression model of Model 4 (VO_{2max} in l/min)

Source	DoF	SS	MS	F	P
Regression	4	12.966	3.241	46.89	<0.001
Age	1	7.307	7.307	105.70	<0.001
Height	1	0.326	0.326	4.71	0.031
Weight	1	0.361	0.361	5.23	0.023
Exercise	1	0.733	0.733	10.60	<0.001
Error	254	17.558	0.069		
Lack-of-Fit	252	17.151	0.068	0.33	0.948
Pure Error	2	0.407	0.204		
Total	258				

Table 5.37. Analysis of variance table of regression model for Model 5 (VO_{2max} in l/min)

Source	DoF	SS	MS	F	P
Regression	3	12.8325	4.2775	61.66	<0.001
Age	1	8.7015	8.7015	125.42	<0.001
BMI	1	0.3954	0.3954	5.70	0.018
Exercise	1	0.6946	0.6946	10.01	0.002
Error	255	17.6910	0.0694		
Lack-of-Fit	246	16.9282	0.0688	0.81	0.724
Pure Error	9	0.7629	0.0848		
Total	258				

Table 5.38. Regression analysis results for Model 5 (VO_{2max} in l/min) for males

Predictor	Coef.	SE Coef.	T	P	VIF
Constant	3.3460	0.1300	25.74	<0.001	
Age	-0.0179	0.0016	-11.20	<0.001	1.07
BMI	-0.0122	0.0051	-2.39	0.018	1.27
Exercise	0.1470	0.0465	3.16	0.002	1.20

Therefore, the selected best regression equation for male AC (VO_{2max} in l/min) is:

VO_{2max} (l/min) = 3.3460 – 0.0179×Age – 0.0122×BMI + 0.147×Exercise

(S = 0.2634; R^2 = 42%; R^2_{adj} = 41.4%; Mallow's C_p = 4)

Where;

Age (in years), BMI (in kg/m²) and

Exercise $\begin{cases} 1 & regular \\ 0 & irregular\ or\ no \end{cases}$

Same calculations are done in order to find a regression equation for AC (VO_{2max} in ml/kg/min). In table 5.39, 16 different model alternatives are represented. When all of the models are checked, Model 5 seems as the most appropriate model due to its highest R^2 adjusted value and the smallest S value. Table 5.40 present analysis of variance table of regression models. Since p value < 0.05, it is clear that at least one of the regressor variables contributes significantly to the model. Model 5 was selected and regression equation aerobic capacity (for males) can be seen in Table 5.41.

Table 5.39. Different regression model alternatives of AC (VO_{2max} in ml/kg/min) for males

Regression Models	Predictors	S	R^2 (%)	R^2 adj. (%)	Cp
Model 1	Age, Height, Weight,Weight^2, BMI, BMI^2, Alcohol Drinking, Smoking, Exercise,	3.6929	77.2	76.5	9
Model 2	Age, Height, Weight, BMI, Alcohol Drinking, Smoking, Exercise	3.67950	77.2	76.5	7
Model 3	Age, Height, Weight, BMI, Smoking, Exercise	3.67500	77.2	76.6	5
Model 4	Age, Height, Weight, Exercise	3.67130	77.0	76.7	3
Model 5	**Age, Weight, Weight^2, Exercise**	**3.66635**	**77.6**	**77.2**	**5**
Model 6	Age, Weight, Exercise	3.67660	76.9	76.6	3
Model 7	Age, Height, Weight	3.79680	75.3	75.0	19
Model 8	Age, BMI, BMI^2, Exercise	3.95548	73.3	72.9	5
Model 9	Age, BMI, Exercise	4.00970	72.5	72.2	2
Model 10	Age, Weight,Weight^2	3.8056	75.9	75.6	19
Model 11	Age, Weight	3.80890	75.1	74.9	20
Model 12	Age, BMI	4.15480	70.3	70.1	72
Model 13	BMI, Exercise	4.45670	65.9	65.6	121
Model 14	BMI	4.58150	63.8	63.6	142
Model 15	Weight	4.72950	61.4	61.3	168
Model 16	Age	6.78760	20.5	20.2	616

Table 5.40. Analysis of variance table of regression model of AC (VO_{2max} in ml/kg/min)

Source	DoF	SS	MS	F	P
Regression	4	11554.8	2888.7	219.66	<0.001
Age	1	1792.7	1792.7	136.32	<0.001
Weight	1	296.1	296.1	22.52	<0.001
Exercise	1	219.7	219.7	16.70	<0.001
Weight *Weight	1	106.7	106.7	8.11	0.005
Error	254	3340.2	13.2		
Lack-of-Fit	235	3063.2	13.0	0.89	0.667
Pure Error	19	277.0	14.6		
Total	258				

Table 5.41. Regression analysis results AC (VO_{2max} in ml/kg/min) for males

Predictor	Coef.	SE Coef.	T	P	VIF
Constant	102.2400	9.2600	11.04	<0.001	
Age	-0.2529	0.0217	-11.68	<0.001	1,03
Weight	-1.1380	0.2400	-4.75	<0.001	146,04
Exercise	2.6360	0.6450	4.09	<0.001	1,22
Weight*Weight	0.0043	0.0015	2.85	0.005	144,12

Therefore, the selected best regression equation for male AC (VO_{2max} in ml/kg/min) is:

VO_{2max} (ml/kg/min) = 102.24 – 0.2529×Age – 1.138×Weight + 0.0043×Weight^2 +2.636×Exercise

(S = 3.66635; R-sq = 77.6%; R^2_{adj} = 77.2%; Mallow's C_p = 5)

Where;

Age (in years), Weight (in kg) and

$$\text{Exercise} \quad \begin{cases} 1 & \textit{regular} \\ 0 & \textit{irregular or no} \end{cases}$$

6. DISCUSSION

6.1. Discussion on the Results of Current Study

Aerobic capacity measurement is a necessary factor in any equation that aims to calculate physical fitness level and readiness to perform physical tasks that are requiring great exertion. In place of accurate determination of aerobic capacity, the prediction of this parameter by heart rate responses to submaximal exercise is an appealing option because it is easy to administrate and has a relative safety methodology when it is compared with maximal graded tests. This study is carried out to determine a definite computer-guided protocol for predicting aerobic capacity from heart responses within a six-minute graded of precise and modified submaximal exercise on a cycle ergometer. This effort was primarily conducted with evaluating the safety, the reliability of specific cycle ergometer protocol which provides an estimate of aerobic capacity in the male population of Turkey.

6.1.1. Test Safety

This specific cycle ergometer protocol has an optimal safety level which can be interpreted from the results demonstrated in Table 5.2. which shows that subjects are exposed to relatively moderate levels of physical exertion. ACSM suggests that regular exercises at intensities that are resulting in heart rates up to %85 of predicted maximal lasting 20 minutes or longer, is optimally beneficial and safe, which does not require both medical clearance or supervision for a group of the subject which is essentially at low risk in terms of heart disease. Test workloads appointed by the cycle ergometer protocol brought out heart rates with average 141.9 bpm and about %76 of the subjects’ predicted maximal heart rates which are valid for less than six minutes in duration. Heart rate that is exceeding %85 of predicted maximal are observed only in 3 subjects and this rate is sustained for less than two minutes at the end of the test. Therefore, it can be concluded that this cycle ergometer test protocol satisfies the determination of workloads which meet optimal safety.

6.1.2. Test Reliability

The repeatability and reliability of aerobic capacity values were evaluated from data obtained when 32 of the subjects repeated this test on two separate occasions within a period of a few weeks. Even these scores were consistent, subjects tended to improve their first trial with a difference + 0.06 in l/min and +1.77 in ml/kg/min. Although these mean differences are not statistically significant, it should be noted that a few of the subjects who are not familiar with cycling benefited quietly from the possible learning effect. Based on the repeatability test, one can be 95% confident that any score obtained within 0.14 in l/min and 2.14 in ml/kg/min of the true score for any given subject.

6.1.3. Test Results

Aerobic capacity, $VO_{2max,}$ for adult male population of Turkey in this study is found to be 2.5 l/min with a standard deviation of 0.3 l/min and body weighted adjusted maximum volumetric oxygen consumption is 33.2 ml/kg/min with a standard deviation of 7.7 ml/kg/min. Findings and figures of the current study were interpreted and the probable factors that have an effect on aerobic capacity were discussed in detail. Table 6.1 summarizes findings of the literature review in terms of factors that are affecting aerobic capacity. In this study, it is found that age and body size and composition that can be represented as body mass index have the significant main effect on aerobic capacity with a contribution of %38.6 and %6.64 to variation, respectively, in ANOVA model for VO_{2max} in l/min. For VO_{2max} in ml/kg/min values, ANOVA of GLM shows that age and BMI have a contribution of %19.64 and %49.77, respectively total variation of the model. Even some interaction effects are also investigated and found statistically significant, their contribution to R^2 was relatively low. Because of that, interaction effects are not examined in regression analysis. Quadratic terms and categorical predictors are also evaluated in regression analysis.

Regression analysis for VO_{2max} in l/min is determined as;

VO_{2max} in l/min = 3,3460 - 0,0179×Age - 0,0122×BMI + 0,147×Exercise

with R^2_{adj} = 41.4%, S=0,26 l/min

Regression analysis for VO_{2max} in ml/kg/min is determined as;

VO_{2max} in ml/kg/min = 102,24 – 0,2529×Age – 1,138×Weight + 0,0043×Weight^2 + 2,636×Exercise with R^2_{adj} = 77.2%, S=3,66 l/min

Table 6.1. Summary result table of Factors on AC studies in the literature

Statistical Analyses Employed		**Significant Factors on AC**	**R^2**	**References**
ANOVA		Age, Gender, Estimation methods	-	Balderrama *et al.* (2010)
Correlation analysis		Region (Urban & Rural), Age, Height, Weight, Body Surface Area (BSA), Body Mass Index (BMI)	-	Das (2013)
		Occupation, BMI, Age, Type of Training	-	Prieto *et al.* (2013)
Regression Models	Linear	Heart rate at submaximal exercise	0.58	Astrand & Ryhming (1954)
		Respiratory quotient	0.22	Issekutz *et al.* (2005)
	Multiple Linear	Astrand-Rhyming test, 12 minutes run and some anthropometric measurements	0.66	Jessup *et al.* (1978)
		Respiratory exchange ratio, Work rate, Diastolic blood pressure, Expired volume, Expired oxygen	0.86	Mastropaolo (1970)
		Age, Fat-free weight, HR, Fraction of carbondioxide in expired gas, tidal volume at submaximal work level, rate of change of the respiratory exchange ratio	0.81	Hermiston & Faulkner (1991)
		Body weight, elbow width, stature and juxtra nipple skinfold thickness	0.35	Verma *et al.* (1979)
		Body weight, time for 3.2 km run	0.37	Verma *et al.* (1979)
		Body weight, time for 3.2 km run and exercise dyspnoeic index	0.43	Verma *et al.* (1979)
		Gender, Age, Body mass, power and exercise heart rate at submaximal cycle test	0.88	George *et al.* (2007)
		Gender, Age, Body mass, self selected treadmill jogging speed, steady-state heart rate at treadmill test,	0.91	Vehrs and Fellingham (2006)
		Gender, Age, Body mass, Ending self-selected treadmill speed,Perceived functional ability, Physical activity rating	0.89	George *et al.* (2009)

Table 6.1. Summary result table of Factors on AC studies in the literature (cont.)

Statistical Analyses Employed		**Significant Factors on AC**	R^2	**References**
Regression Models	Multiple Linear	Gender, Body mass, Perceived functional ability,exercise work rate, exercise steady-state HR	0.91	Nielson *et al.* (2010)
		Gender, BMI, Intensity of physical activity in sports	0.38	Duque and Parra (2009)
		Gender, Age, BMI, Physical activity score	0.69	Sloan *et al.* (2013)
		Age, Body composition - BMI, 3 minute walk distance,	0.60	Cao *et al.* (2013)
		Age, Body composition - WC (waist circumference), 3 minute walk distance,	0.63	
		Age, Body composition - % Fat, 3 minute walk distance,	0.70	
		Age, Gender, Activity habit, BMI, Smoking	0.65	Suminski *et al.* (2009)
	Non-Linear	Cardioresriratory strains	0.66	Verma *et al.* (1979)

(i) *Age Factor:* Findings of the current study are parallel with previous studies in the literature which indicated that age is an important variable in predicting aerobic capacity (Astrand *et al.*, Nielson *et al.*, Duque and Parra). In general, results correspond to a decrease in the VO_{2max} as the age of the people increases. It can be said that the VO_{2max} is strongly inversely correlated with age. In parallel to that phrase, results of the age group between 45 and 54 have the lowest mean of AC whereas the age group between 18 and 24 has the highest one in the current study. Bugajska *et al.* (2005) aimed to evaluate aerobic capacity and work ability of men and women in employment age. The results of the study regarding age indicated that AC has a strong negative correlation with age. In the study of Singh *et al.* (2008), the subjects were classified into two age-groups of 25-35 years and 36-45 years. The sub-maximal exercise technique was conducted to the subjects and it is indicated that the mean aerobic capacity of the group one (25-35 years) was 17.2% higher than the other group.

