DETERMINING THE AEROBIC CAPACITY (VO_{2max}) OF ADULT FEMALE POPULATION OF TURKEY

by

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ABSTRACT

DETERMINING THE AEROBIC CAPACITY (VO_{2max}) OF ADULT FEMALE POPULATION OF TURKEY

Aerobic capacity (AC) data of workforce are needed for ergonomic design of the physically demanding jobs in industry to establish safe and productive work designs. Workforce performance and production output depend on sustaining the effort over a period of time that depends on AC and type of tasks. In addition, excessive cardiovascular load may put the individuals in the risks of cardiovascular diseases such as coronary heart disease. AC data are also needed to form baselines for treatment of patients and also for sports to determine the fitness levels. There are a number of studies performed around the world related to the AC of the various populations. These studies shows that AC varies among some world populations and within the sub groups of a given population due to the differences in genetics, lifestyle, nutrition, geographical region, fitness level, gender and age. Therefore, it is a need to develop AC norms for the population of Turkey. Therefore, the objectives of the study are (i) estimating the aerobic capacity of healthy (normal) adult female population of Turkey, (ii) examining the effects of age, BMI and job-group on AC and (iii) comparing the AC data of the female population of Turkey with the AC data of female population of other countries. A sample of 256 healthy adult female volunteers aged between 18 and 54 with family roots from all seven regions of Turkey participated in the study. A modified submaximal cycle ergometer test, called Astrand - Myhre Bike Test, was used to collect AC data from the participants. Based on the statistical analysis results, mean and std of AC was found as 2 ± 0.2 l/min and 32.3 ± 7.8 ml/kg/min. The mean values of VO_{2max} are decreasing from 18-24 years group to 45-54 years group and from under-weight group to obese group. In contrary, regular exercise had significant positive effect on AC. The established norms can serve as baseline in industrial work design and also clinical and sports settings. The results were compared with other world populations.

ÖZET

TÜRKİYE YETİŞKİN KADIN NÜFUSUNUN AEROBİK KAPASİTESİNİN BELİRLENMESİ

Bireylerin aerobik kapasitesi, hem ağır sanayi hem de hizmet sektörlerinde fiziksel çalışma ortamı tasarımları için çok önemlidir. Çalışanları aşırı zorlanmadan doğabilecek zararlardan korumak için fiziksel çalışma koşulları bireylerin aerobik kapasitelerindeki azami sınırlar bilinerek tasarlanmalıdır. Ek olarak, aşırı kardiyovasküler yük, bireyleri koroner kalp rahatsızlığı gibi kardivasküler hastalıkların riskine sokabilir. Aerobik kapasite verileri, hastalık tedavilerindeki temel sınırları belirlemek ve aynı zamanda spor bilimlerinde fitness seviyelerini ölçmek için de gereklidir. Dünyada ulusların ya da belirli grupların aerobik kapasitelerine ait veritabanı oluşturmayı amaçlayan çok sayıda çalışma bulunmaktadır. Bu çalışmalar aerobik kapasitenin popülasyonlar ve bu popülasyonun alt grupları arasında genetik, yaşam tarzı, beslenme, coğrafi bölge, egzersiz seviyesi, cinsiyet ve yaş gibi nedenlerden dolayı farklılaştığını göstermektedir. Bu nedenle Türkiye için AC normlarının oluşturulmasına ihtiyaç duyulmaktadır. Bu nedenle, bu çalışmanın amacı (i) Türkiye'nin sağlıklı (normal) yetişkin kadın nüfusunun aerobik kapasitesini tahmin etmek, (ii) yaş, vücut kitle indeksi ve meslek grubunun AC üzerindeki etkilerini incelemek ve (iii) Türkiye verilerini diğer ülkelerdeki gruplara ait verilerle karşılaştırmaktır.Araştırmaya, Türkiye'nin yedi bölgesinden, yaşları 18 ile 54 arasında değişen 256 sağlıklı yetişkin kadın gönüllü katılmıştır. Çalışma kapsamında ortalama aerobik kapasite 2 ± 0.2 l/dk ve 32.3 ± 7.8 ml/kg/dk olarak bulundu. Ortalamanın yaş grubu büyüdükçe, obezite arttıkça, egzersiz seviyesi düştükçe düştüğü gözlemlendi. Bu çalışma kapsmaında oluşturulan veriler, Türkiye'deki kadın nüfusu için iş veya işyeri tasarımında, sağlık ve spor alanlarında referans olabilir. Çalışma kapsamında bulunan veriler diğer ülkelerin verileri ile de karşılaştırılmıştır.

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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,σ^2)
μ	Overall mean

LIST OF ACRONYMS/ABBREBIATIONS

AC	Aerobic Capacity
ACSM	American Collage of Sports Medicine
ANOVA	Analysis of Variance
BMI	Body mass index
bpm	Beats per minute
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
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
PUMA	Portable Unit of Mechanical Analysis
RHR	Relative Heart Rate
RPE	Rating of perceived exertion
rpm	Rotation per minute
RVO_2	Relative Oxygen uptake
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

1. INTRODUCTION

Aerobic capacity (AC) of individuals has always been crucial when restructuring the physical work environment both in heavy industry and service sectors. The working hours allocated for physical work in a given period of time should be determined in accordance with the limits defined by this maximal capacity in order to protect workers from overexertion.

There exist previous studies which state some acceptable upper limits for energy expenditure during work. The study of National Institute for Occupational Safety and Health (NIOSH) in 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). Using existing norms adopted by other countries may give rise to problems in work and work station design which may reduce the work performance since there is a great variety of physical work performance capacity among societies due to factors such as nutrition, exercise, environment and heredity.

In Turkey, there are studies related to health and sports sciences that aimed to examine aerobic capacity variations of small groups of people including the studies of Gökbel *et al.* (2005), Güvenç (2007) and Pınar *et al.* (2018). The aim of previous studies was investigating the effect of age, training etc. on aerobic capacity of small groups and the result of these studies were not satisfactory for designing the industrial work conditions. The lack of a comprehensive investigation on AC distribution of large amount of people in Turkey was the basic rationale of the current study.

The AC, as known as, the maximal energy expenditure of a human being is highly correlated oxygen amount consumed in unit time. The level of AC indicated by VO_{2max} (aerobic capacity) determines the capacity to perform hard or prolonged work, good tolerance and the possibility to eliminate changes due to fatigue. Thus, 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).

Two well-known techniques are proposed in order to define the aerobic capacity: Direct and indirect measurements. Direct measurements are basically could be described as the measurement of direct oxygen consumption within unit time per kg. In general, graded exercise methods are being used with a specific testing protocol that is the most appropriate for the physical condition of the subjects attending the experiments.

In addition to this, indirect measurement could be described as estimation of aerobic capacity regarding the other related body outputs such as lactic acid and/or rise of heart rate (HR) because of the increased oxygen consumption within the metabolism. Indirect measurements also include non-exercise questionnaire methods employing Physical Activity Rating (PA-R) values which give predefined scores for general activity levels (Jackson *et al.*, 1990). The VO_{2max} can be predicted using linear relation of oxygen consumption volume between power level and HR. The most common method used in indirect measurements is using the Fick equation that determines the linearity between HR and oxygen consumption (Ricci, 1967).

HR recording and monitoring systems enlarged indirect estimation of VO_{2max} studies since they are allowed the use of the tests that found less exhaustive by the subjects. The major factors that define test protocols are mainly the used equipment such as treadmill and cycle ergometer and the physical fitness of people that perform the tests. In literature, the test protocols are divided into two groups in general: Maximal and sub-maximal measurement methods. Maximal measurements are generally used in clinical studies since the subject is required to be get exhausted during the test and it is necessary to perform that test under the control of a qualified clinicians. Sub-maximal testing is commonly used in practical settings and across different subject groups. It allows the prediction of VO_{2max} using the linear relationship between the work rate and HR. The most well-known sub-maximal test protocol is Astrand Bike Test which simply estimates how the heart rate would continue to increasing, according to workload, as a maximal test would do. Astrand & Ryhming designed a nomogram that enables estimation of aerobic capacity from heart rate and oxygen uptake level during a graded exercise test by using the linearity between HR and oxygen uptake volume. The Astrand protocol is held in six minutes and in the first three minute the test workload can be rearranged according the subject's heart rate. In order to get successful test results the heart rate of the subject is needed to be reached a steady state which requires maximum 4 bpm change according to last observation. The test workload and accepted heart rate value of the sub-maximal tests are applied to Astrand nomogram and aerobic capacity (VO_{2max}) is obtained.

The main purposes of the current study are to construct aerobic capacity database of Turkey for adult women, to make a statistical analysis in order to investigate the factors that stimulate the variation of aerobic capacity values such as Body-Mass Index (BMI), age, occupation and to compare the developed physiological norms of the adult women population in Turkey with the results of several other countries. The experiments was conducted in Boğaziçi University Ergonomics Laboratory. In order to determine aerobic capacity of the subjects the Astrand protocol was applied with Monark cycle ergometer.

The thesis is organized as follows: Chapter 2 provides information about literature about aerobic capacity studies on various populations from different countries. In Chapter 3, the rationale behind the study and also the main objectives of the current study are introduced. Chapter 4 includes the methodology of study, definition and distribution of the subjects, test requirements, exercise protocol and statistical models followed to analyze the collected data. In Chapter 5, the results of the VO_{2max} data and the statistical analysis of the study are presented. Chapter 6 provides discussions about the results of the current study and a comparison with the results of the previous studies carried out in other countries. Finally, in the last part, conclusions of the current study and recommendations for practitioners and researchers are presented.

2. LITERATURE REVIEW

There are various studies in the literature regarding the aerobic capacity of people. In general these studies aimed to examine how several anthropometric, professional or rational characteristics affect aerobic capacity of selected groups instead of establishing a national database for any population.

The maximum capacity of performing a prolonged physical activity is generally defined by the aerobic capacity of a person. Physical activity is completed with muscular system with the help of oxidative metabolic process in which especially fats and carbohydrate is oxidized in the existence of oxygen. The oxygen consumption can be defined as an indication of the physical work capacity (Rodahl, 1989). Therefore, before analyzing previous studies about the estimation of aerobic capacity the term "VO_{2max}" is needed to be described and measurement types of "VO_{2max}" should be examined.

2.1. Maximum Oxygen Uptake (VO_{2max})

In order to have a healthy lifestyle and performing daily activities the capability of aerobic exercise is crucial. Although there are a number of methods in order to define aerobic capacity, one of the main ways to measure it is determining the required oxygen amount. In the study of Foss *et al.* (1998) it is stated that physical fitness level of an individual is determined by the ability of transportation and utilization capability of oxygen by lung bloods, heart, muscles or other organ systems of a human body.

VO_{2max} is considered as the most precise term to examine the level of aerobic capacity. It is important to notice that the volume of oxygen consumed per minute (VO_2) is taken into consideration as the reference measure for recommendations of the physical activity intensity of the American College of Sports Medicine (ACSM, 2000). In brief, aerobic capacity determines the capacity of a human body to transfer and use oxygen while performing the vital activities such as ventilation. It has known that heart rate and stroke volume and peripheral utilization of oxygen have an influence on maximum aerobic capacity. Thus, the measurement of VO_{2max} is considered to be the most valid and accurate measure of fitness level. (Foss *et al.*, 1998).

The measurement of VO_{2max} is generally done while the subjects are performing graded work out tests and selecting a test convention that best fits the aerobic conditions of them. It has seen that in literature, the estimation methods of aerobic capacity is divided in two fundamental groups such as “direct” and “indirect”.

2.2. Direct Measurement of VO_{2max}

VO_{2max}, as an indicator of aerobic capacity, can be determined directly by measuring the oxygen uptake of a person while performing a graded exercise test. In general, direct determination of aerobic capacity is conducted with maximal graded exercise tests that encourage subjects to continue to work out until exhaustion. Although there are several ways to conduct measurements today, fundamentally, the equipment types used in the experiments are stratified into two groups in literature: Closed or open circuit systems.

2.2.1. Equipment used in direct measurement of VO_{2max}

(Ricci, 1967) was investigated closed and open circuit systems and gave a comprehensive comparison of two systems. Basically, closed circuit systems incorporate a gas source within a system which does not interact with the atmosphere. On the contrary, open ones deliver opportunity to the subjects breathing surrounding air. The working method of the system can be described as follows: The breathed out respiratory gasses are coordinated through a tubing and valve course of action into collapsible backs. Breathed out gasses, collected for indicated time periods in numbered packs (to diminish mistake), are coordinated to gas meter in arrange that volume be ascertained.

The open circuit systems have several advantages over the closed ones. Basically, they work correctly and give the subject a more comfortable test experience. In addition, they permit the collection of critical information amid work states of any metabolic intensity. In early stages of direct measurements of VO_{2max} in graded exercise tests, there were two main equipment configurations: Tissot spirometer-volumetric gas analyzer system and Douglas bag- volumetric gas analyzer system. Afterwards, lightweight meteorological balloons were introduced to the market in order to overcome measurement difficulties because of heavy Douglas bags. In later years, electronic system that is called meteorological balloon-electronic gas analyzer replaced the volumetric one (Maud and Foster, 2006). Over time, semi-automated systems took place in the market as a further step of the historical development of direct measurement of VO_{2max}. Metabolic cards developed by Beckman Instruments were the first semi-automated systems. In this system, by the help of a turbine volume transducer, ventilation had been measured. It had a mixing chamber and mixed expired gas fractions had been measured by O_2 and CO_2 electronic gas analyzers (Maud and Foster, 2006).

Considering that over twenty different automated systems have been developed by more than a dozen commercial manufacturers, the amount of automated systems developed in the recent years is significant. Because of the low number of studies published on these, the validity and reliability of such automated systems are not commonly known. Among these, the automated system of meteorological balloon-electronic gas analyzers, Cosmed and Cortex systems are being used currently. In recent years, NASA has been developed the portable unit of mechanical analysis (PUMA) system. It is known that PUMA system was not launched for the commercial market, but it still has a potential to be delivered to the field in the future.

2.2.2. Achievement of VO_{2max}

In order to reach and measure $VO_{2max,}$ one of the most accurate and reliable ways is measuring it during a graded exercise test until the subject reaches exhaustion voluntarily. In general, a treadmill or ergometer is used during the graded exercise tests. The maximal oxygen uptake (VO_{2max}) is commonly accepted to be reached if any increment in work rate results in no additional increase in volume of O_2 consumed in unit time. In many studies in the literature, this method based which is based on the achievement of a plateau value is the most frequent accepted standard while measuring the aerobic capacity. Figure 2.1 shows the relationship between the work rate and VO_2 during a maximal graded exercise test.

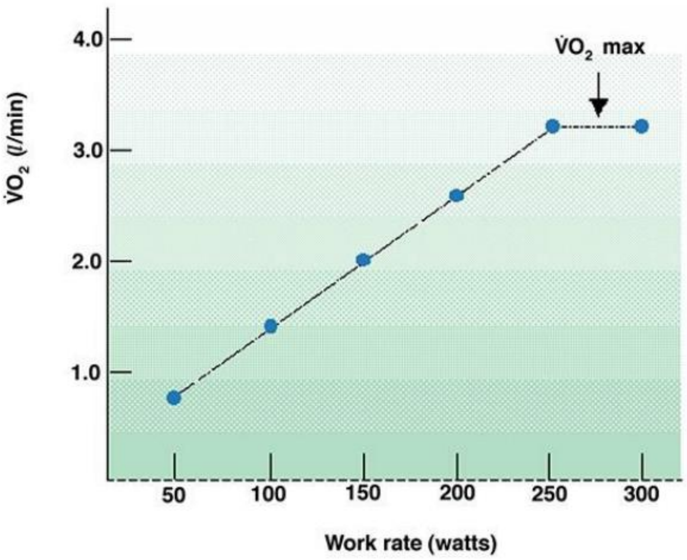


Figure 2.1. The relationship between the work rate (watts) and VO_2.

Direct measurement of VO_{2max} during a maximal test is generally considered the most accurate way. On the other hand, this method has various negative aspects. Limited laboratory and clinical conditions, requirement of expensive equipment, dependency on trained technicians, requirement of physician supervision in individuals who are stratified in the moderate or high risk categories based on current exercise testing guidelines are main drawbacks of the implementation of direct and maximal tests (ACSM, 2006). Due to above reasons maximal tests are not applicable for general health screening and testing of large groups of people. Therefore, other body outputs are being used in order to estimate VO_{2max} indirectly. In literature, there are three main criteria to explain the VO_{2max} achievement. First one is the lactate concentration of blood. If it is greater than 8mmol/L in the first 5 minutes of recovery after the experiments VO_{2max} is considered to be achieved. Secondly, respiratory exchange ratio is one of the most important indicators of $VO_{2max.}$ It is expected to be greater than 1 when VO_{2max} is achieved. Last but not least, heart rate is the most common predictor of VO_{2max}. When VO_{2max} is achieved, heart rate is need to be greater than 90% of age predicted maximum (220-age) at the end of the experiments. Between these factors, although it is very frequent and well known, age predicted maximum formula is the least reliable one. Because, the maximal heart rate varies from person to person at any given age (Maud and Foster, 2006).

Besides, previous studies show that the people are not always tend to reach a plateau in VO_2 as the work rate continues to increase during graded exercise tests. Noakes (1988) has declared that the researchers who stated the plateau theory went wrong to discover a true plateau in VO_2 while the work rate continued to increase. A lot of people specifically with chronic disease or disability reach a point at which they are not be able to continue because of other body limitations such as mental fatigue, fear, lack of motivation or symptoms such as chest pain instead of achieving a true VO_{2max} plateau (Maud and Foster, 2006).

2.3. Maximal Exercise Test Protocols

Depending on the period of test, two general maximal exercise tests exist, continuous and discontinuous maximal exercise tests. Among these continuous and graded testing protocols are the more common methods. In this type of protocol, the maximum oxygen uptake is gathered with the help of continuous progressively increasing workload by using a certain type of exercise. Examples of continuous maximal tests can be the ramp test in which the workload increases without pause or the test in which the workload increases at certain intervals.

As contrast to this, discontinuous tests consist of resting and exercise periods. The test continues until the test subject is at his/her limit of tolerance. Since the discontinuous tests last longer, the subjects usually prefer the continuous tests. The well-known maximal test protocols consist of:

- Balke test
- Bruce protocol
- Ellestad protocol
- Rockport 1 mile walking test
- Maksud and Coutss protocol

In fact, due to the difficulties in performing a maximal test, sub-maximal testing is extensively used as a substitute of direct measurement of VO_{2max}. In order to overcome the difficulties of direct determination not only the exercise methods but also the non-exercise techniques are developed. The further part of this study provides comprehensive information about indirect estimation of VO_{2max} including both exercise and non-exercise methodologies.

2.4. Indirect estimation of VO_{2max}

Despite the fact that maximal tests give accurate results regarding the measurement of AC of the people, they have also several disadvantages. In order to overcome difficulties of maximal tests, many indirect estimation methods were introduced to the field. Lots of regression equation, using the data collected during exercises or from surveys and questionaries', have been constructed in order to determine aerobic capacity. In general, indirect estimation methods are divided into two groups. In exercise methods, subjects complete graded exercises below their maximum performance. In non-exercise methods, personal data such as exercise level, age, gender, and BMI are being used to construct regression models.

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

Several non-exercise regression equations are available in order to predict VO_{2max} without the need to perform an exercise test. Jackson *et al.* (1990) used an approach to estimate VO_{2max} by identifying various factors including age, gender, BMI and ranking of physical activity. The physical activity rating (PA-R) questionnaire is used for the ranking. In fact, physical activity questionnaires are the most widely used methods for the prediction of VO_{2max}. Jackson *et al.* (1990) generated a non-exercise regression model using PA-R as a predictor variable in a sample of healthy adults between 18 and 70 ages. In the study of Bradshaw *et al.* (2005) AC values of 18-65 healthy adults are examined by using non-exercise regression models where the perceived functional was a predictor.

Among self-reported measurements, The International Physical Activity Questionnaire (IPAQ) is known as the most common and the valid non-exercise methodology. The aim of IPAQ questionnaires is to construct a valid and detailed system that allows comparable predictions of AC worldwide. There are two versions of the questionnaire: The short version is suitable for use in national and regional observance systems and the long version provide more detailed information often required in research work or for evaluation purposes. The study of Schembre and Riebe (2011) stated that the short IPAQ can be used to successfully estimate VO_{2max} as well as submaximal exercise tests. The study is conducted on healthy adults aged 18 to 25 years. Bruce protocol is implied in order to direct determination of VO_{2max}. Afterwards, determinate VO_{2max} values are used to conduct a cross validation of the regression model that includes IPAQ results as input variables.

2.4.2. Estimation of VO_{2max} using exercise methods

In literature, it is stated that there is a linear relationship between VO_2 and mechanical power output and between VO_2 and heart rate according Fick equation. These relationships allow indirect estimations of aerobic capacity during graded tests (Maud and Foster, 2006). Although the current indirect methods are complicated a plenty of them are based on Fick principle. This principle was introduced in 1870 by the German physician Adolph Fick. According to the Fick principle the cardiac output is equal to the ratio of volume of oxygen uptake to the difference in the oxygen of arterial and mixed venous blood.

$$\dot{Q} = \frac{VO_2}{AVO_2\ diff} \tag{2.1}$$

$\dot{Q}$: The cardiac output

VO_2 : The oxygen uptake

AVO_2diff : Arterial-venous oxygen difference

Inside the lungs, the amount of the oxygen consumed per minute and the amount of oxygen absorbed by each milliliter of blood gives out the cardiac output in ml/min (Ricci, 1967). Estimation of VO_{2max} in sub-maximal exercise tests is possible due to the linear relationship between heart rate and VO_2. The base of sub-maximal tests relies on the fact that with harder work rate or greater VO_2, the heart rate (HR) increases. As can be seen in Figure 2.2, the relationship between the work rate and HR is linear. Considering the work rate and VO_2 also have a linear relation, extrapolation of the information produces the value of VO_{2max}.

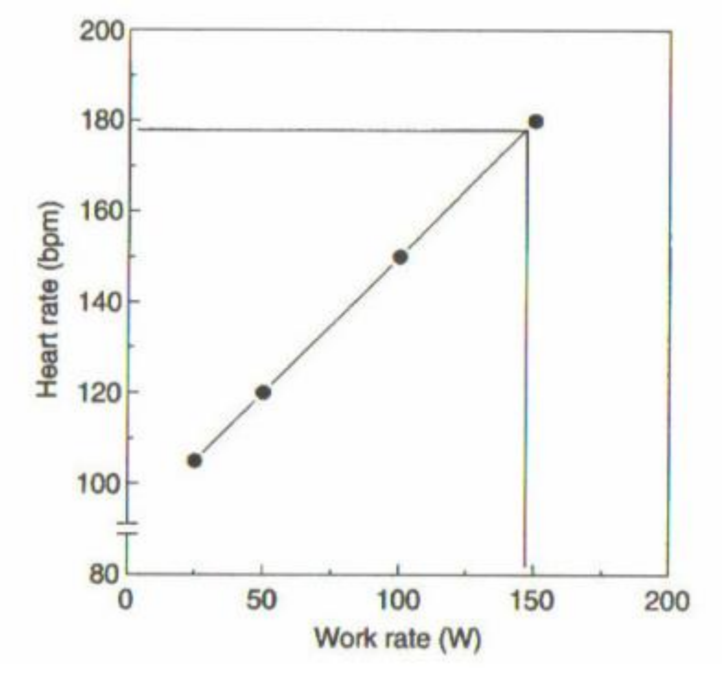


Figure 2.2. The relationship between the work rate (watts) and heart rate

(Maud and Foster, 2006).

2.4.3. Sub-maximal exercise test protocols

In literature, sub-maximal test protocols are basically performed while the subjects are walking, jogging or running. These tests botch can be indoor or outdoor. Common equipment used in the test are treadmill or cycle ergometers. Another exercise method consists of bench stepping or completing the 20 meter shuttle run (George *et al.*, 2009). Among these, motor driven treadmills and cycle ergometers are the most popular equipment used in exercise testing. In literature, there are several studies that compare the results of different testing procedures. Some of them proved that the aerobic capacity is significantly higher when the test is conducted with treadmill instead of cycle ergometer. For instance, in the study of Davis and Kasch (1975) it is stated that when aerobic capacity of the subjects are examined during cycle ergometer test, the results were established almost 10% less compared with treadmill. Similar to maximal tests, sub-maximal tests are also based on predefined protocols.

The well-known sub-maximal exercise protocols are as follows:

- Astrand Protocol
- ACSM Bike Test
- YMCA Protocol
- Harvard Step Test

In literature there are several tests that validate those protocols. Asrtrand Rhyming test is one of the most applicable tests due to its advantages such as simplicity and flexibility. Besides, it has a well-known nomogram that make calculations quite easy (Appendix A). In this study, the exercise and estimations of AC have been conducted according to Astrand protocol.

In order to estimate aerobic capacity, the six minute Astrand-Rhyming test is conducted on a cycle ergometer by measuring the steady state heart rate while the subject is performing sub-maximal test. Basically, subjects performed the exercises under nine workloads according to Astrand protocol. The work load of the tests ranges between 300 kpm/min to 900 kpm/min in 75 kpm/min steps for female subjects. On the other hand, the workload range is between 300 kpm/min to 1500 kpm/min in 150 kpm/min steps for males. According to the basic principles of the Astrand protocol, the heart rate is expected to reach a plateau at 120 beats per minute and test workloads are supposed to be in ideal range in order to reach and sustain heart rate in that level. Minimum six minutes of workload should be completed by the subjects while reaching a steady hart rate. Steady state level can be descried at the point that HR do not change more than 4 bpm. Later, aerobic capacity is predicted using the steady HR and the work load by using well known Astrand nomogram (Appendix A). At last, the prediction is multiplied with the age correction factor of the subject. The age correction factors are demonstrated in Table 2.1.

Table 2.1. Age correction factor of Astrand Protocol (Manual, Ergomedic 839).

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

The following principles summarize the validation of sub-maximal tests while determining the aerobic capacity:

- Heart rate and work load during graded exercise tests are increase in direct proportion.
- An increment in the capacity of working muscles utilize oxygen is highly related to the cardiovascular system's ability to increase the distribution of oxygenated blood.
- The maximum limit for consuming oxygen, correspond to the maximal distribution of oxygenated blood to the active muscles.
- During the first minutes of constant sub-maximal tests heart rate increases. Then, it reaches a plateau between the third and fifth minutes of the tests.

- During graded exercise tests, maximum aerobic capacity of a subject can be determined as a function of relative heart rate (Myhre *et al.*, 1998).

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

A person's aerobic capacity can be measured by various methods. These methods are categorized depending on the test protocol or the measurement type of $VO_{2max.}$ Using direct or indirect methods and maximal and sub-maximal test protocols, maximum oxygen intake of a subject can be estimated. It is knowing that, measurement of the consumed oxygen during maximal exercise tests gives the most accurate results regarding aerobic capacity. This method simply consists of measuring a person's inhaled /exhaled oxygen and carbon dioxide by analyzing their breath during the treadmill, cycle ergometer of field tests. Although maximal exercise tests allow us to predict aerobic capacity accurately, there are some clinical constrictions such as laboratory settings or safety threats. In addition to this, maximal exercise tests have the disadvantage of requiring expensive equipment and constant supervision of the subjects in the case of a health problem. In comparison, indirect methods consist of field tests which helps the estimation of subject's aerobic capacity, their ability of covering distances and completion times relating to the protocol. The ease of performing sub-maximal tests without costly laboratory equipment or highly trained test supervisors is a great advantage against maximal tests. Besides, one of the advantages of sub-maximal tests is that they can be applied to the patients that have potential cardiovascular risks or various chronic diseases with the help of a safe and appropriate protocol.

Many tests focus on HR when estimating aerobic capacity since HR and VO_{2max} are highly correlated. This is performed during field or treadmill running, using a cycle ergometer or a step test. Since maximal and sub-maximal tests can be used in order to measure aerobic capacity, it is known that sub-maximal tests are more common and applicable. Sub-maximal cycle ergometer protocol is first created by Astrand and Rhyming (1954). After that, many tests have been utilizing the cycle ergometer sub-maximal test. The advantages of a cycle ergometer are the ease of transportation and the requirement of minimal space. In addition to these, cycle ergometer makes collecting HR, oxygen consumption and blood pressure uncomplicated. Also the precision of the cycle ergometer for AC values is proven by many studies. 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 applied. The study of Myhre *et al.* (1998) proves that the difference between maximal and sub-maximal tests are minimal. Test methodology of Myhre *et al.* (1998) is taken into consideration during the measurements of AC in this study as well. In the third section, detailed information is presented regarding the test protocol and methodology of the current study.

There still exists some concern about sub-maximal protocols in contrast to their advantages. The lack of standardization is the most important one of these concerns. In order to get accurate results, giving the participants warnings about avoiding heavy exercises 24 hours prior to the experiments and heavy meals, caffeine, nicotine 2 or 3 hours prior to the test is very important. In order to minimize anxiety, the subjects should be introduced to the testing procedures and equipment before the tests. Another important point regarding to the experiment is the need to calibrate the equipment for accurate results. Untrained subjects are another constraint in sub-maximal exercise tests. The level of aerobic capacity can be estimated higher and lower since the subjects are not used to perform cycling on ergometers. For instance, in the study of George *et al.* (2009) it is stated that caused by the untrained samples in cycle ergometer testing, a 3% to 29% lower VO_{2max} measurements are reported on cycle ergometer comparing to the ones measured in treadmills.

There are also non-exercise methods for predicting aerobic capacity. These methods are using linear regression equations to compute aerobic capacity asking the subjects simple questions about their physical activities. Currently, The International Physical Activity Questionnaire (IPAQ) is the most widely used and validated self-report measure of physical activity.

The testing method preferences do not only rely on the equipment of the test conductor but also the health and physical capacity of the participants. The maximal tests are more suitable for the subjects of high health conditions and training with the help of experienced physician supervision. Table 2.2 shows the relationship between the available tools, tested subjects and the test method by referring the study of Maud and Foster (2006):

Table 2.2. Choice of tests according to the tools and population.

Tools	**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 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	

2.6. Previous AC Studies

In order to measure the aerobic capacity of various subjects, a wide range of methods and studies exist in the literature. In these studies, various measurement and estimation methods have been performed in order to determine aerobic capacity and the factors that influence it. Besides, in some studies regression models have been determined to find an equation to predict the aerobic capacity. In this part, some significant studies are examined prior to conducting the current study.

Storer *et al.* (1990) examined a study in order to develop an equation that claims that aerobic capacity have a very direct relation with test work load and it can be accurately estimated by cycle ergometer tests. During the experiments 116 female and 115 male subjects completed maximal exercise tests using cycle ergometer. According to the protocol of the tests each subject cycled at zero level of workload for 4 min. Afterwards, the work rate is increased in 15 W/min increments until the subject reached his/ her limit of tolerance. In the study it is noted that for the practitioners who tested young and fit subjects this protocol can result in long test durations. Therefore; the protocol with 30 W/min work rate increments could be more appropriate to employ to the younger subjects. Results of the experiment indicated that the accurate equations depend on workload, height and age can be generated in order to predict VO_{2max} form the cycle ergometer graded exercise tests. It is claimed that the demonstrated accuracy of the equations is primarily based on the high correlation between workload and maximal oxygen uptake. According to the results of the separate prediction equations of male and female subjects it has seen that the females have significantly lower levels of $VO_{2max.}$ Lastly, it was found that the age was an important factor that decreases the aerobic capacity due to the factors including decrease in body mass and reduction in maximal exercise values for cardiac output, pulmonary ventilation and pulmonary diffusing 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 witch 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. In our study, the experiments are executed based on this protocol which modifies Astrand Cycle Ergometer protocol in accordance with subject's weights. In treadmill exercises maximal oxygen consumption (ml/kg/min) was determined by basic calorimetric techniques. The walking speed was kept constant and the grade of treadmill increased until the subject's exhaustion. The results of the study showed that the mean difference between the maximal oxygen uptake values collected from maximal treadmill tests and estimated from submaximal cycle ergometer tests remained insignificant, for e gender. Besides, the fact that there was high correlation between estimated and determined values was the one of main findings of the study. On the other hand, it was found that human variability is an important issue during the tests since cycle ergometer significantly under or overestimated the true values of maximal oxygen uptake for some subjects. This problem is solved by repeated exercises.

Another study of George *et al.* (2000) was subject to create a modified sub-maximal cycle ergometer exercise in order to estimate aerobic capacity during treadmill exercises. 156 subjects with ages from 18 to 39 participated in the study. The subjects both completed a sub-maximal cycle protocol and a maximal graded exercise test. Their aerobic capacity is measured by an open circuit calorimetry system. A multiple linear regression model is generated in the study in order to predict aerobic capacity. According to the model age, gender, BMI and power output are the significant independent variables that create the model. George *et al.* (2000) also discussed also the accuracy of Astrand nomogram for treadmill and ergometer tests. They concluded that the nomogram tends to give underestimated results for treadmills while it is accurate to predict aerobic capacity in cycle ergometer tests. As conclusion, the modified protocol that have been generated by authors had given accurate results to predict aerobic capacity for treadmill tests in healthy and young adults. On the other hand, although the suggested protocol for cycle ergometer is an appropriate and practical regression model had smallest shrinking for the same age, BMI and exercise level groups.

In order to examine the validity of the use of heart rate in predicting the aerobic capacity during non-steady state exercises Bot and Hollander (2000) conducted a study in Netherland with 5 groups of subjects. The first group (8 female, 8 male subjects) with the mean age 25±5 completed sub-maximal cycle ergometer and interval cycling tests. The second group (8 males, 4 female) with the mean age 33± 10, conducted a field test in three 20-min periods including various leg exercises. The third group (14 males) with the mean age 23±3, was responsible for dynamic and static exercises using a small muscle mass. The fourth group was comprised of 10 females and 5 males with the mean age 32±8, completed dynamic and static exercises using both large and small muscle masses. Lastly, a group of subjects including 2 males and 3 females with the mean age 22±1 completed only field test including arm and/or leg exercises. The results of the experiments showed that for the first two groups the relationship between the heart rate and aerobic capacity was significant with the level of statistical significance $p<0.05$. According to the experiments of the third group, it was found that all subjects during both the interval and the field tests gave significantly related results. Only for the fourth group, there was no significant relationship between the HR and VO_{2max} for eleven of fifteen subjects. The experiments of the last group showed that, there were significant relationships for all subjects for both the low and high strain activities and for all activities together. Considering the results of all groups, it was concluded that there was a linear relation between HR and aerobic capacity during non-steady exercise. In other words, the estimation of VO_{2max} by measuring the HR is not limited to steady state exercise, but also could be estimated form individual HR - VO_{2max} regression lines during non-steady state activities.