Lastly, one of the most comprehensive studies about aerobic capacity of the populations was the study of Kang *et al.* (2007) that is carried out to identify the distribution and to find out determinants of aerobic capacity of Korean male metal workers. The mean value of AC for age group 50-59 is 33,2 in ml/kg/min which was lowest whereas it is 36.2 in ml/kg/min for subjects that have age lower than 30.

(ii) *BMI Factor :* The findings of the current study indicated that BMI is a strong factor in aerobic capacity (VO_{2max} in l/min) that is validated by significant differences between each BMI group. It has seen that the mean values of VO_{2max} results (in ml/kg/min) were decreasing from under-weight group to obese group and each BMI group statistically differ from each other. Bradshaw *et al.* (2005) aimed to build up a regression model in order to estimate VO_{2max} with the help of non-exercise data. For this purpose, 100 participants, aged 18-65 years old, participated in the study. After the subjects completed the graded maximal exercises, a multiple linear regression generated in order to create a prediction equation for VO_{2max} using non-exercise data. According to the non-exercise prediction equation, BMI was one of the statistically significant ($p < .05$) effect in predicting VO_{2max}. In line with the current study, the findings of the study of Kang *et al.* (2007) indicated that aerobic capacity was affected by BMI values of the employees. In the study, workers with high BMI values were founded to have lower VO_{2max} values. In addition to these, Afolabi & Akanbi (2013) found BMI as a significant factor on aerobic capacity.

(iii) *Occupation Factor:* The effect of occupation on aerobic capacity is also investigated in the current study. In literature, there are no acceptable and validated findings related to the difference of AC values between manual and non-manual workers. The results of the current study indicated that occupation does not have any significant effect on aerobic capacity and there is no significant difference between each occupation group. It is seen that the mean values of VO_{2max} results do not statistically differ from each other.

(iv) *Exercise Factor:* Regarding the current study, having an exercise habit is a reasonable effect on aerobic capacity. Results of the study showed that the mean values of VO_{2max} were decreasing from “regular” group to “irregular or no” group and the mean values of each group statistically differ from each other. Güvenç (2007) carried out a study aiming to determine aerobic, anaerobic power and capacity differences as a function of age, maturation, training, and physical activity among normal untrained and trained boys with age between 11 and 15. The findings of the study indicated that the trained boys have higher aerobic, anaerobic power and capacity values compared to untrained counterparts. Another study that is also carried out in Turkey is aimed to identify aerobic capacity values of referees and evaluate the effect of working classification (B, C, D) on aerobic capacity (Ceyhun *et al.* 2014). 28 male referees from different classifications participated and aerobic capacity values are measured by shuttle run test of 20 m. Apart from classification effect, exercise effect is also investigated in the study thereby generating 2 groups which are named as active sportively and inactive sportively, including 23 and 5 referees in related groups, respectively. VO_{2max} (ml/kg/min) of active sportive and inactive sportive groups are measured as 47.54±3.50 and 44.64±2.59, respectively. Depending on t-test results, it has been determined that there is no significant evidence ($p>0.05$) that there is a difference between active sportive and inactive sportive groups. However, it is found that the classification of participants has a significant effect on aerobic capacity ($p<0.05$). On the contrary, the results of the current study showed that exercise has a main effect on aerobic capacity. This could be explained also with the difference in definitions of exercise factor on aerobic capacity in each study.

(v) *Smoking Factor:* In the literature, there were not many studies investigating the effect of smoking on aerobic capacity. Suminski *et al.* (2009) conducted a study to find the effect of smoking on aerobic capacity and concluded that after taking into account the effects of gender, age, BMI and physical activity status, smoking habit's effect on aerobic capacity is minimal with a negative contribution nearly 0,85 ml/kg/min. But when the smoking habit exceeds 20 packs/year, an additional 1.71 ml/kg/min decrease is observed. In the study of Kang *et al.* (2007) conducted by 570 male metal workers, including also exercise and alcohol consumption factors, smoking does not have a significant relationship with the relative VO_{2max}. The results of the current study showed that smoking has only an interaction effect with age on aerobic capacity (VO_{2max} in ml/kg/min) with a smaller contribution to R^2. On the other hand, the mean values of aerobic capacity (VO_{2max} in l/min) of each smoking group does not statistically differ from each other.

(vi) *Alcohol Drinking Factor:* Finally, according to the current study, findings indicated that alcohol drinking habit of men does not have a significant effect on aerobic capacity. The mean values of each alcohol drinking group do not statistically differ from each other. This result is similar to the result of the study of Kang *et al.* (2007) conducted with 570 male workers.

6.2. Comparison with Other Studies

In this part, the main results of the current study were compared to other studies in the literature. In order to make accurate comparisons, it was tried to find the most similar methods and only the studies conducted on men were taken into account.

For aerobic capacity, the most similar studies for comparison:

- Storer *et al*. (1990)
- Jackson *et al*. (1995)
- Mamansari *et al*. (1996)
- Myhre *et al.* (1998)
- Wu and Wang (2001)
- Bugajska *et al.* (2005)
- Gökbel *et al.* (2005)
- Pennathur *et al*. (2005)
- Pulkinken *et al*. (2005)
- Vehrs and Fellingham (2006)
- Kang *et al*. (2007)
- Sloan *et al*. (2013)
- Ciao *et al*. (2013)
- Myers *et al*. (2017)
- Hosick *et al*. (2018)
- Ando *et al*. (2018)

All of the related studies were examined and explained in detail in the literature review part. However, some specific information about the compared studies that are affected by anthropometric, demographic characteristics and measurement methods are given once again.

6.2.1. Current study vs. Storer *et al*. (1990) for Aerobic Capacity

Storer *et al*. (1990) examined a study in order to develop an equation hypothesizing that cycle ergometer VO_{2max} could be accurately predicted due to its more direct relationship with work rate. During the experiments, 115 male subjects, aged between 20-70 (42,5±14,8), completed maximal exercise tests using cycle ergometer. It was seen from independent t-test results, that there is a statistical difference between the mean values of the current study and the previous study of Storer *et al*. (1990). The current study is carried out with a sample of having 32,6±10,5 age distribution whose mean value is approximately 10 years lower than study of Storer *et al*. Having known that aerobic capacity is strongly inversely correlated with age, related study's AC mean values are statistically greater that the current study even it has a higher mean value in age. All participants were elected and underwent test exercises at two institutions: El Camino Collage in Torrance, CA and the University of California at Irvine. The data of the participants' nationality were not observed in the study. Since there is no data available regarding BMI and physical activity status and nationality of participants in the study of Storer *et al*., the difference may attribute to variations occurred both in physical characteristics' distribution of samples and also the genetics, the ethnicity, geographic environment differentiation. This inference is valid for all other comparisons discussed in the current study.

Table 6.2. Comparison of results for AC results (VO_{2max} l/min) of Storer *et al.*'s study (age range: 20-70)

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Storer *et al.* (1990)	115	2.77	0.60	0.056	0.28	4.68	<0.001	151
Current Study	260	2.49	0.35	0.022				

6.2.2. Current study vs. Jackson *et al.* (1995) for Aerobic Capacity

Jackson *et al*. (1995) studied 145 college educated, white-collar male employees at NASA/Johnson Space Center. These men were from 25 to 34 years of age. The AC values which were measured in the study of Jackson *et al.* (1995) were compared with the values of current study. P values of independent t-test show that there is a significant difference between the results of two studies for the same age groups and it can be inferred that

American white-collar male employees have higher AC values than the ones with the same age group and occupation category in Turkey that are measured in the current study.

Table 6.3. Comparison of results for AC (VO_{2max} in ml/kg/min) of current study with Jackson *et al.*'s study (age range: 25-34)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T-value**	**p-value**	**DoF**
Jackson *et al.* (1995)	145	45.8	7.7	0.64	11.20	10.23	<0.001	212
Current Study	69	34.6	7.01	0.84				

Table 6.4. Comparison of results for AC results (VO_{2max} l/min) of current study with Jackson *et al.*'s study (age range: 25-34)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T-value**	**p-value**	**DoF**
Jackson *et al.* (1995)	145	3.57	0.67	0.056	0.95	14.18	<0.001	211
Current Study	69	2.62	0.31	0.037				

6.2.3. Current study vs. Mamansari *et al.* (1996) for Aerobic Capacity

Mamansari *et al.* (1996) investigated the aerobic capacity of agricultural laborers in Thailand. Ten men aged 20–52, participated in a submaximal bicycle ergometer test to determine aerobic capacity. According to the comparison results, AC values of Turkish male population is significantly higher than AC values of the subjects participated in the study Mamansari *et al.* (1996) in Thailand.

Table 6.5. Comparison of results for AC results (VO_{2max} l/min) of current study with Mamansari *et al.* (1996).'s study (age range: 20-52).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T-value**	**p-value**	**DoF**
Mamansari *et al.* (1996)	10	2.07	0.52	0.160	-0.330	-2.98	0.003	191
Current Study	183	2.40	0.33	0.024				

6.2.4. Current study vs. Myhre *et al.* (1998) for Aerobic Capacity

Myhre *et al.* (1998) examined a comprehensive study on American Air-force workers. 41 females and 58 men ranging in age from 28 to 57 years attended the experiments and conducted maximal tests with treadmill and sub-maximal tests with cycle ergometer. The cycle ergometer test protocol was developed by Myhre *et al.* (1998) using the basic principles of US Air Force Cycle Ergometry Fitness Protocol. It was seen from independent t-test results that there is a statistical difference between the mean values of the current study and the previous study of Myhre *et al.* (1998).

Table 6.6. Comparison of results for AC results (VO_{2max} l/min) of current study with Myhre *et al.*'s study (age range: 20-57)

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T-value	p-value	DoF
Myhre *et al.* (1998)	10	46.1	10.0	3.2	13.38	5.58	<0.001	224
Current Study	216	32.7	7.2	0.5				

6.2.5. Current study vs. Wu and Wang (2001) for Aerobic Capacity

Wu and Wang (2001) aimed to determine the maximum acceptable work duration for high-intensity work. 15 male subjects whose body heights matched body height distribution of the typical worker in Taiwan, participated voluntarily in the study. The age range was specified at 20-30 years since high-intensity work is more proper for young and healthy workers. Aerobic capacity and maximum work rate of subjects were measured by the help of an electrical cycle ergometer (Ergometrics er800 s, Ergoline, Germany) used for the incremental and constant cycling tests in the experiments. The AC values which were measured in the study of Wu and Wand (2001) were compared with the values of current study. Since p value is lower than 0.05, it can be said that there is a statistically significant difference between the two samples that are compared.

Table 6.7. Comparison of results for AC results (VO2max l/min) of current study with Wu and Wang's study (age range: 20-30)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p-value**	**DoF**
Wu and Wang (2001)	15	3.31	0.49	0.13	0.64	7.18	<0.001	132
Current Study	119	2.67	0.30	0.02				

6.2.6. Current study vs. Bugajska *et al.* (2005) for Aerobic Capacity

The aim of the study carried out by Bugajska *et al.* (2005) was to evaluate the level of aerobic capacity and the value of work ability in working people and assess the effect of the aerobic capacity on work ability. In the experiments, 664 occupationally active men performed 2-4 submaximal exercise tests on a bicycle ergometer. On the basis of VO_2 and heart rate during these tests, linear regression was estimated and extrapolated to maximal heart rate assessed according to age. Except the comparison with the age group 50+, the obtained results that are summarized in Table 6.8, Table 6.9, Table 6.10 and Table 11. indicate that AC values of occupationally active men in Poland do significantly differ from ones that measured in the current study ($p < 0.05$).

Table 6.8. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Bugajska *et al.*'s study (age range: 18-24)

Studies	**Sampl e Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Bugajska *et al.* (2005)	20	42.8	9.8	2.2	5.65	2.65	0.009	95
Current Study	77	37.1	8.1	0.9				

Table 6.9. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Bugajska *et al.*'s study (age range: 25-30)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Bugajska *et al.* (2005)	79	44.1	10.4	1.2	9.34	6.39	<0.001	136
Current Study	63	34.7	6.9	0.8				

Table 6.10. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Bugajska *et al*.'s study (age range: 31-40).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Bugajska *et al.* (2005)	182	43.5	10.9	0.81	12.92	10.68	<0.001	128
Current Study	47	30.5	6.1	0.90				

Table 6.11. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Bugajska *et al*.'s study (age range: 41-50).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Bugajska *et al.* (2005)	224	38.5	10.9	0.73	8.78	8.09	<0.001	177
Current Study	65	29.7	6.4	0.80				

Table 6.12. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Bugajska *et al*.'s study (age range: 50+).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Bugajska *et al.* (2005)	134	33.4	10.6	0.9	6.00	1.59	0.115	140
Current Study	8	27. 4	5.3	1.9				

6.2.7. Current study vs. Gökbel (2005) for Aerobic Capacity

Gökbel *et al.* (2005) conducted a study in order to evaluate the validity of Astrand-Rhyming nomogram and Fox equation and to determine if these methods could be used for the estimation of anaerobic threshold. A maximal cycle exercise test was applied to 15 sedentary, 7 trained young males. It was seen from independent t-test results, that there is not a statistical difference between the mean values of the current study and the previous study of Gökbel *et al.* (2005).

Table 6.13. Comparison of results for AC results (VO2max l/min) of current study with Gökbel *et al.*'se study (age range: 18-24).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Gökbel *et al.* (2005)	15	2.88	0.46	0.12	0.18	1.46	0.163	16
Current Study	77	2.70	0.28	0.03				

6.2.8. Current study vs. Pennathur *et al.* (2005) for Aerobic Capacity

Pennathur *et al*. (2005) carried out an experimental study to determine the aerobic capacity in Mexican American young adults. The subjects were 16 male and 5 female healthy students with age ranged from 22 to 30 years. The aerobic capacity was measured using a submaximal treadmill exercise using the Bruce protocol. Pennathur *et al*. (2005) concluded that there is little evidence to suggest that the aerobic capacities of Mexican American young male adults (especially university students) may be any different from other population groups. It has to be noted, however, that study sample in this research did not include full-time industrial workers as a result, the aerobic capacities for male participants in this study may be overestimated of aerobic capacities of typical Mexican industrial workers. P values of independent t-tests show that there is a significant difference between the results of two studies for the same age groups and it can be inferred that Mexican American young adults have higher AC values than the ones with the same age group and occupation category in Turkey that are measured in the current study.

Table 6.14. Comparison of results for aerobic capacity (VO_2max in l/min) of current study with Pennathur *et al*.'s study (age range: 20-28).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T-value**	**p-value**	**DoF**
Pennathur *et al.* (2005)	16	4.81	1.75	0.44	2.14	4.88	0.000	15
Current Study	97	2.67	0.29	0.02				

Table 6.15. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Pennathur *et al.*'s study (age range: 20-28).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T-value	p-value	DoF
Pennathur *et al.* (2005)	16	56.30	12.2	3.00	20.24	6.47	0.000	16
Current Study	97	36.08	7.28	0.74				

6.2.9. Current study vs. Pulkkinen *et al.* (2005) for Aerobic Capacity

In the study of Pulkkinen *et al.* (2005), the purpose was to evaluate whether energy expenditure can be accurately estimated from heart rate without individual laboratory calibration during real-life tasks and physical exercises. VO_{2max} data from 16 male and 16 female Finnish healthy untrained adults were collected by employing maximal stepwise test on bicycle ergometer. According to the comparison results, AC values of Turkish male sample is significantly lower than AC values of the subjects participated in the study of Pulkkinen *et al*. (2005) in Finland.

Table 6.16. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Pulkinken *et al.*'s study (age range: 24-50).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T-value	p-value	DoF
Pulkinken *et al.* (2005)	16	49	8	2.0	17	9.20	0.000	195
Current Study	181	32	7	0.5				

6.2.10. Current study vs. Vehrs and Fellingham (2006) for Aerobic Capacity

Vehrs and Fellingham (2006) conducted a study that compared ethnic differences in heart rate and aerobic capacity that are measured in submaximal cycle ergometer. Thirty-two men (White, n = 16; African American, n = 16) performed a graded maximal exercise test in a cycle ergometer. When the results of this study and the current study are compared, it is obtained that AC values of both White and African American are statistically higher than the Turkish male sample in the current study for age groups: 18-24.

Table 6.17. Comparison of results for aerobic capacity (VO_2max in l /min) of current study with Vehrs and Fellingham's study for White men (age range: 18-24).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Vehrs and Fellingham (2006)	16	3.51	0.10	0.025	0.81	19.98	0.000	68
Current study	77	2.7	0.28	0.032				

Table 6.18. Comparison of results for aerobic capacity (VO_2max in l /min) of current study with Vehrs and Fellingham's study for African American men (age range: 18-24).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Vehrs and Fellingham (2006)	16	3.99	0.20	0.050	1.29	17.49	0.000	91
Current study	77	2.7	0.28	0.032				

6.2.11. Current study vs. Kang *et al*. (2007) for Aerobic Capacity

One of the most comprehensive studies about aerobic capacity of the populations was the study of Kang *et al.* (2007). It is conducted to determine the distribution and determinants of aerobic capacity of Korean male metal workers. The total of 570 male metal employees from several metal industries were the subjects of the study. The VO_{2max} was evaluated with a sub-maximal ramp test using a bicycle ergometer. The results of the study showed that the maximal aerobic capacity was influenced by the age of the employees. The mean values of absolute and relative VO_{2max} (ml/kg/min), were lowest for subjects aged 50-59 years. Besides, it was stated that there was no significant difference regarding again absolute and relative VO_{2max} between longer or shorter work tenure groups. On the other hand, a worker with a high BMI was founded to have lower relative VO_{2max}. Lastly, no other variables including marital status, education and exercise level, alcohol drinking or smoking had a significant relationship with the relative VO_{2max}. The AC values which were measured in the study of Kang *et al.* (2001) were compared with the values of current study. P value of independent t-test shows that there are no statistical differences between the results of two studies.

Table 6.19. Comparison of results for aerobic capacity (VO_2max in l /min) of current study with Kang *et al.*'s study (age range: 20-60).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Kang *et al.* (2007)	507	2.40	0.40	0.018	-0.09	-3.21	0.001	587
Current study	260	2.49	0.35	0.022				

6.2.12. Current study vs. Sloan *et al.* (2013) for Aerobic Capacity

A more recent study conducted by Sloan *et al.* (2013) in order to investigate the validation of non-exercise fitness assessment equation developed by Jurca *et al.* in 2005 among adult Singaporean population. In the experiments, a total of 100 participants (57 men, 43 women; aged 18–65 years) were completed a treadmill exercise with Bruce protocol and their maximal oxygen consumption was measured in the laboratory by indirect calorimetry. P value of independent t-test shows that there is a significant difference between the results of two studies and it can be inferred that the Singaporean male population has higher AC values than Turkish male population.

Table 6.20. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Sloan *et al.*'s study (age range: 18-65).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Sloan *et al.* (2008)	57	35.20	5.00	0.66	1.97	2.41	0.017	122
Current Study	260	33.23	7.71	0.48				

6.2.13. Current study vs. Cao *et al. (*2013) for Aerobic Capacity

Cao *et al.* (2013) conducted a study in order to develop new maximal oxygen uptake prediction models using a perceptually regulated 3-minute walk test. In this purpose 283 (143 men, 140 women) healthy Japanese adults 20-69 years of age were recruited. P value of independent t-test shows that there is a significant difference between the results of two studies and it can be inferred that the Japanese male population has higher AC values than Turkish male population.

Table 6.21. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Cao *et al*.'s study (age range: 20-69).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Cao *et al.* (2013)	143	37.30	8.70	0.73	4.070	4.84	<0.001	401
Current Study	260	33.23	7.71	0.48				

6.2.14. Current study vs. Myers *et al*. (2017) for Aerobic Capacity

Myers *et al*. (2017) aimed to develop regression model for determinants of aerobic capacity to improve previous regression formula in literature with the help of Exercise: A National Data Base (FRIEND) registry initiative which has an objective of enhancing the importance of aerobic capacity and cardiorespiratory fitness across different units of society consisting not only clinical setting and workplaces but also the public so as to inform national regulation efforts on physical fitness, activity and health. The study sample consists of 7759 participants (4601 men, 3158 women with age ranged from 20 to 80 years) from different geographic regions such as Indiana, Louisiana, North Carolina, Oregon, Pennsylvania, Tennessee, and Texas in USA. P value of independent t-test shows that there is a significant difference between the results of Myers *et al*. and current study for each age group and it can be said that male population living in USA has higher AC values than Turkish male population.

Table 6.22. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Myers *et al*.'s study (age range: 20-29)

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Myers *et al.* (2017)	505	47.9	10.9	0.49	11.73	14.2	<0.001	286
Current Study	133	36.17	7.71	0.67				

Table 6.23. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Myers *et al*.'s study (age range: 30-39)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Myers *et al.* (2017)	963	42.90	9.80	0.32	12.22	12.22	<0.001	50
Current Study	42	30.68	6.15	0.95				

Table 6.24. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Myers *et al*.'s study (age range: 40-49)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Myers *et al.* (2017)	1326	38.8	9.60	0.26	8.55	10.18	<0.001	87
Current Study	72	30.25	6.77	0.80				

Table 6.25. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Myers *et al*.'s study (age range: 50-59)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Myers *et al.* (2017)	1077	33.80	4.99	0.28	13.02	9.22	<0.001	12
Current Study	13	20.78	9.10	1.4				

6.2.15. Current study vs. Hosick *et al*. (2018) for Aerobic Capacity

Hosick *et al*. (2018) examined a study to investigate the effect of aerobic capacity on the correlation between body mass index and resting testosterone level (RTL) in males. A subset of male subjects from 2003-2004 National Health Nutrition Examination Survey of USA is gathered and analyzed by weight status as normal, overweight, obese. The subset of participants is determined and restricted to young adults (18-35 years of age) since sex steroid hormones may be influenced by age. The racial profile of related sample consists of Mexican American, Non-Hispanic White, Non-Hispanic Black, Other Hispanic, Multi or other race males living in USA. When the results of this study and the current study are compared, it can be concluded that AC values of males from different ethnicity living in USA are statistically higher than the Turkish male sample in the current study for different BMI groups within age groups: 18-35.

Table 6.26. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Hosick *et al*.'s study (Normal Weight - Age Range: 18-35)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Hosick *et al.* (2018)	59	47.1	7.7	1.0	7.39	6.08	<0.001	123
Current Study	66	39.7	5.8	0.72				

Table 6.27. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Hosick *et al*.'s study (Overweight - Age Range: 18-35)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Hosick *et al.* (2018)	45	42.40	7.9	1.2	9.84	7.40	<0.001	66
Current Study	45	32.56	4.15	0.62				

Table 6.28. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Hosick *et al*.'s study (Obese - Age Range: 18-35)

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Hosick *et al.* (2018)	37	39.3	5.5	0.90	13.37	10.85	<0.001	44
Current Study	16	25.9	3.3	0.84				

6.2.16. Current study vs. Ando *et al*. (2018) for Aerobic Capacity

Ando *et al*. (2018) conducted a study to investigate whether there is an association between directly measured aerobic capacity values and weight change since it is known that energy expenditure measured under living conditions estimates weight change. 80 American Indian males from southwestern heritage aged 18 to 45 years participated to graded exercise test with discontinuous work bouts on treadmill. P values of independent t-tests show that there is a significant difference between the results of two studies for the same age group and it can be inferred that American Indian males from southwestern heritage have higher AC values than the ones with the same age in Turkey that are measured in the current study.

Table 6.29. Comparison of results for aerobic capacity (VO_2max in ml/kg/min) of current study with Ando *et al*.'s study (Age Range: 18-45)

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Ando *et al.* (2018)	80	3.42	0.52	0.059	0.8510	13.63	<0.001	100
Current Study	213	2.57	0.31	0.021				

Table 6.30. Summary results of compared previous studies.

Study	Country-Nationality	Sample Size	Factor (Range)	Method	Equipment	Protocol	AC
Storer *et al.* (1990)	USA	115	Age (20-70)	Maximal	Cycle Ergometer	Modified	2.77±0.60 (l/min)
Jackson *et al.* (1995)	USA	145	Age (25-34)	Not Mentioned	Not Mentioned	Not Mentioned	3.57±0.67 (l/min)
Jackson *et al.* (1995)	USA	145	Age (25-34)	Not Mentioned	Not Mentioned	Not Mentioned	45.8±7. 7 (ml/kg/min)
Mamansari *et al.* (1996)	Thailand	10	Age (20-52)	Sub-Maximal	Cycle Ergometer	Not Mentioned	2.07±0.52 (l/min)
Myhre *et al.* (1998)	USA	58	Age (20-59)	Sub-Maximal	Cycle Ergometer	US Air Force	44.76±12.25 (ml/kg/min)
Wu and Wang (2001)	Taiwan	15	Age (20-30)	Sub-Maximal	Cycle ergometer	Not Mentioned	3.31±0.49 (l/min)
Bugajska *et al.* (2005)	Poland	20	Age (18-24)	Sub-maximal	Cycle Ergometer	Modified	42.8 ±9.8 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	79	Age (25-30)	Sub-maximal	Cycle Ergometer	Modified	44.1 ± 10.4 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	182	Age (31-40)	Sub-maximal	Cycle Ergometer	Modified	43.5 ± 10.9 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	224	Age (41-50)	Sub-maximal	Cycle Ergometer	Modified	38.5 ± 10.9 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	134	Age (51-60)	Sub-maximal	Cycle Ergometer	Modified	33.4 ± 10.6 (ml/kg/min)
Gökbel *et al.* (2005)	Turkish	15	Age (18-24)	Maximal	Cycle Ergometer	Modified	2.88 ± 0.46 (l/min)
Pennathur *et al.* (2005)	USA	16	Age (20-28)	Sub-maximal	Treadmill	Bruce	4.80±1.75 (l/min)
Pennathur *et al.* (2005)	USA	16	Age (20-28)	Sub-maximal	Treadmill	Bruce	56.32±12.16 (ml/kg/min)
Pulkinken *et al.* (2005)	Finland	16	Age (24-50)	Maximal	Cycle Ergometer	Modified	49 ±8.0 (ml/kg/min)

Table 6.30. Summary results of compared previous studies. (cont.)