In order to examine the maximum acceptable work duration (MAWD) for high-intensity work Wu and Wang (2001) conducted an experimental study on 15 females and 15 male untrained adults. Maximum acceptable work duration was described as the period of time that the subject remained with the heart rate not greater than 150 bpm while working and the peak heart rate not greater than 180 bpm at the end of the test. On the other hand, MWR was described as the test workload when VO_{2max} is achieved. Since the high-intensity work is more suitable for young workers, the age group of the subjects was limited at 20-30 years. In the study, as the first step the aerobic and the relative maximum work rate (MWR) of the subjects were measured by a maximal incremental cycling test. Afterwards, two levels of high intensity work (60% and 70% of maximum work rate) were implement on different days. The results of the study showed that the maximum acceptable work duration in the 70% maximum work rate test was less than the maximum acceptable work duration in the 60% maximum work rate test. RVO_2 (relative VO_2) was described as the percentage of difference between maximum and resting O_2 uptake. RHR was described as the resting heart rate during the resting period of subjects before test. These two variables were stated the most significant factors when generating the linear regression model of MAWD. In the study, the maximum acceptable work duration was stated as inversely correlated with the relative work load, oxygen uptake and heart rate. Another critical finding of the study is its suggested MAWD values for healthy young adults in high intensity work design: 18.8 min at 65% of RVO_2; 6.5 min at 80% of RVO_2.

The study of Farazdaghi and Wohlfart (2001) satisfied the need of the reference values for the AC within a wide range of ages. In the study, 87 women between the ages 20 and 80 years completed maximal exercise tests on a bicycle. A computerized system was used in all tests and the systolic blood pressure was checked every 2 minutes followed by Borg's RPE scale. The exercise test started at 30 W and increased by 5 W per 30 seconds, until exhaustion. The maximal test proceeded until Borg scale is 19. Analysis of the factors showed that the rate of work decline increased progressively with age. Similarly, the maximum HR attained during the cycling test was dependent on age and the reduction in maximum HR increased progressively with age. Another finding of the study was that the work capacity was dependent of height but not one weight. The maximum work load was also found to be dependent the height of the subjects.

Another study of Wu and Wang (2002) was about the relationship between the maximum acceptable work time and given workload. In the study, 12 healthy adults performed cycling tests at six different work rates relative to their maximum work capacity. During the tests, VO_{2max}, relative HR and relative VO_2 of the subjects were collected. The results showed that maximum acceptable work time was negatively correlated with VO_{2max}, relative HR and relative VO_2 ($p < 0.01$). According three regression model that were found out at the study work shifts that is longer than 10 hours should assign lower work intensity than for an 8 hours work day. It had seen that for 4-hour work shift the workload limit could be about 10% VO_{2max} higher than the given limit for an 8-h workday. 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. In the study, it could not be found any statistical difference between the dependent variables of men and women. Therefore, the suggested results of the study were considered applicable both genders.

The primary objective of the study of Bugajska *et al.* (2005) was determining the physical work capacity and work ability in men and women in employment age. Second purpose was to examine the effect of aerobic capacity on work ability. 524 occupationally active women and 664 occupationally active men were volunteered to the study. In order to estimate VO_{2max}, the subjects performed sub-maximal exercise tests on cycle ergometer. Work ability was determined with the Work Ability Index, describing work ability in the range of 7–49 points. Result of the study related to age showed that the VO_{2max} and work ability index have a strong inverse correlation with age. Also, it is found out that, there was a large variability of the distribution of the level of AC (according to Astrand qualification), in individual age groups of women and men. In the youngest group of men, a large share of those with low and very low physical capacity was found, whereas in the group of the youngest women the number of them with low or very low physical capacity was the smallest in comparison with other age groups. Last but not least, the man values of work ability index were found to be positively correlated with the level of AC and negatively correlated with age.

Pennathur *et al.* (2005) conducted an experimental study to discover 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. Although it was a sub-maximal test the VO_2 values were not estimated but was measured directly using the oxygen consumption monitor. Moreover, the HR and the rating of perceived exertion (RPE) were measured using the Borg's rating of perceived exertion. The results of the study indicated that for both and males and females VO_2, HR and RPE proportionally increase with increasing workload. Moreover, the HR was found to be approximately 10 times that of the RPE at each workload for both male and female subjects. Although, the results of the study are not statistically compared with previous studies in literature, it concluded that there may not be significant differences in aerobic capacities of young women of Mexican origin and young women from another countries according overall magnitudes of $VO_{2max.}$ The aerobic capacity of females was 58.33% of male aerobic capacity. The mean weight adjusted VO_{2max} value of females was 79.4% compared to mean of male VO_{2max}.

The study of Garatachea *et al.* (2007) aimed to investigate the validity of YMCA submaximal cycle ergometer protocol to predict energy expenditure at submaximal workloads. Twenty-eight participants of each gender, attended to the study and conducted a maximal oxygen uptake incremental test, a submaximal exercise test and the YMCA test that provides an extrapolation according to heart rate to estimate oxygen consumption. The results of the study showed that maximal oxygen uptake results collected from YMCA test was significantly different from the gold standard and study concluded that YMCA protocol could not replace the gold standard. On the other hand, predicted $VO_{2max.}$ at different relative submaximal workloads did not significantly differ from directly measured VO_2. To sum up, the heart rate method using YMCA VO_2 and HR relationship appears to be effective in estimating energy expenditure at submaximal intensities but not at maximum efforts.

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 maximal physical work capacity of Korean male metal workers. Kang *et al.* (2007) created a new a term that describing the energy expenditure during work (EE_{work}) and asserted that the 5^{th} percentile of aerobic capacity values would be an upper limit for it. The total 570 male metal employees from several metal industries were the subjects of the study. The VO_{2max} was evaluated with a sub-maximal test using a cycle ergometer. The results of the study showed that the aerobic capacity was influenced by the age of the employees. The mean values of absolute VO_{2max} (l/min) and relative VO_{2max}

(ml/kg/min), were lowest for subjects aged 50-59 years. Besides, it was stated that, there was no significance difference regarding again absolute and relative VO_{2max} between longer or shorter work tenure groups. On the other hand, 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}.

In the study of Vehrs *et al.* (2007) 250 men and 150 women, ages 18 to 40 years old from three university volunteered in order to examine the predictive accuracy of an existing regression model used to estimate aerobic capacity from the treadmill test. Secondary aim of the study was generating a new prediction model for aerobic capacity which is more practical for varying age groups. All participants completed a maximal exercise test and tests were performed on a treadmill. Oxygen consumption was measured during the tests using a standard laboratory metabolic chart. Gender, age, body mass, jogging speed, and HR were counted as independent variables in stepwise multiple linear regression to estimate measured $VO_{2max.}$ In the study it was concluded that based on the predicted residual sum of squares and small total error the suggested prediction equation displayed minimal shrinkage.

In literature, there are a number of studies subject to discuss if VO_2 really reach a plateau during sub-maximal graded exercise tests. Yoon *et al.* (2007) conducted a study in order to investigate VO_2 behavior for different test protocols. The study mainly aimed to compare VO_{2max} and VO_2 time slopes at the end of the protocol and the presence of VO_2 plateau across four protocol durations by conducting a study with the participation of eight male and eight female subjects of moderate high fitness levels. The results of the study showed that for all testes protocols the aerobic capacity of men was significantly higher than the aerobic capacity of women. While aerobic capacity of women did not differ for each protocol duration, it was found that aerobic capacity was significantly higher for men in 8 minutes protocol compared to other durations. The study concluded that the protocol durations of the tests to VO_{2max} should be between 8 and 10 minutes for healthy, moderately to highly trained subjects. Considering the VO_2 plateau it was not achieved for all the subjects. Among 16 subjects, Aerobic capacity of 5 male subjects in 16 min duration test and 5 female subjects in 8 min duration test demonstrated a plateau.

A study specialized on women is conducted by Singh *et al.* (2008). In the study fifteen farm women working were examined in order to predict their aerobic capacities. The subjects consisted of two age-groups: 25-35; 36-45 years. The subjects completed sub-maximal tests on a computerized treadmill according to Naughton protocol. A metabolic measurement system was used to measure both the HR and consumed VO_2. As a result of the study, a regression equation was generated in order to predict oxygen consumption at known heart rate levels during agricultural operations. The study concluded that the mean aerobic capacity of the group one (25-35 years) was 17.2% higher than the elder subjects. There were three regression equations suggested by the study in order to predict aerobic capacity. One of was for 25-35 age group, second one was for 36-45 age group and the last one was general linear regression equation. The main aerobic capacity values are stated as 33.5 + 4.86 ml/kg/min for 25-35 age group and 32.65 + 5.77 ml/kg/min for 36-45 age group. The comparison of the result of this study and the current study is demonstrated at the Chapter 6.

In the previous parts of current study, it is explained that there are both exercise and non-exercise methods to predict aerobic capacity in literature. George *et al.* (2009) conducted a study in order to generate a predictive regression model between exercise and non-exercise techniques. Aiming this, 116 subjects from 18 to 65 years old were invited and participated in the experiments. Previous exercise-based studies include demographic, biometric, and exercise data (such as age, gender, body mass, and exercise pace) inVO_{2max} regression models, but this study was the first exercise-based study that also includes meaningful questionnaire data in the same equation. It was seen that, the accuracy of this model caught or exceeded that of other age generalized equations. It is notable that, in the study unlike other studies the heart rate during the exercises was found to be statistically insignificant in estimation aerobic capacity and was now included to the final regression model. This finding is extraordinary since almost all protocols and models in literature take HR into consideration as the basic predictor of $VO_{2max.}$ In the study the cause of insignificant HR explained as relatively narrow range of age predicted

HR_{max} in the final exercise levels. Therefore, HR was not sufficient to differentiate relatively low and high aerobic capacities.

Balderrama *et al.* (2010) conducted a study in order to compare the aerobic capacity of people from 21 to 71 years old. In the experiments 33 subjects were tested with a sub-maximal step test in order to measure the VO_2 using a portable metabolic system and a heart rate monitor. The study basically compared the main three methods of determining the aerobic capacity: A direct measurement of VO_2, a prediction of it by using heart rate and lastly Manero step test using predetermined charts. According the statistical analysis of results of the study, it was found that there were significant differences between the three studied VO_{2max} estimation methods. An analysis carried out comparing the results of same gender. While the results for women were similar to the ones obtained before, where differences between the Manero method and direct measurements were clear; for men there was not enough evidence to conclude that the 3 methods statistically differed from each other.

In order to examine if non-exercise test protocol developed by Jurca *et al.* (2005) is valid or not Sloan *et al.* (2013) conducted another study with adult Singaporean population. 100 subjects consist of 57 men and 43 women (aged 18-65 years) participated to the experiment and completed treadmill exercise following the Bruce protocol. VO_{2max} values were measured by indirect calorimetry and test sessions were conducted with the participants walking on a treadmill. They were also asked the complete non-exercise fitness assessment forms developed by Jurca *et al.* (2005). The results of the study concluded that predicted and laboratory measured VO_{2max} values are highly correlated with R = 0.83.

Another study focused on manual works in food industry was the study of Afolabi & Akanbi (2013). The purpose of that study was to investigate body mass index (BMI) effect of on aerobic capacity and energy expenditure during manual operation in agro-processing. This processing mainly included lifting loads from ground level into the inlet of stationary threshing machines. The subjects of the experiments were 13 students (11 males, 2 females) that are randomly selected. The results of the study demonstrated that energy expenditure and BMI were increasing proportionally. On the other hand, maximal oxygen uptake had an inverse correlation with BMI. Therefore, study suggested that low BMI values were more convenient for manual lifting operations. Similarly, in the current study BMI was found as one of the most important variables when predicting aerobic capacity of adult women population. Detailed information about BMI effect on aerobic capacity can be found in Chapter 6.

Another study specifically focused on female subjects conducted by Das (2013) in India. The primary objective of the study was to evaluate and compare the capacity of the urban and rural female students of by making them to run 12 min following Cooper test protocol. The participants of the study were thirty female students (aged 16 to 21 years) from both urban and areas of West Bengal. Indirect estimation of VO_{2max} was executed with help of 12 min running Cooper test of each group of subjects. According to this protocol the participants were required to run or walk for 12 minutes and at the end of the running or walking process they were asked to stop suddenly. After the total distance covered after 12 minutes by the subjects was recorded, VO_{2max} was predicted by using a prediction equation with respect to distance covered in kilometers. The results of the study showed that the rural female students had a significantly higher value of predicted aerobic capacity than the urban female students. Another conclusion of the study stated that age was an important factor that affect VO_{2max}. Both for rural and urban females a significant correlation coefficient was stated between age and aerobic capacity. Last but not least, BMI was one of the most important predictors and BMI of the rural female students was stated statistically high correlation with aerobic capacity.

As it can be seen in the previous sections, many studies have been conducted in order to investigate prediction models in order to determine aerobic capacity without performing exercise. One of them belongs to Cao *et al.* (2013) that was examined in order to develop new aerobic capacity prediction models using a 3-minute walk test. For this purpose, 283 healthy Japanese adults (143 men, 140 women, aged 20-69 years) participated to experiments. Firstly, the subjects were required to complete a maximal graded exercise test with cycle ergometers and VO_{2max} results were collected. A modified protocol was implemented to the subject basically started with an initial work load was

30–60 W and continued with 15 W increments each minute until the subject get exhausted. In the study three prediction models were developed by multiple regression in order to predict VO_{2max} by variables of gender, age, 3-minute walk distance and BMI. The study concluded that the suggested 3 min walk test is a practical and applicable tool for predicting work capacity of Japanese adult men and women.

The lack of a comprehensive study related to VO_{2max} was the main rationale of the current study. The existing local studies mainly focus on small groups. For instance Gökbel *et al.* (2005) conducted a study aiming the evaluation of Astrand nomogram and Fox equation. The age of the subjects were between 18 and 24 years. 15 sedentary and 7 trained young men attended the maximal cycle ergometer experiments. It was seen that, both in sedentary and trained groups, measured AC values were significantly higher than the estimated ones by using Fox equation. On the other hand, for the trained groups, measured AC values were significantly higher than the estimated ones using the well-known Astrand-Rhyming. In contrast to many validation studies in literature, the results of that study showed that measured and estimated AC values are significantly different from each other. Therefore, study suggested that for athletes AC should be directly measured instead of being indirectly estimated.

Güvenç (2007) performed a study with 150 young boys (75 untrained and 75 trained) boys where the trained ones attend sports activities or doing regular exercise for more than one year. The aim of that study was to compare the effect of training on aerobic capacity. According to the results of the study, AC values were higher in trained groups. In addition to this, age was found also found as a significant factor that affects AC. It was stated that AC values were decreasing by age and maturation.

Regarding female population, one of the recent studies belongs to Pınar *et al.* (2018). Pınar *et al.* (2018) conducted a study in order to determine the effect of step aerobic exercises on AC values of females. 24 healthy adult women participated in the study. The first group was composed of 13 females between the ages of 30-41. Second group had 11 females between the ages of 21-26. Bruce Protocol had been employed during the experiments. Before the experiments the mean and SD of AC values was found as 25.69 ± 3.90 ml/kg/min for the first group and 34.26±5.10 ml/kg/min for the second group. After 8 weeks of exercise the AC values was obtained as 27.57±3.92 ml/kg/min for the first group and 35.31±4.94 for the second group. There a number of study in literature that concluded that exercise level has a significant effect on AC. Similarly, in the study of Pınar *et al.* (2018) exercise effect was found significant. However, for elder group the difference between the AC values that were measured before and after the experiments, was not statistically significant.

2.6.1. Summary and Critics of Findings

Table 2.3 demonstrates the summary of prior studies. Major part of the literature is concerned about the validity of the non-exercise or sub-maximal tests to estimate physical work capacity due to the fact that maximal tests are not applicable for all the subjects and requires qualified technical personnel. Table 2.4 shows the classification of the studies according to VO_2 measure type. Besides, classification of the studies based on the exercise type and equipment used is shown in Table 2.5.

Most of the studies focused on the relationship with HR and oxygen consumption and used HR_{max} as an indicator of the VO_{2max}. Pennathur *et al.* (2005) conducted an experimental study to determine the aerobic capacity in Mexican American young adults with The 16 male and 5 female healthy student subjects with age ranged from 22 to 30 years. The results of the study of Pennathur *et al.* (2005) showed that both and males and females HR increases with increasing workload. The study of Nes *et al.* (2012) was one of the most comprehensive studies that determine the relation between HR_{max} and age, including 3320 healthy men and women subjects.

In many studies, the effect of age on VO_{2max} is investigated. The age effect on VO_{2max} was the most obvious finding of the literature studies. It is generally reported that, the VO_{2max} was strongly inversely correlated with age. In the study of Singh *et al.* (2008) fifteen farm women working on various farm operations were investigated in terms of their aerobic capacity. The subjects were categorized in two age-groups of 25-35 years and 36-45 years and it was concluded that the mean aerobic capacity of the group one

(25-35 years) was 17.2% higher than the other subjects. Besides, in the study of Kang *et al.* (2007) the mean values of absolute and relative VO_{2max} (ml/kg/min), were lowest for subjects aged 50-59 years.

The effect of BMI on physical work capacity has been investigated most prevalently in the literature. The study of Kang *et al.* (2007) conducted with 570 male metal employees from several metal industries suggested that the worker with a high BMI was founded to have lower relative VO_{2max}. In addition to this the aim of the study of Afolabi & Akanbi (2013) was to determine the effect of body mass index (BMI) on aerobic power and energy expenditure during manual operation in primary agro-processing. The study suggested that increase in energy expenditure relate positively to BMI, while increase in VO_{2max} relate negatively to BMI and low BMI (not below normal) would be suitable for manual lifting operations. The objective of the experimental study conducted by Bradshaw (2003) was to develop a regression model in order to estimate VO_{2max} based on non-exercise data. For this purpose, 100 participants, aged 18-65 years old, attended the study, according to the results of the study gender, age, BMI and PFA were found statistically significant ($p < .05$) in predicting $VO_{2max.}$ On the other hand, in the study of Wohlfart (2001) it is stated that the work capacity was dependent of height but not one weight. The maximum work load was also found to be dependent the height of the subjects.

In literature there are findings about the difference between the physical work capacity values of women and men. The studies of Wu and Wang (2001) , Garatachea *et al.* (2007), Farazdaghi *et al.* (2003) showed that the physical work capacity of men were higher than woman. Pennathur *et al.* (2005) conducted 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 results of the study indicated that for both and males and females VO_2, HR and RPE progressively increase with increasing workload and the maximal oxygen uptake of females was 58.33% of male aerobic capacity.

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

- There is a strong correlation between between HR and oxygen consumption. This was the the main focus area of the majority of studies. Results showed that both for male and female subjects HR increase with increasing workload. Therefore, VO_{2max} predictions become possible by using maximum HR values reached at the end of the exercise tests.
- During the sub-maximal tests, HR increases rapidly at the beginning of test, then it stabilizes and reaches a plateau between the forth and the fifth minutes.
- It is possible to determine the aerobic capacity of people from exercise heart rate of them during sub-maximal exercise tests and there are severeal pre-defined protocols for these tests.
- Age was one of the main factors that had been investigated in previous studies. The results show that there exists a negative correlation between aerobic capacity and age. In many studies younger subjects had higher VO_{2max} values when compared to elder ones. The reults of the studies of Bugajska *et al.* (2005) and Singh *et al.* (2008) showed that AC of younger females are greater than the AC of elder ones.
- The body mass index (BMI) is an important indicator that defines height and weight characteristics of adults for classifying them into groups. BMI was also an important factor that affect aerobic capacity. The results of the previous studies show that High BMI values are correlated with reduced levels of physical fitness, resulting with lower VO_{2max}.
- There are many studies that proved that exercise level of people is an important factor on their aerobic capacities. Generally, HR at any given level of sub-maximal exercise decreases with exercise level of a person and that causes higher VO_{2max}. The study of Pınar *et al.* (2018) proved that aerobic capacity of females increases with exercise.
- According to the literature, gender was another significant factor on AC. It is observed that, women have lower VO_{2max} values than men generally. It is possible to state that the main reason of that difference is the difference between the

physiology of each gender. Due to the fact that women are generally smaller than men, their hearts pump less blood and lung less oxygen.

- Last but not least, regarding the effect of smoking on AC, there was not enough proof to evaluate the direct relationship between smoking and VO_{2max}. Suminski *et al.* (2009) performed a study and stated that AC of heavy smoking group was significantly lower than the other groups. On the contrary, the study of Kang *et al.* (2007) including 570 male metal workers concluded that exercise level, alcohol drinking or smoking did not have a significant relationship with the relative VO_{2max}. Since the study of Kang *et al.* (2007) were investigating the AC distribution of male workers, a study that mainly focus on the effect of smoking on AC for women is still a need.

Table 2.3. 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	116F	(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
			115M					
Myhre *et al.* (1998)	USA	American Air Force Workers	41 F	(20-59)	Direct	Maximal	Treadmill	Constant speed and increased treadmill grade until exhaustion.
			58M		Indirect	Sub-maximal	Cycle Ergometer	US Air Force Cycle Ergometry Fitness Protocol (modified)

Table 2.3. 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	80F	27.6 ± 7.1	Direct	Maximal	Treadmill	Brigham Young University Cycle Ergometer Protocol
			76M	28.6 ± 6.3		Sub-maximal	Cycle ergometer	NM
Bot and Hollander (2000)	Netherlands	Healthy Adults	8F, 8M	25 ± 5	Direct Indirect	Submaximal Maximal	Cycle Ergometer	Astrand Cycle Ergometer Interval Cycle Ergometer Test
			4F, 8 M	33± 10		Submaximal	Field test	In three 20-min periods various leg exercises
			5M, 10F	32± 8		Submaximal	Cycle Ergometer	Astrand Cycle Ergometer Protocol
			2M,3F	22± 1		Submaximal	Field test	Two rounds of six low-strain activities
			14M	23± 3		Maximal	Wheelchair	Interval Wheelchair Ergometer Test

Table 2.3. 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	15F	23.5± 2.1	Direct	Maximal	Cycle ergometer	NM
			15M	23.3± 3.6				
Farazdaghi and Wohlfart (2001)	Sweden	Swedish Adult Women	87F	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	6F	25.3± 1.0	Direct	Maximal	Cycle ergometer	Astrand Cycle Ergometer Protocol
			6M	27.2± 2.4				

Table 2.3. 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	81M	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 (2003)	USA	Adults	50F	37.24± 13.8	Direct	Maximal	Treadmill	Arizona State University Maximal GXT protocol
			50M	37.76 ± 12.76				

Table 2.3. 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 (2003)	USA	NM	50F	37.24± 13.8	Direct	Maximal	Treadmill	Arizona State University Maximal GXT protocol
			50M	37.76 ± 12.76				
Bugajska *et al.* (2005)	Poland	Polish Workers	524F	43.7 ± 10.1	Indirect	Sub- maximal	Cycle ergometer	NM
			664M	42.7 ± 10.4				
Gökbel *et al.* (2005)	Turkey	Turkish Healthy Men	15M Sedentary	18-24	Direct	Maximal	Cycle Ergometer	Initial workload 60-100W, increase in 10W/min until exhaustion
			7M Trained					

Table 2.3. 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	5F	22.60± 0.89	Direct	Sub- maximal	Treadmill	Bruce Protocol
			16M	23.94 ± 2.38				
Pulkkinen *et al.* (2005)	Finland	Healthy Untrained Adults	16M	36 ± 8	Direct	Maximal	Cycle Ergometer	5 minutes prior to, during and 15 minutes after 10-min exercises at 40% and 70% VO_{2max} and maximal stepwise test
			16F	39 ± 10				
Vehrs and Fellingham (2006)	USA	White and African American Men	16M White	21.10 ± 1.0	Direct	Sub-maximal	Cycle ergometer	Astrand Cycle Ergometer Protocol
			16M African					

Table 2.3. 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	28F	43.6 ± 6.1	Direct	Maximal	Cycle Ergometer	YMCA Cycle Ergometer Protocol
			28M	43.5 ± 5.9	Indirect	Sub-maximal		
Smolander *et al.* (2007)	Finland	Postal workers	9F	42 ± 8	Indirect	Sub-maximal	Cycle Ergometer	NM
			13M	41 ± 8				
Kang *et al.* (2007)	Korea	Korean Metal Workers	507M	39.3± 7.7	Indirect	Sub-maximal	Cycle Ergometer	NM

Table 2.3. 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	150F	(18-40)	Direct	Sub-maximal	Treadmill	Single-stage Submaximal Treadmill Jogging Protocol
			250M					
Güvenç (2007)	Turkey	Turkish young boys	75M untrained	(11-15)	Direct	Sub-maximal	NA	3 minutes running, 1 minute recovery
			75M trained					
Yoon *et al.* (2007)	USA	Healthy Adults	8F	26.0 ± 8.9	Direct	Maximal	Cycle ergometer	Computer-controlled ramp function on the basis of maximal power output from the familiarization trial
			8M	23.8 ± 3.2				
Mou Liu and Fu Lin (2007)	Taiwan	College male students	31M	19.77±1.20	Direct	Maximal	Treadmill	Bruce protocol

Table 2.3. 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 (2008)	Italy	Italian Patients	NM	NM	NM	Sub-maximal	NM	6 minutes walk test
Singh *et al.* (2008)	India	Indian Farm Women	15F	n= 9 (25-35)	Direct	Sub-maximal	Treadmill	Naughton protocol
				n= 6 (36-45)				
George *et al.* (2009)	USA	NM	50F	n= 57 (18-39)	Direct	Maximal	NM	Arizona State University
			50M	n= 43 (40-65)		Sub-maximal		Maximal GXT protocol
Duque *et al.* (2009)	Colombia	Adult Patients with Chronic Low Back Pain	33F	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 2.3. 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	52F	22.4 ± 3.1	Direct	Maximal	Treadmill	Arizona State University Maximal GXT protocol
			53M	24.6 ± 1.87		Sub-maximal	Cycle Ergometer	Modified Brigham Young University Cycle Ergometer Protocol
Balderrama *et al.* (2010)	Mexico	Mexican	19F	(20-71)	Direct	Maximal	NM	Manero Step Test Protocol
			14M		Indirect	Sub-Maximal		
Levin (2012)	Australia	Australian Soccer and Football Players	17M	(18-24)	Indirect	Sub-Maximal	Cycle Ergometer	Astrand Cycle Ergometer Protocol
Nes *et al.* (2012)	Norway	Norwegian Healthy Adults	1594F	45.3 ± 12.7	Direct	Maximal	Treadmill	Individualized protocol with different initial workload levels
			1726M	46.9 ± 12.8				

Table 2.3. 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	88F 142M	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 57M	18-65	Indirect	Maximal	Treadmill	The Bruce Treadmill Ramp Protocol
Afolabi & Akanbi (2013)	Nigeria	Students	2F 11M	21-30	Direct	Sub-maximal	Lifting	Three iterative manual lifting of loads through the vertical distance of 0.92m.

Table 2.3. 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				
Pınar *et al.* (2019)	Turkey	Adult female	24 healthy women			Maximal	Step	Bruce Protocol

Table 2.4. 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 (2000) • Wu and Wang (2002) • Bradshaw (2003) • Gökbel *et al.* (2005) • Pennathur *et al.* (2005) • Pulkkinen *et al.* (2005) • Vehrs *et al.* (2006) • Garatachea *et al.* (2007) • Yoon *et al.* (2007) • Güvenç (2007) • George *et al.* (2007) • Chin-Mou-Liu (2007) • Singh *et al.* (2008) • George *et al.* (2009) • George *et al.* (2010) • Duque *et al.* (2009) • Balderrama *et al.* (2010) • Nes *et al.* (2012) • Ahmadian *et al.* (2013) • Afolabi & Akanbi (2013) • Cao *et al.* (2013) • Prieto *et al.* (2013) • Pınar *et al.* (2018)	• Cink and Thomas (1981) • Myhre *et al.* (1998) • Bot (2001) • Farazdaghi and Wohlfart (2001) • Farazdaghi and Wohlfart (2003) • Bugajska *et al.* (2005) • Garatachea *et al.* (2007) • Smolander (2007) • Kang (2007) • Balderrama *et al.* (2010) • Levin (2012) • Das (2013) • Cao *et al.* (2013) • Sloan *et al.* (2013) • Myers *et al.* (2017)

Table 2.5. Summary of studies classified according to Exercise 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 (2000) • Wohlfart (2001) • Wu and Wang (2002) • Farazdaghi and Wohlfart (2003) • Bradshaw (2003) • Gökbel *et al.* (2005) • Pulkkinen *et al.* (2005) • Garatachea *et al.* (2007) • Yoon *et al.* (2007) • Chin-Mou-Liu (2007) • George *et al.* (2009) • George *et al.* (2010) • Duque *et al.* (2009) • Balderrama *et al.* (2010) • Nes *et al.* (2012) • Ahmadian *et al.* (2013) • Sloan *et al.* (2013) • Cao *et al.* (2013) • Prieto *et al.* (2013) • Pınar *et al.* (2018)	• Cink and Thomas (1981) • Myhre *et al.* (1998) • George *et al.* (2000) • Bot and Hollander (2000) • Bugajska *et al.* (2005) • Pennathur *et al.* (2005) • Vehrs *et al.* (2006) • Garatachea *et al.* (2007) • Smolander (2007) • Kang *et al.* (2007) • George *et al.* (2007) • Güvenç (2007) • Crocetta (2008) • Singh *et al.* (2008) • George *et al.* (2009) • George *et al.* (2010) • Levin (2012) • Afolabi & Akanbi (2013) • Das (2013) • Cao *et al.* (2013)	• Myhre *et al.* (1998) • George *et al.* (2000) • Bradshaw (2003) • Pennathur *et al.* (2005) • Chin-Mou-Liu (2007) • Singh *et al.* (2008) • George *et al.* (2010) • Nes *et al.* (2012) • Sloan *et al.* (2013) • Prieto *et al.* (2013)	• Cink and Thomas (1981) • Storer (1990) • Myhre (1998) • George *et al.* (2000) • Wu and Wang (2001) • Wohlfart (2001) • Bot (2001) • Wu and Wang (2002) • Farazdaghi and Wohlfart (2003) • Bugajska *et al.* (2005) • Gökbel *et al.* (2005) • Pulkkinen *et al.* (2005) • Vehrs *et al.* (2006) • Garatachea *et al.* (2007) • Yoon *et al.* (2007) • Smolander (2007) • Kang *et al.* (2007) • George *et al.* (2009) • Duque *et al.* (2009) • Levin (2012) • Ahmadian *et al.* (2013) • Cao *et al.* (2013)	• Bot and Hollander (2000) • Güvenç (2007) • George *et al.* (2009) • Balderrama *et al.* (2010) • Afolabi & Akanbi (2013) • Das (2013) • Cao *et al.* (2013)

Table 2.6. Summary result table of AC studies in the literature.

Author	**Year**	**Gender**	**Sample Size**	**Age**				**AC (l/min)**	**AC (ml//kg/min)**	**Max HR (beats/min)**	**Nationality**	**Population Type**
				Min	**Max**	**Mean**	**SD**	**Mean - SD**	**Mean - SD**	**Mean**		
Mac Nab *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 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				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		
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 *et al.*	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 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				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 Cycle: 36.91 ± 11.48	-	American	American Air Force Workers
		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 2.6. Summary result table of AC studies in the literature (cont.).

Author	**Year**	**Gender**	**Sample Size**	**Age**				**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		
		F	11	-	-	23.7	2.8	2.86 ± 0.33	44.60 ± 7.60	-		

Table 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				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	F	5	-	-	23.3	4.0	-	45.50 ± 4.50		English	Adults
Kirk and Sullman	2001	F	5	-	-	23.3	4.0	-	45.50 ± 4.50		English	Adults
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 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
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 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				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	2003	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 2.6. Summary result table of AC studies in the literature (cont.).

Author	**Year**	**Gender**	**Sample Size**	**Age**				**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 2.6. Summary result table of AC studies in the literature (cont.).

Author	**Year**	**Gender**	**Sample Size**	**Age**				**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		
Pulkkinen *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 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				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 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				AC (l/min)	AC (ml/kg/min)	Max HR (beats/min)	Nationality	Population Type
				Min	Max	Mean	SD	Mean - SD	Mean - SD	Mean		
Mou Liu and Fu Lin	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	1.72 ± 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 *et al.*	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			
George *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 2.6. Summary result table of AC studies in the literature (cont.).

Author	Year	Gender	Sample Size	Age				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
Cao et al.	2013	F	140	-	-	44.1	13.9	-	31.2 ± 6.6	-	Japan	Female Adults

Table 2.6. Summary result table of AC studies in the literature (cont.).

Author	**Year**	**Gender**	**Sample Size**	**Age**				**AC (l/min)**	**AC (ml/kg/min)**	**Max HR (beats/min)**	**Nationality**	**Population Type**
				Min	**Max**	**Mean**	**SD**	**Mean - SD**	**Mean - SD**	**Mean**		
Myers *et al.*	2017	F	396	20	29	-		-	37.9 ± 3.92	-	USA	Female Adults
		F	608	30	39	-	-	-	30.9 ± 8.10	-		
		F	843	40	49	-	-	-	27.9 ± 7.80	-		
		F	805	50	59	-	-	-	24.2 ± 6.10	-		
Ando *et al.*	2018	F	162	18	44	26.8	6.1	2.92 ± 0.78	-			
Pınar *et al.*	2018	F	13	-	-	36.03	4.4	-	27.5 ± 3.92	-	Turkish	Female Adults
		f	11	-	-	23.15	1.5	-	35.3 ± 4.94	-		

3. RATIONALE AND OBJECTIVES OF THE STUDY

3.1. Rationale of the Study

In industry, aerobic capacity (AC) data of the target populations are needed to establish safe and productive work designs. Workforce performance and production output depend on sustaining the effort over a period of time that depends on AC and type of tasks. On the other hand, excessive cardiovascular load may put the individuals in the risks of cardiovascular diseases such as coronary heart disease. Due to this fact, the researchers in the area of ergonomics seek to establish norms to protect workforce and increase performance. AC data are also needed to form baselines for treatment of patients and also for sports to determine the fitness levels. There are a number of studies performed around the world related to the AC of the various populations. These studies shows that AC varies among some world populations and within the sub groups of a given population due to the differences in genetics, lifestyle, nutrition, geographical region, fitness level, gender and age. Therefore, it is a need to develop AC norms for the population of Turkey. There are a few AC studies of the population of Turkey which involve specific small groups of people stratified by region, age, training and so on. These studies mainly related to health and sport sciences. Thus, the results of them are not adequate to be used in work design and also to establish AC norms. Therefore, a comprehensive AC study which includes wide range of people of working age of population of Turkey is a need. This study, specifically, aims to contribute to the establishment of AC norms of adult female population of Turkey.