Study	Country-Nationality	Sample Size	Factor (Range)	Method	Equipment	Protocol	AC
Vehrs and Fellingham (2006)	USA - White Men	16	Age (18-24)	Sub-maximal	Cycle Ergometer	Astrand	3.51±0.1 (l/min)
Vehrs and Fellingham (2006)	USA-African American	16	Age (18-24)	Sub-maximal	Cycle Ergometer	Astrand	3.99±0.2 (l/min)
Kang *et al.* (2008)	Korean	507	Age (20-60)	Sub-maximal	Cycle Ergometer	Not Mentioned	2.40±0.40 (l/min)
Sloan *et al.* (2013)	Singapore	57	Age (18-65)	Maximal	Treadmill	The Bruce Treadmill Ramp	35.2±5.00 (ml/kg/min)
Cao *et al.* (2013)	Japan	143	Age (20-69)	Maximal	Cycle Ergometer	Graded Exercise Test	37.30±8.70 (ml/kg/min)
Myers *et al.* (2017)	USA	505	Age (20-29)	Maximal	Treadmill	Not Mentioned	47.90±10.9 (ml/kg/min)
Myers *et al.* (2017)	USA	963	Age (30-39)	Maximal	Treadmill	Not Mentioned	42.90±9.80 (ml/kg/min)
Myers *et al.* (2017)	USA	1326	Age (40-49)	Maximal	Treadmill	Not Mentioned	38.8±9.60 (ml/kg/min)
Myers *et al.* (2017)	USA	1077	Age (50-59)	Maximal	Treadmill	Not Mentioned	33.80±4.99 (ml/kg/min)
Hosick *et al.* (2018)	USA	59	Age (18-35) Normal weight	Sub-Maximal	Treadmill	Modified	47.1±7.7 (ml/kg/min)
Hosick *et al.* (2018)	USA	45	Age (18-35) Over weight	Sub-Maximal	Treadmill	Modified	42.4±7.9 (ml/kg/min)
Hosick *et al.* (2018)	USA	37	Age (18-35) Obese	Sub-Maximal	Treadmill	Modified	39.3±5.5 (ml/kg/min)
Ando *et al.* (2018)	USA	80	Age (18-45)	Sub-maximal	Treadmill	Graded Exercise Test	3.42±0.52 (l/min)

Table 6.31. Summary of comparisons.

Current study vs.	Population (Male)	Sample Size	Age Range	AC	% Diff.	t-value (p-value)
Storer *et al.* (1990)	USA Adults	115	20-70	2.77±0.60 (l/min)	-11.2	4.68 (<0.001)
Jackson *et al.* (1995)	American White Collars	145	25-34	3.57±0.67 (l/min)	-36.2	14.18 (<0.001)
Jackson *et al.* (1995)	American White Collars	145	25-34	45.8±7. 7 (ml/kg/min)	-32.3	10.23 (<0.001)
Mamansari *et al.* (1996)	Thai Agricultural Laborers	10	20-52	2.07±0.52 (l/min)	13.75	-2.98 (0.003)

Table 6.31. Summary of comparisons. (cont.)

Current study vs.	Population (Male)	Sample Size	Age Range	AC	% Diff.	t-value (p-value)
Myhre *et al.* (1998)	American Airforce Workers	58	20-59	44.76±12.25 (ml/kg/min)	-40.8	5.58 (<0.001)
Wu and Wang (2001)	Taiwanese Healthy Adults	15	20-30	3.31±0.49 (l/min)	-23.9	7.18 (<0.001)
Bugajska *et al.* (2005)	Polish Workers	20	18-24	42.8±9.8 (ml/kg/min)	-15.2	2.65 (0.009)
Bugajska *et al.* (2005)	Polish Workers	79	25-30	44.1±10.4 (ml/kg/min)	-26.8	6.39 (<0.001)
Bugajska *et al.* (2005)	Polish Workers	182	31-40	43.5±10.9 (ml/kg/min)	-42.2	10.68 (<0.001)
Bugajska *et al.* (2005)	Polish Workers	224	41-50	38.5±10.9 (ml/kg/min)	-29.5	8.09 (<0.001)
Bugajska *et al.* (2005)	Polish Workers	134	51-60	33.4±10.6 (ml/kg/min)	-21.8	1.59 (<0.001)
Gökbel *et al.* (2005)	Turkish Sedentary Men	15	18-24	2.88±0.46 (l/min)	-6.6.	1.46 (<0.163)
Pennathur *et al.* (2005)	Mexican American Young Adults	16	20-28	4.80±1.75 (l/min)	-80.0	4.88 (<0.001)
Pennathur *et al.* (2005)	Mexican American Young Adults	16	20-28	56.32±12.16 (ml/kg/min)	-56.0	4.88 (<0.001)
Pulkinken *et al.* (2005)	Healthy untrained adults	16	24-50	49±8.0 (ml/kg/min)	-53.0	9.20 (<0.001)
Vehrs and Fellingham (2006)	USA -White Men	16	18-24	3.51±0.1 (l/min)	-30.0	19.98 (<0.001)
Vehrs and Fellingham (2006)	USA-African American	16	18-24	3.99±0.2 (l/min)	-47.7	17.49 (<0.001)
Kang *et al*. (2008)	Korean Metal Workers	507	20-60	2.40±0.40 (l/min)	3.6	-3.21 (0.001)
Sloan *et al*. (2013)	Singaporean Adults	57	18-65	35.2±5.00 (ml/kg/min)	-5.9	2.41 (0.017)
Cao *et al*. (2013)	Japanese Healthy Adults	143	20-69	37.30±8.70 (ml/kg/min)	-12,2	-2.79 (0.006)
Myers *et al.* (2017)	USA	505	20-29	47.90±10.9 (ml/kg/min)	-24.5	14.2 (<0.001)
Myers *et al.* (2017)	USA	963	30-39	42.90±9.80 (ml/kg/min)	-28.5	12.2 (<0.001)
Myers *et al.* (2017)	USA	1326	40-49	38.8±9.60 (ml/kg/min)	-22.0	10.8 (<0.001)
Myers *et al*. (2017)	USA	1077	50-59	33.80±4.99 (ml/kg/min)	-38.5	9.22 (<0.001)

Table 6.31. Summary of comparisons. (cont.)

Current study vs.	Population (Male)	Sample Size	Age Range	AC	% Diff.	t-value (p-value)
Hosick *et al*. (2018)	USA	59	18-35 Normal weight	47.1±7.7 (ml/kg/min)	-15.7	6.08 (<0.001)
Hosick *et al*. (2018)	USA	45	(8-35 Over weight	42.4±7.9 (ml/kg/min)	-23.2	7.40 (<0.001)
Hosick *et al*. (2018)	USA	37	18-35 Obese	39.3±5.5 (ml/kg/min)	-34.1	10.85 (<0.001)
Ando *et al*. (2018)	USA	80	18-45	3.42±0.52 (l/min)	-24.9	13.63 (<0.001)

% Difference = 100 x (mean for Pop. of Turkey - mean for comparison nationality)/mean of Pop. of Turkey

7. CONCLUSIONS

Objective of this study was to determine the aerobic capacity for the healthy adult male population of Turkey, to investigate the effects of age, BMI (Body Mass Index), weight, occupation, exercise habits, smoking and alcohol consumption on aerobic capacity and to compare the aerobic capacity of the male population of Turkey with the population of several other countries. Based on the analysis results, the following conclusions can be drawn:

- An estimation of VO_{2max} results (in l/min and in ml/kg/min) of the adult male population of Turkey was made.
- Aerobic capacity, VO_{2max}, for male adult population of Turkey in this study is found to be 2.5 l/min with a standard deviation of 0.3 l/min and body weighted adjusted maximum volumetric oxygen consumption is 33.2 ml/kg/min with a standard deviation of 7.7 ml/kg/min.
- The mean values of Test Workload (in kpm/min) and Accepted HR (in bpm) are decreasing from 18-24 years group to 45-54 years group and from under-weight group to obese group.
- Test workloads appointed by the cycle ergometer protocol brought out heart rates with average 141.9 bpm and about %76 of the subjects' predicted maximal heart rates which are valid for less than six minutes in duration. Heart rate that is exceeding %85 of predicted maximal are observed only in 3 subjects and this rate is sustained for less than two minutes at the end of the test. Therefore, it can be concluded that this cycle ergometer test protocol satisfies the determination of work-loads which meet optimal safety. The repeatability and reliability of aerobic capacity values were evaluated from data obtained when 32 of the subjects repeated this test on two separate occasions within a period of a few weeks. Even these scores were consistent, subjects tended to improve their first trial with a difference + 0.06 in l/min and +1.77 in ml/kg/min. Based on repeatability test, one can be 95% confident that any score given within 0.14 in l/min and 2.14 in ml/kg/min of the true score for any given subject.
- The mean values of VO_{2max} results (in l/min and in ml/kg/min) are decreasing from 18-24 years group to 45-54 years group and from under-weight group to obese group.

- Occupation does not have any effect on aerobic capacity and there are no significant differences between each occupation group.
- Smoking or alcohol drinking does not have a significant effect on aerobic capacity and similarly, the mean values of each smoking or drinking group do not statistically differ from each other.
- Comparison results indicate that AC values of Turkish male population are statistically greater than Thai and Korean Male population. Apart from examples discussed formerly, it can be said that the male population of Turkey has statistically lower AC values than other male population from USA, Japan, Poland, Taiwan.

7.1. Limitations of the Study and Recommendations for Practicioners

The results of the modified Astrand-Myhre Bike test and accompanying multivariate regression model developed in this study provide accurate estimates of VO_{2max} in healthy adults ages 18–54 years for male population of Turkey. However, these results are obtained and analysed based on some assumptions which also somehow limit the frame and scope of the study. These limitations are concluded as follows:

- The sample of the study consists of 260 male volunteers which were recruited from İstanbul, a metropolitan city whose population is composed of people from all regions of Turkey. Therefore, it is assumed that population of İstanbul nearly represents the general population of Turkey. In 2013, when all measurements were conducted, according to Atlas of Urban Expansion report, urban and suburban area composition of Istanbul was nearly 77% in total, whereas rural area only had a share of 1%. The remaining area with 22% was composed of urbanized open space. Therefore, having known that even in this study sample was tried to capture the representation of Turkey with its all regions, due to rural area composition of Istanbul, it can be figured out that the sample of the study was limited to urban population.

- A modified submaximal Astrand-Myhre Bike Test and its nomogram for the estimation of aerobic capacity of the subjects were designated based on the maximal test results of the Swedish population. Although the validity of the Astrand Bike Test for populations of different countries such as USA, England were evaluated and accepted through several studies in literature (Cink and Thomas, 1981; George *et al*., 2007; George *et al*., 2009; Nielson *et al*., 2010), there were not any studies carried out for the validation of Astrand Bike Test among the population of Turkey. Maximal tests involve the participant giving maximum effort or working to exhaustion which may lead to injury and fatique. Thus, they require trained technicians and physician supervision to prevent such cases. So, in order not to confront such cases this study was conducted under the assumption of validitiy of submaximal Astrand-Rhyming test among male population of Turkey. Additionally, due to the same reason, older adults over 54 years old and males under 18 years old were not in the scope of the study. The lack of a comprehensive study related to AC on older adults and children in Turkey still remains. Future studies shoul also focus on this remaining part.

- In this study the effects of smoking habit and alcohol consumption on AC are also evaluated and analyzed. The results of ANOVA and Tukey's test indicated that there is no significant effect regarding smoking habit and alcohol consumption. In the study, completely randomized design (CRD) with multi factors was conducted where subjects were randomly selected including different levels in each factor group. In some sub-groups there were less than 10 subjects which may not be enough to indicate any significant difference between groups. Thus, future studies can focus on full-factorial designs to bring out the related factor effects. Additionally, the increase in the factor levels of exercise, smoking habit and alcohol consumption factors may lead to a roboust observation in differientation of relevant effects and it also may induce an increase in the accuracy of the regression equation.

Although it has some limitations, current study is the first initiative so as to set reference standards for aerobic capacity among male population of Turkey to enhance the value of cardiorespiratory fitness across environments, including the clinical setting and workplace as well as the public, to better inform national policy efforts on physical fitness, activity and health. Current study provided an ideal opportunity to develop an equation given that it includes a diverse sample of healthy men in Turkey whose exercise tests met objectively verified criteria for maximal effort. In addition to assessment of outcomes, future studies should further investigate the portability of the equation in additional data sets and its applications in clinical and research settings.

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APPENDIX A: ASTRAND NOMOGRAM

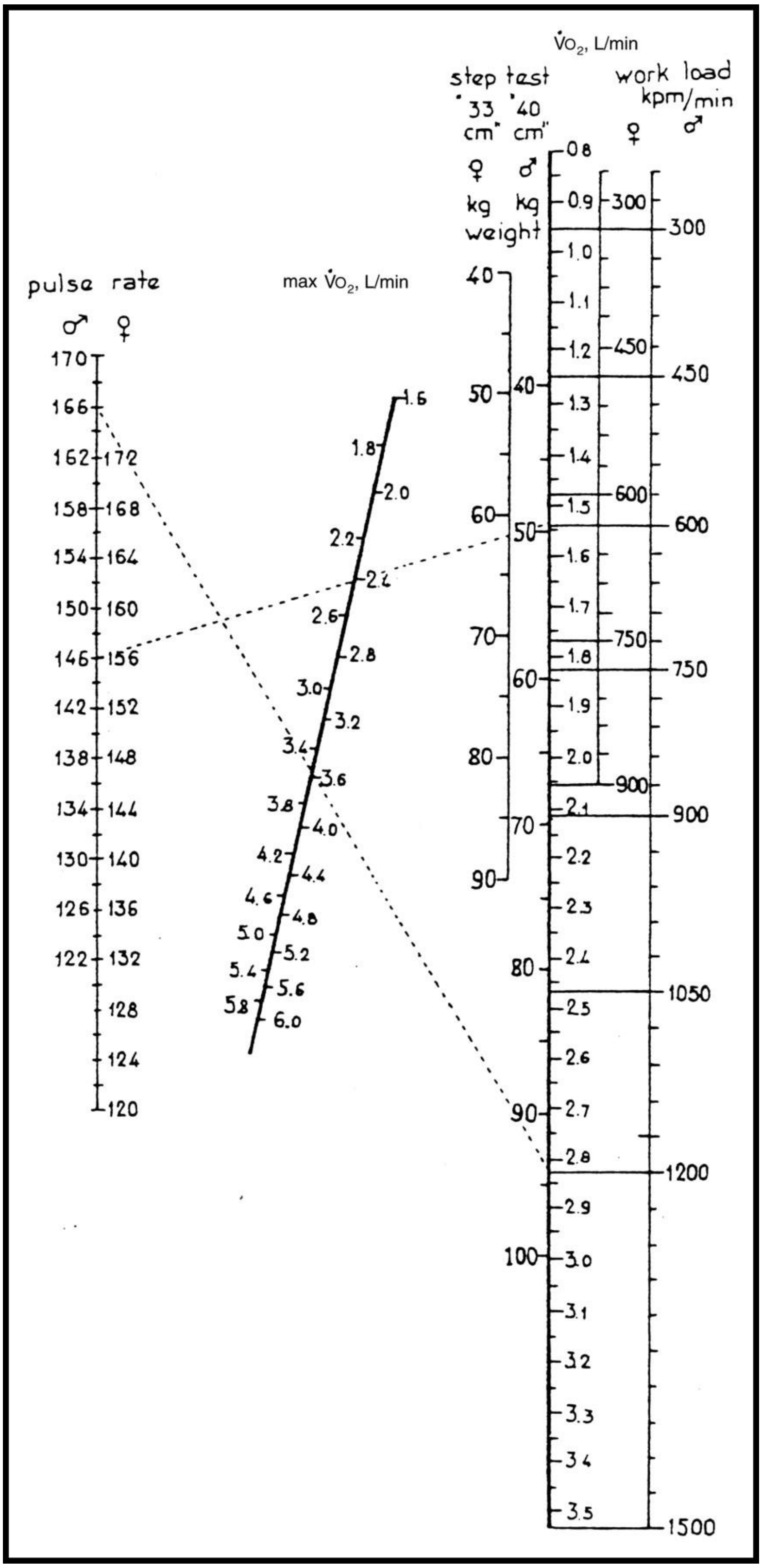

Figure A.1. Astrand Nomogram

APPENDIX B: FORMS

Appendix B includes the necessary forms that were used during the experiments. These forms are brief medical history form, personal consent form and data collection form respectively. Since, the experiment was conducted in Turkey; Brief Medical History form and Personal Consent form are also prepared in Turkish.

(i) Brief Medical History Form: The health conditions of the candidates were questioned by this form because the subjects must be healthy enough for the experiments. All candidates are asked some health questions and only the ones who are free from any musculoskeletal disorders and related health problems according to ACSM (2006) guideline are accepted to participate in the study.

(ii) Personal Consent Form: The participants then must sign the "Personal Consent Form", which includes a detailed description of the objectives and procedures of the study. In order to ensure the voluntary participation of the subjects to the study, this form was being signed. In this form, it was reported that all information obtained during the study would be held in strict confidence.

(iii) Personal Data Form: The participants also give the information related age, occupation, family origin, and mother and father's birthplace, smoking and alcohol consumption habits and physical exercise level, these information are recorded on form, which called "Personal Data Form". Some anthropometric measurements like height and weight are also measured during the study and are recorded on "Personal Data Form".

(iv) Instructions: In order to prevent the confusion of the participant, the experimenter will direct the subjects according to these instructions.

B.1. Brief Medical History Form

Name: __________________Date:________________________

Assess your health needs by marking all true statements.

History: You have had:

__ a heart attack
__ heart surgery
__ cardiac catheterization
__ coronary angioplasty (PTCA)
__ pacemaker/implantable cardiac defibrillator/rhythm disturbance
__ heart valve disease
__ heart failure
__ heart transplantation
__ congenital heart disease

Symptoms:

__ You experienced chest discomfort with exertion.
__ You experience unreasonable breathlessness.
__ You experience dizziness, fainting, blackouts.
__ You take heart medications.

Other health issues:

__ You have musculoskeletal problems.
__ You have concerns about the safety of exercise.
__ You take prescription medication(s).
__ You are pregnant.

Cardiovascular Risk Factors:

__ You are a man older than 45 years.
__ You are a woman older than 55 years or
you have had a hysterectomy or you are post menopausal.
__ You smoke.
__ Your blood pressure is > 140/90.
__ You don't know your blood pressure.
__ You take blood pressure medication.
__ Your blood cholesterol level is > 240 mg/dl.
__ You don't know your cholesterol level.
__ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
__ You are physically inactive (ie, you get < 30 minutes of physical activity on at least 3 days per week.
__ You are > 20 pounds overweight.
__ None of the above is true.

B.2. Sağlık Anketi

Name: ___________________Date:__________________________

Doğru olan seçenekleri işaretleyerek sağlık durumunuzu değerlendiriniz.

Sağlık geçmişi: Daha önce aşağıdakilerden hangisini geçirdiniz?

__ kalp krizi
__ kalp ameliyatı
__ kalp kateterizasyonu
__ koroner anjiyoplasti/stent
__ kalp pili/ ritim bozukluğu
__ Kalp kapakçığı bozuklukları
__ kalp yetmezliği
__ kalp nakli
__ konjenital kalp rahatsızlığı

Semptomlar:

__ Göğüs ağrısı çekiyorsunuz.
__ Nefes darlığı çekiyorsunuz.
__ Baş dönmesi, bayılma, göz kararması yaşıyorsunuz.
__ Kalp ilacı kullanıyorsunuz.

Diğer sağlık konuları:

__ Kas/İskelet sistemi rahatsızlıklarınız var.
__ Güvenli bir şekilde egzersiz yapabileceğiniz konusunda endişe duyuyorsunuz.
__ Düzenli olarak kullandığınız ilaç ya da ilaçlarınız mevcut.
__ Hamilesiniz.

Kardiyovasküler Risk Faktörleri:

__ 45 yaşın üzerinde bir erkeksiniz.
__ 55 yaşın üzerinde bir bayansınız ya da menopoz sonrası dönemde yer alıyorsunuz.
__ Sigara içiyorsunuz.
__ Tansiyonunuz 140/90'ın üzerinde.
__ Tansiyonunuz bilmiyorsunuz.
__ Tansiyon ilacı kullanıyorsunuz.
__ Kolestoreol seviyesiniz 240 mg/dl üzerinde.
__ Kolestorel seviyeinizi bilmiyorsunuz.
__ 55 yaşından önce kalp krizi geçiren birinci derece erkek (baba ya da erkek kardeş) ya da 65 yaşından önce kalp krizi geçiren birinci derece kadın yakınınız (anne ya da kız kardeş) bulunuyor.
__ Fiziksel olarak aktif değilsiniz (Haftada 3 gün, günde 30 dk egzersiz)
__ 90 kg'ın üzerindesiniz.
__ Yukarıdakilerin hiçbiri.

B.3. Personal Consent Form

In this thesis study, the purpose is to determine the aerobic capacity statistics of Turkish male population ranging between 18 and 54 years old. You do not have any serious health problem which affects your participation to the experiments adversely. You will execute a graded exercise test with a cycle ergometer within 6-9 minutes of duration. The equipment used in the experiments does not contain any risk for your health.

The aerobic capacity statistics that is determined via this study can be used to design work conditions which are appropriate for the Turkish males in the daily life and industrial work. Thanks to designs which are made by using this data, the worker satisfaction and also productivity will increase in the daily and industrial life.

If you decided to participate, please take into consideration the issues below.

1. Before the experiments, your birthday, birth place, your family origin, occupation, exercise abilities, alcohol drinking or smoking habits will be asked, after that, your height, weight, and heart rate will be measured. You will be fitted with an HR monitor to measure HR during the tests. The HR monitor will be placed around the chest and over the heart, and will be checked if the pulse signal is being picked up by the computer. After having a 20 min rest your resting HR value will be measured and you will be ready to start the experiments. Your heart rate will be recorded continuously during the experiment.

1. Experiments will be performed in predetermined random order utilizing the Astrand protocol. The experiments will be performed with a cycle ergometer. After checking that you are in the correct position and you are ready for the tests, experimenter will say “start” and you will start to cycle. After cycling 1 minute with a predefined pedal rate, your workload will be adjusted according to your heart rate measured by a heart rate monitor and computer. You will cycle with this workload for one another minute and your workload will be adjusted again according to your heart rate at the end of the 2nd minute. One another minute this process will be repeated. After the 3rd minute your heart rate is expected to reach a steady state and you will cycle with this stable

workload for 3 more minutes. At the end of the 6th minute, your heart rate will be recorded and experiment will finish. After the experiment, you are expected to stop cycling slowly.

2. Before the tests, participants are expected to avoid vigorous exercise the day of testing and to avoid large meals, caffeine, alcohol, and tobacco products within at least three hours of their appointment.

Your participation is completely voluntary. You may choose to withdraw from participation at any time. All information obtained during this study will be held in strict confidence and will be shared with you with your request.

If at any time you have questions regarding this research, you may contact either Altuğ Yılmaz or Dr. Mahmut Ekşioğlu from Department of Industrial Engineering of Boğaziçi University.

By placing your signature below, you will accept that your participation to this study is voluntary. However, you can choose to withdraw from participation at any time at no cost or obligation to you.

Signature of Participant: Date:

B.4. Kişisel Kabul Formu

Bu tez çalışmasında, 18 ile 54 yaş arasındaki Türk erkeklerinin maksimum aerobic kapasitelerinin istatistiklerini belirlemek hedeflenmektedir. Bu çalışmaya engel teşkil edecek herhangi bir sağlık probleminizin olmamasından dolayı, deneylere katılmak için uygun durumda bulunmaktasınız. Bisiklet ergometre ile 6 ile 9 dakika arasında sürecek bir aşamalı egzersiz testine katılacaksınız. Testler sırasında kullanılan ekipmanlar herhangi bir sağlık riski taşımamaktadır.

Bu çalışmadan elde edilecek fiziksel iş yapabilme kapasitelerinin istatistikleri, endüstride ve günlük hayattaki iş koşullarının, Türk erkeklerinin kullanımına uygun bir şekilde tasarlanması için kullanılabilecektir. Bu veriler kullanılarak yapılacak tasarımlar sayesinde hem günlük hayatta hem de iş yaşamında çalışan memnuniyeti ve dolayısıyla verimlilik artacaktır.

Eğer katılmaya karar verdiyseniz, lütfen aşağıdaki hususlara dikkat ediniz.

1. Deneye başlamadan önce doğum tarihiniz, doğum yeriniz, ailenizin doğum yeri, mesleğiniz, spor, alkol, sigara gibi alışkanlıklarınız sorulacak ve akabininde boyunuz, kilonuz ve kalp atışlarınız ölçülecektir. Göğsünüze deney sırasındaki kalp atışlarınızı ölçmek üzere bir kalp monitoru bağlanacaktır ve bilgisayar aracılığı ile kalp atışlarınız takip edilecektir. 20 dakika dinlendikten sonra dinlenme sırasındaki kalp atışlarınız kaydedilecek ve deneye başlanacaktır. Deney boyunca kalp atışlarınız düzenli olarak kaydedilmeye devam edecektir.

2. Deneyler rassal sıraya göre ve Astrand protokolüne uygun olarak gerçekleştirilecektir. Doğru ve rahat bir pozisyonda testler için hazır olduğunuz kontrol edildikten sonra, deneyi yürüten kişinin başla koşulu ile bisikleti çevirmeye başlayacaksınız. Daha önceden belirlenmiş bir çevirme hızında 1 dakika boyunca pedalları çevirdikten sonra, göğsünüze bağlı bir kemer ve bilgisayar yolu ile ölçülen kalp atışlarınıza göre, bisiklet üzerindeki iş yükünüz ayarlanacak. Bu iş yükü ile 1 dakika daha pedalları çevirmeye devam edeceksiniz ve birinci dakikanın sonunda iş yükünüz kalp atış hızınıza göre tekrar ayarlanacak. Bu iş yükü ile 1 dakika daha pedal

çevirmeye devam edeceksiniz. Üçüncü dakikadan sonra kalp atış hızınızın sabitlenmesi beklenir ve sabit bir iş yükü ile üç dakika boyunca pedal çevirmeye devam edersiniz. Altıncı dakikanın sonunda kalp atış hızınız kaydedilir ve deney sona erer. Deney sonrasında yavaşca pedalları çevirmeyi bırakmanız beklenmektedir.