3.2. Objectives of the Study

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

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

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

(iii) Comparing the aerobic capacity data of the female population of Turkey with the aerobic capacity data of female population of other countries.

4. METHODOLOGY

4.1. Sampling

256 healthy adult women from different regions of Turkey volunteered for the study. All subjects are selected from Istanbul and its surrounding area. Since the population of Istanbul is composed of people whose family origins are from every region of Turkey, it is assumed that the population of this city is an approximate representation of Turkey.

In the extent of this study, stratified sample of volunteer females between the ages of 18 and 54 years attended the experiments. Age groups of the subjects are divided into four groups as following (in years): (18-24), (25-34), (35-44) and (45-54). Selection of the age groups are based on the TURKSTAT Health Survey which was the first study that reflects the whole country and provides data for national and international comparisons. (TURKSTAT, 2012). Before the main experiments, in order to determine the required sample size of the actual study, the pilot study is performed. In order to calculate required sample size, data obtained from pilot study is used with formula for normative data studies which is stated in the ISO standards (ISO 15535:2006). In the Table 4.1, distribution of whole Turkey female population and defined sample sizes for each age group for the tests.

Table 4.1. Distribution of age groups of the subjects.

Age group	Female population (Turkey)	Ratio (%)	Sample size	Ratio (%)
18-24	6,153.524	27.8%	71	27.7%
25-34	6,322.849	28.5%	72	28.1%
35-44	5,339.568	24.1%	62	24.2%
45-54	4,341.061	19.6%	51	19.9%
Total	**22,157.002**	**100%**	**256**	**100%**

Subjects were asked about their family origin, father’s and mother’s birthplaces and city of family origin and region data were collected in order to provide a balanced distribution to cover whole country. The regional distribution of the family origin of the subjects can be seen in Table 4.2.

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

Regions	**Number of subjects**	**Ratio (%)**
Marmara	51	20%
Black Sea	41	16%
Central Anatolia	35	14%
Mediterranean	34	13%
Southeastern Anatolia	34	13%
Eastern Anatolia	31	12%
Aegean	30	12%
Total	256	100%

Another factor that is investigated in the current study is occupation. In order to examine the effect of occupation, volunteered subjects were divided into two job groups: manual workers and non-manual workers. The “Regulation of Heavy and Dangerous Labors” which was published in the “Turkish Official Newspaper” on 16 June 2004 was the baseline of classifications. In the current study, there were 99 manual workers whereas 157 of the subjects were non-manual workers. In Table 4.3, the classification of the groups according to occupation can be seen in detail.

Table 4.3. Occupation Classification.

Manual (99)	**Non-manual (157)**
Beautician (2)	Medical practitioner (2)
Assembly worker (9)	Receptionists (2)
Caretaker (2)	Accountant (1)
Charwoman (21)	Advocate (1)
Coiffeur (4)	Architect (1)
Cook (3)	Author (3)
Decorator (1)	Bank employee (2)
Dental technician (1)	Bank Employee (retired) (1)
Dry cleaner (1)	Biologist (1)
Farmer (6)	Business Analyst (4)
Flight attendant (1)	Call center operator (6)
Gardener (1)	Caricaturist (1)
Grosser (1)	Cashier (2)
Housekeeper (2)	Chemical Engineer (1)
Housewife (11)	Chemist (2)
Security officer (15)	Clerk (20)
Slop seller (1)	Clerk (retired) (9)
Tailor (3)	Clothing designer (2)
Tea seller (5)	Computer programmer (1)
Technician (1)	Consultant (4)
Textile worker (1)	Economists (4)
Tourism worker (1)	Entrepreneur (1)
Tourist guide (3)	Executive Assistant (2)
Waitress (3)	Financier (2)
	Fitness Instructor (2)
	Graphic designer (1)
	Housewife (light) (4)
	Kinder garden Teacher (2)
	Marketing expert (7)
	Musician (2)
	Nurse (2)
	Officer (2)
	Opticians (1)
	Pharmacist (3)
	Physiotherapist (1)
	Police officer (2)
	Psychologist (1)
	Restaurant manager (1)
	Research assistant (3)
	Sales Executive (4)
	Student (25)
	Taxation expert (1)
	Teacher (12)
	Teacher (retired) (6)

BMI effect on AC was proved in many previous studies in literature. In the experiments in this study, subjects are divided into four BMI groups. The body mass index (BMI) can be defined as a statistical measure of the weight of a person scaled according to height. It is basically individual's body weight divided by the square of their height (kg/ m^2) (ACSM, 2009). The equation 4.1 demonstrates the BMI formula used in the current study. Moreover, Table 4.5 shows the number of subjects of the current study belong to each BMI category:

$$\text{BMI (kg / m}^2\text{)} = \text{Weight (kg) / Height}^2 \text{ (m}^2\text{)} \tag{4.1}$$

Table 4.4. BMI categories.

Category	**BMI Range (kg/m²)**	**Subjects**	**Ratio (%)**
Underweight	< 18.5	19	7%
Normal	18.5 ≤ x < 25	113	44%
Overweight	25 ≤ x < 30	87	34%
Obese	> 30	37	14%

To sum up, in order to divide popultain in strata (age group, occupation and seven geographical region of Turkey based on family roots and birth place) stratified random sampling method was employed in this study. The number of subjects categorized by age, occupation groups and BMI can be seen in Table 4.5.

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

Occupation Group	**BMI Category**	**Age Group**				**All**
		18-24	**25-34**	**35-44**	**45-54**	
Manual	Under-weight	1	1	1	1	4
	Normal-weight	11	21	15	9	56
	Over-weight	3	7	14	6	30
	Obese	2	3	1	3	9
	Sub-total	17	32	31	19	99
Non-Manual	Under-weight	6	4	3	2	15
	Normal-weight	35	11	9	2	57
	Over-weight	11	21	9	16	57
	Obese	2	4	10	12	28
	Sub-total	54	40	31	32	157
Total		71	72	62	51	256

In addition to age, BMI and job classification, the smoking, exercise and alcohol habits of the subjects were also collected in this study.

Subjects were divided into two groups regarding smoking:

(i) *Smokers:* The subjects who are smoking currently.
(ii) *Non or Ex-Smokers:* The subjects who never smoked before or smoked more than 100 cigarettes in lifetime and does not smoke currently.

Subjects were divided into two groups according to their alcohol consumption:

(i) *Drinkers:* Subjects who consume more than 2-3 drinks per day or more than 7 drinks per week.
(ii) *Non-Drinkers:* The remaining subjects.

Subjects were divided into two groups according to their exercise level:

(i) *Exercise:* The subjects who 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.
(ii) *Non-Exercise:* The remaining subjects.

NASA Physical Activity Scale Survey (PASS) is used to make classifications while collecting personal data forms. Table 4.6 demonstrates the number of subjects according to their smoking status, exercise level and alcohol consumption.

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

Smoking habit	**Alcohol Consumption**	**Physical Activity**		**All**
		Irregular or No	**Regular**	
Smoker	Drinker	6	2	8
	Non-drinker	51	14	65
	Sub-total	57	16	73
Non or Ex-Smoker	Drinker	18	2	20
	Non-drinker	134	29	163
	Sub-total	152	31	183
Total		209	47	256

4.2. Equipment

In the section of the study, the details about the equipment used in the studies are explained.

4.2.1. Monark 839 E Cycle Ergometer

Cycle ergometer is a fixed machine that allows people to conduct performance with its adjustable power output and pedaling rate. Monark 839 E cycle ergometer was the main equipment of the current study. It is a computerized cycle ergometer and its removable control unit makes it also removable. There are many protocols that can be followed with Monark 839 E cycle ergometer such as Astrand, Bruce and Naughton, protocols. In the Figure 4.1 the cycle ergometer employed in the current study can be seen.

The followigs are the technical construction features of the cycle ergometer used in tests of the current study:

- Brake-power 0-1400 W (depending on rpm).
- Large, well-balanced flywheel 22 kg (48 lbs).
- Adjustable saddle; vertically and forward/backwards.
- Adjustable handlebar with quick release lever.
- Stable frame, with square tubing.
- Length 1150 mm
- Width 530 mm at handlebar.
- Width 460 mm at support tubes.
- Height 760-1135 mm at handlebar.
- Height 800-1120 mm at seat.
- Weight 56 kg (123 lbs).

The computer system of Monark 839 E cycle ergometer basically contains one basic unit and one terminal. Pedal speed, test force and the heart rate of the subjects are read the main unit. In addition to this, the motor is activated by base controller in order to change the belt tension and regulate the applied breaking force. According to changes in pedal speed, the force may be automatically varied to preserve a constant power workload.

4.2.2. Polar T-31 Heart Rate Monitor

The heart rates of the subjects are measured by the Polar T-31 heart rate monitor during the experiments. The HR were being read by the computer and the workload selections are made according to these HR values. In the last section of experiments HR values are used to estimate AC values as well. The wireless heart rate monitor used in the current study is demonstrated in Figure 4.2.

Figure 4.1. Monark 839 E Cycle Ergometer.

Figure 4.2. Polar T-31 HR Monitor.

4.2.3. The calibration check of Cycle Ergometer

It was not a tough procedure Since Monark 839 E cycle ergometer it is a mechanically weighted and braked ergometer. Calibration was performed regularly in order to obtain more accurate results during the experiments. The following steps were followed while doing calibrations:

- Remove the cover from the flywheel.
- Loose the brake belt at the balancing spring.
- Wait until the flywheel is not moving any longer.
- The pendulum weight index should be aligned with “0” on the scale.
- Attach the calibration weight to the point at which the spring was attached.
- The known weight should match the value on the scale.
- Reattach the tension belt.
- Re-assembe the cover.

4.3. Testing Procedure

People from different age, BMI and job groups were volunteered for the aerobic capacity measurement experiments. Subjects were asked to drink plenty of water and avoid hard physical activities and fatiguing exercises at the test day and to avoid heavy meals, caffeine, alcohol, and tobacco products within at least three hours of their test day (ACSM, 2006). At the experiment day, they were also asked to dress in light clothes and comfortable sports shoes. Before experiments, all candidates were asked to fill “Medical History Form”. According to the guideline of American College of Sports Medicine, subjects who were free from musculoskeletal or cardiovascular disorders were invited to participate in the measurement test (ACSM, 2006). Later, the participants signed the “Personal Consent Form”, which includes a detailed description of the aim and procedures of the study, to show that she was voluntarily participating in 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 birthdate, 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).

4.4. Anthropometric measurements

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

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

(ii) *Measurement of Weight:* In order to measure weight a mechanical scale was used. Prior to experiments, this mechanical scale had been checked for accuracy with known weights. The subjects were asked to wear light clothes and attend the tests free from any accessories that might cause extra weight. Moreover, the participants were informed about not being very hungry or full during the experiments.

4.4.1. Heart rate measurements

Each subject was fitted with an HR monitor to measure HR during the submaximal cycle ergometer exercise. The HR monitor was placed middle of the chest and it was checked if the pulse signal was being read by the computer system of Monark Cycle Ergometer. Resting HR values of the subjects were collected and age predicted HR_{max} values were calculated using the common age predicted HR_{max} (220-age) formula after the subjects had a 20 min rest before experiments. Moreover, the HR values of the subjects were continuously being recorded during the sub-maximal cycle ergometer exercises.

4.4.2. Sub-maximal Cycle Ergometer Test

(i) *Preparation for the test:* The seat of the bike was adjusted as the knee of the subjects were 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:* It is known that sub-maximal testing is widely used in practical settings and across different subject groups, and does not require medically qualified staff. Therefore, in the current study, the estimation of VO_{2max} of female subjects was completed during sub-maximal cycle ergometer tests. In order to get more accurate test results, following a structured protocol is very crucial in sub-maximal exercise tests. The followed protocol was The Astrand Bike Test (also known as the Astrand-Ryhming test) in the experiments of the current study since it is the most recognized way of sub-maximal cycle ergometer testing and the validity of the test had proved by previous studies. Astrand and Ryhming (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}. In this protocol there were nine workloads. For the female subjects, the workloads span from 300 kpm/min to 900 kpm/min in 75 kpm/min steps. In that protocol, it can be hard to overcome the difficulties about selection the initial work rate and decide how to adjust to work load in the first 3 minutes of the test. Myhre *et al.* (1998) developed a procedure to select most appropriate initial test work load and adjustment criteria for the work load in the first 3 minute of the test according the subjects HR and age. This protocol enables the practitions to select the most appropriate workload in the beginning of the test, overcome the arbitrary workload selection difficulty of Astrand protocol and maintain the convenient workloads for six minutes to ensure that the heart rate reached a steady state (Myhre *et al.*,1998). The workload adjustments of the current study was conducted according to the Astrand Protocol using the suggested workload selection steps by Myhre *et al.* (1998). In the following part the methodology used in the current study were described in detail.

- *Step 1:* Initial workload is selected according the subject's age and weight.

Table 4.7 demonstrated initial workload selection rules of the subjects. For instance, a subject whose weight is 64 kg and age is 24 started to test with the workload 300 kpm/min.

Table 4.7. Initial work load selection rules (Myhre *et al.*, 1998).

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

- *Step 2:* The workload of the test is adjusted according the subject's age and HR at the end of the 1^{st} minute. Table 4.8 shows the workload selection criteria for the 1^{st} minute of the test. For the selected subject, workload was not adjusted and continued at 300 kpm/min since HR was 130 bpm.

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

18 to 29 yr.		**30 to 39 yr.**		**40 to 49 yr.**		**50 to 62 yr.**	
HR (bpm)	**Workload**	HR (bpm)	**Workload**	HR (bpm)	**Workload**	HR (bpm)	**Workload**
<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:* According to the age and HR of the subjects, the workload is adjusted again at the end of the 2^{nd} minute. Table 4.9 shows the workload selection criteria for the 2^{nd} minute of the test. Since HR of the selected subject that is mentioned in step 1 and 2, was between 120 and 135 bpm at the end of the 2^{nd} minute of the test, existing workload is sustained.

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

18 to 29yr.		**30 to 39 yr.**		**40 to 49 yr.**		**50 to 62 yr.**	
HR (bpm)	**Workload**	HR (bpm)	**Workload**	HR (bpm)	**Workload**	HR (bpm)	**Workload**
<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:* In order to obtain a steady state heart rate, the workload of the test is adjusted according the subject's age and HR at the end of the 3rd minute. Table 4.10 depicts the workload selection criteria for the 3rd minute of the test. Since HR of the subject was between 130 and 145 workload sustained as 300 kpm/min.

In brief, for the selected subject whose age is 24 and weight is 64 kg, initial workload was 300 kpm/min. At the end of the 2nd and 3rd minute, workload was not increased or decreased and she finished the test with 300 kpm/min. This last workload is defined as "test workload" in the study.

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

18 to 29 yr.		**30 to 39 yr.**		**40 to 49 yr.**		**50 to 62 yr.**	
HR (bpm)	**Workload**	HR (bpm)	**Workload**	HR (bpm)	**Workload**	HR (bpm)	**Workload**
<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 remaining 3 minutes of the test for any indications such as exhaustion regarding legs and related body muscles or any increase in steady state HR that causes to exceed approximately 85% of age-predicted maximum HR (220-age) of the subject to stop the test. If there is no indication to stop the test subjects are motivated to perform and finish the test at given workload.
- *Step 6:* The heart rate is recorded at the end of the fifth minute. If, by the end of the sixth minute the heart rate is within 4 bpm of the observation of 5^{th} minute the protocol is finished. If not, the test continues until the pulse rate is within 4 beats for one or two minutes.
- *Step 7:* The accepted HR and workload is recorded for the test. Accepted HR is basically the last steady state HR at the end of the test.
- *Step 8:* The subject is asked to continue to cycle, with workload lower than 300 kept/min until recovery HR is less than 120 bpm for 1 minute and stop the test.
- *Step 9:* VO_{2max} value is recorded obtained from the computer report of test that is making the calculations based on Astrand nomogram (Appendix A) and age correction factors that are stated in Table 2.1.

For example, for the selected subject at the end of the step 7 accepted HR is found as 145 bpm. Test workload was 300 kpm/min and age correction factor is 1 since age of the subject is between 20 and 29 years. Using the accepted HR (145 bpm) and test workload (300 kpm/min) the VO_{2max} value was obtained as 1.7 l/min from the nomogram. Since the age correction factor was 1, 1.7 was calculated with 1 and final VO_{2max} was recorded as 1.7 l/min.

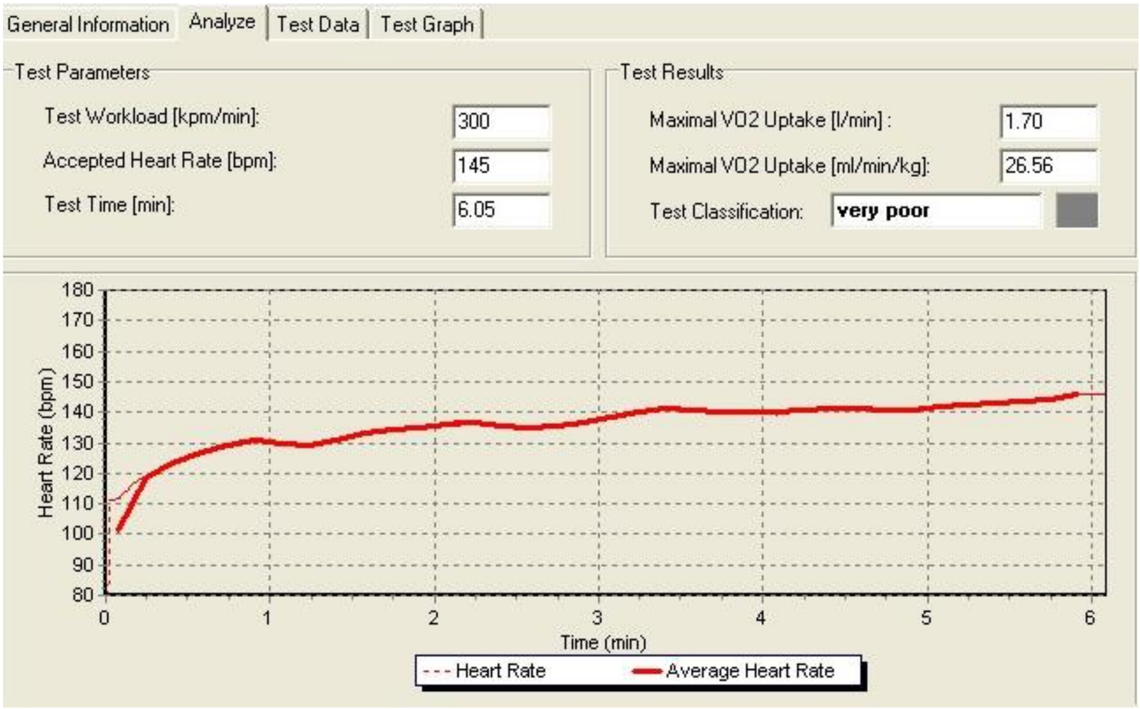


Figure 4.3. Test example in Monark 839 E.

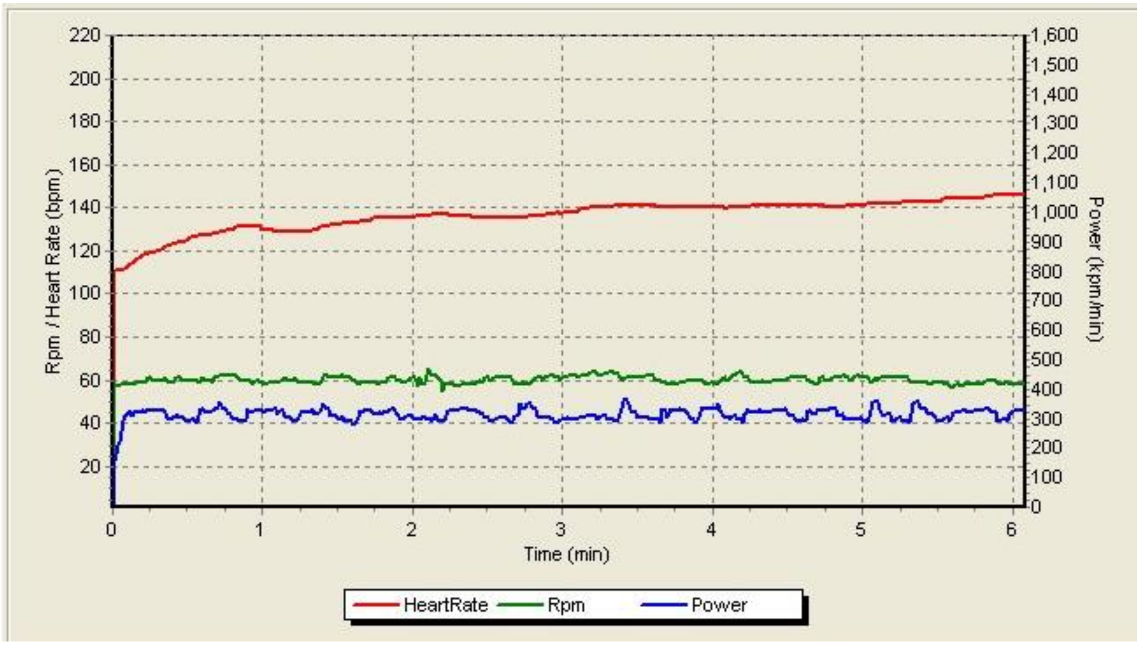


Figure 4.4. Test example in Monark 839 E.

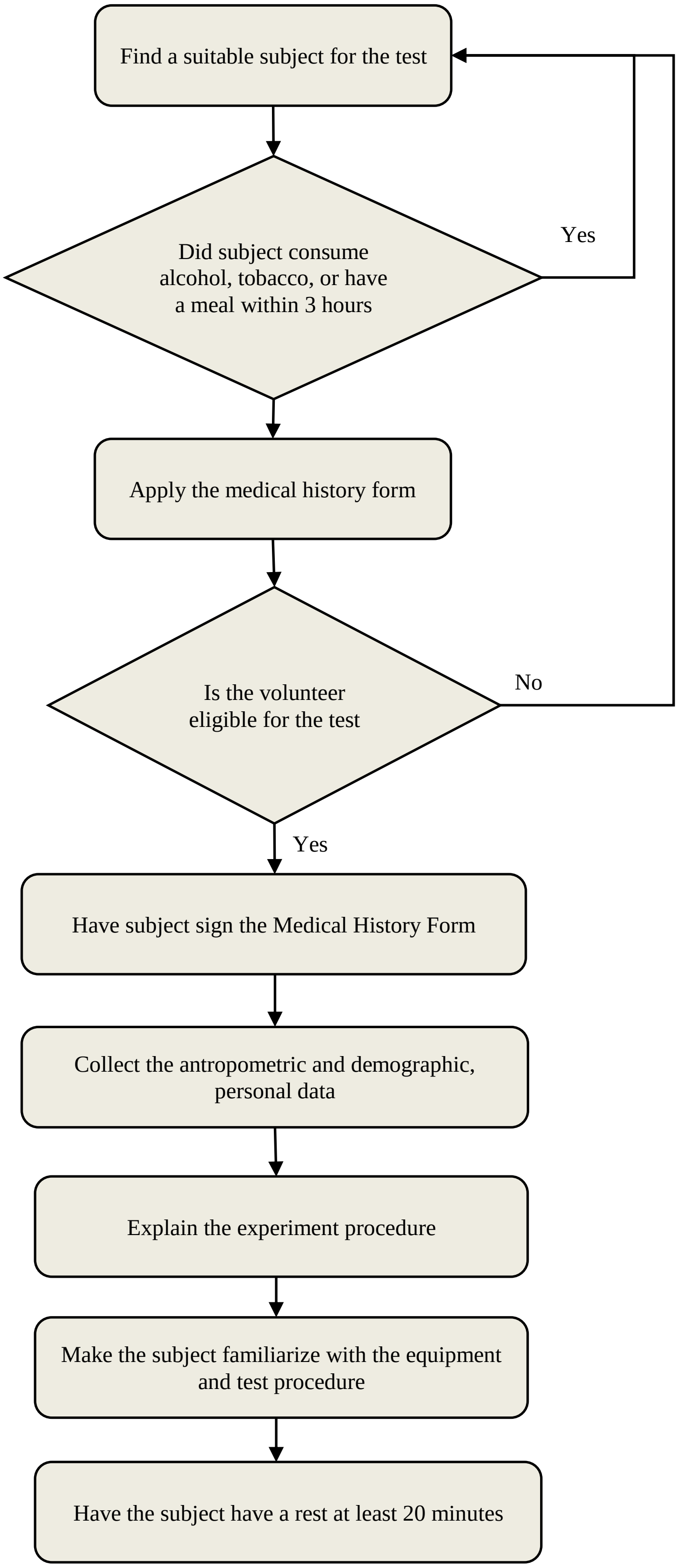


Figure 4.5. Flow chart of the experimental procedure.

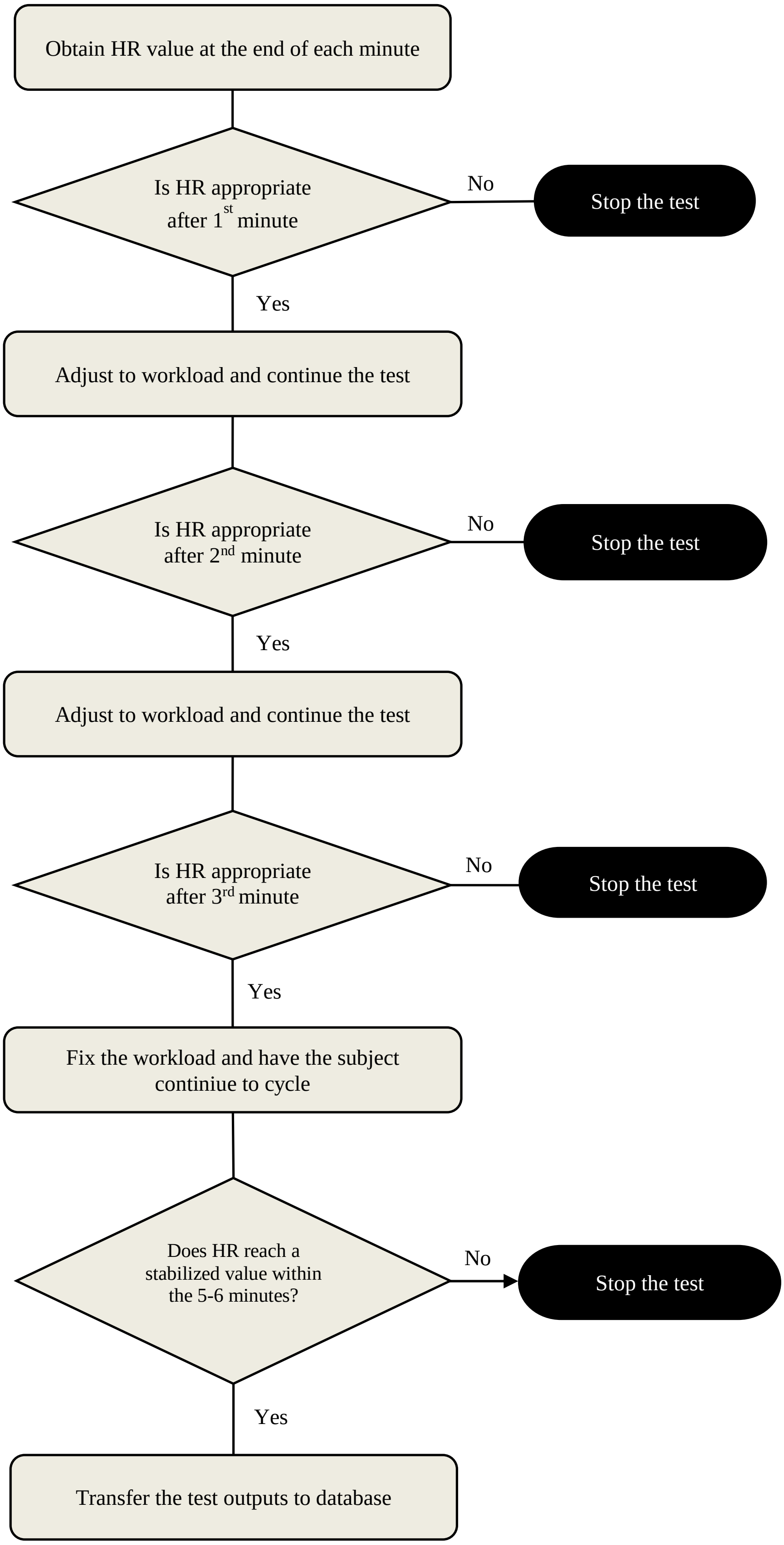


Figure 4.5. Flow chart of the experimental procedure (cont.).

4.5. Experimental Design and Statistical Analysis

4.5.1. Pilot Study

The main response of the the current study was aerobic capacity. In literature, AC is expressed in two forms: Absolute (l/min) and relative (ml/kg/min) forms. In the extent of the current study, both forms are calculated and evaluated. Before conducting the main experiments to predict AC, a pilot study was performed with randomly selected 56 female subjects (7 subjects from each age-occupation category). The pilot study was necessary to practice experimental methodology and get the main statistical parameters such as mean and standard deviation in order to calculate required sample size .Table 4.11 depicts the results of the pilot study:

Table 4.11. Sample Statistics

Responses	$\bar{x}$	SD	CV
VO_{2max} (l/min)	1.98	0.23	11.61
VO_{2max} (ml/kg/min)	31.91	6.92	21.6

4.5.2. Sample Size Determination

Sample size calculation is an important part of the experimental studies. It is known that the sample size must be adequate to ensure the reliability of the study. On the other hand, it must be small enough to finish experiments in a suitable time period.

Sample size was calculated according to the sample size calculation formula which is stated in the the ISO standards (ISO 15535:2006) for normative data studies in order to construct anthropometric databases. Equation 4.2 shows the sample size calculation formula of the current study:

$$N = \left(\frac{1.96 \times CV}{a}\right)^2 \times 1.534^2 \qquad (4.2)$$

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 desired percentage of relative accuracy (CI is to be no larger than ± some percentage of the mean).

The following formula depicts how CV is calculated:

$$CV = \frac{SD}{\bar{x}} \times 100 \tag{4.3}$$

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

As decribed above, the results of the pilot study were used in order to estimate required sample size of the study, since the true mean and standart deviation of the population are unknown prior to experiments. In addition to this, predetermined relative accuracy was at least 5%.

As a result, sample size calculation formula for the subjects is formed as in equation 4.4:

$$N = \left(\frac{1.96 \times CV}{5}\right)^2 \times 1.534^2 \tag{4.4}$$

The main response of the current study was aerobic capacity (VO_{2max}) and it was expressed in either as an absolute rate (in l/min) or as a relative rate (ml/kg/min) that is subject to body weight of the people. Minimum required sample sizes were calculated for the both forms and the largest of them were taken into consideration. Minimum required sample size was 51 for absolute and 171 for relative AC. Therefore, it was decided that at least 171 subjects were required for the experiments in order to ensure reliability of the study.

Table 4.12 shows the result of the sample size calculations for 95% confidence and 5% relative accuracy. It was obtanined that the desired levels of relative accurate and confidence can be achieved by conductiong the experiments with 171 female subjects. On the other hand, total 256 females were participated in the current study in order to improve the statistical power.

Table 4.12. Minimum required sample size calculations.

VO_{2max} (l/min)	$N = \left(\frac{1.96 \times 11.81}{5}\right)^2 \times 1.534^2 = 50.43 \approx 51$
VO_{2max} (ml/kg/min)	$N = \left(\frac{1.96 \times 21.69}{5}\right)^2 \times 1.534^2 = 170.11 \approx 171$

4.5.3. Repeatability Study

Prior to main experiments, 32 females from different age and job categories attended the repeatability study. In the extent of that study, each group performed their second tests at least a week later from their first trials. In that study, the mean values of the first and second trials were compared and checked if they were equal or not. Paired t test was used in order to make calculations. The results showed that there was no significant difference between the mean values of first and second trials since the p value was greater than 0.05.

Table 4.13. Result of paired t-test for repeatability study.

	N	Mean	St Dev.	SE Mean	T-value	P-value
1. Trails	32	1.99	0.20	0.14	-1.73	0.09
2. Trails	32	2.03	0.24	0.14		
Difference	32	-0.34	0.11	0.02		

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

4.5.4. ClassificationVariables

Absolute (l/min) and relative (ml/kg/min) aerobic capacity are the dependent variables of the current study. Moreover, age, BMI, occupation, exercise, smoking and alcohol drinking are classification factors. Table 4.14 depicts the levels of classification factors:

Table 4.14. Design factors and levels.

Design Factors	Type	Levels	Values
Age Factor	Fixed	4	18-24; 25-34; 35-44; 45-54
BMI Factor	Fixed	4	Normal-weight; Obese; Over-weight; Under-weight
Alcohol Drinking Factor	Fixed	2	Drinking; Non-drinking
Smoking Factor	Fixed	2	Non or ex smoker; Smoker
Exercise Factor	Fixed	2	Irregular or no; Regular
Occupation Factor	Fixed	2	Manual; Non-manual

4.5.5. Experimental Model

4.5.5.1. Completely randomized design. An ANOVA was constructed in order to obtain the effects of classification factors (age, job, BMI, smoking, exercise and occupation) on aerobic capacities both in absolute (l/min) and relative (ml/kg/min) forms. Minitab 17.0 was employed for calculations. In order to examine interaction effects, that were also included to the models. The p values of all interactions were greater than 0.05. However, the marginally significant interactions, BMI and exercise for AC (in l/min) and BMI and smoking for AC (in ml/kg/min), were included to the models with p values between 0.05 and 0.1 The results of ANOVA were depicted in part 5 of the current study. It is notable that, the interaction effects were neglected while constructing the regression models. The model for complete randomized design including the interactions can be seen in the following formula:

$$y_{ijklmn} = \mu + a_i + b_j + c_k + d_l + e_m + f_n + (ab)_{ij} + \cdots + (ef)_{mn} + \varepsilon_{ijklmn} \quad (4.5)$$

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 hypothesis of interest is:

$H_0 = \mu_1 = \mu_2 = ... = \mu_{256}$

H_1 = At least one μ_{ijklmn} is dif.

4.5.6. Statistical Analysis

Minitab 17.0 was employed in order to complete statistical analysis part of the current study. P-values that is less than or equal to 0.05 were accepted as significant in the study. On the other hand, p-values between 0.05 and 0.1 were also investigated and stated as marginal. The calculated descriptive statistics for aerobic capacity were mean, standard deviation, minimum and maximum, percentages and correlation coefficients. In order to examine the effects of age, job, BMI, smoking, exercise and alcohol consumption analysis of variance (ANOVA) model was used. In order to use ANOVA to examine factor effects on aerobic capacity, three main assumptions of ANOVA were also checked. In the following part, ANOVA assumptions are listed and described in detail:

4.5.6.1. ANOVA Assumptions. Three assumptions must be checked and validated.

(i) *Normality assumption:* In order to satisfy normality assumption of ANOVA, the residuals, in other words, the error terms of the model need to follow a normal distribution (ε ~ NID Normal $(0,\sigma^2)$). In order to check the distrubiton of the errors, a histogram of residuals must be plotted. The first evaluation about normalitu can be done by observing the shape of that plot. It looks like a normal distribution curve if the NID (0, σ^2) assumption on the residuals is satisfied. In order to be more confident about the normality and evaluate it quantatively, Anderson Darling test can be used. The hypotheses for the Anderson Darling test are depicted below. If the p-value for the Anderson Darling test is greater than the chosen significance level (0.05 for the current study), it is concluded that the data follow the normal distribution.

$$H_0 : \text{The data follow normal distribution}$$
$$H_1 : \text{The data do not follow normal distribution} \quad (4.6)$$

(ii) *Independence assumption:* According to the independence assumption of ANOVA, there must not be any correlation between the error terms and independent variables. In general, in order to examine the correlation between independent variables and errors the plot of residuals versus time is used. It provides insight to plot the residuals against the order in which the data was collected about the independency of observations. In general, if the plot shows no trend, the error terms are considered to be independent and the independence assumption of ANOVA is satisfied. If there is a visible trend in the plot, it can be concluded that the ANOVA assumption is likely violated. In plot, patterns in the points could indicate that there may be a correlation between the residuals that near each other and they are not independent. In ideal case, the residuals on the plot need to fall randomly around the center line. In the extent of the current study, the plot of residuals versus observation order and Pearson’s correlation coefficients between independent variables and residuals were calculated in order to ensure to satisfy independence assumption.

(iii) *Homogeneity of variance assumption:* The assumption of homogeneity of variance is basically controlled in order to examine if the variance within each of the populations is equal. According to homogeneity of variance assumption, the error variances of all data points of the dependent variable are equal or homogenous throughout the sample. In other words, the variability in the measurement error should be constant along the scale and not change with larger values. A common way to check this assumption is plotting the residuals versus the fitted values. This graph has the residuals on the y-axis and the fitted values on the x-axis and be used to ensure that the residuals are randomly distributes and the variance of them is constant. In ideal case, the points need to fall randomly on both sides of zero point and must not show any recognizable pattern. In the extent of the current study, the plot of residuals versus fitted values is investigated and it was observed that there is no indication about the violence of variance homogeneity assumption. After that Bartlett’s test was used to check that the sample variances in each treatment were not differ from each other statistically.

Three main assumptions of ANOVA were approximately satisfied in the current study. Detailed information about the calculations and related plots of residuals can be found in the Appendix D.

4.5.6.2. Multiple Comparisons. The Tukey Test can be described as is a post-hoc test based on the studentized range distribution. When ANOVA is constructed, it is possible to see if the results are significant overall. On the other hand, ANOVA do not show exactly what is the root cause of differences. After running ANOVA and discovering the significant results it is possible to run Tukey test to examine which specific groups's means are different. In Tukey test, all possible pairs of means are compared. Formula 4.7 shows the hypotheses of Tukey test (Montgomery, 2005):

$$H_0: \mu_i = \mu_j \qquad H_1: \mu_i \neq \mu_j \tag{4.7}$$

where i and j are treatment levels ($i \neq j$). The distribution of the studentized range statistic is used in Tukey test. In a sample, the difference between the minimum and maximum defines the studentized range (q) and it is measured in terms of sample standart deviation. The formula for calculating a q ratio for differences between means is:

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

where $\bar{y}_{max}$ and $\bar{y}_{min}$ are the maximum and the minimum means of the sample, MS_E is mean squares regarding error and n is the sample size. In addition to this, where the sample sizes are different from each other, T values of Tukey test can be found using the following formula (Montgomery, 2005):

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

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

In order to compare the results of the current study with another studies in literature, two sample t-test was used. Before running two sample t-tests the variances of compared populations are examined. It is known that two-sample t-test with a pooled variances is more powerful than the two-sample t-test with unequal variances. But use of that can result in serious errors in analysis if the variance of the samples is not equal. Therefore, the pooled variance was only used when a hypothesis test suggested that the variances of two samples were equal. The test for equal variances of Minitab 17.0 was used in order to check equal variance assumption.

4.5.6.3. Regression Analysis. In the extent of the current study, after running the ANOVA to check the significant effects of the factors and Tukey test for multiple comparisons, regression analysis was conducted in order to generate equations to predict aerobic capacity of female adults. As it mentioned in the previous part, some interactions were found to be marginally significant for absolute and relative VO_{2max} values. However, the contribution of those interactions to the models were quite low. Therefore, whiles constructing the regression models interaction effects were neglected and had not been included to the prediction models. On the other hand, quadratic terms are investigated in regression models. Regression models were developed using both stepwise and best subset approaches. In Stepwise approach, the least significant variable of the model is removed from the model while the most significant one is added in each step. The level of significance for regression models was 0.01 in this study. In addition to this, in order to see whole models and compare the prediction strength of them best subsets approach was used. In that method, alternative models with selected predictors are listed with their R^2, R^2_{adj} and Mallow C_P values. Mallows' Cp is used to compare the precision and bias of the models with the best subsets of selected predictors. It basically gives an information to select the best model with ideal number of predictors. When the number of predictors is high, the model can be relatively A model with too many predictors can be relatively inaccurate. On the other hand, when the number of predictors is too low model can be biased. In general, a Mallows' Cp is expected to be close to the number of predictors plus constant in accurate regression models. Both Mallows' Cp and R^2_{adj} values were taken into consideration when making the regression analysis of the current study. The following formula shows the general form of the multiple regression model (Montgomery, 2005):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_1 x_1 + \beta_m x_1^2 + \beta_n x_2^2 \ldots. + \beta_k x_k + \varepsilon \qquad (4.10)$$

where, y is the response (Aerobic capacity), β_0 is constant, β_1, β_2,…, are the regression coefficients for independent variables, x_1, x_2 are the regression variables and ε is the error term (normally and independently distributed, ≈NID $(0,\sigma^2)$).

In order to check the significance level of the selected regression model and regression coeefficients following hypothesis test was performed (Montgomery, 2005):

$$H_0: \beta_1 = \beta_2 = \cdots = \beta_n = 0$$
$$H_1: \beta_j \neq 0 \; for \; at \; least \; one \; j \; (j = 1, \ldots, n) \qquad (4.11)$$

According to this hypothesis p-values that are less than α significance level causes the rejection of the null hypothesis H_0, and thus, it is concluded that at least one of the regressor variables contributes significantly to the regression model (Montgomery, 2005).

Similar to ANOVA, the regression models have several assumptions that have to be checked and satisfied before concluding that the regarding regression model is reliable and gives accurate predictions. In the following part regression assumptions are listed (Montgomery, 2005):

(i) *Linearity asssumption:* First of all, in linear regression models needs the relationship between the independent and dependent variables have to be linear. The linearity assumption can be checked by using scatter plots.

(ii) *Normality assumption:* Secondly, in order to satisfy normality assumption of regression, the residuals, in other words, the error terms of the model need to follow a normal distribution (ε ~ NID Normal $(0,\sigma^2)$). In order to check the distrubiton of the errors, a histogram of residuals must be plotted.

(iii) *Multicollinearity assumption:* Thirdly, in regression models, there must be no multicollinearity in the data. In general, multicollinearity occurs when there is a high correlation between the independent variables. Multicollinearity can be checked by using the correlation matrix. In correlation analysis, correlation coefficients among all predictors need to be less than 1. Another way to check multicollinearity is controlling the variance inflation factor (VIF). VIF values must have to be smaller than 5 in order to satisfy multicollinearity assumption. If multicollinearity occurs in data, removing the terms that cause high VIF values will solve the problem.

(iv) *Autocorrelation assumption:* Fouthly, in linear regression models, there must be little or no autocorrelation in the data. In order to satisty autocorrelation assumption, residuals have to be independent from each other.

(v) *Homogeneity of variance assumption:* Last but not least, the assumption of homogeneity of variance asuumption of regression basically requires that the variance within each of the populations is equal. According to this assumption, the error variances of all data points of the dependent variable are equal or homogenous throughout the sample. The residuals versus the fitted plots, Bartlett or Levene tests are in use in order to check homogeneity of variance assumption.

5. RESULTS

5.1. Overview

In this section of the study, the collected data are analyzed and presented. Descriptive statistics of subjects, 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 are covered in detail.

5.2. Descriptive Statistics

5.2.1. Summary Statistics

In Table 5.1, the demographic profile and anthropometric characteristics of female subjects are summarized.

Table 5.2 depicts the descriptive statistics (mean, standard deviation (SD) and range (min - max) of Test Workload (in kpm/min), Accepted HR (in bpm) and $\%HR_{max}$ by age and BMI groups. Accepted HR is last steady state HR at the end of the test whereas $\%HR_{max}$ defines the ratio of accepted HR to age predicted maximum HR (220-age).

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

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

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

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

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

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

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

Table 5.10 and 5.11 show the descriptive statistics (mean, standard deviation (SD) and range (min - max) VO_{2max} results (in both l/min and ml/kg/min) by exercise, smoking and exercise factors.

The statistical inferences according to tables from Table 5.2 to Table 5.11 are summarized as below:

- The mean values of Test Workload (kpm/min) and Accepted HR (bpm) are decreasing from 18-24 years group to 45-54 years groups.
- The mean values of $\%HR_{max}$ are increasing from 18-24 years group to 45-54 years group and from under-weight group to obese group.
- There is only a slight difference between manual and non-manual groups due to mean values of Test Workload (kpm/min), Accepted HR (bpm) and VO_{2max} results (in l/min and in ml/kg/min).
- The mean values of $VO2_{max}$ 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 AC distributions (VO_{2max} in l/min and VO_{2max} in ml/kg/min). It is seen that both of them are fairly symmetrical.

Table 5.1. Anthropometric characteristics of female participants.

	N	Age (years)			Height (cm)			Weight (kg)			BMI (kg/m²)		
		Mean ± St.Dev	Min	Max	Mean ± St.Dev	Min	Max	Mean ± St.Dev	Min	Max	Mean ± St.Dev	Min	Max
All	**256**	**33.5 ± 10.6**	**18**	**54**	**160.9 ± 6.5**	**144**	**181**	**63.9 ± 10.5**	**42**	**91**	**24.7 ± 3.9**	**16.9**	**33.8**
18-24 yrs	71	**21.2 ± 1.2**	**18**	**24**	**161.4 ± 6.8**	**147**	**181**	**59.5 ± 9.3**	**43**	**85**	**22.8 ± 3.3**	**17.1**	**30.8**
Under-weight	7	21.3 ± 1	20	23	163.1 ± 7.3	154	176	48 ± 4.6	43	57	18 ± 0.5	17.1	18.4
Normal-weight	46	21.1 ± 1.3	18	24	161.1 ± 6.7	147	181	56.7 ± 5.8	44	73	21.9 ± 1.8	18.5	24.7
Over-weight	14	21.1 ± 0.9	20	23	162.1 ± 6.8	149	172	69.4 ± 5.1	59	77	26.4 ± 1	25.1	28.2
Obese	4	21.8 ± 1	21	23	158.8 ± 8.3	148	168	76.5 ± 7.9	66	85	30.3 ± 0.4	30.1	30.8
25-34 yrs	**72**	**29.4 ± 2.3**	**25**	**33**	**162.1 ± 7**	**144**	**179**	**63.7 ± 10.3**	**45**	**91**	**24.2 ± 3.6**	**17.6**	**30.5**
Under-weight	5	27 ± 1	26	28	167 ± 6.8	160	174	50.8 ± 4.6	45	55	18.2 ± 0.4	17.6	18.4
Normal-weight	32	28.5 ± 2.4	25	33	160.8 ± 7.2	144	179	56.7 ± 6.4	46	77	21.9 ± 2	18.8	24.6
Over-weight	28	31 ± 0.9	30	33	162.9 ± 6.6	151	177	70.3 ± 5.7	61	82	26.5 ± 1	25.1	28.2
Obese	7	28.4 ± 2.4	25	31	160.9 ± 6.3	155	174	78.3 ± 6.1	73	91	30.2 ± 0.2	30.0	30.5
35-44 yrs	**62**	**39.3 ± 3.1**	**35**	**44**	**159.8 ± 6.7**	**145**	**177**	**65 ± 9.8**	**47**	**86**	**25.4 ± 3.4**	**17.5**	**31.3**
Under-weight	4	37.3 ± 1.9	36	40	167.3 ± 3	164	171	50.8 ± 3	47	54	18.1 ± 0.5	17.5	18.5
Normal-weight	24	36.2 ± 0.8	35	38	158 ± 6	145	170	58 ± 5.6	47	71	23.2 ± 1.2	20.7	24.7
Over-weight	23	41.5 ± 2	37	44	161 ± 7.5	146	177	68.9 ± 6.5	57	79	26.5 ± 1.2	25.2	29.0
Obese	11	42.3 ± 1.3	40	44	158.8 ± 5.7	148	169	77.3 ± 5.2	67	86	30.6 ± 0.5	30.0	31.3
45-54 yrs	**51**	**49.6 ± 2.7**	**45**	**54**	**159.7 ± 4.9**	**147**	**169**	**69.2 ± 10.8**	**42**	**87**	**27.1 ± 4.1**	**16.9**	**33.8**
Under-weight	3	48.7 ± 2.9	47	52	160 ± 8.2	151	167	45 ± 2.6	42	47	17.6 ± 0.8	16.9	18.4
Normal-weight	11	48 ± 2.1	46	53	160 ± 4.2	154	167	58.8 ± 3.8	54	65	23 ± 1.2	21.2	24.9
Over-weight	22	49.6 ± 2.6	46	54	160 ± 3.8	151	164	70.6 ± 5.2	62	79	27.6 ± 1.4	25.1	29.7
Obese	15	50.8 ± 2.7	45	54	158.9 ± 6.5	147	169	79.6 ± 5.7	70	87	31.5 ± 1.4	30.1	33.8

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

		Test Workload (kpm/min)			Accepted HR (bpm)			% HR_{max}		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**256**	**405.8 ± 95.1**	**300**	**600**	**141.6 ± 11.4**	**120**	**168**	**76% ± 7%**	**61%**	**93%**
18-24 yrs	**71**	**422.5 ± 91.6**	**300**	**600**	**143.2 ± 11**	**122**	**167**	**72% ± 6%**	**61%**	**83%**
Under-weight	7	342.9 ± 73.2	300	450	133.4 ± 5.3	124	140	67% ± 3%	62%	71%
Normal-weight	46	420.7 ± 95.5	300	600	142.3 ± 11.5	122	167	75% ± 4%	71%	82%
Over-weight	14	466.1 ± 60.1	375	600	149.1 ± 7.7	141	163	75% ± 4%	72%	81%
Obese	4	431.3 ± 94.4	300	525	149.5 ± 7.8	144	161	72% ± 6%	61%	83%
25-34 yrs	**72**	**407.3 ± 99.8**	**300**	**600**	**142.7 ± 13.4**	**120**	**168**	**75% ± 7%**	**63%**	**89%**
Under-weight	5	345 ± 67.1	300	450	132.4 ± 6.1	126	141	69% ± 3%	65%	73%
Normal-weight	32	382 ± 99.6	300	600	140.8 ± 14	122	168	76% ± 7%	64%	89%
Over-weight	28	439.3 ± 101.5	300	600	144.3 ± 12.3	120	167	80% ± 6%	70%	87%
Obese	7	439.3 ± 67.5	300	525	153.1 ± 12.1	132	167	73% ± 7%	63%	87%
35-44 yrs	**62**	**404 ± 93.5**	**300**	**600**	**141.1 ± 10.5**	**122**	**168**	**78% ± 6%**	**68%**	**91%**
Under-weight	4	337.5 ± 75	300	450	131 ± 7.4	122	140	72% ± 4%	68%	77%
Normal-weight	24	418.8 ± 108.2	300	600	142.6 ± 11.4	128	168	79% ± 6%	69%	91%
Over-weight	23	420.7 ± 74.1	300	600	141.5 ± 10.3	124	161	79% ± 5%	72%	89%
Obese	11	361.4 ± 87.6	300	525	140.5 ± 8.7	128	159	78% ± 6%	70%	91%
45-54 yrs	**51**	**382.4 ± 92.8**	**300**	**600**	**138.2 ± 9.6**	**122**	**160**	**81% ± 6%**	**72%**	**93%**
Under-weight	3	450 ± 0	450	450	140.7 ± 5.1	135	145	82% ± 2%	80%	84%
Normal-weight	11	388.6 ± 87.6	300	525	137.1 ± 9.9	126	156	82% ± 6%	72%	93%
Over-weight	22	392 ± 98	300	600	139.7 ± 10.7	122	160	80% ± 6%	74%	91%
Obese	15	350 ± 92.6	300	600	136.3 ± 8.6	126	152	80% ± 6%	72%	91%

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

	N	VO_2max (l/min) Mean ± St.Dev	Min	Max	VO_2max (ml/kg/min) Mean ± St.Dev	Min	Max
All	**256**	**2 ± 0.2**	**1.3**	**2.6**	**32.3 ± 7.8**	**16.0**	**53.3**
18-24 yrs	**71**	**2.2 ± 0.2**	**1.7**	**2.6**	**37.7 ± 6.8**	**25.6**	**53.3**
Under-weight	7	2.2 ± 0.2	1.9	2.5	46.1 ± 5.9	34.7	53.3
Normal-weight	46	2.2 ± 0.1	1.8	2.6	39.5 ± 4.9	28.3	50.6
Over-weight	14	2.1 ± 0.2	1.7	2.4	30.8 ± 2.5	26.9	34.7
Obese	4	2 ± 0.2	1.7	2.2	26.1 ± 0.9	25.6	27.5
25-34 yrs	**72**	**2 ± 0.2**	**1.6**	**2.5**	**33.2 ± 6.8**	**21.4**	**49.7**
Under-weight	5	2.2 ± 0.1	2.0	2.3	44.2 ± 4.4	39.4	49.7
Normal-weight	32	2.1 ± 0.2	1.6	2.5	36.9 ± 5.1	28.2	46.7
Over-weight	28	2 ± 0.2	1.7	2.4	29.3 ± 3.6	21.4	36.6
Obese	7	1.9 ± 0.2	1.7	2.2	24.2 ± 2.1	21.4	26.9
35-44 yrs	**62**	**1.9 ± 0.2**	**1.5**	**2.4**	**30.2 ± 6.6**	**19.3**	**45.2**
Under-weight	4	2 ± 0.1	1.9	2.2	40.4 ± 2.8	36.2	42.4
Normal-weight	24	2 ± 0.2	1.7	2.4	35.1 ± 4.4	27.3	45.2
Over-weight	23	1.9 ± 0.1	1.7	2.1	27.4 ± 3.4	21.7	34.2
Obese	11	1.7 ± 0.2	1.5	2.0	21.8 ± 1.4	19.3	23.5
45-54 yrs	**51**	**1.7 ± 0.2**	**1.3**	**2.0**	**25.9 ± 6.2**	**16.0**	**46.3**
Under-weight	3	1.9 ± 0.1	1.8	1.9	42.2 ± 3.8	38.6	46.3
Normal-weight	11	1.8 ± 0.1	1.6	2.0	31.3 ± 2.7	26.3	35.4
Over-weight	22	1.7 ± 0.1	1.3	1.9	24.4 ± 2.5	19.6	29.6
Obese	15	1.7 ± 0.2	1.3	2.0	20.9 ± 2.9	16.0	25.9

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

	N	Test Workload (kpm)			Accepted HR (bpm)			% HR_{max}		
		Mean ± St.Dev	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**256**	**405.8 ± 95.1**	**300**	**600**	**141.5 ± 11.4**	**120**	**168**	**76% ± 7%**	**61%**	**93%**
Manual	**99**	**406.1 ± 97**	**300**	**600**	**142.6 ± 12.1**	**122**	**168**	**77% ± 7%**	**63%**	**93%**
18-24 yrs	17	436.8 ± 88.9	300	525	146.4 ± 11.9	126	164	74% ± 6%	63%	83%
25-34 yrs	32	389.1 ± 98	300	600	142.8 ± 14	124	168	75% ± 7%	65%	87%
35-44 yrs	31	411.3 ± 102.2	300	600	142.1 ± 11.3	122	168	78% ± 7%	68%	91%
45-54 yrs	19	398.7 ± 93.7	300	600	139.8 ± 10.1	126	160	81% ± 6%	72%	93%
Non-manual	**157**	**405.6 ± 94.2**	**300**	**600**	**140.8 ± 11**	**120**	**167**	**76% ± 7%**	**61%**	**91%**
18-24 yrs	54	418.1 ± 92.8	300	600	142.2 ± 10.6	122	167	71% ± 5%	61%	83%
25-34 yrs	40	421.9 ± 100	300	600	142.7 ± 13	120	167	75% ± 7%	63%	89%
35-44 yrs	31	396.8 ± 84.8	300	600	140.1 ± 9.6	124	161	78% ± 5%	69%	89%
45-54 yrs	32	372.7 ± 92.3	300	600	136.8 ± 9.4	122	152	81% ± 6%	72%	91%

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

	N	Test Workload (kpm)			Accepted HR (bpm)			$\%HR_{max}$		
		Mean ± St.Dev	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**256**	**405.8 ± 95.1**	**300**	**600**	**141.5 ± 11.4**	**120**	**168**	**76% ± 7%**	**61%**	**93%**
Manual	**99**	**406.1 ± 97**	**300**	**600**	**142.6 ± 12.1**	**122**	**168**	**77% ± 7%**	**63%**	**93%**
Under-weight	4	356.3 ± 71.8	300	450	133 ± 9.6	122	145	72% ± 8%	65%	84%
Normal-weight	56	397.8 ± 99	300	600	141.4 ± 12.1	124	168	75% ± 6%	63%	91%
Over-weight	30	435 ± 91.1	300	600	144.9 ± 10.5	124	163	80% ± 7%	66%	93%
Obese	9	383.3 ± 102.3	300	525	147 ± 16.4	126	167	79% ± 5%	72%	87%
Non-manual	**157**	**405.6 ± 94.2**	**300**	**600**	**140.8 ± 11**	**120**	**167**	**76% ± 7%**	**61%**	**91%**
Under-weight	15	360 ± 76.1	300	450	134 ± 5.6	124	142	71% ± 6%	62%	82%
Normal-weight	57	414.5 ± 99.3	300	600	141.5 ± 12.1	122	167	73% ± 7%	61%	87%
Over-weight	57	422.4 ± 90.3	300	600	142.2 ± 11.2	120	167	78% ± 6%	64%	89%
Obese	28	377.7 ± 90.1	300	600	140.2 ± 9	124	159	79% ± 5%	70%	91%

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

	N	VO_2max (l/min) Mean ± St.Dev	Min	Max	VO_2max (ml/kg/min) Mean ± St.Dev	Min	Max
All	**256**	**2 ± 0.2**	**1.3**	**2.6**	**32.3 ± 7.8**	**16.0**	**53.3**
Manual	**99**	**2 ± 0.2**	**1.5**	**2.4**	**32.2 ± 6.7**	**18.1**	**49.7**
18-24 yrs	17	2.1 ± 0.2	1.7	2.4	36.1 ± 6.5	25.7	45.9
25-34 yrs	32	2 ± 0.2	1.6	2.3	34.1 ± 6.8	21.4	49.7
35-44 yrs	31	1.9 ± 0.2	1.6	2.4	30.4 ± 5.4	21.3	42.0
45-54 yrs	19	1.8 ± 0.1	1.5	2.0	28.2 ± 5.7	18.1	38.6
Non-manual	**157**	**2 ± 0.3**	**1.3**	**2.6**	**32.3 ± 8.5**	**16.0**	**53.3**
18-24 yrs	54	2.2 ± 0.2	1.8	2.6	38.2 ± 6.8	25.6	53.3
25-34 yrs	40	2.1 ± 0.2	1.7	2.5	32.5 ± 6.8	23.7	47.9
35-44 yrs	31	1.9 ± 0.2	1.5	2.3	29.9 ± 7.8	19.3	45.2
45-54 yrs	32	1.7 ± 0.2	1.3	2.0	24.6 ± 6.1	16.0	46.3

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

	N	VO_2max (l/min) Mean ± St.Dev	Min	Max	VO_2max (ml/kg/min) Mean ± St.Dev	Min	Max
All	**256**	**2 ± 0.2**	**1.3**	**2.6**	**32.3 ± 7.8**	**16.0**	**53.3**
Manual	**99**	**2 ± 0.2**	**1.5**	**2.4**	**32.2 ± 6.7**	**18.1**	**49.7**
Under-weight	4	2.1 ± 0.2	1.8	2.2	44.1 ± 4.8	38.6	49.7
Normal-weight	56	2 ± 0.2	1.6	2.4	35.3 ± 4.7	26.3	45.6
Over-weight	30	1.9 ± 0.2	1.5	2.3	27.3 ± 3.9	19.6	35.3
Obese	9	1.8 ± 0.2	1.6	2.0	23.2 ± 2.9	18.1	26.9
Non-manual	**157**	**2 ± 0.3**	**1.3**	**2.6**	**32.3 ± 8.5**	**16.0**	**53.3**
Under-weight	15	2.1 ± 0.2	1.9	2.5	43.7 ± 5.1	34.7	53.3
Normal-weight	57	2.2 ± 0.2	1.7	2.6	38.7 ± 5.3	27.9	50.6
Over-weight	57	1.9 ± 0.2	1.3	2.4	28 ± 3.8	19.9	36.6
Obese	28	1.7 ± 0.2	1.3	2.2	22.1 ± 2.7	16.0	27.5

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

		Test Workload (kpm)			Accepted HR (bpm)			$\%HR_{max}$		
	N	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**256**	**405.8 ± 95.1**	**300**	**600**	**141.5 ± 11.4**	**120**	**168**	**76% ± 7%**	**61%**	**93%**
Under-weight	**19**	**359.2 ± 73.2**	**300**	**450**	**133.8 ± 6.3**	**122**	**145**	**71% ± 6%**	**62%**	**84%**
18-24 yrs	7	342.9 ± 73.2	300	450	133.4 ± 5.3	124	140	67% ± 3%	62%	71%
25-34 yrs	5	345 ± 67.1	300	450	132.4 ± 6.1	126	141	69% ± 3%	65%	73%
35-44 yrs	4	337.5 ± 75	300	450	131 ± 7.4	122	140	72% ± 4%	68%	77%
45-54 yrs	3	450 ± 0	450	450	140.7 ± 5.1	135	145	82% ± 2%	80%	84%
Normal-weight	**113**	**406.2 ± 99.1**	**300**	**600**	**141.4 ± 12**	**122**	**168**	**74% ± 7%**	**61%**	**91%**
18-24 yrs	46	420.7 ± 95.5	300	600	142.3 ± 11.5	122	167	72% ± 6%	61%	83%
25-34 yrs	32	382 ± 99.6	300	600	140.8 ± 14	122	168	73% ± 7%	63%	87%
35-44 yrs	24	418.8 ± 108.2	300	600	142.6 ± 11.4	128	168	78% ± 6%	70%	91%
45-54 yrs	11	388.6 ± 87.6	300	525	137.1 ± 9.9	126	156	80% ± 6%	72%	91%
Over-weight	**87**	**426.7 ± 90.3**	**300**	**600**	**143.1 ± 11**	**120**	**167**	**78% ± 6%**	**64%**	**93%**
18-24 yrs	14	466.1 ± 60.1	375	600	149.1 ± 7.7	141	163	75% ± 4%	71%	82%
25-34 yrs	28	439.3 ± 101.5	300	600	144.3 ± 12.3	120	167	76% ± 7%	64%	89%
35-44 yrs	23	420.7 ± 74.1	300	600	141.5 ± 10.3	124	161	79% ± 6%	69%	91%
45-54 yrs	22	392 ± 98	300	600	139.7 ± 10.7	122	160	82% ± 6%	72%	93%
Obese	**37**	**379.1 ± 91.8**	**300**	**600**	**141.8 ± 11.4**	**124**	**167**	**79% ± 5%**	**70%**	**91%**
18-24 yrs	4	431.3 ± 94.4	300	525	149.5 ± 7.8	144	161	75% ± 4%	72%	81%
25-34 yrs	7	439.3 ± 67.5	300	525	153.1 ± 12.1	132	167	80% ± 6%	70%	87%
35-44 yrs	11	361.4 ± 87.6	300	525	140.5 ± 8.7	128	159	79% ± 5%	72%	89%
45-54 yrs	15	350 ± 92.6	300	600	135.5 ± 8.8	124	152	80% ± 6%	74%	91%

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

		VO_2max (l/min)			VO_2max (ml/kg/min)		
	256	**Mean ± St.Dev**	**Min**	**Max**	**Mean ± St.Dev**	**Min**	**Max**
All	**19**	**2 ± 0.2**	**1.3**	**2.6**	**32.3 ± 7.8**	**16.0**	**53.3**
Under-weight	7	**2.1 ± 0.2**	**1.8**	**2.5**	**43.8 ± 4.9**	**34.7**	**53.3**
18-24 yrs	5	2.2 ± 0.2	1.9	2.5	46.1 ± 5.9	34.7	53.3
25-34 yrs	4	2.2 ± 0.1	2.0	2.3	44.2 ± 4.4	39.4	49.7
35-44 yrs	3	2 ± 0.1	1.9	2.2	40.4 ± 2.8	36.2	42.4
45-54 yrs	**113**	1.9 ± 0.1	1.8	1.9	42.2 ± 3.8	38.6	46.3
Normal-weight	46	**2.1 ± 0.2**	**1.6**	**2.6**	**37 ± 5.3**	**26.3**	**50.6**
18-24 yrs	32	2.2 ± 0.1	1.8	2.6	39.5 ± 4.9	28.3	50.6
25-34 yrs	24	2.1 ± 0.2	1.6	2.5	36.9 ± 5.1	28.2	46.7
35-44 yrs	11	2 ± 0.2	1.7	2.4	35.1 ± 4.4	27.3	45.2
45-54 yrs	**87**	1.8 ± 0.1	1.6	2.0	31.3 ± 2.7	26.3	35.4
Over-weight	**14**	**1.9 ± 0.2**	**1.3**	**2.4**	**27.8 ± 3.8**	**19.6**	**36.6**
18-24 yrs	28	2.1 ± 0.2	1.7	2.4	30.8 ± 2.5	26.9	34.7
25-34 yrs	23	2 ± 0.2	1.7	2.4	29.3 ± 3.6	21.4	36.6
35-44 yrs	22	1.9 ± 0.1	1.7	2.1	27.4 ± 3.4	21.7	34.2
45-54 yrs	**37**	1.7 ± 0.1	1.3	1.9	24.4 ± 2.5	19.6	29.6
Obese	**4**	**1.7 ± 0.2**	**1.3**	**2.2**	**22.3 ± 2.8**	**16.0**	**27.5**
18-24 yrs	7	2 ± 0.2	1.7	2.2	26.1 ± 0.9	25.6	27.5
25-34 yrs	11	1.9 ± 0.2	1.7	2.2	24.2 ± 2.1	21.4	26.9
35-44 yrs	15	1.7 ± 0.2	1.5	2.0	21.8 ± 1.4	19.3	23.5
45-54 yrs	**256**	1.7 ± 0.2	1.3	2.0	20.9 ± 2.9	16.0	25.9

Table 5.10. Descriptive statistics of VO_{2max} (l/min) results by smoking, alcohol drinking and exercise level.

		VO2max (l/min)					
		Regular			Irregular or No		
	256	Mean ± St.Dev	Min	Max	Mean ± St.Dev	Min	Max
All	**256**	**2.1 ± 0.2**	**1.4**	**2.6**	**2.0 ± 0.2**	**1.3**	**2.5**
Non or ex smoker	**152**	**2.1 ± 0.3**	**1.4**	**2.6**	**2.0 ± 0.2**	**1.3**	**2.5**
Drinking	18	2.2 ± 0.4	1.9	2.5	1.9 ± 0.2	1.6	2.3
Non drinking	134	2.1 ± 0.3	1.4	2.6	2.0 ± 0.2	1.3	2.5
Smoker	**57**	**2.2 ± 0.2**	**1.9**	**2.5**	**1.9 ± 0.2**	**1.5**	**2.4**
Drinking	6	2.1 ± 0.3	1.9	2.4	1.9 ± 0.3	1.5	2.2
Non drinking	51	2.2 ± 0.1	2.0	2.5	1.9 ± 0.2	1.5	2.4

Table 5.11. Descriptive statistics of VO_{2max} (ml/kg/min) results by smoking, alcohol drinking and exercise level.