3. Katılımcıların deney gününde yorucu bir egzersiz yapmaktan kaçınması ve deneylerden 3 saat öncesine kadar ağır yemek, kafein, alkol, tütün ve tütün ürünleri kullanmamış olması gerekmektedir.

Katılımınız tamamen gönüllü olup, katılmanız için herhangi bir zorlamayla karşılaşmayacaksınız. Dilediğinizde. çalışmanın herhangi bir aşamasında çalışmayı terk edebilirsiniz. Elde edilecek kişisel bilgiler kimseyle paylaşılmayacak, tez çalışmasında ise sadece verilerin ortalaması (kime ait olduğu belirtilmeksizin), maksimum ve minimum değerleri belirtilecektir.

Bu çalışmayla ilgili sorularınız ve katkılarınız olması durumunda Boğaziçi Üniversitesi Endüstri Mühendisliği Bölümü'nde Altuğ YILMAZ veya Doç. Dr. Mahmut Ekşioğlu ile temasa geçebilirsiniz.

Aşağıya atacağınız imza bu çalışmaya gönüllü olarak katılmak istediğinizi belirtmektedir ancak çalışmayı yarıda bırakmanız durumunda size herhangi bir yükümlülük getirmemektedir.

Katılımcının İmzası: Tarih:

B.5. Personal Data Form

1. General Information about the Subject

Information	**Datum**
Birth date	Day: Month: Year:
Birthplace	
The place he/she lives now	
Family origin city	
Mother and father's birthplace	
Ethnicity	
Gender	
Occupation	
Exercise	☐ Regular
	☐ Irregular or no
Smoking	☐ Daily/occasional
	☐ Never smoked/ non-smoker
Alcohol Drinking	☐ Never-consumed / does not consume
	☐ Consumes

2. Anthropometric Measurements of the Subject

Height (cm)	
Weight (kg)	
BMI (kg/m^2)	

3. Test Data of the Subject

Measure	
Resting HR (bpm)	
HR_{max} (bpm)	
Accepted HR (bpm)	
% of HR_{max}	
Workload	
VO_{2max} in l/min	
VO_{2max} in ml/kg/min	

B.6. Instructions

1. You have read the personal consent form and received information about the experiment.
2. Place the HR monitor on your chest with the help of the experimenter.
3. Sit down and have a rest for 20 minutes.
4. Take a trial cycling session in order to get used to cycle ergometer and pedal rate. You can adjust your pedal rate according to the metronome that placed in front of the cycle ergometer.
5. When you are ready for the experiments, inform the experimenter.
6. Start cycling with experimenter's "START" command. Cycle at a consistent pedal rate until the experimenter's "STOP" command.
7. Stop cycling slowly with the experimenter's "STOP" command.
8. Take off your HR monitor and give it back to the experimenter.

.

B.7. Talimatlar

1. Kişisel kabul formunu okudunuz ve deney hakkında bilgi edindiniz.
2. Kalp monitörünü deneyi yürüten kişinin yardımı ile göğsünüze yerleştirin.
3. 20 dakika boyunca bir sandalyeye oturarak dinlenin.
4. Bisiklet ergometreye geçerek pedalları doğru hız ile çevirmeyi deneyin. Bisiklet ergometrenin önünde yer alan metronom ile pedal hızınızı ayarlayabilirsiniz.
5. Deney için hazır olduğunuzda deneyi yürüten kişiyi bilgilendirin.
6. Deneyi yürüten kişinin "BAŞLA" komutu ile pedalları çevirmeye başlayın ve "BİTİR" komutuna kadar doğru hızda çevirmeye devam edin.
7. Deneyi yürüten kişinin "BİTİR" komutu ile pedalları çevirmeyi yavaşça bırakın.
8. Göğsünüzde yer alan kalp monitorunu çıkarıp deneyi yürüten kişiye teslim edin.

APPENDIX C: REGRESSION EQUATION

C.1. Regression Models for VO_{2max} (in l/min)

Model 1. The regression equation is

VO_{2max} (l/min) = -0.71 - 0.01788xAge + 0.0229xHeight - 0.0218xWeight + 0.0555xBMI + 0.0459xAlcohol Drinking + 0.0377xSmoking + 0.1555xExercise + 0.0011xOccupation

Model 2. The regression equation is

VO_{2max} (l/min) = -0.71 - 0.01788xAge + 0.0229xHeight - 0.0218xWeight + 0.0555xBMI + 0.0373xAlcohol Drinking + 0.0376xSmoking + 0.1555xExercise

Model 3. The regression equation is

VO_{2max} (l/min) = -1 - 0.0178xAge + 0.0245xHeight - 0.0237xWeight + 0.0617xBMI + 0.0509xSmoking + 0.1566xExercise

Model 4. The regression equation is

VO_{2max} (l/min) = 1.967 - 0.01728xAge + 0.0077xHeight - 0.0038xWeight + 0.1514xExercise

Model 5. The regression equation is

VO_{2max} (l/min) = 3.346 - 0.01794xAge -0.0122xBMI + 0.147xExercise

Model 6. The regression equation is

VO_{2max} (l/min) = 3.271 - 0.01865xAge - 0.0027xWeight + 0.1597xExercise

Model 7. The regression equation is

VO_{2max} (l/min) = 2.118 - 0.01798xAge + 0.0052xHeight + 0.1938xExercise

Model 8. The regression equation is

VO_{2max} (l/min) = 3.0645 - 0.0179xAge - 0.0185xExercise

Model 9. The regression equation is

VO_{2max} (l/min) = 3.531 - 0.0179xAge -0.0185xBMI

Model 10. The regression equation is

VO_{2max} (l/min) = 3.475 - 0.01897xAge - 0.0048xWeight

Model 11. The regression equation is

VO_{2max} (l/min) = 2.294 - 0.01877xAge + 0.00457xHeight

Model 12. The regression equation is

VO_{2max} (l/min) = 3.1211- 0.01953xAge

C.2. Regression Models for VO_{2max} (in ml/kg/min)

Model 1. The regression equation is

VO_{2max} (ml/kg/min) = 157 - 0.2411xAge - 0.23xHeight - 0.25xWeight + 0,00085x$Weight^2$ – 3.80xBMI + 0.0529xBMI^2 - 0.688xAlcohol Drinking + 0.450xSmoking + 2.295xExercise

Model 2. The regression equation is

VO_{2max} (ml/kg/min) = 89.2 - 0.2509xAge - 0.071xHeight - 0.309xWeight - 0.49xBMI - 0.4xAlcohol Drinking + 0.401xSmoking + 2.828xExercise

Model 3. The regression equation is

VO_{2max} (ml/kg/min) = 94.6 - 0.2396xAge - 0.097xHeight - 0.279xWeight - 0.63xBMI + 2.577xExercise

Model 4. The regression equation is

VO_{2max} (ml/kg/min) = 65.33 - 0.2494xAge + 0.0648xHeight - 0.4669xWeight + 2.81xExercise

Model 5. The regression equation is

VO_{2max} (ml/kg/min) = 102.24 – 0.2529×Age – 1.138×Weight + 0.0043×$Weight^2$ +2.636×Exercise

Model 6. The regression equation is

VO_{2max} (ml/kg/min) = 76.37 - 0.261xAge - 0.4578xWeight + 2.881xExercise

Model 7. The regression equation is

VO_{2max} (ml/kg/min) = 65.89 - 0.2517xAge + 0.0824xHeight - 0.0567xWeight

Model 8. The regression equation is

VO_{2max} (ml/kg/min) = 104.2 - 0.1891xAge - 3.86xBMI + 0.0486xBMI2 + 2.874xExercise

Model 9. The regression equation is

VO_{2max} (ml/kg/min) = 73.56 - 0.1909xAge - 1.3922xBMI + 3.153xExercise

Model 10. The regression equation is

VO_{2max} (ml/kg/min) = 115.5 - 0.2506xAge – 1.43xWeight + 0.00593XWeight^2

Model 11. The regression equation is

VO_{2max} (ml/kg/min) = 80.65 - 0.2615xAge – 0.5057xWeight

Model 12. The regression equation is

VO_{2max} (ml/kg/min) = 77.52 - 0.19xAge - 1.529xBMI

Model 13. The regression equation is

VO_{2max} (ml/kg/min) = 71.87 – 1.57xBMI + 2.923xExercise

Model 14. The regression equation is

VO_{2max} (ml/kg/min) = 75.48 – 1.6936xBMI

Model 15. The regression equation is

VO_{2max} (ml/kg/min) = 74.02 – 0.5305xWeight

Model 16. The regression equation is

VO_{2max} (ml/kg/min) = 43.60 – 0.3176xAge

APPENDIX D: CHECKING ANOVA & REGRESSION ASSUMPTIONS

1) Checking ANOVA and Regression Assumptions

a) Normality Test

To use ANOVA, residuals of aerobic capacity values must fit to normal distribution. Therefore, normality of the residuals of the aerobic capacity data were tested by using Anderson-Darling normality test (α= 0.05) in Minitab 17.0. According to Anderson- Darling normality test, the p-values of residuals of aerobic capacity data is > 0.05. Thus it can be said that residuals of aerobic capacity are assumed to be normally distributed.

Moreover, another procedure to prove normality is to investigate the normal probability plots of the residuals which were shown in Figure D-1, D-2, D-3 and D-4. Since the plots approximately resemble a straight line the underlying error distribution for males is normal.

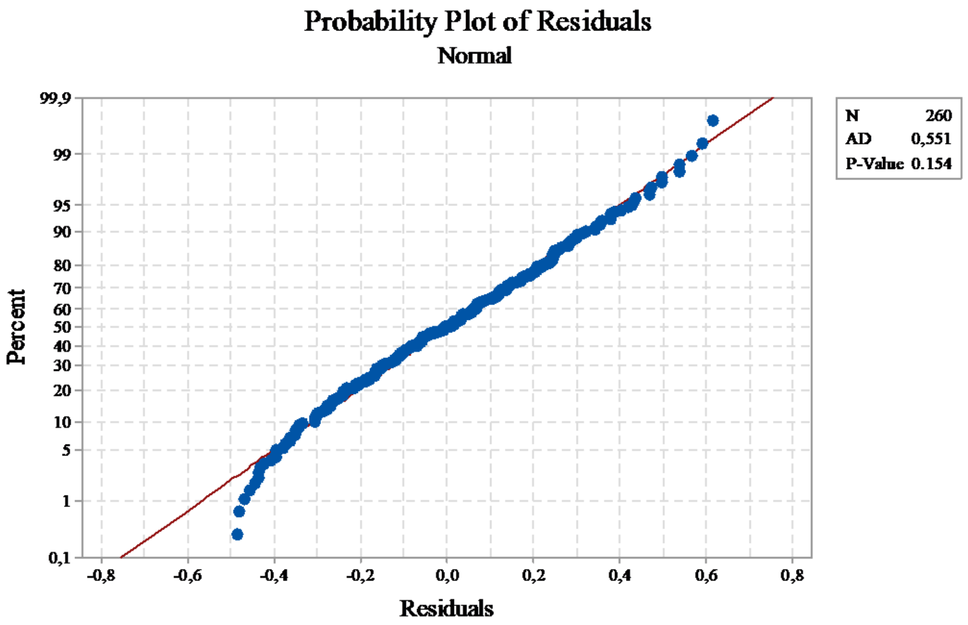

Figure D.1. Normal probability plots of residuals of VO_{2max} (l/min) for GLM.

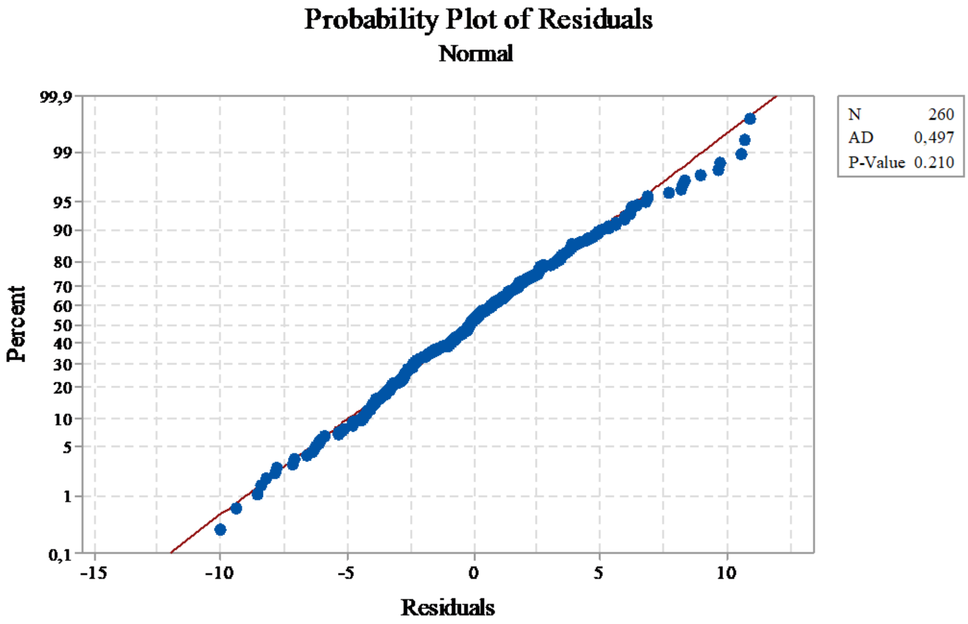

Figure D.2. Normal probability plots of residuals of VO_{2max} (ml/kg/min) for GLM.