		VO2max (ml/kg/min)					
		Regular			Irregular or No		
	256	Mean ± St.Dev	Min	Max	Mean ± St.Dev	Min	Max
All	**256**	**34.7 ± 8.2**	**16.0**	**50.6**	**31.7 ± 7.6**	**16.2**	**53.3**
Non or ex smoker	**152**	**34.8 ± 9.0**	**16.0**	**50.6**	**31.3 ± 7.5**	**16.2**	**50.6**
Drinking	18	46.1 ± 6.3	41.7	50.6	31.1 ± 7.0	18.1	49.7
Non drinking	134	34.0 ± 8.7	16.0	48.9	31.3 ± 7.6	16.2	50.6
Smoker	**57**	**34.6 ± 6.8**	**26.8**	**48.6**	**32.8 ± 7.8**	**19.6**	**53.3**
Drinking	6	38.9 ± 8.3	33.0	44.8	34.0 ± 11.1	19.9	45.9
Non drinking	51	34.0 ± 6.7	26.8	48.6	32.7 ± 7.5	19.6	53.3

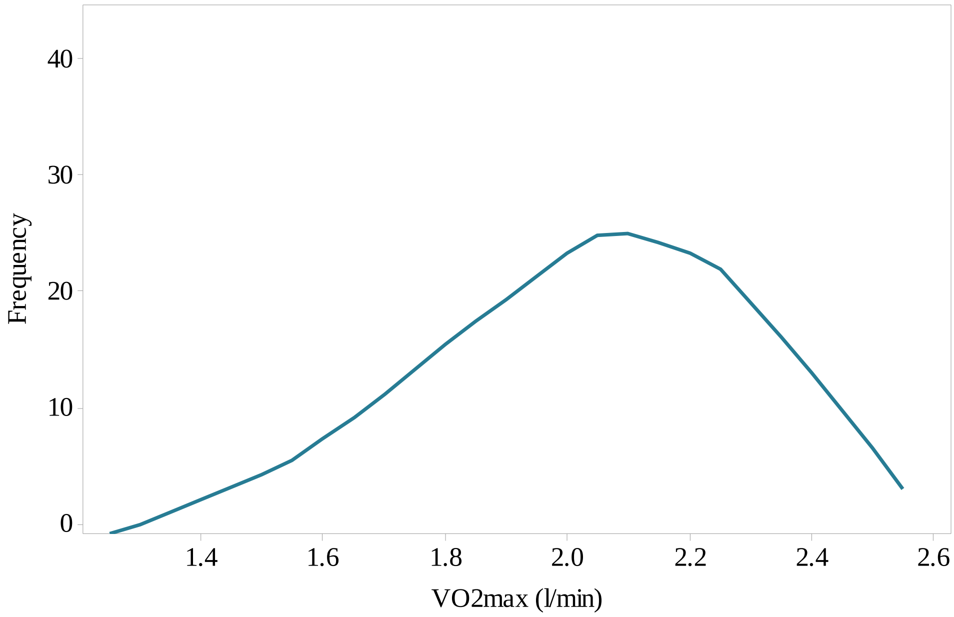


Figure 5.1. Distribution of Aerobic Capacity (VO_{2max} in l/min).

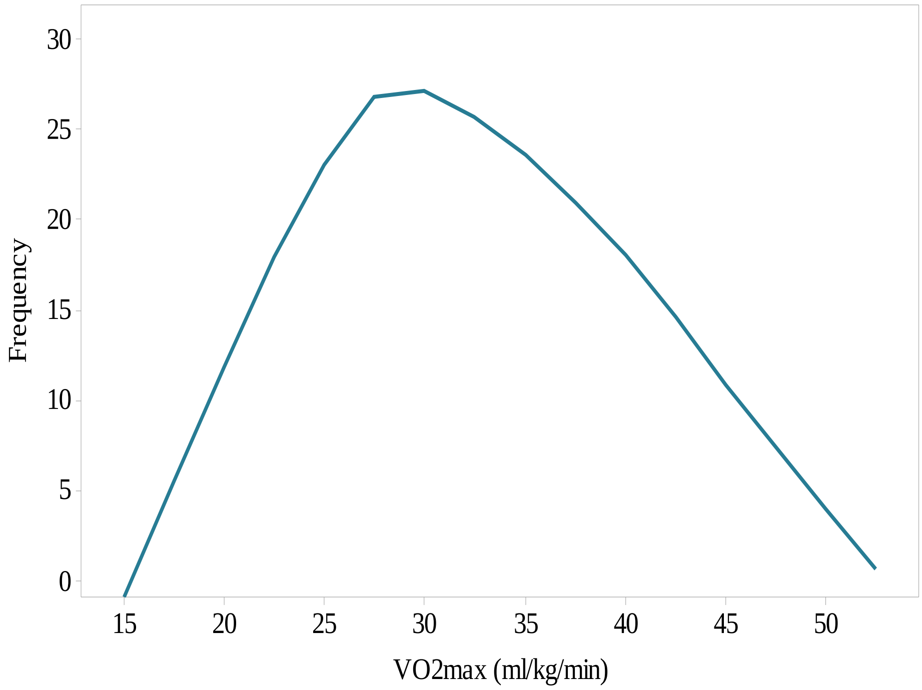


Figure 5.2. Distribution of Aerobic Capacity (VO_{2max} in ml/kg/min).

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

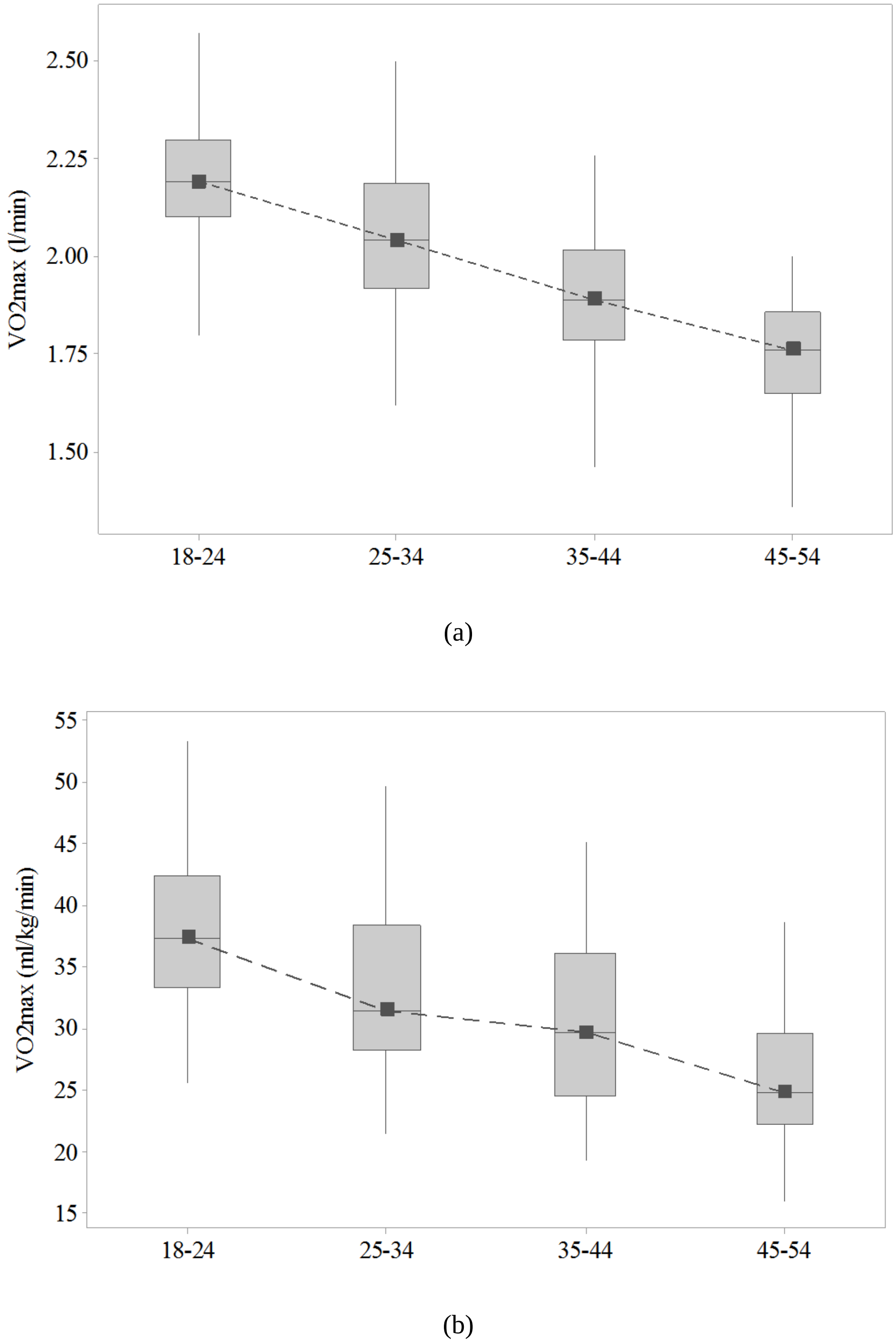
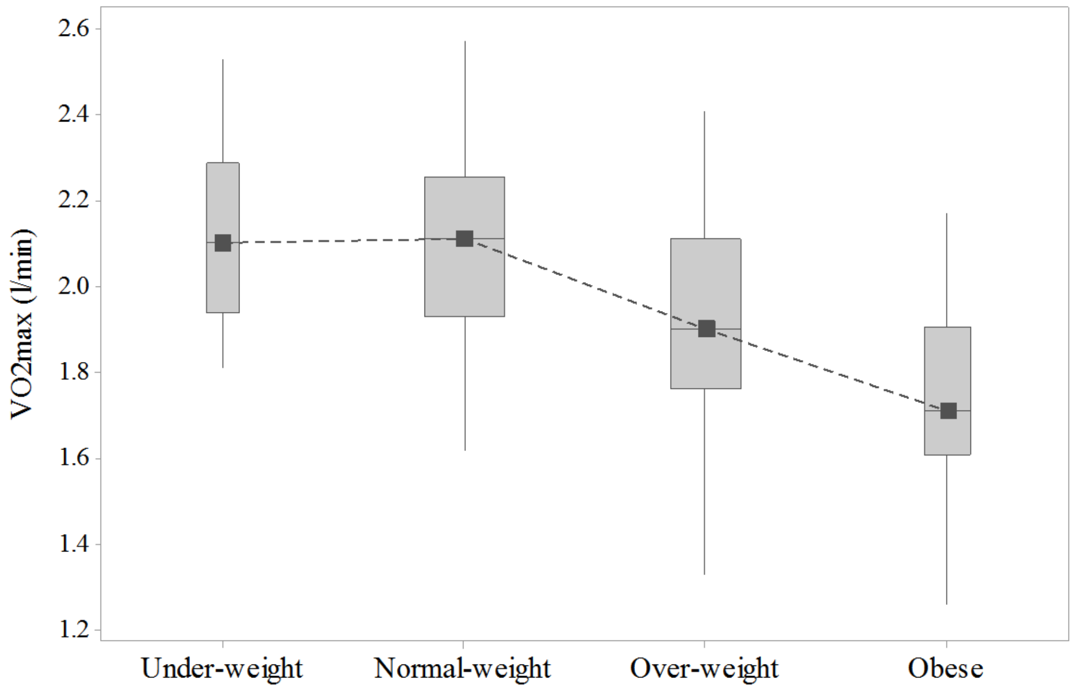
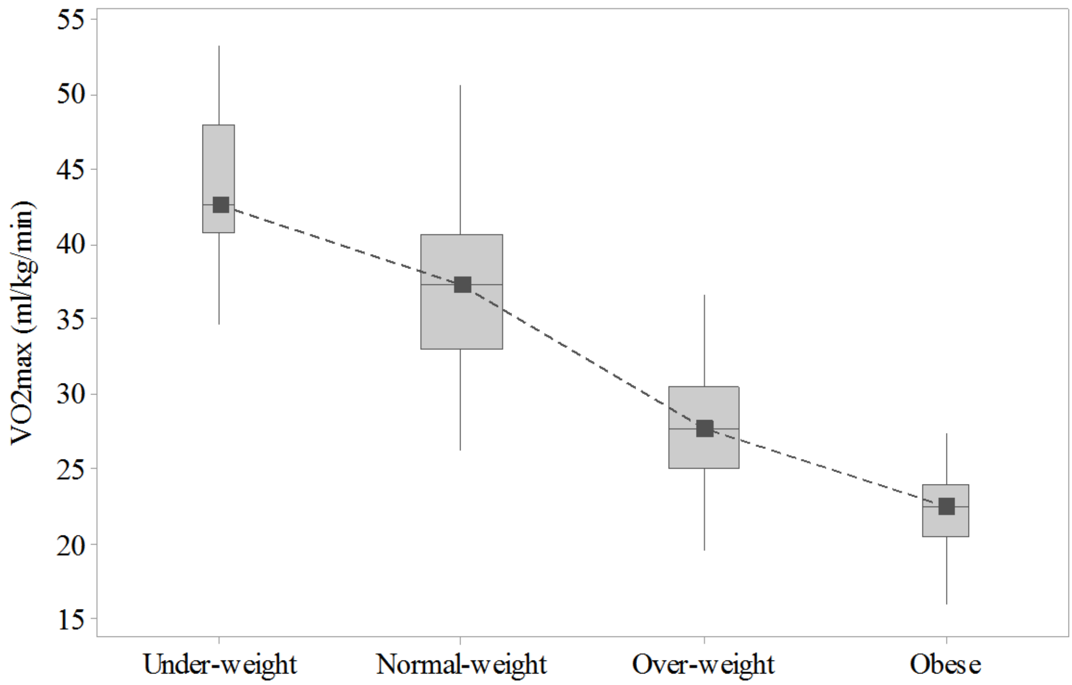


Figure 5.3. Box plot of aerobic capacity for different age groups.

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



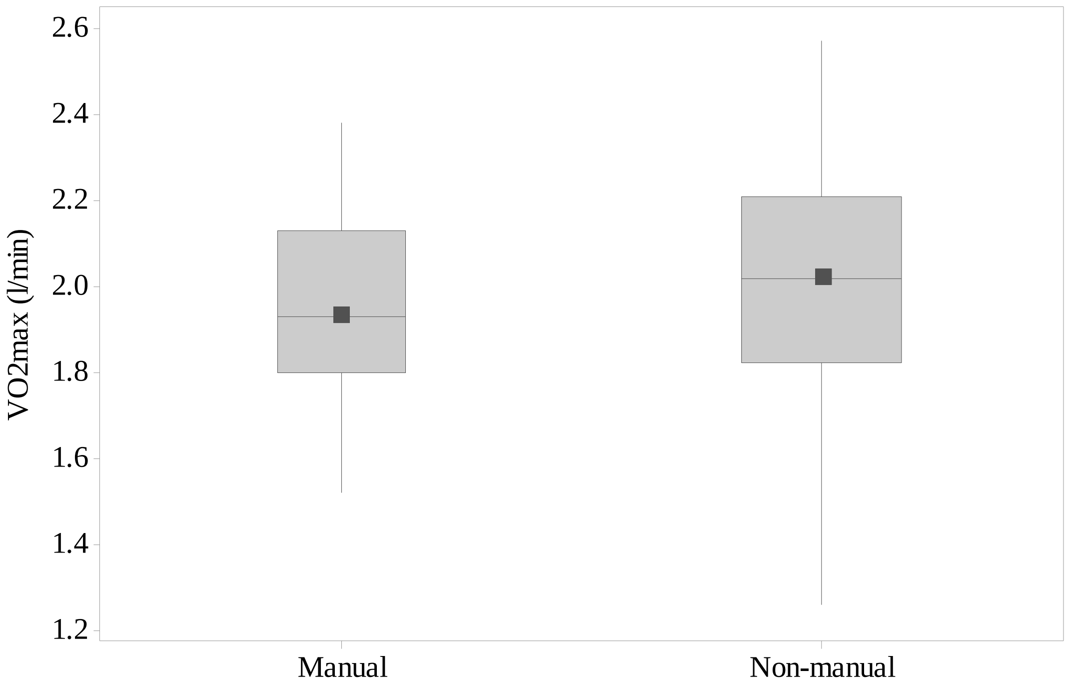
(a)



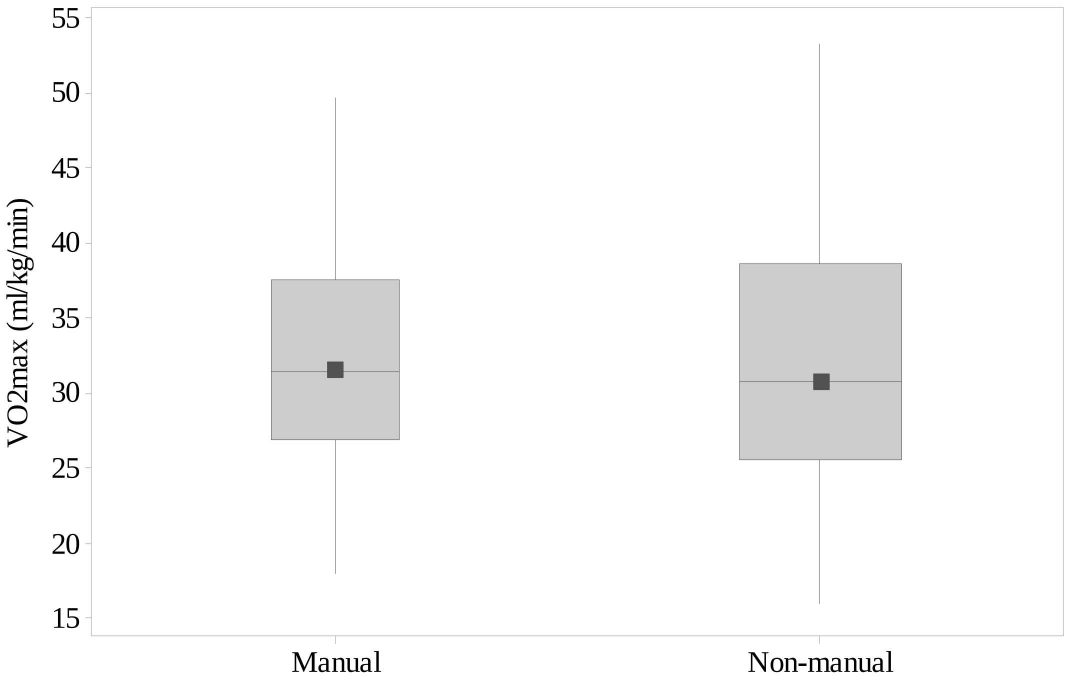
(b)

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



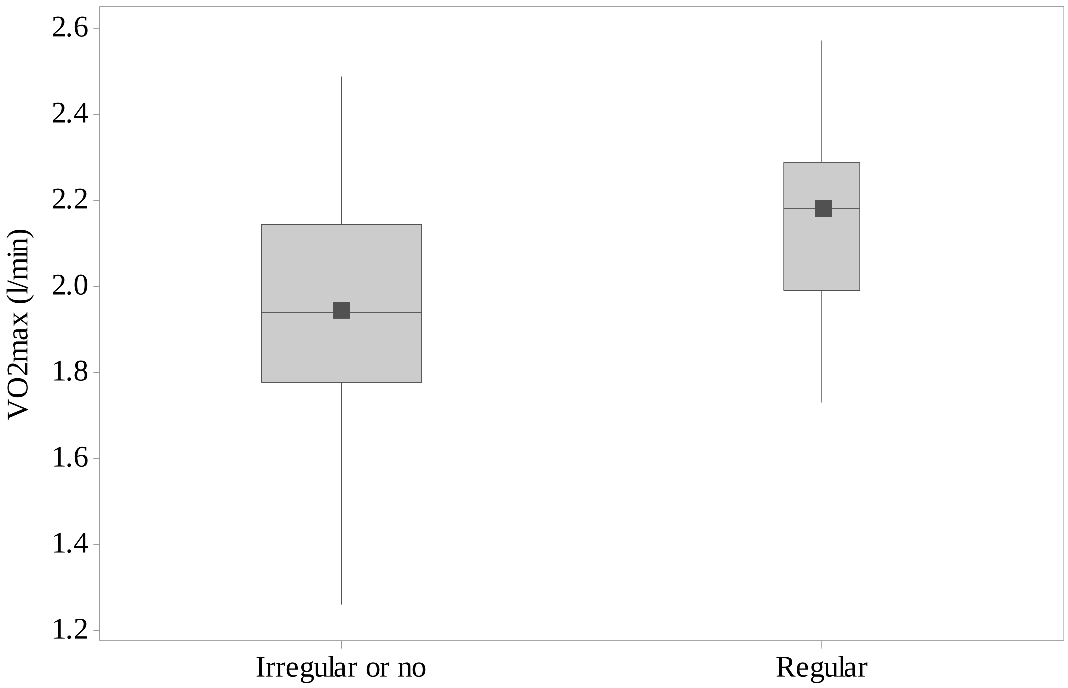
(a)



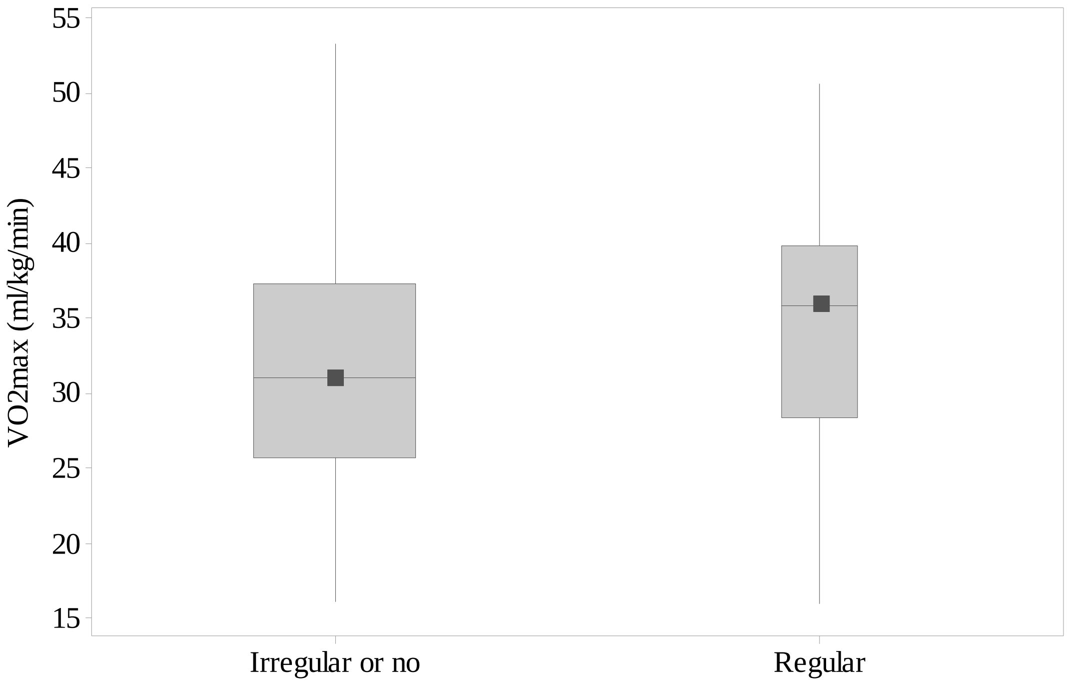
(b)

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



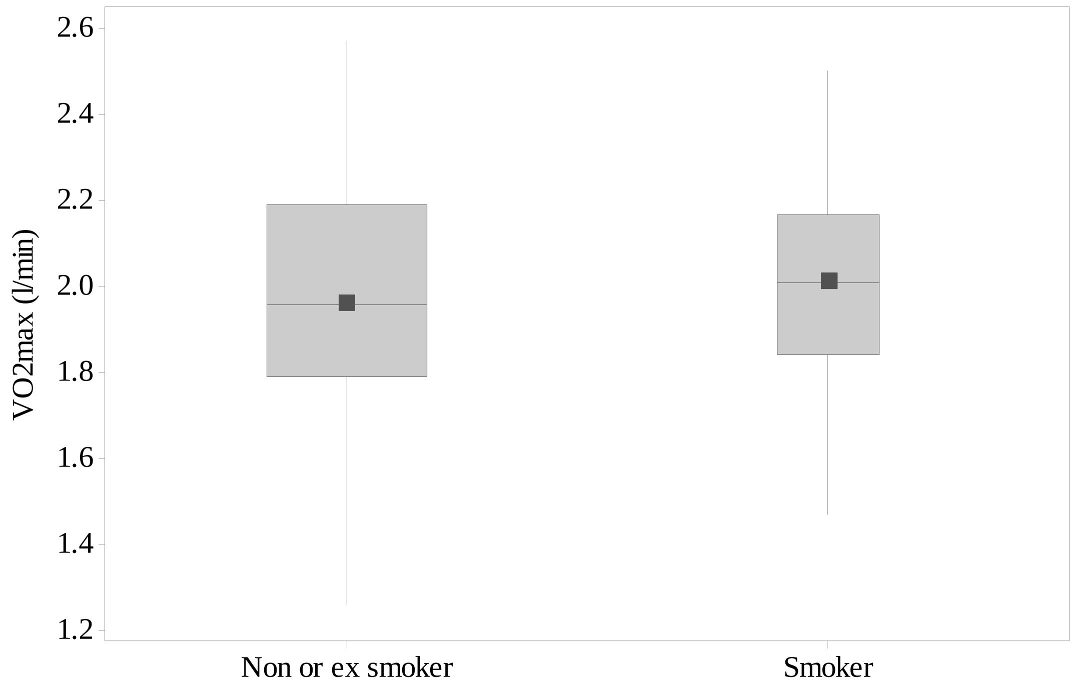
(a)



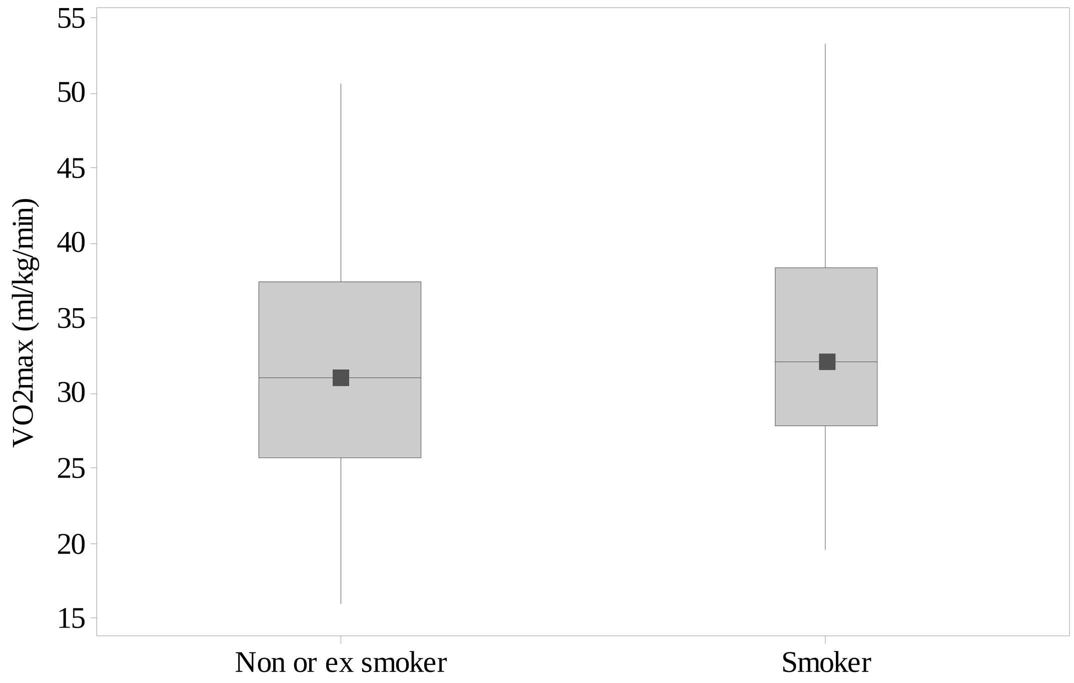
(b)

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



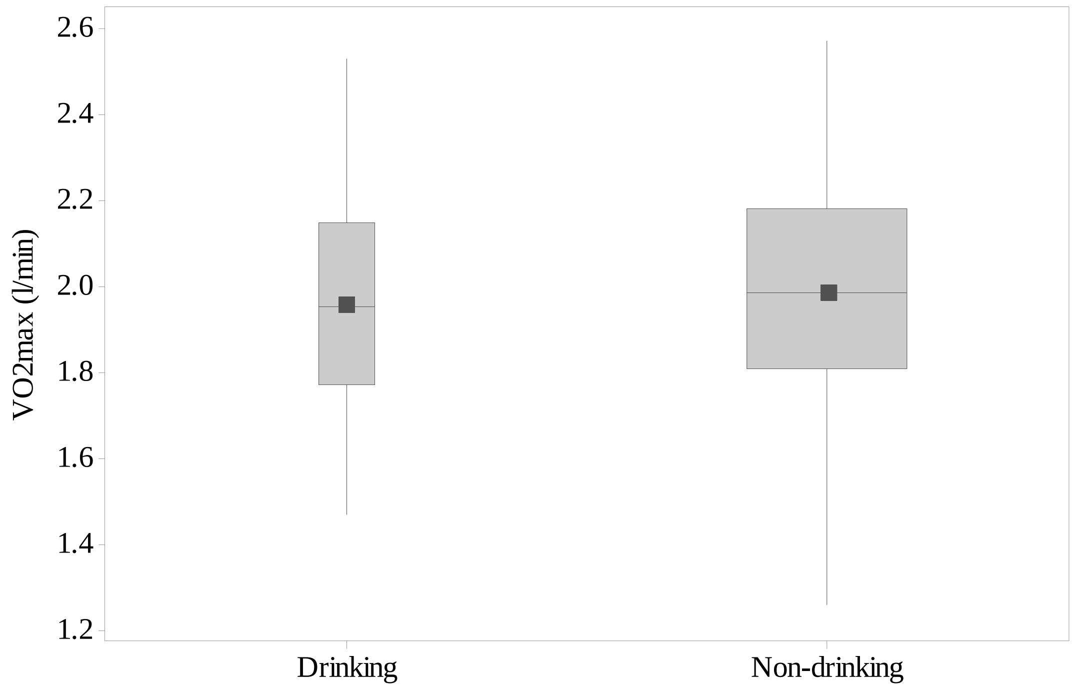
(a)



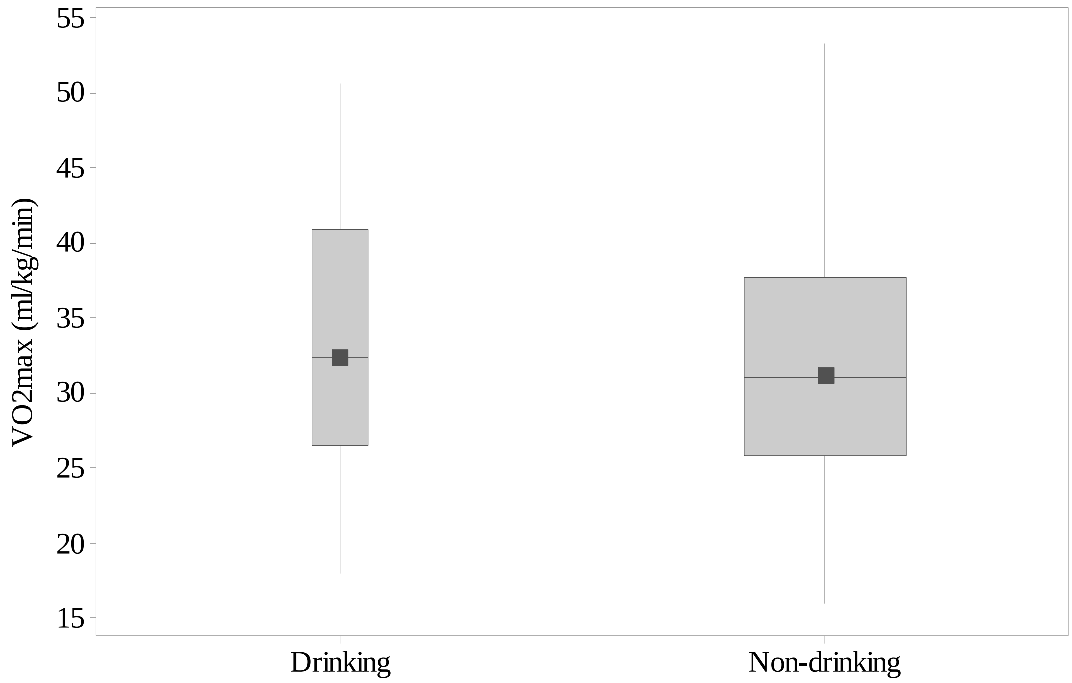
(b)

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



(a)



(b)

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 section, for different age, BMI, occupation groups, the percentiles of the measured values were calculated (Table 5.12 – Table 5.19).

Table 5.12. Percentiles of Test Workload (kpm/min), Accepted HR (bpm) and $\%HR_{max}$ by age and BMI groups.

		Test Workload			**Accepted HR**			**$\%HR_{max}$**		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	256	300	450	600	126	141	161	65%	76%	87%
18-24 yrs	71	300	450	600	126	144	162	63%	72%	82%
Under-weight	7	300	300	450	126	135	139	63%	68%	70%
Normal-weight	46	300	450	581	126	143	161	63%	72%	81%
Over-weight	14	424	450	600	142	145	162	71%	73%	82%
Obese	4	323	450	514	144	147	159	73%	74%	80%
25-34 yrs	72	300	450	600	124	142	165	65%	74%	86%
Under-weight	5	300	300	435	126	133	140	65%	69%	72%
Normal-weight	32	300	300	559	123	136	165	65%	71%	86%
Over-weight	28	300	450	600	125	146	158	66%	77%	84%
Obese	7	345	450	503	137	151	166	72%	79%	86%
35-44 yrs	62	300	450	600	127	141	161	70%	78%	89%
Under-weight	4	300	300	428	123	131	139	68%	71%	76%
Normal-weight	24	300	450	600	128	140	163	70%	76%	89%
Over-weight	23	300	450	518	124	142	157	70%	79%	88%
Obese	11	300	300	488	130	140	155	74%	79%	87%
45-54 yrs	51	300	300	563	125	137	152	73%	80%	91%
Under-weight	3	450	450	450	136	142	145	81%	82%	84%
Normal-weight	11	300	450	488	126	135	153	73%	78%	88%
Over-weight	22	300	413	593	124	141	152	74%	83%	89%
Obese	15	300	300	495	125	135	151	74%	79%	91%

Table 5.13. Percentiles of VO_{2max} results by age and BMI groups.

	N	VO_{2max} (l/min) 5th	50th	95th	VO_{2max} (ml/min/kg) 5th	50th	95th
All	256	1.6	2.0	2.4	21.4	31.3	45.9
18-24 yrs	71	1.9	2.2	2.4	27.2	37.3	49.2
Under-weight	7	1.9	2.1	2.5	37.6	45.9	52.5
Normal-weight	46	1.9	2.2	2.4	33.0	38.5	48.3
Over-weight	14	1.8	2.2	2.3	27.7	30.5	34.3
Obese	4	1.7	2.1	2.2	25.6	25.7	27.2
25-34 yrs	72	1.7	2.0	2.3	23.8	31.5	44.4
Under-weight	5	2.1	2.3	2.3	39.8	42.6	49.3
Normal-weight	32	1.7	2.1	2.4	29.3	37.6	44.4
Over-weight	28	1.7	2.0	2.3	24.3	28.9	35.8
Obese	7	1.7	1.9	2.1	21.6	24.0	26.6
35-44 yrs	62	1.6	1.9	2.3	21.3	29.7	41.9
Under-weight	4	1.9	2.0	2.2	36.9	41.4	42.3
Normal-weight	24	1.8	2.0	2.3	28.9	35.7	41.7
Over-weight	23	1.7	1.9	2.0	22.4	26.3	32.9
Obese	11	1.5	1.7	1.9	19.7	21.8	23.5
45-54 yrs	51	1.4	1.8	1.9	18.1	24.8	37.0
Under-weight	3	1.8	1.9	1.9	38.9	41.7	45.8
Normal-weight	11	1.7	1.8	2.0	27.1	31.3	34.8
Over-weight	22	1.5	1.8	1.9	20.0	24.7	28.2
Obese	15	1.3	1.7	1.9	16.1	21.5	24.6

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

		Test Workload			Accepted HR			$\%HR_{max}$		
	N	5th	50th	95th	5th	50th	95th	5th	50th	95th
All	256	300	450	600	126	141	161	65%	76%	87%
Manuel	99	300	450	600	126	142	164	66%	76%	89%
18-24 yrs	17	300	450	525	129	147	163	65%	75%	82%
25-34 yrs	32	300	375	559	125	138	166	66%	72%	86%
35-44 yrs	31	300	450	600	128	139	162	70%	77%	90%
45-54 yrs	19	300	450	533	126	141	156	74%	82%	91%
Nonmanuel	157	300	450	600	124	141	159	65%	75%	87%
18-24 yrs	54	300	450	600	126	143	160	63%	72%	81%
25-34 yrs	40	300	450	600	122	143	164	65%	75%	86%
35-44 yrs	31	300	450	488	126	141	157	70%	78%	86%
45-54 yrs	32	300	300	518	124	136	150	73%	80%	89%

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

		VO_{2max} (l/min)			VO_{2max} (ml/min/kg)		
	N	5th	50th	95th	5th	50th	95th
All	256	1.6	2.0	2.4	21.4	31.3	45.9
Manual	99	1.6	1.9	2.3	21.7	31.5	42.5
18-24 yrs	17	1.7	2.2	2.4	25.7	37.4	45.1
25-34 yrs	32	1.6	2.0	2.2	21.7	33.4	43.7
35-44 yrs	31	1.7	1.9	2.3	22.8	29.8	40.2
45-54 yrs	19	1.5	1.8	1.9	19.4	28.3	35.7
Non-manual	157	1.5	2.0	2.4	20.2	30.7	46.8
18-24 yrs	54	1.9	2.2	2.4	28.2	37.3	49.9
25-34 yrs	40	1.8	2.1	2.4	24.0	30.5	43.7
35-44 yrs	31	1.5	1.9	2.2	20.3	27.9	41.6
45-54 yrs	32	1.3	1.8	1.9	17.2	23.6	35.6

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

	N	Test Workload 5th	50th	95th	Accepted HR 5th	50th	95th	$\%HR_{max}$ 5th	50th	95th
All	256	300	450	600	126	141	161	65%	76%	87%
Manual	99	300	450	600	126	141	161	66%	76%	89%
Under-weight	4	300	338	439	123	133	144	66%	69%	82%
Normal-weight	56	300	413	544	126	139	164	66%	75%	88%
Over-weight	30	300	450	600	127	144	161	67%	81%	90%
Obese	9	300	300	525	127	144	166	73%	78%	86%
Non-manual	157	300	450	600	124	141	161	65%	75%	87%
Under-weight	15	300	300	450	125	135	141	64%	69%	81%
Normal-weight	57	300	450	600	125	142	162	63%	72%	86%
Over-weight	57	300	450	600	124	143	159	70%	77%	87%
Obese	28	300	300	499	127	141	152	73%	79%	90%

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

	N	VO_{2max} (l/min) 5th	50th	95th	VO_{2max} (ml/min/kg) 5th	50th	95th
All	256	1.6	2.0	2.4	21.4	31.3	45.9
Manual	99	1.6	1.9	2.3	21.7	31.5	42.5
Under-weight	4	1.9	2.1	2.2	39.1	44.0	49.1
Normal-weight	56	1.7	2.0	2.3	28.6	35.6	42.8
Over-weight	30	1.7	1.9	2.2	21.6	27.2	33.2
Obese	9	1.6	1.7	2.0	19.3	22.2	26.5
Non-manual	157	1.5	2.0	2.4	20.2	30.7	46.8
Under-weight	15	1.9	2.1	2.4	35.8	42.6	51.4
Normal-weight	57	1.8	2.2	2.4	29.9	38.0	47.2
Over-weight	57	1.6	2.0	2.3	22.5	28.2	34.3
Obese	28	1.4	1.7	2.1	16.8	22.6	25.9

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

		Test Workload			Accepted HR			%HR_{max}		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	256	300	450	600	126	141	161	65%	76%	87%
Under-weight	19	300	300	450	124	135	142	65%	69%	82%
18-24 yrs	7	300	300	450	126	135	139	63%	68%	70%
25-34 yrs	5	300	300	435	126	133	140	65%	69%	72%
35-44 yrs	4	300	300	428	123	131	139	68%	71%	76%
45-54 yrs	3	450	450	450	136	142	145	81%	82%	84%
Normal-weight	113	300	450	600	126	141	164	65%	74%	86%
18-24 yrs	46	300	450	581	126	143	161	63%	72%	81%
25-34 yrs	32	300	300	559	123	136	165	65%	71%	86%
35-44 yrs	24	300	450	600	128	140	163	70%	76%	89%
45-54 yrs	11	300	450	488	126	135	153	73%	78%	88%
Over-weight	87	300	450	600	124	144	160	68%	78%	89%
18-24 yrs	14	424	450	600	142	145	162	71%	73%	82%
25-34 yrs	28	300	450	600	125	146	158	66%	77%	84%
35-44 yrs	23	300	450	518	124	142	157	70%	79%	88%
45-54 yrs	22	300	413	593	124	141	152	74%	83%	89%
Obese	37	300	300	525	126	141	162	72%	79%	90%
18-24 yrs	4	323	450	514	144	147	159	73%	74%	80%
25-34 yrs	7	345	450	503	137	151	166	72%	79%	86%
35-44 yrs	11	300	300	488	130	140	155	74%	79%	87%
45-54 yrs	15	300	300	495	125	135	151	74%	79%	91%

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

		VO_{2max} (l/min)			VO_{2max} (ml/min/kg)		
	N	**5th**	**50th**	**95th**	**5th**	**50th**	**95th**
All	256	1.6	2.0	2.4	21.4	31.3	45.9
Under-weight	19	1.9	2.1	2.4	36.1	42.6	50.9
18-24 yrs	7	1.9	2.1	2.5	37.6	45.9	52.5
25-34 yrs	5	2.1	2.3	2.3	39.8	42.6	49.3
35-44 yrs	4	1.9	2.0	2.2	36.9	41.4	42.3
45-54 yrs	3	1.8	1.9	1.9	38.9	41.7	45.8
Normal-weight	113	1.8	2.1	2.4	29.0	37.3	46.0
18-24 yrs	46	1.9	2.2	2.4	33.0	38.5	48.3
25-34 yrs	32	1.7	2.1	2.4	29.3	37.6	44.4
35-44 yrs	24	1.8	2.0	2.3	28.9	35.7	41.7
45-54 yrs	11	1.7	1.8	2.0	27.1	31.3	34.8
Over-weight	87	1.6	1.9	2.3	21.8	27.7	34.2
18-24 yrs	14	1.8	2.2	2.3	27.7	30.5	34.3
25-34 yrs	28	1.7	2.0	2.3	24.3	28.9	35.8
35-44 yrs	23	1.7	1.9	2.0	22.4	26.3	32.9
45-54 yrs	22	1.5	1.8	1.9	20.0	24.7	28.2
Obese	37	1.4	1.7	2.1	17.7	22.5	26.2
18-24 yrs	4	1.7	2.1	2.2	25.6	25.7	27.2
25-34 yrs	7	1.7	1.9	2.1	21.6	24.0	26.6
35-44 yrs	11	1.5	1.7	1.9	19.7	21.8	23.5
45-54 yrs	15	1.3	1.7	1.9	16.1	21.5	24.6

5.3. Correlation Analysis

In order to understand, the linearity between independent variables and responses. The responses were absolute and relative VO2max values in the current study. The hypotheses to be checked while conducting the correlation analysis as following:

$$H_0: \rho = 0$$
$$H_1: \rho \neq 0 \quad (5.1)$$

Table 5.20 presents the Pearson correlation matrix between anthropometric measures (age, height, weight, BMI) and test results (Test Workload (kpm/min), Accepted HR (bpm)) and responses (VO_{2max} in l/min and in ml/kg/min). According to the comparison of anthropometric data (age, height, weight, BMI), it is seen that with moderate and high correlation coefficients and with p-values < 0.001, there is a significant correlation between anthropometric measures. Moreover, there is a highly positive correlation between Test Workload and Accepted HR. The performed analyses indicate that there is a correlation between the values regarding aerobic capacity (VO_{2max} in l/min) and the test results (Test Workload (kpm/min), Accepted HR (bpm)). Besides, relative aerobic capacity (VO_{2max} in ml/kg/min) is correlated with Accepted HR. Aerobic capacity (VO_{2max} in l/min) is positively correlated with test workload and negatively correlated with age, weight, BMI with p-values < 0.001. Relative maximum aerobic capacity (VO_{2max} in ml/kg/min) has the same correlation pattern with absolute aerobic capacity (VO_{2max} in l/min) whilst having a negative correlation with height. Additionally, relative maximum aerobic capacity (VO_{2max} in ml/kg/min) has stronger relationships with the anthropometric data and test results than absolute aerobic capacity (VO_{2max} in l/min) in terms of correlation coefficients except age and test workload.

Table 5.20. Pearson correlations between test results and anthropometric data.

Correlations	**Age**	**Height**	**Weight**	**BMI**	**Test Workload**	**Accepted HR**	**Predicted HR_{max}**	**% HR_{max}**	**VO_{2max} (l/min)**
Height	-0.132* 0.034**								
Weight	0.391 <0.001	0.323 <0.001							
BMI	0.480 <0.001	-0.175 0.006	0.872 <0.001						
Test Workload	-0.130 0.037	0.087 0.164	0.052 0.406	-0.006 0.930					
Accepted HR	-0.177 0.004	0.051 0.412	0.078 0.212	0.053 0.398	0.838 <0.001				
Predicted HR_{max}	-1 0	0.132 0.034	-0.391 <0.001	-0.480 <0.001	0.130 0.037	0.177 0.004			
% HR_{max}	0.480 <0.001	-0.037 0.559	0.315 <0.001	0.348 <0.001	0.665 <0.001	0.777 <0.001	-0.480 <0.001		
VO_{2max} (l/min)	-0.684 <0.001	0.128 0.041	-0.406 <0.001	-0.496 <0.001	0.208 <0.001	-0.143 0.022	0.684 <0.001	-0.563 <0.001	
VO_{2max} (ml/kg/min)	-0.594 <0.001	-0.155 0.013	-0.880 <0.001	-0.842 <0.001	0.044 0.488	-0.147 0.019	0.594 <0.001	-0.505 <0.001	0.765 <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 classification variables. In order to examine the effects of age, occupation, BMI, smoking, alcohol consumption and exercise groups on aerobic capacity, General Linear Model (GLM) and ANOVA models are used. Tukey test is adopted in order to conduct post-hoc analysis of ANOVA results. The details of the analysis results are covered in the following sections.

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

Table 5.21. ANOVA Model of Aerobic Capacity.

Factor Information	Type	Levels	Values
Age Factor	Fixed	4	18-24; 25-34; 35-44; 45-54
BMI Factor	Fixed	4	Normal-weight; Obese; Over-weight; Under-weight
Alcohol Drinking Factor	Fixed	2	Drinking; Non-drinking
Smoking Factor	Fixed	2	Non or ex smoker; Smoker
Exercise Factor	Fixed	2	Irregular or no; Regular
Occupation Factor	Fixed	2	Manual; Non-manual

Table 5.22 and Table 5.23 show the summary of ANOVA of CRD for aerobic capacity (VO_{2max} in l/min and in ml/kg/min). The results indicate that age, BMI, exercise and occupation have a significant main effect on aerobic capacity (VO_{2max} in l/min) and age, BMI and exercise have significant effect on VO_{2max} in ml/kg/min. Two way interaction effects of BMI-exercise and BMI-smoking are also included to the model since their p values were between 0.05 and 0.1. They were considered as marginally significant even their contribution is quite low to the ANOVA model of aerobic capacity.

Table 5.22. ANOVA of Aerobic Capacity (VO_{2max} in l/min).

Source	DoF	Sequential SS	Adjusted SS	Adjusted MS	F	P
Age Factor	3	6.8384	3.446	1.148	45.83	0.000
BMI Factor	3	1.5447	1.420	0.473	18.89	0.000
Exercise Factor	1	0.6049	0.187	0.187	7.50	0.007
Occupation Factor	1	0.1119	1.116	0.116	4.65	0.032
BMI Factor*Exercise Factor	3	0.1812	0.181	0.060	2.41	0.068
Error	244		6.11	0.025		
Total	255	15.396				

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

Source	DoF	Sequential SS	Adjusted SS	Adjusted MS	F	P
Age Factor	3	4487.6	1119.07	373.02	25.30	0.000
BMI Factor	3	7291.0	6432.97	2144.32	145.42	0.000
Smoking Factor	1	15.6	0.30	0.30	0.02	0.887
Exercise Factor	1	59.3	82.87	82.87	5.62	0.019
BMI Factor*Smoking Factor	3	106.3	106.27	35.42	2.40	0.068
Error	244	3597.9	3597.91	14.75		
Total	255	15557.6				

5.4.2. Age Effect on Aerobic Capacity

In Table 5.24 summary of ANOVA of age factor for aerobic capacity (VO_{2max} in l/min) results are presented. Table 5.25 shows the results of Tukey's test for different age groups for aerobic capacity. Results indicate that there were strong differences between each age group. The 4th group (45-54) has the highest AC values whereas the 1st group (18-24) has the lowest ones.

Table 5.24. 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	-0.0819	0.0276	-2.97	0.016
Group 3- Group 1	-0.2093	0.0293	-7.16	0.000
Group 4- Group 1	-0.3446	0.0316	-10.90	0.000
Group 3- Group 2	-0.1275	0.0276	-4.61	0.000
Group 4- Group 2	-0.2628	0.0298	-8.83	0.000
Group 4- Group 3	-0.1353	0.0304	-4.45	0.000

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

Table 5.25. Grouping information of AC (VO_{2max} in l/min) for age groups using Tukey Method.

Age Factor	N	Mean	Grouping
18-24	71	2.141	A
25-34	72	2.059	B
35-44	62	1.931	C
45-54	51	1.796	D

In Table 5.26 summary of ANOVA of age factor for relative aerobic capacity (VO_{2max} in ml/kg/min) results are presented. Table 5.27 shows the results of Tukey's test for different age groups for relative aerobic capacity (VO_{2max} in ml/kg/min). Results indicate that there were strong differences between the each age group. The 4th group (45-54) has the highest AC values whereas the 1st group (18-24) has the lowest ones.

Table 5.26. 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	-2.054	0.671	-3.06	0.012
Group 3- Group 1	-4.357	0.714	-6.11	0.000
Group 4- Group 1	-6.428	0.794	-8.10	0.000
Group 3- Group 2	-2.304	0.675	-3.41	0.004
Group 4- Group 2	-4.374	0.732	-5.97	0.000
Group 4- Group 3	-2.070	0.750	-2.76	0.030

Table 5.27. Grouping information of AC (VO_{2max} in ml/kg/min) for age groups using Tukey Method.

Age Factor	N	Mean	Grouping
18-24	71	36.2563	A
25-34	72	34.2028	B
35-44	62	31.8989	C
45-54	51	29.8285	D

5.4.3. BMI Effect on Aerobic Capacity

In Table 5.28 summary of ANOVA of BMI factor for aerobic capacity (VO_{2max} in l/min) results are presented. Table 5.29 shows the results of Tukey's test for different BMI groups for aerobic capacity (VO_{2max} in l/min). Results indicate that normal-weight and under-weight groups does not significantly differ from each other regarding VO_{2max} in l/min. Besides, over-weight and under-weight group means do no statistically differ from each other since the adjusted p-value of Tukey test is greater than 0.05.

Table 5.28. 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	-0.3049	0.0422	-7.23	0.000
Group 3- Group 1	-0.0907	0.0317	-2.86	0.022
Group 4- Group 1	0.0192	0.0488	0.39	0.979
Group 3- Group 2	0.2143	0.0437	4.91	0.000
Group 4- Group 2	0.3241	0.0577	5.61	0.000
Group 4- Group 3	0.1099	0.0511	2.15	0.137

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

Table 5.29. Grouping information of AC (VO_{2max} in l/min) for BMI groups using Tukey Method.

BMI Factor	N	Mean	Grouping
Under-weight	19	2.09547	A B
Normal-weight	113	2.07627	A
Over-weight	87	1.98562	B
Obese	37	1.77136	C

In Table 5.30 summary of ANOVA of BMI factor for relative aerobic capacity (VO_{2max} in ml/kg/min) results are presented. Table 5.31 shows the results of Tukey's test for different BMI groups for aerobic capacity (VO_{2max} in ml/kg/min). Results indicate that BMI has a strong effect on relative aerobic capacity (VO_{2max} in ml/kg/min) and there were strong differences between the each BMI group. It is seen that the mean values of VO_{2max} results (in ml/kg/min) are decreasing from under-weight group to obese group and each BMI group statistically differ from each other.

Table 5.30. 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	-12.131	0.828	-14.66	0.000
Group 3- Group 1	-8.503	0.650	-13.09	0.000
Group 4- Group 1	7.65	1.02	7.48	0.000
Group 3- Group 2	3.628	0.892	4.07	0.000
Group 4- Group 2	19.78	1.21	16.35	0.000
Group 4- Group 3	16.15	1.09	14.79	0.000

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

Table 5.31. Grouping information of AC (VO_{2max} in ml/kg/min) for BMI groups using Tukey Method.

BMI Factor	N	Mean	Grouping
Under-weight	19	43.9428	A
Normal-weight	113	36.2923	B
Over-weight	87	27.7897	C
Obese	37	24.1617	D

5.4.4. Occupation Effect on Aerobic Capacity

In Table 5.32 ANOVA of occupation factor on aerobic capacity (VO_{2max} in l/min) results are presented. Table 5.33 shows the results of Tukey's test for different occupation groups. Results indicate that occupation has significant effect on aerobic capacity (VO_{2max} in l/min) and there were significant differences between each occupation group. It is seen that the mean values of VO_{2max} (l/min) statistically differ from each other.

Table 5.32. Tukey test results of AC (VO_{2max} in l/min) for different occupation groups.

Occupation Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group 2- Group 1	0.0469	0.0217	2.16	0.031

Group 1: Manual; Group 2: Non-manual

Table 5.33. Grouping information of AC (VO_{2max} in l/min) for occupation groups using Tukey Method.

Occupation factor	N	Mean	Grouping
Manual	99	1.95875	B
Non-manual	157	2.00561	A

Regarding the results of ANOVA of relative aerobic capacity (VO_{2max} in ml/kg/min) that is shown in Table 5.23 occupation factor was found statistically insignificant.

5.4.5. Exercise Effect on Aerobic Capacity

Table 5.34 shows the results of Tukey's test for different exercise groups for aerobic capacity (VO_{2max} in l/min). It is seen that the mean values of VO_{2max} results (in l/min) are decreasing from regular group to irregular or no group and the mean values of each group statistically differ from each other.

Table 5.34. 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
Group 2- Group 1	0.0889	0.0324	2.74	0.006

Group 1: Irregular or no; Group 2: Regular

Table 5.35. Grouping information of AC (VO_{2max} in l/min) for exercise groups using Tukey Method.

Exercise factor	N	Mean	Grouping	
Regular	47	2.026	A	
Irregular or no	209	1.937		B

Table 5.36 shows the results of Tukey's test for different exercise groups for relative aerobic capacity (VO_{2max} in ml/kg/min). Results indicate that there is a significant difference between the each exercise group. It is seen that the mean values of VO_{2max} (ml/kg/min) are decreasing from regular to irregular or no group. The mean AC of regular group was found as 33.8 ml/kg/min whereas the mean AC of irregular group was 32.3 ml/kg/min.

Table 5.36. Tukey test results of AC (VO_{2max} in ml/kg/min) for different exercise groups.

Exercise Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group 2- Group 1	1.513	0.634	2.37	0.018

Group 1: Irregular or no; Group 2: Regular

Table 5.37. Grouping information of AC (VO_{2max} in ml/kg/min) for exercise groups using Tukey Method.

Exercise factor	N	Mean	Grouping	
Regular	47	33.798	A	
Irregular or no	209	32.295		B

5.4.6. Smoking Effect on Aerobic Capacity

Table 5.38 depicts the results of Tukey's test for different smoking groups for aerobic capacity (VO_{2max} in ml/kg/min). Results indicate the mean values of each smoking group does not statistically differ from each other. Besides Table 5.39 shows that every group has the same letter and could form a group with each other.

Table 5.38. Tukey test results of AC (VO_{2max} in ml/kg/min) for different smoking groups.

Smoking Factor	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Group 2- Group 1	0.098	0.688	0.14	0.887

Group 1: Non or ex smoker; Group 2: Smoker

Table 5.39. Grouping information of AC (VO_{2max} in ml/kg/min) for smoking groups using Tukey Method.

Smoking factor	N	Mean	Grouping
Smoker	73	33.095	A
Non or ex-smoker	183	32.997	A

Regarding the results of ANOVA of aerobic capacity (VO_{2max} in l/min) that is shown in Table 5.22 smoking factor was not found statistically significant.

5.4.7. Alcohol Drinking Effect on Aerobic Capacity

Lastly, it has shown in Table 5.22 and Table 5.23 that alcohol drinking factor does not have any statistically significant effect on aerobic capacity (VO_{2max} in l/min and in ml/kg/min).

5.4.8. Interaction Effects on Aerobic Capacity

Figure 5.9 and Figure 5.10 depicts the interaction effects for both ANOVA results. In the model of aerobic capacity (in l/min) the interaction effect of BMI and exercise was marginally significant and added to model with the p-value 0.068. On the other hand, for relative aerobic capacity (in ml/kg/min) the interaction effect of BMI and smoking factor is included in the model with the similar p-value: 0.068. When conducting ANOVA, the marginally significant terms are wanted to be presented, and thus, two way interactions were included to the reduced model with p values between 0.05 and 0.1. However, the contributoion of these effects to this model were quite low. Therefore, while conduction regression calculations interactions effects were neglected. Figure 5.9 and 5.10 presents the interaction plots for absolute and relative AC of females.

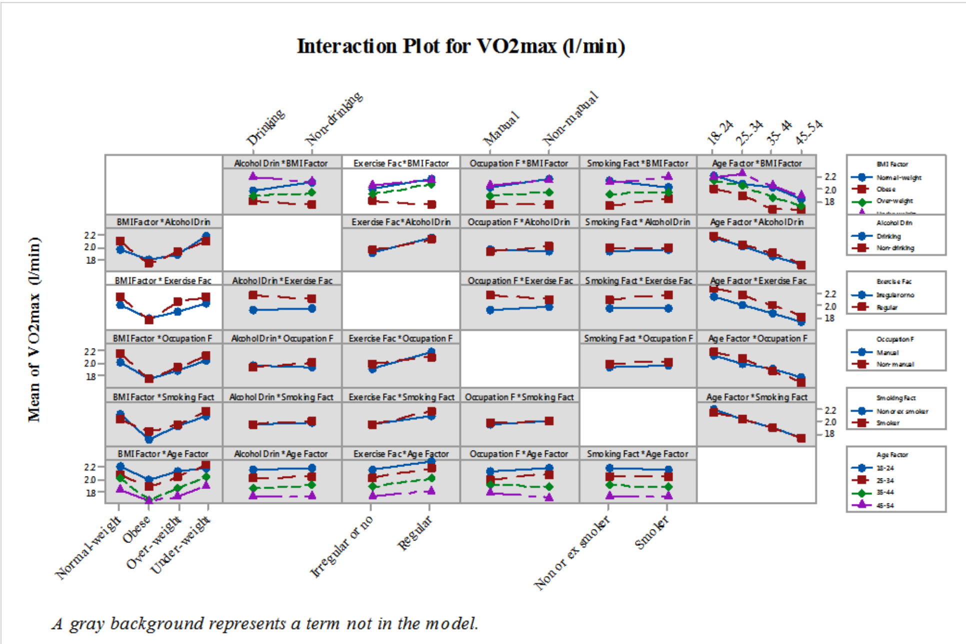


Figure 5.9. Interaction Plot for Aerobic Capacity (VO_{2max} in l/min).

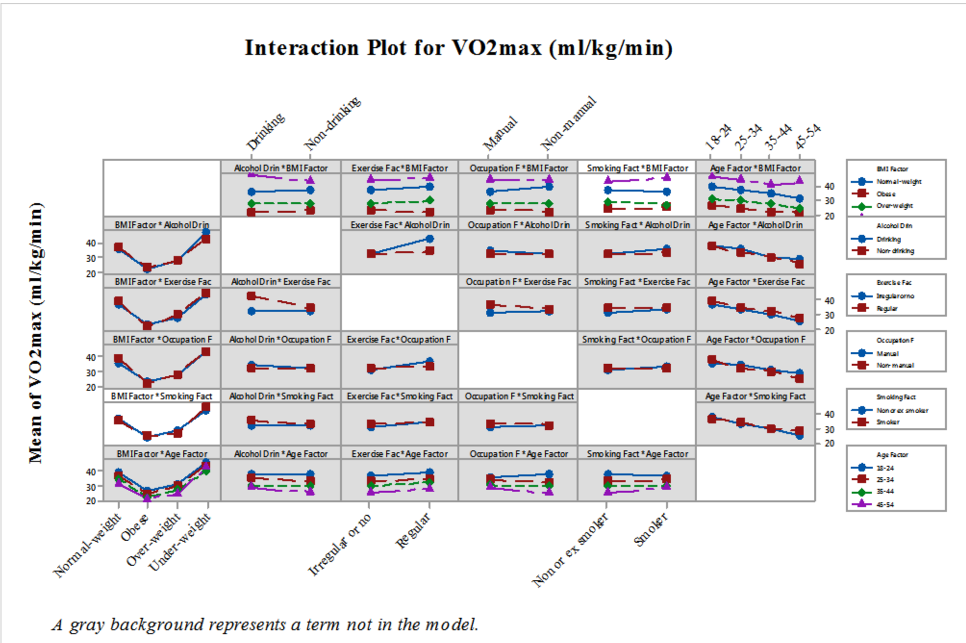
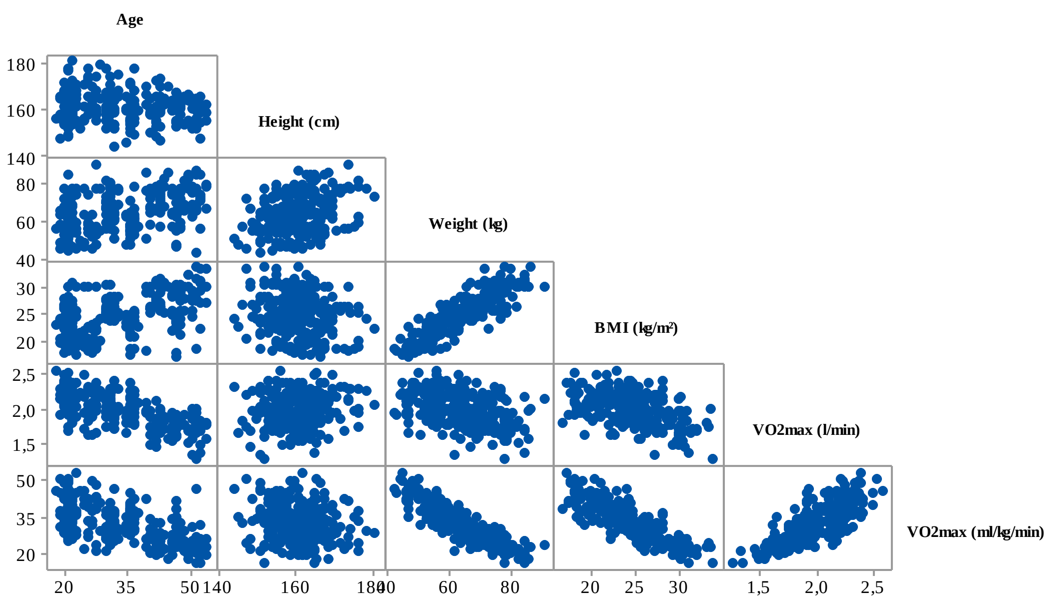


Figure 5.10. Interaction Plot for Aerobic Capacity (VO_{2max} in ml/kg/min).

5.5. Regression Analysis of Aerobic Capacity Values

In the section 5.3 and 5.4 of this study the significant effects of independent variables that were determined by ANOVA and correlation analysis were analyzed. The results of these methods were used to build an accurate regression model to predict aerobic capacity of Turkish female adults. As described in the previous section, interactions effects were neglected while constructing the linear regression model. Table 5.40 shows a matrix plot in order to investigate whether to add any quadratic term in the model.

Table 5.40. Matrix plot of Age, Height, Weight, BMI and VO_{2max}.



In order to build the regression models to predict aerobic capacity of Turkish female adults, the significant independent variables which were determined by ANOVA and correlation analysis were used. Since interacton effects were neglected, a no-interaction multiple linear regression model was determined as a suitable model for female aerobic capacity.

Stepwise regression analysis technique was used in order to develop the best regression equation. In order to verify the results, Best subsets regression analysis method was used as well. As it described before, interaction effects were neglected and only the main effects were taken into consideration. Quadratic effects of BMI and weight are also investigated.

The general form of the female 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 5.41 and 5.44 different model alternatives are represented for absolute and relative aerobic capacity. All models regression equations are listed in Appendix C.

Table 5.41. Different regression model alternatives of AC (VO_{2max} in l/min) for females.

Regression Models	Predictors	S	R^2 (%)	R^2 adj. (%)	Cp
Model 1	Age, Weight, $Weight^2$, BMI, BMI^2, Alcohol, Smoking, Exercise, Occupation	0.1639	57.2	55.6	9.1
Model 2	Age, Weight, BMI, BMI^2, Alcohol, Smoking, Exercise, Occupation	0.1637	57.1	55.7	7.7
Model 3	Age, BMI, BMI^2, Alcohol, Smoking, Exercise, Occupation	0.1634	57.1	55.9	5.7
Model 4	Age, BMI, BMI^2, Smoking, Exercise, Occupation	0.1635	56.9	55.8	4.9
Model 5	Age, BMI, BMI^2, Smoking, Exersice,	0.1651	55.9	55.0	8.7
Model 6	**Age, BMI, BMI^2, Exersice, Occupation**	**0.1639**	**56.5**	**55.6**	**5.1**
Model 7	Age, BMI, BMI^2,Exercise,	0.1657	55.4	54.6	9.5
Model 8	Age, BMI, Exercise	0.1670	54.5	53.9	12.5
Model 9	Age, Exercise	0.1734	50.7	50.3	32
Model 10	Age	0.1798	46.8	46.6	52.5

$$H_0 = \beta_i = 0$$
$$H_1 = \text{Not all } \beta_i \text{ are zero} \qquad (5.3)$$

When all of the models are checked, Model 6 seems as the most appropriate model due to their higher R^2 adjusted values, relatively small S values and valid Cp values. Table 5.42 presents analysis of variance table of regression model. Since p value < 0.05 it is clear that at least one of the regressor variables contributes significantly to the model.

Table 5.42. Analysis of variance table of regression model of AC (VO_{2max} in l/min) for females.

Source	DF	SS	MS	F	P
Regression	5	8.6946	1.73893	64.79	0.000
Age	1	3.0112	3.01119	112.19	0.000
BMI (kg/m²)	1	0.1329	0.13289	4.95	0.027
Exercise	1	0.6235	0.62348	23. 23	0.000
Occupation	1	0.1815	0.18152	6.76	0.010
BMI (kg/m²)*BMI (kg/m²)	1	0.1995	0.19947	7.43	0.007
Error	249	6.6832	0.02684		
Total	254	15.3779			

Table 5.43. Regression analysis results of AC (VO_{2max} in l/min) for females.

Predictor	Coef.	SE Coef.	T	P	VIF
Constant	1.763	0.377	4.68	0.000	
Age	-0.012	0.00114	-10.59	0.000	1.38
BMI (kg/m²)	0.0682	0.0307	2.23	0.027	134.38
Exercise	0.1287	0.0267	4.82	0.000	1.02
Occupation	-0.0567	0.0218	-2.60	0.01	1.07
BMI (kg/m²)*BMI (kg/m²)	-0.0017	0.00062	-2.73	0.007	136.92

Therefore, the regression equation for female aerobic capacity is:

VO_{2max} in l/min = 1.763 – 0.012×Age + 0,0682×BMI + 0,1287×Exercise – 0.0567 Occupation – 0.0017 BMI^2

(S = 0.1638 R-sq = 56.5%. R-sq (adj.) = 55.6%. Mallow Cp = 5.1)

Where, age in years and BMI in kg/m^2.