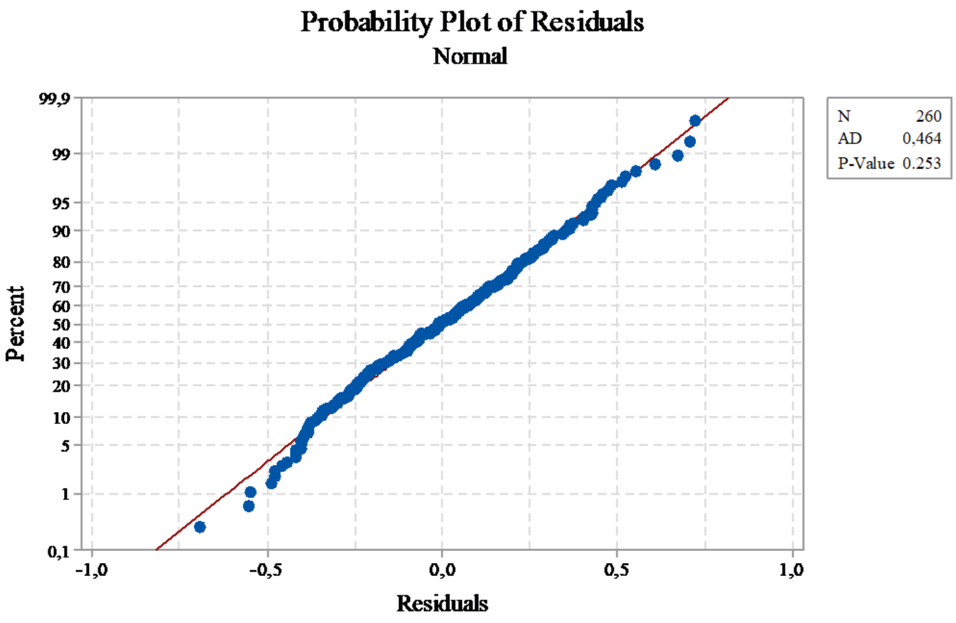

Figure D.3. Normal probability plots of residuals of VO_{2max} (ml/kg/min) for Regression.

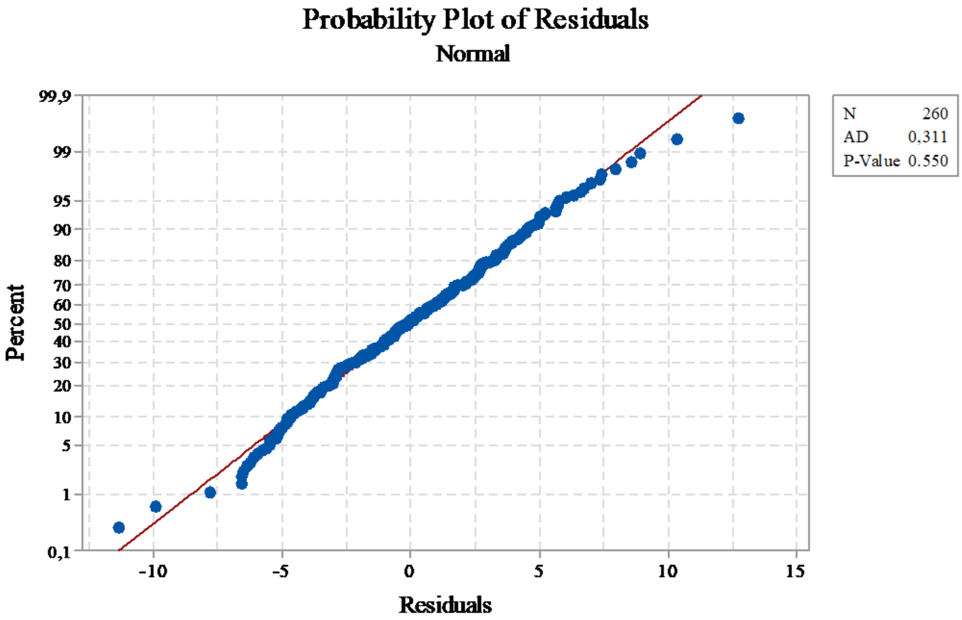

Figure D.4. Normal probability plots of residuals of VO_{2max} (ml/kg/min) for Regression.

b) Independence Test

Another assumption about ANOVA is independence assumption. According to this assumption, there must not be any correlation between residuals (correlation of each value and the value before it) and correlation between independent variables and residuals. Plotting the residuals in observation order of data collection is helpful in detecting correlation between the residuals. A tendency to have runs of positive and negative residuals indicates positive correlation which would imply that the independence assumption on the errors has been violated (Montgomery, 2009).

The plot of the residuals versus observation order for males is shown in Figure D-5, D-6, D-7 and D-8. There is no reason to suspect any violation of the independence assumption.

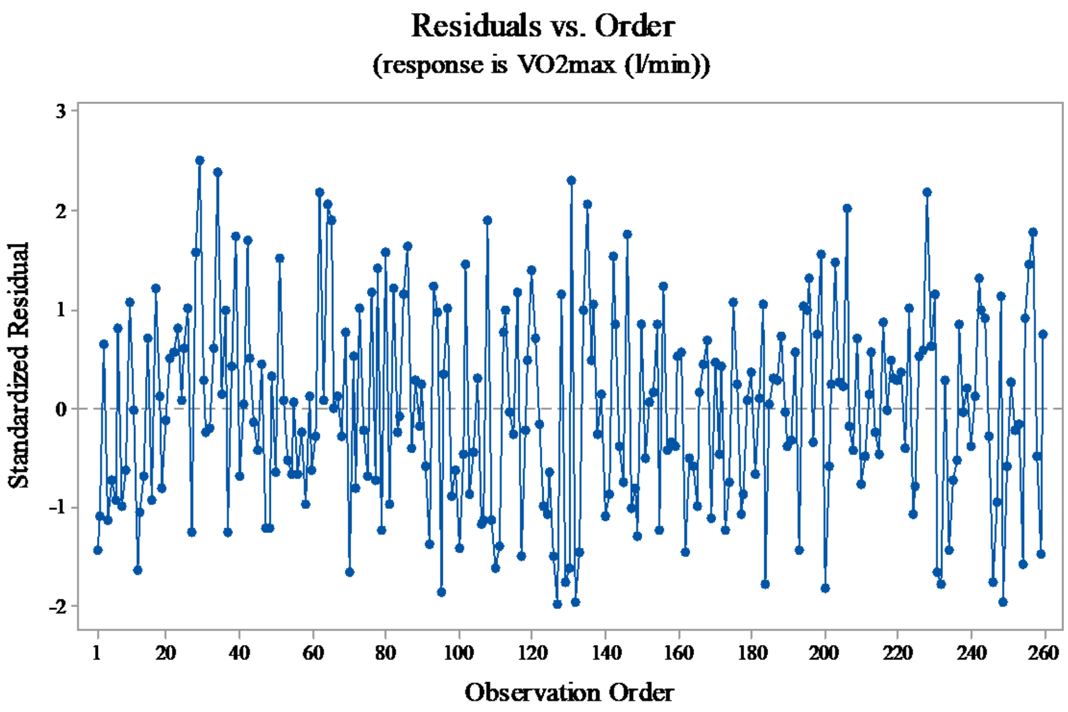

Figure D.5. Plot of residuals versus observation order of VO_{2max} (l /min) for GLM.

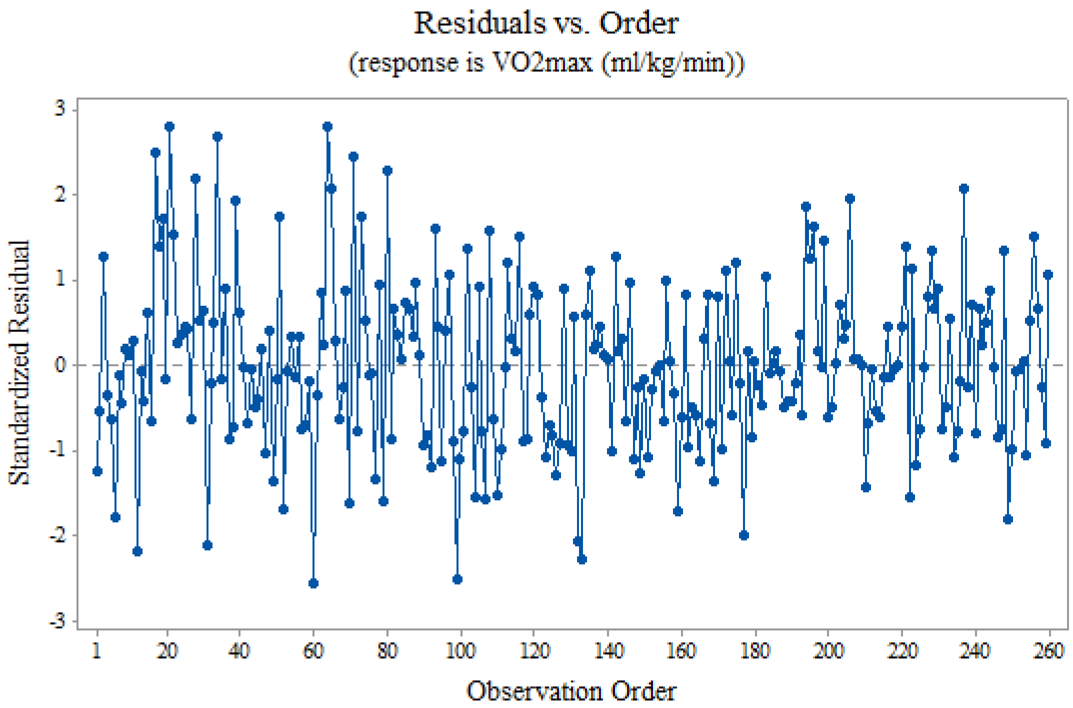

Figure D.6. Plot of residuals versus observation order of VO_{2max} (ml/kg/min) for GLM.

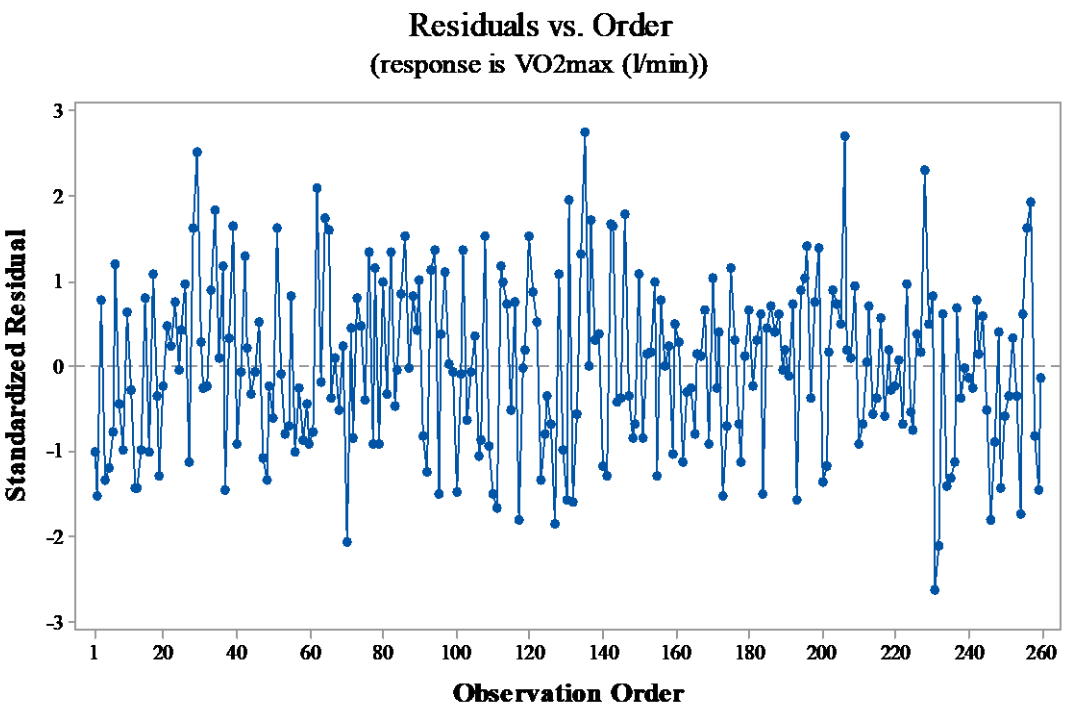

Figure D.7. Plot of residuals versus observation order of VO_{2max} (l /min) for Regression.