Table 5.44. Different regression model alternatives of AC (VO_{2max} in ml/kg/min) for females.

Regression Models	Predictors	S	R^2 (%)	R^2 adj. (%)	Cp
Model 1	Age, Height, Weight, $Weight^2$,BMI, Smoking, Exercise, Occupation	2.6854	88.6	88.2	8.9
Model 2	Age, Weight, $Weight^2$, BMI, Smoking, Exercise, Occupation	2.6925	88.5	88.1	9.2
Model 3	Age, Height, Weight, $Weight^2$, BMI, Exercise, Occupation	2.6948	88.4	88.1	9.6
Model 4	**Age, Weight, $Weight^2$,BMI, Exercise, Occupation**	**2.7027**	**88.3**	**88.0**	**10.1**
Model 5	Age, Weight, $Weight^2$,Exercise, Occupation	2.7262	88.1	87.8	13.5
Model 6	Age, Weight, $Weight^2$, Exercise	2.7481	87.8	87.6	16.7
Model 7	Age, Weight, $Weight^2$	2.8657	86.7	86.5	38.7
Model 8	Age, Weight	3.0693	84.7	84.6	80.0
Model 9	Weight	3.7300	77.3	77.2	236.9

When all of the models are checked, Model 4 seems as the most appropriate model due to their higher R^2 adjusted values, relatively small S values and valid Cp values. Table 5.44 presents analysis of variance table of regression model. Since p value < 0.05 it is clear that at least one of the regressor variables contributes significantly to the model.

Table 5.45. Analysis of variance table of regression model of AC (VO_{2max} in ml/kg/min).

Source	DF	SS	MS	F	P
Regression	6	13697.3	2282.89	313.08	0.000
Age	1	783.1	786.3	107.39	0.000
Weight (kg)	1	7689.7	462.61	63.33	0.000
BMI (kg/m²)	1	38.80	38.82	5.32	0.022
Exercise	1	158.6	158.62	21.75	0.000
Occupation	1	47.9	47.86	6.56	0.011
Weight (kg)* Weight (kg)	1	221.4	221.36	30.36	0.000
Error	248	1808.3	7.52		
Total	254	15505.7			

Table 5.46. Regression analysis results of AC (VO_{2max} in ml/kg/min) for females.

Predictor	Coef.	SE Coef.	T	P	VIF
Constant	109.17	5.89	18.53	0.000	
Age	-0.192	0.018	-10.36	0.000	1.35
Weight (kg)	-1.536	0.194	-7.92	0.000	144.48
BMI (kg/m²)	-0.222	0.096	-2.31	0.022	4.85
Exercise	2.053	0.440	4.66	0.000	1.02
Occupation	-0.912	0.356	-2.56	0.011	1.05
Weight (kg)* Weight (kg)	0.008	0.001	5.51	0.000	134.33

Therefore, the regression equations for female aerobic capacities are:

VO_{2max} in ml/kg/min = 109.17 – 0.1924×Age – 1.536×Weight – 0.2215×BMI + 2.053×Exercise – 0.912 ×Occupation + 0.00792 $Weight^2$

(S = 2.7027 R-sq = 88.32%. R-sq (adj.) = 88.03%. Mallow Cp = 10.1)

Where, age in years , Weight in kg and BMI in kg/m^2.

6. DISCUSSION

6.1. Discussion on the Results of Current Study

In this part of the current study, the major findings were evaluated and the factors that have effect on aerobic capacity were discussed. Besides, a detailed comparison of the results of the current study and the results of the other studies in the literature was conducted and all comparison results were presented.

(i) *Age Factor:* Results of the current study indicated that age is a significant factor affecting aerobic capacity and there were strong differences between the each age group. It has been observed that the 4^{th} age group (45-54) had the lowest aerobic capacity values whereas the 1^{st} age group (18-24) had the highest ones. In general, the age effect on VO_{2max} was the most obvious finding of the literature studies. It is generally reported that, the VO_{2max} was strongly inversely correlated with age. The main objective of the study of Bugajska *et al.* (2005) was determining the aerobic capacity and work ability in men and women in employment age. The results of the study related to age showed that the VO_{2max} was strongly inversely correlated with age. Also, it is found out that, there was a large variability of the distribution of the level of AC (according to Astrand qualification), in individual age groups of women. Moreover, in the study of Singh *et al.* (2008), the subjects were categorized in two age-groups of 25-35 years and 36-45 years. The sub-maximal exercise technique was employed to the subjects and it concluded that the mean aerobic capacity of the group one (25-35 years) was 17.2% higher than the other subjects. Besides, 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 maximal aerobic capacity of Korean male metal workers. The results of that study indicated that the mean values of absolute and relative VO_{2max} (ml/kg/min), were lowest for subjects aged 50-59 years.

(ii) *BMI Factor:* The results of the current study showed that BMI has a strong effect on absolute and relative aerobic capacity and there were strong differences between each BMI group regarding relative aerobic capacity. It has seen that the mean values of VO_{2max} results were decreasing from under-weight group to obese group. Results indicated that normal-weight and under-weight groups does not significantly differ from each other regarding VO_{2max} in l/min. Besides, over-weight and under-weight group means do no statistically differ from each other since the adjusted p-value of Tukey test is greater than 0.05. On the other hand, regarding relative aerobic capacity each BMI group statistically differ from each other. Similarly, the results of the study of Kang *et al.* (2007) showed that the aerobic capacity was influenced by BMI values of the employees. In the study, worker with a high BMI was founded to have lower VO_{2max}. Moreover, in the studies of Bradshaw (2003) and Afolabi & Akanbi (2013) BMI was found a significant factor on aerobic capacity. In addition to that, in the study of Wohlfart (2001) it is stated that the work capacity was dependent of height but not weight.

(iii) *Occupation Factor:* The effect of occupation on absolute and relative aerobic capacity was also investigated in the current study. In literature, there were no satisfactory findings regarding the difference of relative AC values of manual and non-manual workers. The results of the current study indicated that occupation did not have any significant effect on relative aerobic capacity. On the other hand, it is seen that the mean values of VO_{2max} results statistically differ from each other for absolute VO_{2max}.

(iv) *Exercise Factor:* Exercise group is another influential factor on aerobic capacity. Results of the current study indicated that exercise has a strong effect on aerobic capacity. It has seen that the mean values of both absolute and relative VO_{2max} were decreasing from "regular" group to "irregular or no" group and the mean values of each group statistically differ from each other. In literature it has seen that HR at any given level of sub-maximal exercise generally decreases with exercise level of a person. Güvenç (2007) conducted a study 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. 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. Pınar *et al.* (2018) conducted a study in order to determine the effect of step aerobic exercises on AC values of females. In the study of Pınar *et al.* (2018) exercise effect was found significant. However, for elder group (30-41 yrs.) the difference between the AC values that were measured before and after the experiments, was not statistically significant. On the other hand, there were studies that could not find any significant training effect on $VO_{2max.}$

(v) *Smoking Factor:* One of the most comprehensive studies about the effect of smoking on 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}. Similarly, the results of the current study showed that smoking does not have a significant effect on maximal aerobic capacity (VO_{2max} in l/min) and similarly the mean values of each smoking group does not statistically differ from each other. Only for relative AC, smoking and BMI interaction effect was marginally significant. However, this interaction was neglected while conducting the regression models since its contribution to the model quite low.

(vi) *Alcohol Drinking Factor:* Lastly, for the both absolute and relative aerobic capacity values, results indicated that alcohol drinking does not have a significant effect on aerobic capacity on women. The mean values of each alcohol drinking group do not statistically differ from each other. This result is similar with the result of the study of Kang *et al.* (2007) conducted with 570 male workers. However, in that study only the male workers are investigated and for a better comparison a comprehensive study that examine the smoking and alcohol drinking factors on aerobic capacity of women is still a need. In addition to this, alcohol drinking was categorized in two groups in the current study. It is possible get more accurate results with more detailed grouping according the level and duration of drinking.

6.2. Comparison with Other Studies

The main results of current study were compared to other studies in literature in this part. The studies that have used the most similar methods were taken into account in order to conduct accurate comparisons. The results of the other studies include only the statistics that belong to women population.

For aerobic capacity, the most similar studies for comparison:

- Storer *et al.* (1990)
- Myhre *et al.* (1998)
- Wu and Wang (2001)
- Bugajska *et al.* (2005)
- Pennathur *et al.* (2005)
- Pulkkinen *et al.* (2005)
- Singh *et al.* (2008)
- Sloan *et al.* (2013)
- Cao *et al.* (2013)
- Myers *et al.* (2017)
- Ando *et al.* (2018)

The literature review part of the current study includes detailed information about all of the related studies. On the other hand, some further details about the compared studies such as population, protocol or measurement methods are explained once again.

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

The aim of the study of Storer *et al.* (1990) was 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 116 female subjects 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) statistically differed from each other. The mean value of the current study was 1.99 ± 0.24 whereas the results of the study of Storer *et al.* (1990) was 1.61 ± 0.39. The results of the current study were 18.7 % higher than the study of Storer *et al.* (1990). The difference could base on the variations of physical characteristics, the genetics, ethnicity or environment conditions of the samples.

Table 6.1. Comparison of results for aerobic capacity 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)	116	1.61	0.39	0.036	-0.37	-9.42	0. 000	156
Current Study	250	1.99	0.24	0.015				

6.2.2. Current Study vs. Myhre *et al.* (1998) for Aerobic Capacity

In the study of Myhre *et al.* (1998) 41 females ranging in age from 20 to 57 years volunteered for the measurements. The calculation of the estimated AC was accomplished by a computer program according the algorithms developed by this study. The measurement algorithms of Myhre *et al.* was also the base of the protocol of this study. The following table shows the results of independent t-tests for two studies. Since both studies were based on the same protocol, it can be concluded that there are statistical differences between these two studies results.

Table 6.2. Comparison of results for aerobic capacity of Myhre *et al.*'s study (age range: 21-50).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Myhre *et al.* (1998)	41	36.9	11.5	1.8	4.38	2.35	0.018	46
Current Study	217	32.52	7.46	0.51				

6.2.3. Current Study vs. Wu and Wang (2001) for Aerobic Capacity

The aim of the study of Wu and Wang (2001) was to determine the maximum acceptable work duration for high intensity work. The experiments are conducted with 30 young individuals; 15 of the participants were females. The aerobic capacity and maximum work rate of them were measured. In the experiments an electrical cycle ergometer was used for the incremental and constant cycling tests. A pulmonary function testing system was used to measure the oxygen consumption, HR and respiratory quotient of the participants. The AC values which were measured in the study of Wu and Wand (2001) were compared with the values of current study. P values of independent t-test show that there are no statistical differences between the results of two studies for the same age groups (Tables 6.3).

Table 6.3. Comparison of results for aerobic capacity of current study with Wu and Wang's study (age range: 20-27).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Wu and Wang (2001)	15	2.08	0.34	0.088	-0.06	-0.066	0.516	15
Current Study	83	2.14	0.19	0.021				

6.2.4. Current Study vs. Bugajska *et al.* (2005) for Aerobic Capacity

One of the most comprehensive studies regarding aerobic capacity was conducted by Bugajska *et al.* (2005). The aim of the study was to assess the level of aerobic capacity and the value of work ability in working people end to evaluate the impact of the aerobic capacity on work ability. In the experiments, 524 occupationally active women performed 2-4 submaximal exercise tests on a bicycle ergometer. Table 6.4 shows the comparison of the results of two studies regarding the age range 18:24. P values of independent t-test show that there is a significant difference between the mean AC values of two studies. Table 6.5., Table 6.6., Table 6.7., Table 6.8. demonstrate the results for the other age groups. The results of the comparison indicated that mean AC of Turkish female population are significantly less than mean AC of Polish female workers participated the study of Bugajska *et al.* (2005).

Table 6.4. Comparison of results for aerobic capacity (VO_{2max} in ml/kg/min) of current study with Bugajska *et al.*'s study (age range: 19-24).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Bugajska *et al.* (2005)	15	44.1	10.6	2.7	6.51	2.28	0.037	16
Current Study	70	37.59	6.73	0.80				

Table 6.5. 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)	56	42.30	7.70	1.0	7.40	4.74	0.000	95
Current Study	41	34.90	7.43	1.2				

Table 6.6. 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)	101	36.00	7.60	0.76	3.25	3.17	0.002	159
Current Study	64	32.75	5.54	0.69				

Table 6.7. 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)	203	32.90	9.40	0.66	6.79	7.24	0.000	175
Current Study	58	26.11	5.08	0.67				

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: 50+).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Bugajska *et al.* (2005)	139	28.90	8.80	0.75	4.36	2.87	0.007	35
Current Study	22	24.54	6.21	1.3				

6.2.5. Current Study vs. Pennathur *et al.* (2005) for Aerobic Capacity

Pennathur *et al.* (2005) conducted an experimental study to determine the aerobic capacity in Mexican American young adults. The subjects were 5 female healthy students with age ranged from 22 to 30 years. A submaximal treadmill exercise test was employed following the the Bruce protocol in order to measure AC values. Although, the results of the study were not statistically compared with previous studies in literature, it concluded that there may not be significant differences in aerobic capacities of young women of Mexican origin and young women from another countries according overall magnitudes of VO_{2max}. The results of the comparison indicated that mean relative AC of Turkish young adults is significantly less than mean relative AC of Mexican American young adults participated the study of Pennathur *et al.* (2005).

Table 6.9. Comparison of results for aerobic capacity (VO_2 max in l/min) of current study with Pennathur *et al.*'s study (age range: 22-24).

Studies	Sample Size	Mean	SD	SE of Mean	Difference	T- value	p- value	DoF
Pennathur *et al.* (2005)	5	2.810	0.730	0.33	0.650	1.98	0.118	4
Current Study	27	2.160	0.160	0.031				

Table 6.10. Comparison of results for aerobic capacity (VO_2 max in ml/kg/min) of current study with Pennathur *et al.*'s study (age range: 22-24).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Pennathur *et al.* (2005)	5	44.69	6.72	3.0	8.19	2.58	0.015	30
Current Study	27	36.50	6.48	1.3				

6.2.6. Current Study vs. Pulkkinen *et al.* (2005) for Aerobic Capacity

In the study of Pulkkinen *et al.* (2005) 16 female adults participated the experiments. During the experiments subjects completed cycle ergometer exercises and real life tasks. According to the comparison results, the relative AC of Turkish female population is significantly less than the relative AC of the subjects participated the study of Pulkkinen *et al.* (2005).

Table 6.11. Comparison of results for aerobic capacity (VO_2 max in ml/kg/min) of current study with Pulkinken *et al.*'s study (age range: 25-54).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Pulkinken *et al.* (2005)	16	40.00	7.00	1.8	9.82	5.27	0.000	199
Current Study	185	30.18	7.16	0.53				

6.2.7. Current Study vs. Singh *et al.* (2008) for Aerobic Capacity

A study specialized on women is conducted by Singh *et al.* (2008). In the study fifteen farm women working on various farm operations were investigated in terms of their aerobic capacity. The subjects were categorized in two age-groups of 25-35 years and 36-45 years. The sub-maximal exercise technique was employed to the subjects on a computerized treadmill and Naughton protocol was followed in principle. When the results of this study and the current study are compared, it is obtained that the absolute AC values of Turkish female population is significantly higher than the AC of the farm women that participated the study of Singh *et al.* (2008) for the both age groups: 25-35 and 36-45. On the other hand, there were not statistical difference between the relative AC values.

Table 6.12. Comparison of results for aerobic capacity (VO_{2max} in l/min) of current study with Singh *et al.*'s study (age range: 25-35).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Singh *et al.* (2008)	9	1.72	0.33	0.22	-0.310	-2.76	0.025	8
Current Study	76	2.030	0.190	0.022				

Table 6.13. Comparison of results for aerobic capacity (VO_{2max} in l/min) of current study with Singh *et al.*'s study (age range: 36-45).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Singh *et al.* (2008)	6	1.450	0.400	0.16	-0.4400	-2.66	0.000	5
Current Study	59	1.890	0.190	0.025				

Table 6.14. Comparison of results for aerobic capacity (VO_2 max in ml/kg/min) of current study with Singh *et al.*'s study (age range: 25-35).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Singh *et al.* (2008)	9	33.54	4.86	1.6	0.44	0.19	0.848	83
Current Study	76	33.10	6.65	0.76				

Table 6.15. Comparison of results for aerobic capacity (VO_2 max in ml/kg/min) of current study with Singh *et al.*'s study (age range: 36-45).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Singh *et al.* (2008)	6	32.65	5.77	2.4	2.76	0.94	0.351	63
Current Study	59	29.89	6.94	0.90				

6.2.8. Current Study vs. Sloan *et al.* (2013) for Aerobic Capacity

Another latest study is 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 in the adult Singaporean population. In the experiments a total of 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 values of independent t-test show that the relative AC of Turkish female population is significantly higher that the relative AC of Singaporean population (Table 6.16).

Table 6.16. 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)	43	26.90	4.60	0.70	-5.37	-6.20	0.000	89
Current Study	256	32.27	7.81	0.49				

6.2.9. Current Study vs. Cao *et al.* (2013) for Aerobic Capacity

Cao *et al.* (2013) examined a study in order to develop new maximal oxygen uptake prediction models using a perceptually regulated 3-minute walk test. In this purpose two hundred and eighty-three Japanese adults (140 women) were recruited. P values of independent t-test show that there are no statistical differences between the results of two studies for the same age groups (Table 6.17).

Table 6.17. 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)	140	31.20	6.50	0.55	-0.860	-1.17	0.243	329
Current Study	250	32.06	7.71	0.49				

6.2.10. Current Study vs. Myers *et al.* (2017) for Aerobic Capacity

The aim of the study of Myers *et al.* (2017) was to apply fitness registry and the important of exercise. A National Database Registry to improve upon previous regression models for aerobic capacity using treadmill exercise. The experiments are conducted with 3158 women with geographical presentation of different regions of USA such as Texas, North Carolina and Indiana. The AC values which were measured in the study of Myers *et al.* (2017) were compared with the values of current study. P values of independent t-test show that there are no statistical differences between the results of two studies for the same age groups of 20-29; 40-49 and 50-59. On the other hand, the mean value of the current study regarding 30-39 age group was 4.5% higher than the study of Myers *et al.* (2017) for 30-39 age group.

Table 6.18. 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)	396	37.90	9.90	0.50	0.640	0.74	0.461	197
Current Study	95	37.26	6.92	0.71				

Table 6.19. 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)	608	30.90	8.10	0.33	-1.470	-2.07	0.040	114
Current Study	72	32.37	5.33	0.63				

Table 6.20. 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)	843	27.90	7.80	0.27	1.250	1.68	0.098	75
Current Study	58	26.65	5.30	0.70				

Table 6.21. 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)	805	24.20	6.10	0.21	0.20	0.16	0.874	827
Current Study	25	24.00	6.03	1.20				

6.2.11. Current Study vs. Pınar *et al.* (2018) for Aerobic Capacity

Pınar *et al.* (2018) conducted a study in order to determine the effect of step aerobic exercises on AC values of females. 24 healthy adult women participated in the study. The first group was composed of 13 females between the ages of 30-41. Second group had 11 females between the ages of 21-26. P values of independent t-test show that the mean values of relative AC of the current study was statistically higher than the results of the study of Pınar *et al.* (2018) for 30-41 age group.

Table 6.22. Comparison of results for aerobic capacity (VO_{2max} in l/min) of current study with Pınar *et al.*'s study (age range: 30-41).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Pınar *et al.* (2018)	13	25.69	3.90	1.1	-6.09	-3.73	0.000	93
Current Study	82	31.78	5.66	0.63				

Table 6.23. Comparison of results for aerobic capacity (VO_{2max} in l/min) of current study with Pınar *et al.*'s study (age range: 21-26).

Studies	**Sample Size**	**Mean**	**SD**	**SE of Mean**	**Difference**	**T- value**	**p- value**	**DoF**
Pınar *et al.* (2018)	11	34.26	5.10	1.5	-2.80	-1.30	0.198	74
Current Study	65	37.06	6.81	0.84				

Table 6.24. Summary results of compared previous studies.

Study	Country	Sample Size	Age Range	Method	Equipment	Protocol	AC
Storer *et al.* (1990)	USA	116	20-70	Maximal	Cycle Ergometer	Modified	1.61±0.39 (l/min)
Myhre *et al.* (1998)	USA	41	21-50	Sub-Maximal	Cycle Ergometer	US Air Force	36.91±11.48 (ml/kg/min)
Wu and Wang (2001)	Taiwan	15	20-27	Maximal	Cycle Ergometer	NM	2.08±0.34 (l/min)
Bugajska *et al.* (2005)	Poland	15	19-24	Sub-maximal	Cycle Ergometer	Modified	44.1 ±10.6 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	56	25-30	Sub-maximal	Cycle Ergometer	Modified	42.3 ± 7.7 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	101	31-40	Sub-maximal	Cycle Ergometer	Modified	36.0 ± 7.6 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	203	41-50	Sub-maximal	Cycle Ergometer	Modified	32.9 ± 9.4 (ml/kg/min)
Bugajska *et al.* (2005)	Poland	139	51-60	Sub-maximal	Cycle Ergometer	Modified	28.9 ± 8.8 (ml/kg/min)
Pennathur *et al.* (2005)	USA	5	22-24	Sub-maximal	Treadmill	Bruce	2.81 ± 0.73 (l/min)
Pennathur *et al.* (2005)	USA	5	22-24	Sub-maximal	Treadmill	Bruce	44.69 ± 6.72 (ml/kg/min)
Pulkinken *et al.* (2005)	Finland	16	25-54	Maximal	Cycle Ergometer	Maximal Stepwise	40 ± 7.0 (ml/kg/min)
Singh *et al.* (2008)	India	9	25-35	Sub-maximal	Treadmill	Naughton	33.54 ± 4.86 (ml/kg/min)
Singh *et al.* (2008)	India	6	36-45	Sub-maximal	Treadmill	Naughton	32.65 ± 5.77 (ml/kg/min)
Singh *et al.* (2008)	India	9	25-35	Sub-maximal	Treadmill	Naughton	1.72 ± 0.33 (l/min)
Singh *et al.* (2008)	India	6	36-45	Sub-maximal	Treadmill	Naughton	1.45 ± 0.40 (l/min)
Sloan *et al.* (2013)	Singapore	43	18-65	Maximal	Treadmill	The Bruce Treadmill Ramp	26.90 ± 4.60 (ml/kg/min)

Table 6.24. Summary results of compared previous studies (cont.).

Study	**Country**	**Sample Size**	**Age Range**	**Method**	**Equipment**	**Protocol**	**AC**
Cao *et al.* (2013)	Japan	140	20-69	Maximal	Cycle Ergometer	Graded exercise test	31.20 ± 6.50 (ml/kg/min)
Myers *et al.* (2017)	USA	396	20-29	Maximal	Treadmill	Graded exercise test	37.90 ± 9.90 (ml/kg/min)
Myers *et al.* (2017)	USA	608	30-39	Maximal	Treadmill	Graded exercise test	30.90 ± 8.10 (ml/kg/min)
Myers *et al.* (2017)	USA	843	40-49	Maximal	Treadmill	Graded exercise test	27.90 ± 7.80 (ml/kg/min)
Myers *et al.* (2017)	USA	805	50-59	Maximal	Treadmill	Graded exercise test	24.20 ± 6.10 (ml/kg/min)
Pınar *et al.* (2017)	Turkey	11	21-26	Maximal	Step	Bruce	34.26 ± 5.10 (ml/kg/min)
Pınar *et al.* (2017)	Turkey	13	30-41	Maximal	Step	Bruce	25.69 ± 3.90 (ml/kg/min)

Table 6.25. Summary of comparisons.

Current study vs.	Population (Female)	Sample Size	Age Range	AC	% Diff.	t-value (p-value)
Storer *et al.* (1990)	USA Adults	116	20-70	(l/min)	18.68	-9.42 (0.000)
Myhre *et al.* (1998)	American Air Force workers	41	21-50	(ml/kg/min)	-13.47	2.55 (0.018)
Wu and Wang (2001)	Taiwanese Healthy Adults	15	20-27	(l/min)	2.8	-0.066 (0.516)
Bugajska *et al.* (2005)	Polish workers	15	19-24	(ml/kg/min)	-17.31	2.28 (0.037)
Bugajska *et al.* (2005)		56	25-30	(ml/kg/min)	-21.20	4.74 (0.000)
Bugajska *et al.* (2005)		101	31-40	(ml/kg/min)	-9.92	3.17 (0.002)
Bugajska *et al.* (2005)		203	41-50	(ml/kg/min)	-26.00	7.24 (0.000)
Bugajska *et al.* (2005)		139	51-60	(ml/kg/min)	-17.76	2.87 (0.007)
Pennathur *et al.* (2005)	Mexican-American Graduate Students	5	22-24	(l/min)	-30	1.98 (0.118)
Pennathur *et al.* (2005)		5	22-24	(ml/kg/min)	-22.43	2.58 (0.015)
Pulkinken *et al.* (2005)	Finland healthy untrained adults	16	25-54	(ml/kg/min)	-32.50	5.27 (0.000)
Singh *et al.* (2008)	Indian farm women	9	25-35	(ml/kg/min)	-1.3	0.19 (0.848)
Singh *et al.* (2008)		6	36-45	(ml/kg/min)	-9.2	0.94 (0.351)
Singh *et al.* (2008)	Indian farm women	9	25-35	(l/min)	15.27	-2.76 (0.025)
Singh *et al.* (2008)	Singaporean adults	6	36-45	(l/min)	23.28	-2.66 (0.000)
Sloan *et al.* (2013)	Singaporean adults	43	18-65	(ml/kg/min)	16.64	-6.20 (0.000)
Cao *et al.* (2013)	Japan adults	140	20-69	(ml/kg/min)	2.68	-1.17 (0.243)

Table 6.25. Summary of comparisons (cont.).

Current study vs.	Population (Female)	Sample Size	Age Range	AC	% Diff.	t-value (p-value)
Myers *et al.* (2017)	American Adults	396	20-29	(ml/kg/min)	-1.70	0.74 (0.461)
Myers *et al.* (2017)	American Adults	608	30-39	(ml/kg/min)	4.50	-2.07 (0.040)
Myers *et al.* (2017)	American Adults	843	40-49	(ml/kg/min)	-4.69	1.68 (0.098)
Myers *et al.* (2017)	American Adults	805	50-59	(ml/kg/min)	-0.8	0.16 (0.874)
Pınar *et al.* (2017)	Turkish Adults	11	21-26	Maximal	19	-1.30 (0.000)
Pınar *et al.* (2017)	Turkish Adults	13	30-41	Maximal	7.5	-3.73 (0.198)

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

7. CONCLUSION

The aims of the current study were estimating the aerobic capacity of healthy (normal) adult female population of Turkey; investigating the effects of age, BMI and job-group on aerobic capacity; and lastly comparing the aerobic capacity data of the female population of Turkey with the aerobic capacity data of female population of other countries. The sub-maximal exercise data were collected and statistical analyses were performed to investigate the effects of age, BMI, job group, smoking, alcohol drinking habits and exercise level on aerobic capacity. Based on analysis results, the following conclusions can be drawn:

- Aerobic capacity norms of adult female population of Turkey were established for the age group of 18 to 54 years.
- The mean aerobic capacity (AC: VO_{2max}) is found to be 1.99 l/min (±0.24 l/min) and body weight adjusted AC is 32.3 ml/kg/min (±7.8 ml/kg/min).
- The factor effects:
    - The mean values of VO_{2max} results (in l/min and ml/kg/min) are decreasing from 18-24 years group to 45-54 years group and from under-weight group to obese group.
    - It is found that age and BMI have significant main effect on aerobic capacity for both VO_{2max} in l/min and VO_{2max} in ml/kg/min values.
    - Smoking has marginally significant effect on AC (in ml/kg/min).
    - Alcohol drinking did not have a significant effect on aerobic capacity.

- 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.
- Average accepted HR of the subjects are 141.5 bpm and %88 of the subjects' accepted heart rates are lower than %85 of age predicted maximal. 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 subject which is essentially at low risk in terms of heart disease.

- The mean values of % HR_{max} are increasing from 18-24 years group to 45-54 years group and from under-weight group to obese group linearly.
- There is only a slight difference between manual and non-manual groups due to mean values of Test Workload (kpm/min), Accepted HR (bpm) and VO_{2max} results (in l/min and in ml/kg/min).
- P values < 0.05 are shown that there are significant differences between the mean values of this study and other studies in literature listed in the Table 6.24.
- The AC of population of Turkey is found significantly lower than some world populations and the same or significantly higher than some other world populations.

7.1. Limitations of the Current Study and Recommendations for Future Research and Practicionary

In the current study, AC of female population of Turkey aged between 18 to 54 years was investigated. This study was an initial step in order predict aerobic capacity of female population of Turkey. The results of the current study may be used in industrial work design and clinical settings. In addition to this, this study could be a reference for future studies in sports and health studies.

It is notable to accept that the current study had several limitations. Firstly, although an adequate number of subjects were attended to the study, they were limited to female population. The subjects were chosen from Istanbul district and most of them had been living in cities. The effect of rural and urban living conditions on aerobic capacity is still a research are in the field.

In order to predict aerobic capacity of females of Turkey, a modified sub-maximal protocol is employed in the current study. Although there were several studies that proved the validity of the sub-maximal tests, future studies in needed that subject to measure aerobic capacity of females of Turkey directly instead of estimating it using prediction methods. On the other hand, using different sub-maximal protocols when estimating the AC of female population of Turkey would also be a further research area. In addition to this, the future studies should focus on construction non-exercise prediction models in order to determine aerobic capacity of female population of Turkey. Constructing non-exercise prediction models would give the opportunity to make more comprehensive statistical analysis with larger groups of subjects in a short time interval.

Due to health and safety concerns, in that study subjects that was over 54 years old are not invited to the experiments although the implemented protocol was sub-maximal and participants were not forced to achieve their maximum capacity. For elder age groups, an aerobic capacity study is still a need and it might be more safe to conduct that experiments under the supervision of health professionals. Similarly, future studies should focus on the aerobic capacity values and the factors that have effect on it for young adults and children.

In this study, smoking effect on AC was also examined. The smoking people were divided only into two groups as smokers and non-smokers. The results of ANOVA of the current study showed that smoking and BMI interaction effect was marginally significant on AC. However, different grouping methods and experiments with higher number of subjects in specific smoking groups would give us the opportunity to separate the results of more frequent and heavy smokers than light or non-smokers. Similarly, alcohol drinking effect on AC was also examined in the current study. There were only two groups: Drinkers and non-drinkers. A more detailed and comprehensive study should be examined with more groups and adequate number of subjects in each group in order to analyze effect of alcohol on aerobic capacity and separate heavy drinkers from light, moderate or non-drinkers. In brief, smoking or alcohol consumption, duration and volume of them should be examined in detail in future studies.

Last but not least, the experiments of the current study were conducted in predetermined environmental conditions. The temperature or humidity can vary in real working conditions. Therefore, measurements with changing temperature or humidity conditions should be a future topic to investigate regarding aerobic capacity of female population of Turkey.

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APPENDIX A: ASTRAND NOMOGRAM

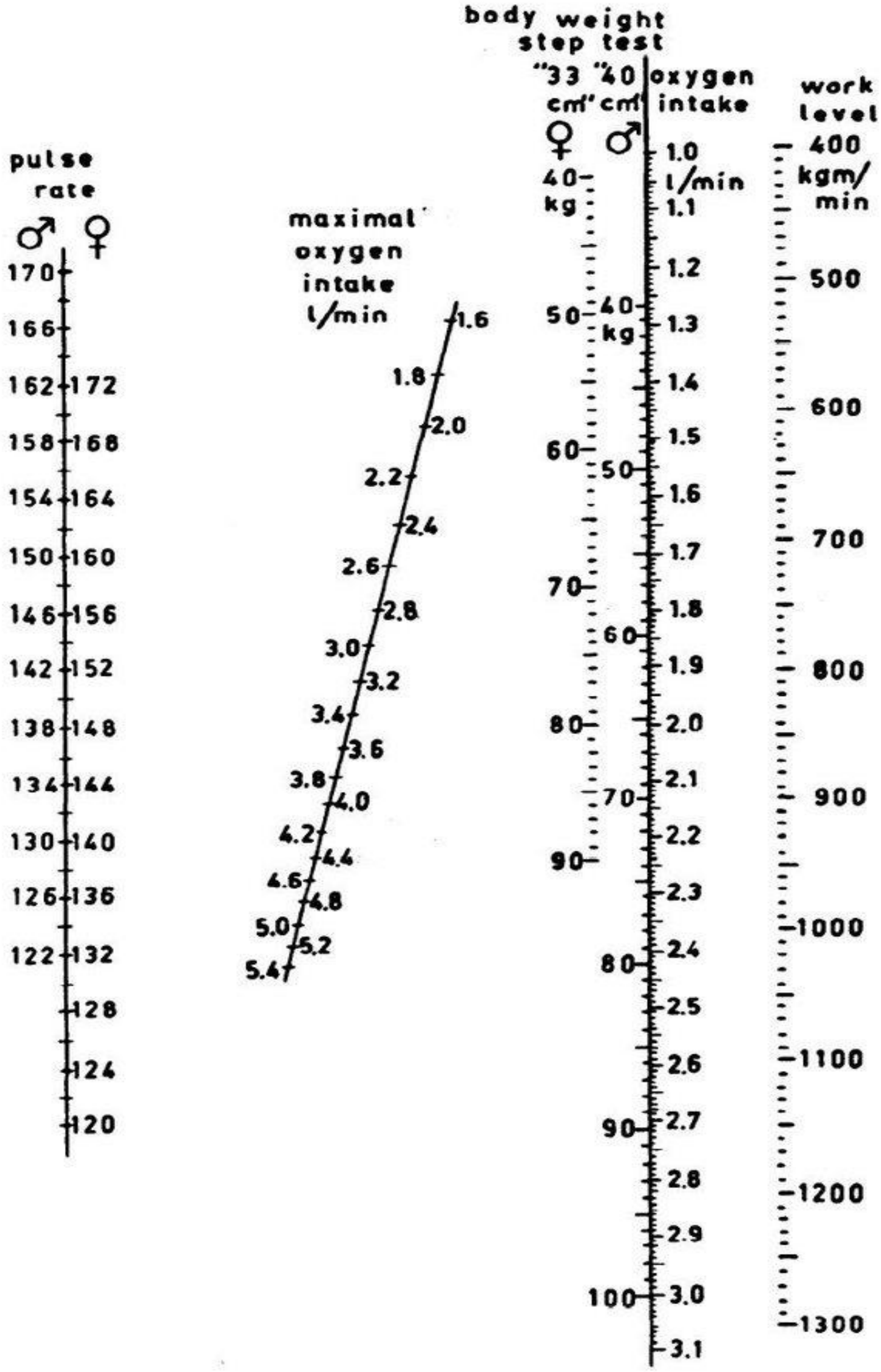

Figure A.1. Astrand Nomogram.