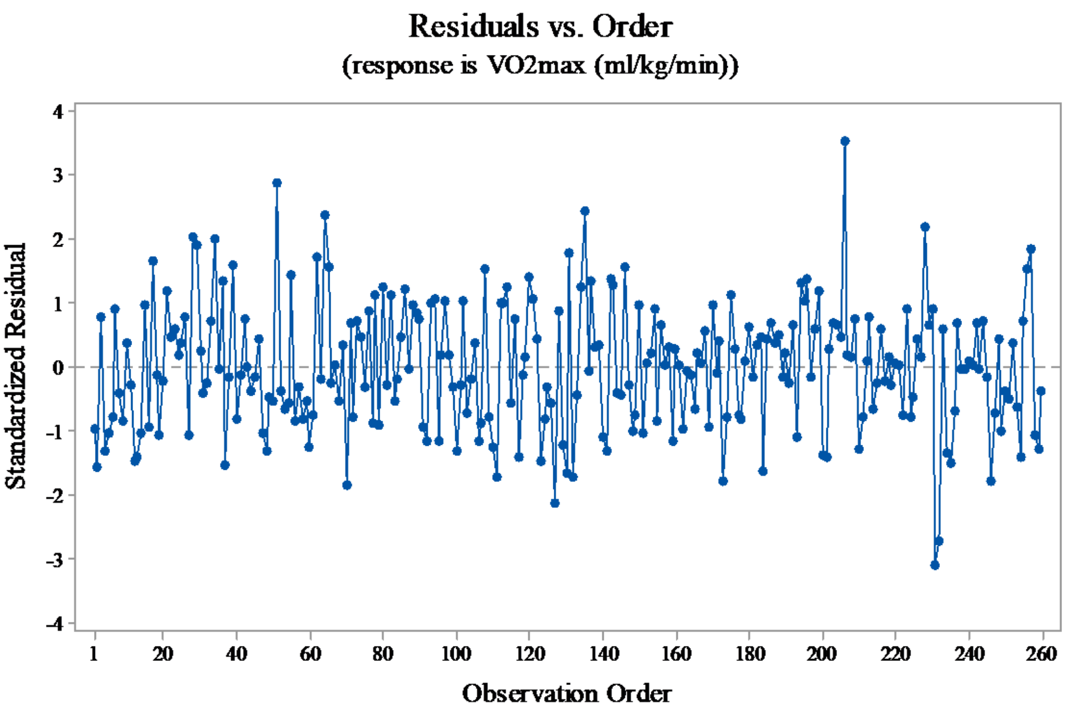

Figure D.8. Plot of residuals versus observation order of VO_{2max} (ml/kg/min) for Regression.

c) Variance Equality Test

The last assumption about ANOVA is that variances of response variables for each treatment must not be different from each other (homogeneity assumption). Therefore, the residuals should be unrelated to any other variable including the predicted response. A simple check is to plot the residuals versus the fitted values. This plot should not reveal any obvious pattern (Montgomery, 2009). In Figure D-9, D-10, D-11, D-12 below, plots of residuals versus fitted values for males can be seen. Since there is no apparent unusual structure is equality variance assumption was satisfied.

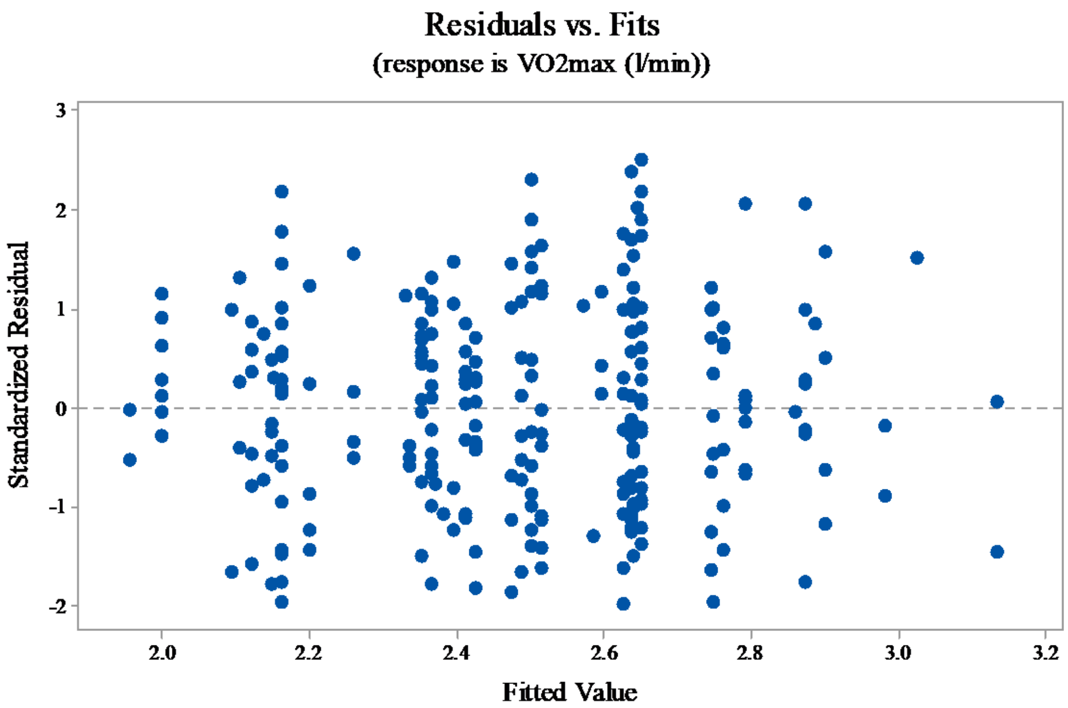

Figure D.9. Plot of residuals versus fitted values of VO_{2max} (l/min) for GLM.

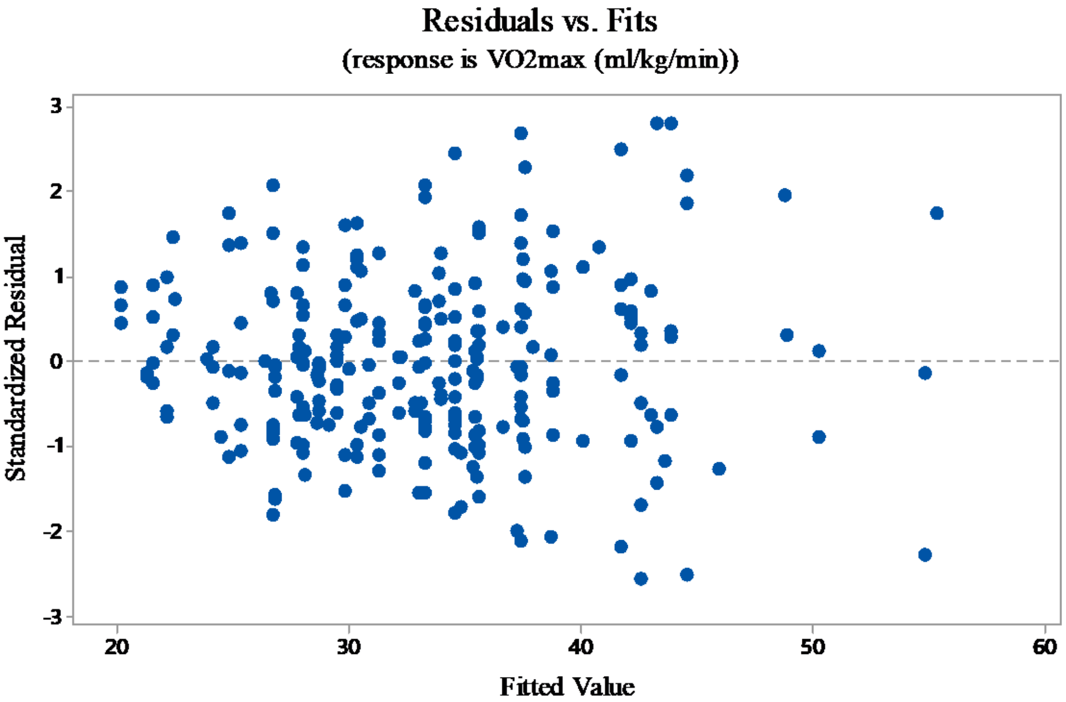

Figure D.10. Plot of residuals versus fitted values of VO_{2max} (ml/kg/min) for GLM.

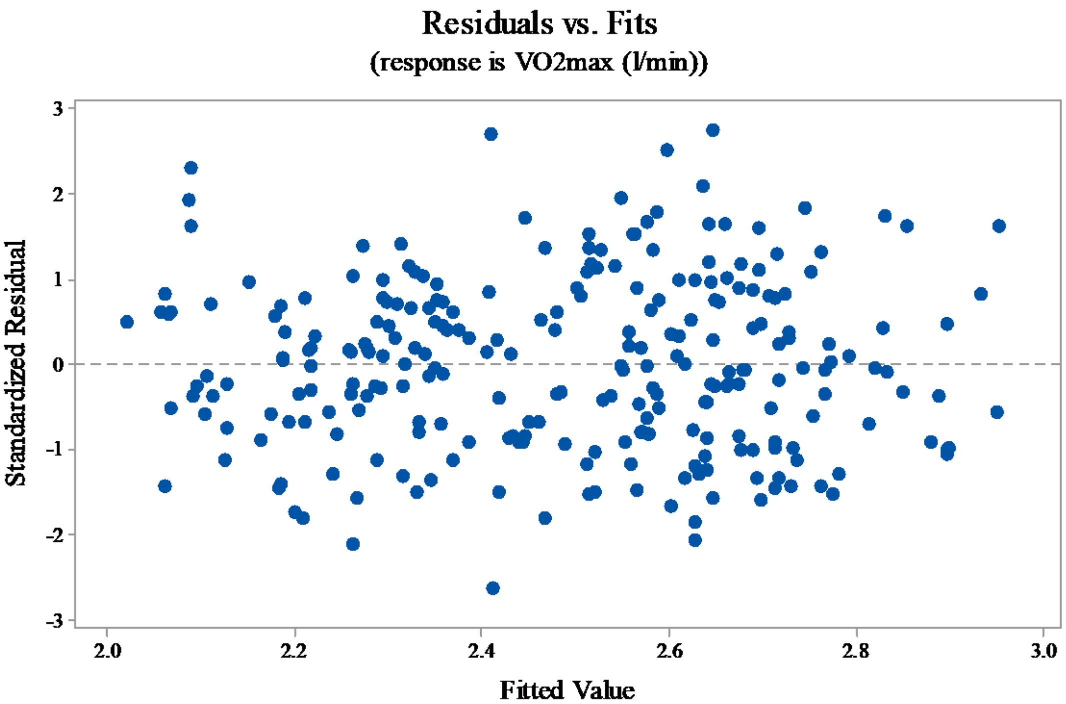

Figure D.11. Plot of residuals versus fitted values of VO_{2max} (l/min) for Regression.

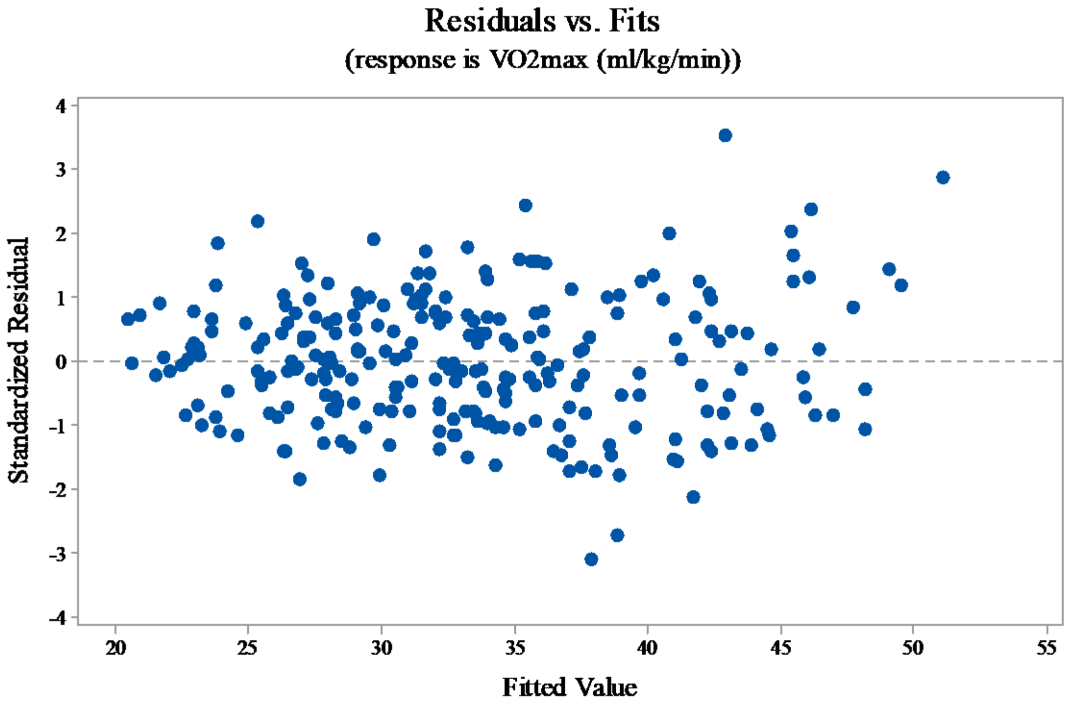

Figure D.12. Plot of residuals versus fitted values of VO_{2max} (ml/kg/min) for Regression.

Residuals versus fitted value displayed above and Results of Bartlett's test displayed in the Table D-1 and Table D-2 indicated that there is no suspect of any violation of equality of variance assumption.

Table D.1. The Result of Bartlett's test for VO_{2max} (l/min)

Test	Test Statistic	P-Value
Bartlett's test for ANOVA	51.97	0.698

Table D.2. The Result of Bartlett's test for VO_{2max} (ml/kg/min)

Test	Test Statistic	P-Value
Bartlett's test for ANOVA	73.95	0.077