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 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.

__ Yukarıdakilerden hiçbiri.

B.3. Personal Consent Form

In this thesis study, the purpose is to determine the aerobic capacity statistics of Turkish female 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 females 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.

2. 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 2^{nd} minute. One another minute this process will be repeated. After the 3^{rd} 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 6^{th} minute, your heart rate will be

recorded and experiment will finish. After the experiment, you are expected to stop cycling slowly.

3. 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 B. Didem BOZ 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 kadınlarının fiziksel iş yapabilme 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 kadınlarının 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 B.Didem BOZ 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

4. Anthropometric Measurements of the Subject

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

5. 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) = 2.004 - 0.01215xAge + 0.000088xWeight^2 - 0.0114xWeight (kg)
+ 0.0796xBMI (kg/m^2) - 0.001935xBMI^2 - 0.0399xAlcohol Drinking
- 0.0339xSmoking + 0.1309xExercise - 0.0501xOccupation

Model 2. The regression equation is

VO_{2max} (l/min) = 1.882 - 0.01216xAge + 0.00042xWeight (kg) + 0.0591xBMI (kg/m^2)
- 0.001543xBMI^2 - 0.0361xAlcohol Drinking - 0.0348xSmoking
+ 0.1305xExercise - 0.0507xOccupation

Model 3. The regression equation is

VO_{2max} (l/min) = 1.883 - 0.01218xAge + 0.0602xBMI (kg/m^2) - 0.001544xBMI^2
- 0.0367xAlcohol Drinking - 0.0345xSmoking + 0.1307xExercise
- 0.0508xOccupation

Model 4. The regression equation is

VO_{2max} (l/min) = 1.845 - 0.01217xAge + 0.0629xBMI (kg/m^2) - 0.001596xBMI^2
- 0.0343xSmoking + 0.1318xExercise - 0.0524xOccupation

Model 5. The regression equation is

VO_{2max} (l/min) = 1.979 - 0.01257xAge + 0.0500xBMI (kg/m^2) - 0.001312xBMI^2
- 0.0388xSmoking + 0.1341xExercise

Model 6. The regression equation is

VO_{2max} (l/min) = 1.787 - 0.01207xAge + 0.0663xBMI (kg/m²) - 0.001657xBMI^2 + 0.1299xExercise - 0.0550xOccupation

Model 7. The regression equation is

VO_{2max} (l/min) = 1.920 - 0.01248xAge + 0.0532xBMI (kg/m²) - 0.001365xBMI^2 + 0.1321xExercise

Model 8. The regression equation is

VO_{2max} (l/min) = 2.7405 - 0.01287xAge - 0.01401xBMI (kg/m²) + 0.1286xExercise

Model 9. The regression equation is

VO_{2max} (l/min) = 2.4773 - 0.01534xAge + 0.1266xExercise

Model 10. The regression equation is

VO_{2max} (l/min) = 2.5181 - 0.01586xAge

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

Model 1. The regression equation is

VO_{2max} (ml/kg/min) = 153.2 - 0.1906xAge - 0.298xHeight (cm) - 1.022xWeight (kg)
+ 0.00685xWeight^2 - 1.214xBMI (kg/m^2) - 0.627xSmoking
+ 2.150xExercise - 0.901xOccupation

Model 2. The regression equation is

VO_{2max} (ml/kg/min) = 109.81 - 0.1942xAge - 1.540xWeight (kg) + 0.00798xWeight^2
- 0.2388xBMI (kg/m^2) - 0.645xSmoking + 2.109xExercise - 0.835xOccupation

Model 3. The regression equation is

VO_{2max} (ml/kg/min) = 154.4 - 0.1892xAge - 0.308xHeight (cm) - 1.005xWeight (kg)
+ 0.00680xWeight^2 - 1.232xBMI (kg/m^2) + 2.117xExercise - 0.946xOccupation

Model 4. The regression equation is

VO_{2max} (ml/kg/min) = 109.38 - 0.1928xAge - 1.543xWeight (kg) + 0.00797xWeight^2
- 0.2222xBMI (kg/m^2) + 2.073xExercise - 0.878xOccupation

Model 5. The regression equation is

VO_{2max} (ml/kg/min) = 111.09 - 0.2067xAge - 1.690xWeight (kg) + 0.00859xWeight^2
+ 2.104xExercise - 0.800xOccupation

Model 6. The regression equation is

VO_{2max} (ml/kg/min) = 112.15 - 0.2107xAge - 1.735xWeight (kg) + 0.00899xWeight^2
+ 2.141xExercise

Model 7. The regression equation is

VO_{2max} (ml/kg/min) = 113.32 - 0.2207xAge - 1.753xWeight (kg) + 0.00915xWeight^2

Model 8. The regression equation is

VO_{2max} (ml/kg/min) = 75.89 - 0.2172xAge - 0.5684xWeight (kg)

Model 9. The regression equation is

VO_{2max} (ml/kg/min) = 74.09 - 0.6542xWeight (kg)

APPENDIX D: CHECKING ANOVA ASSUMPTIONS

Checking ANOVA Assumptions

a) Normality Test

To use ANOVA, residuals of maximal 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 ($\alpha = 0.05$) in Minitab 17.0. According to Anderson- Darling normality test the p-value of residuals of aerobic capacity data is > 0.05.

Moreover, another procedure to prove normality is to investigate the normal probability plots of the residuals which were shown in Figure. Since the plots approximately resemble a straight line the underlying error distribution for females is normal.

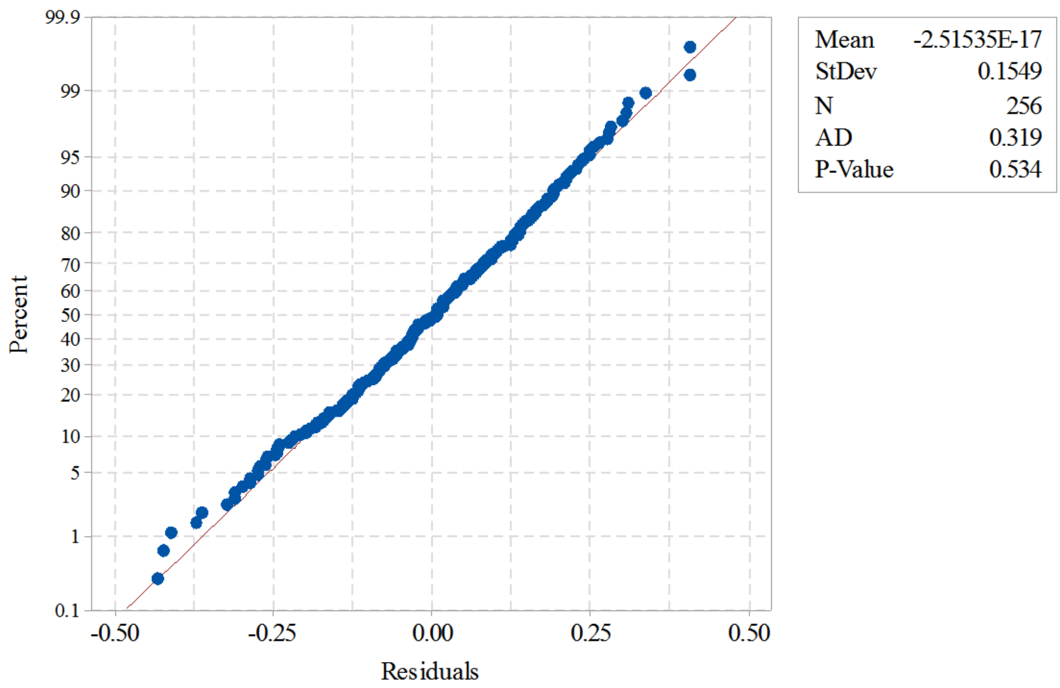

Figure D.1. Normal probability plots of residuals of VO_{2max} (l/min) for ANOVA.

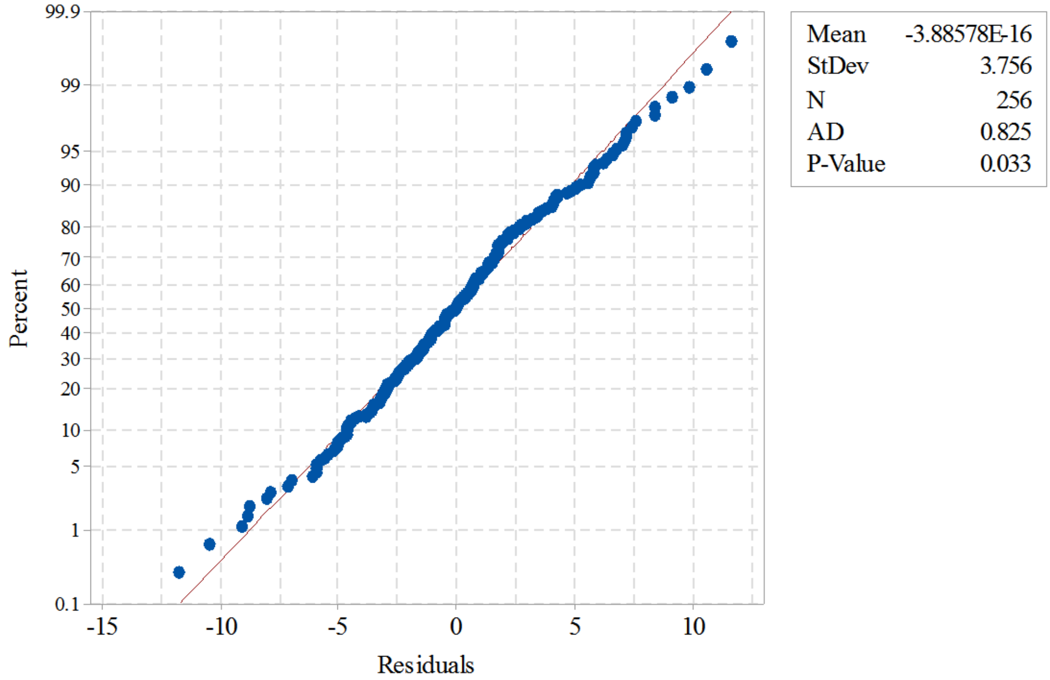

Figure D.2. Normal probability plots of residuals of VO_{2max} (ml/kg/min) for ANOVA.

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, 2005).

The plot of the residuals versus observation order for females is shown in Figure D-3. There is no reason to suspect any violation of the independence assumption.

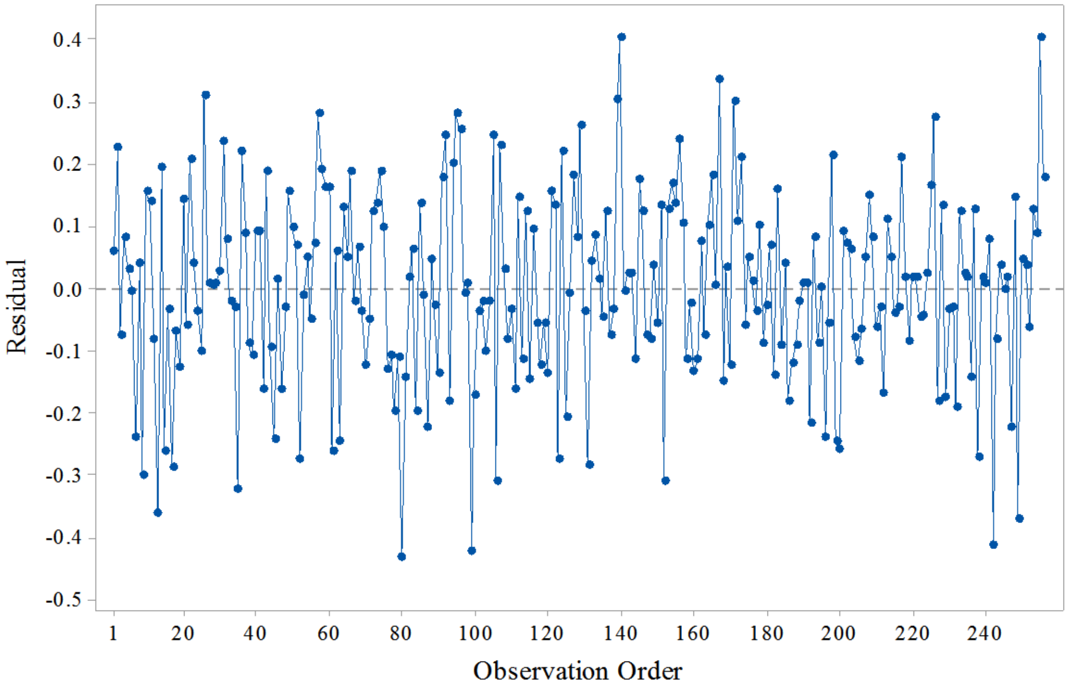

Figure D.3. Plot of residuals versus observation order of VO_{2max} (l /min) for ANOVA.

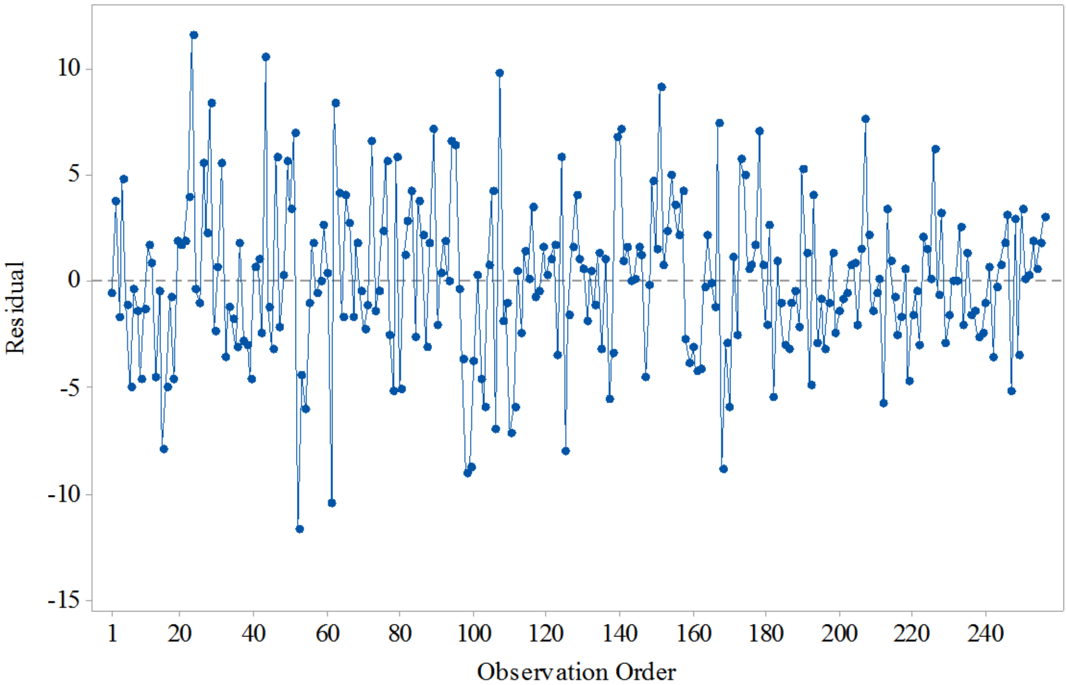

Figure D.4. Plot of residuals versus observation order of VO_{2max} (ml/kg/min) for ANOVA.

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, 2005). In Figure D-5 below plot of residuals versus fitted values for males can be seen. Since there is no apparent unusual structure is equality variance assumption was satisfied.

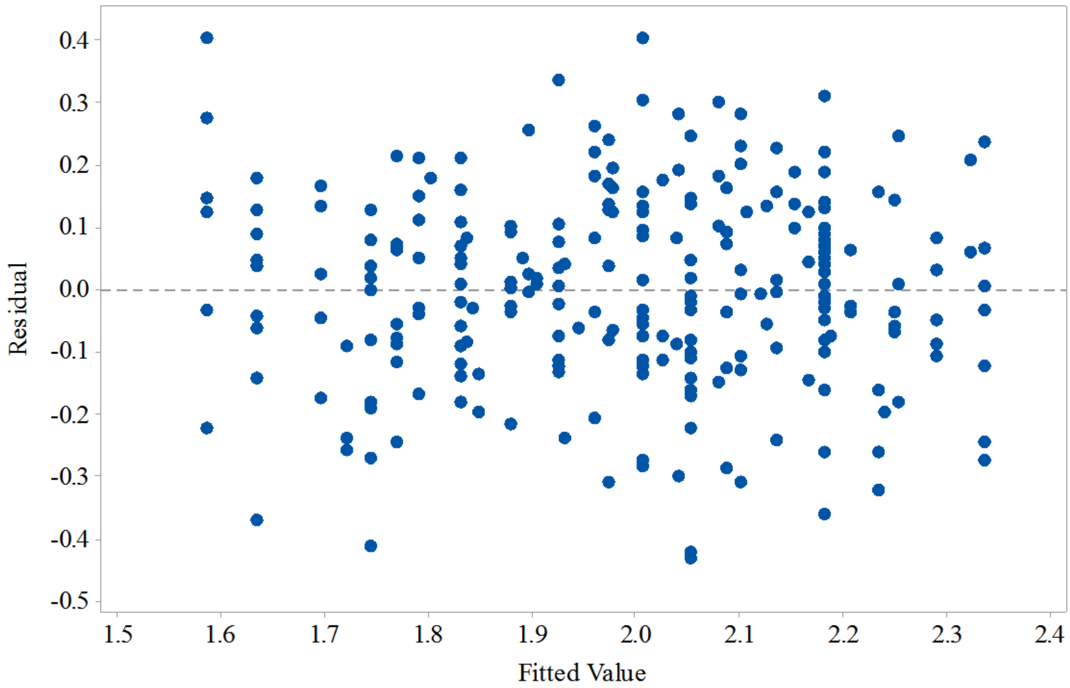

Figure D.5. Plot of residuals versus fitted values of VO_{2max} (l/min) for ANOVA.

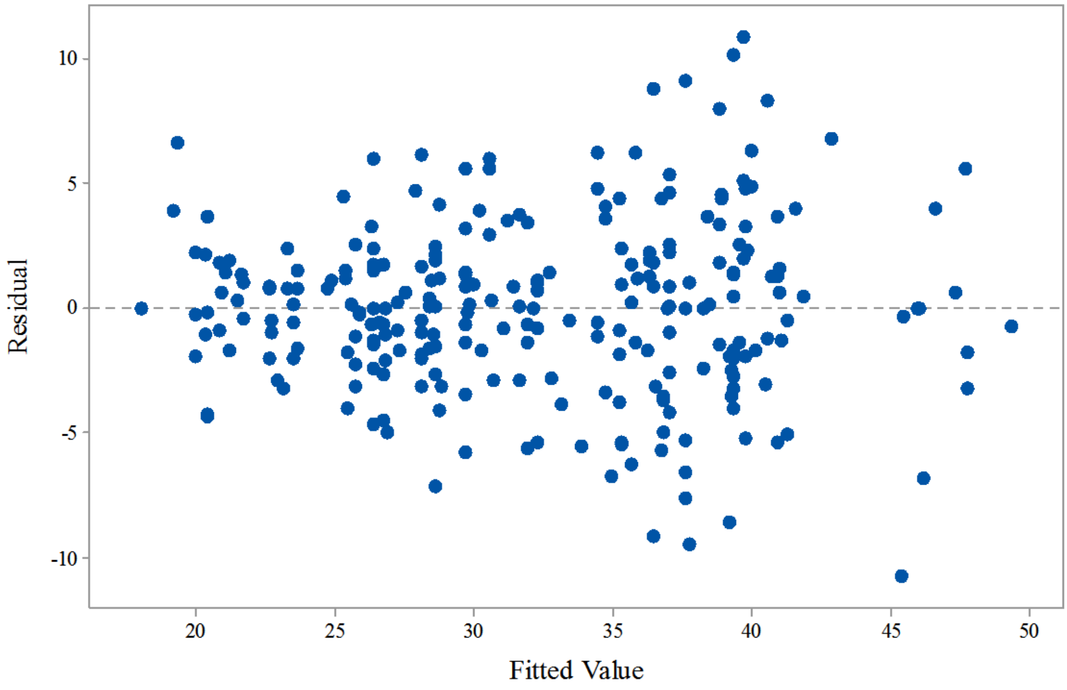

Figure D.6. Plot of residuals versus fitted values of VO_{2max} (ml/kg/min) for ANOVA.

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

Test	Test Statistic	P-Value
Levene's test for CRD ANOVA	0.66	0.937

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

Test	Test Statistic	P-Value
Levene's test for CRD ANOVA	0.93	0.602

Checking ANOVA Assumptions for the selected Regression Models

a) Normality Test

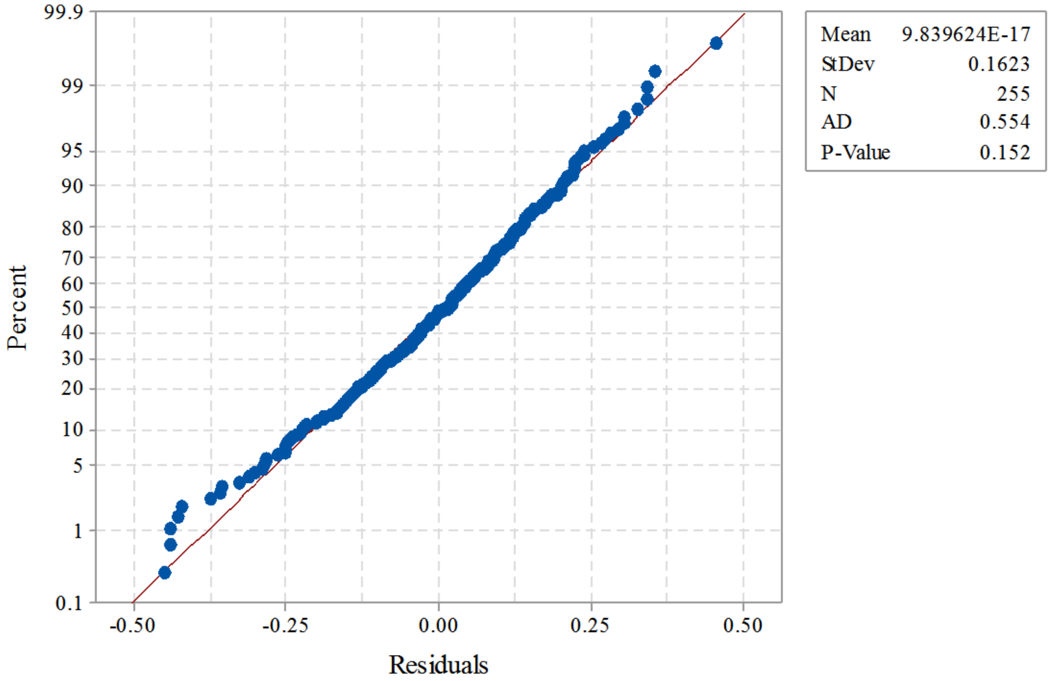

Figure D.7. Normal probability plots of residuals of VO_{2max} (l/min) for ANOVA.

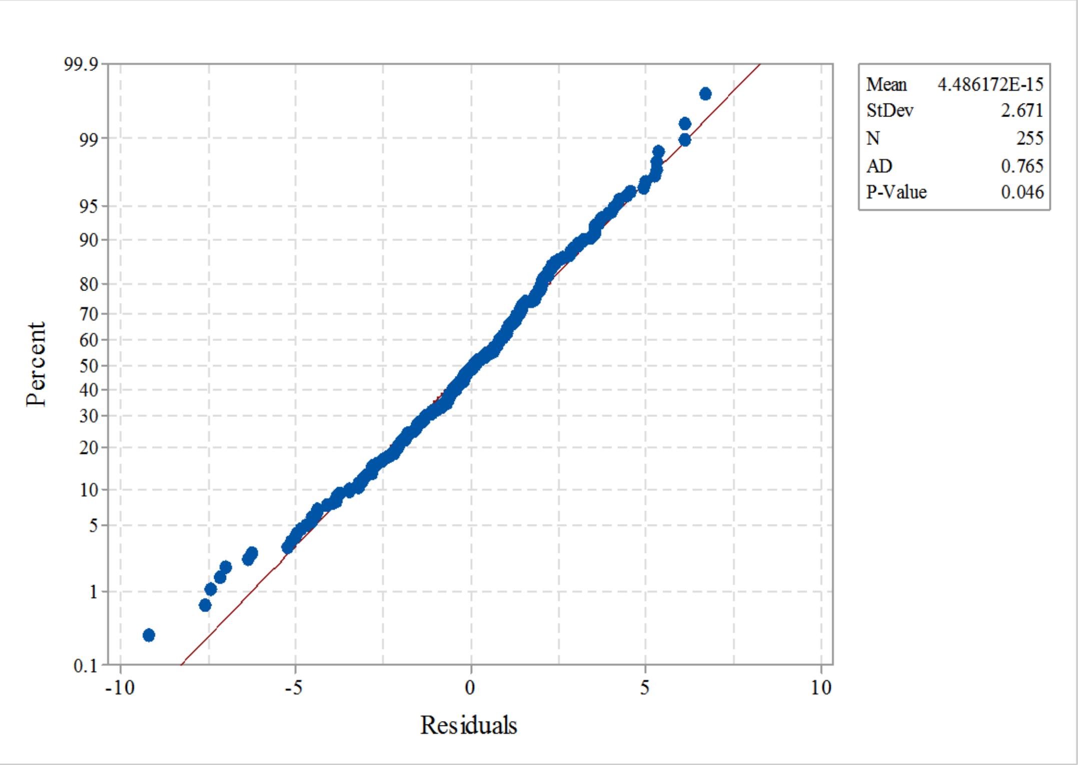

Figure D.8. Normal probability plots of residuals of VO_{2max} (ml/kg/min) for ANOVA for the regression model.

b) Independence Test

The plots of the residuals versus observation order for regression models are shown in Figure D-9 and Figure D-10. There is no reason to suspect any violation of the independence assumption.

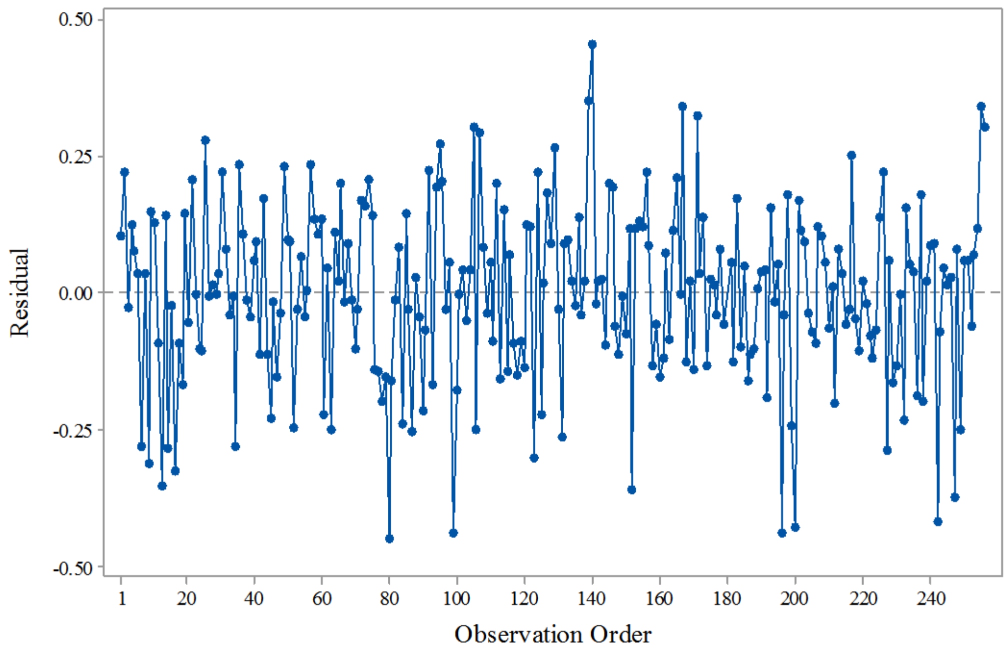

Figure D.9. Plot of residuals versus observation order of VO_{2max} (l /min) for ANOVA of the regression model.

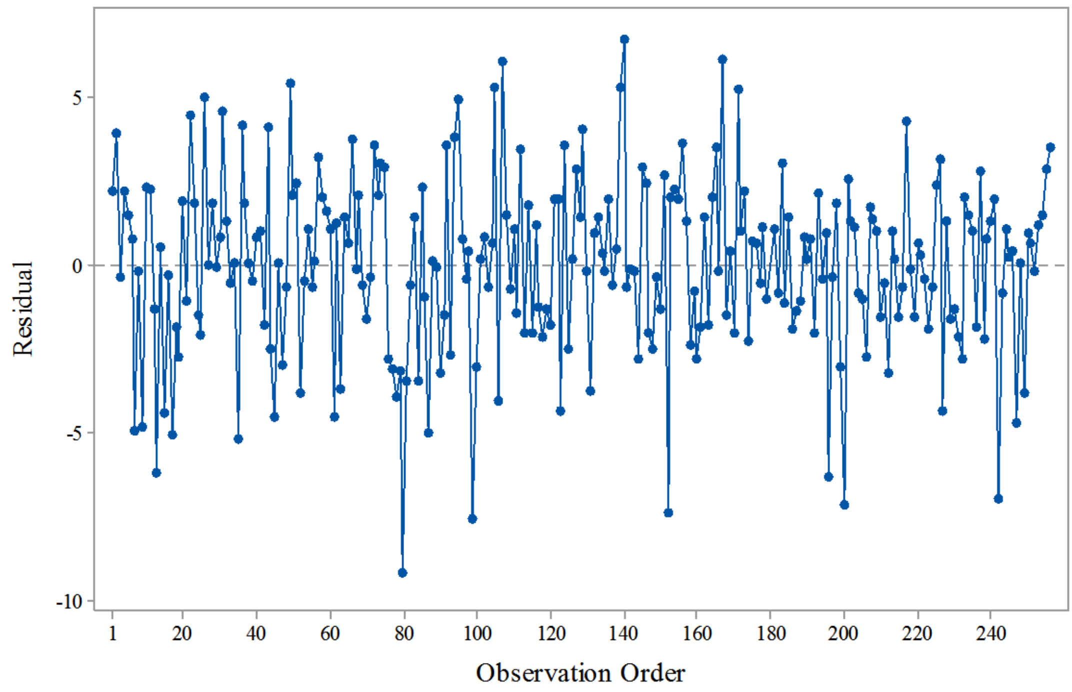

Figure D.10. Plot of residuals versus observation order of VO_{2max} (ml/kg/min) for ANOVA of the regression model.

c) Variance Equality Test

In Figure D-11 and D-12 below plot of residuals versus fitted values for females can be seen. Since there is no apparent unusual structure is equality variance assumption was satisfied.

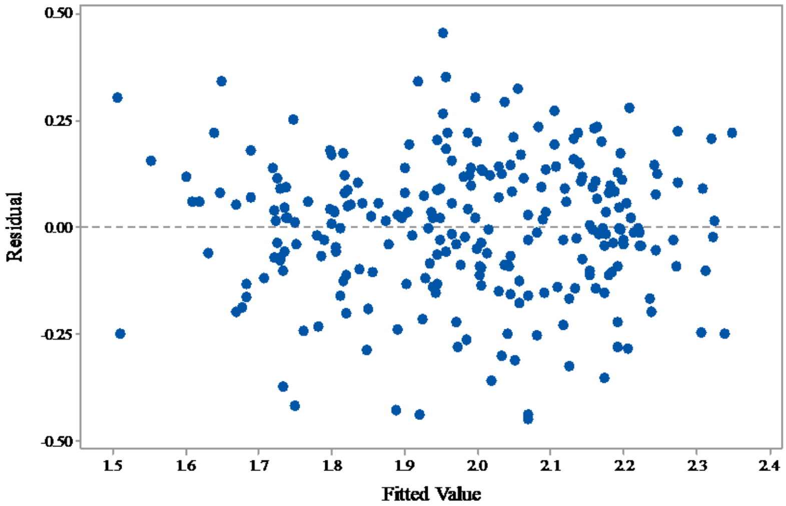

Figure D.11. Plot of residuals versus fitted values of VO_{2max} (l/min) for ANOVA of the regression model.

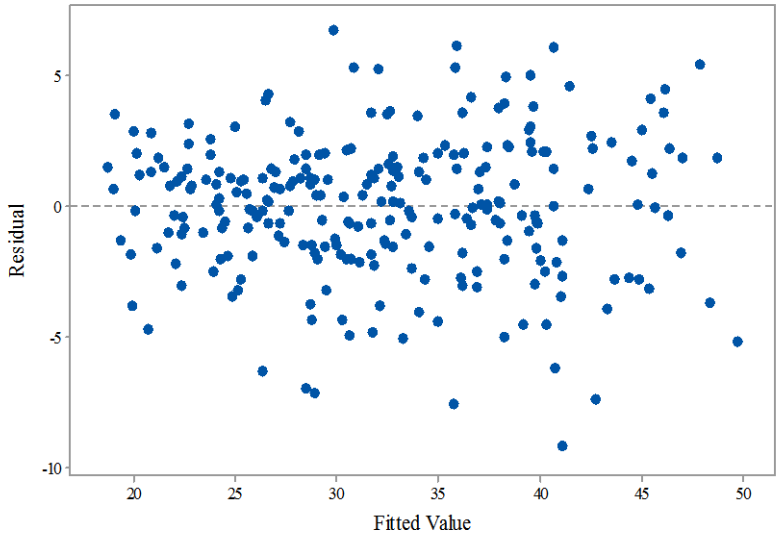

Figure D.12. Plot of residuals versus fitted values of VO_{2max} (ml/kg/min) for ANOVA of the regression model.