

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

**A STUDY OF THE CORRELATION OF MIDDLE
DISTANCE ATHLETICS PERFORMANCE
WITH CARDIOPULMONARY FUNCTIONS
AND SKINFOLD THICKNESS**

*A Thesis Submitted to the School of Graduate Studies of Addis Ababa
University in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Medical Physiology*

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Acronyms

AAU-FM	Addis Ababa University, Faculty of Medicine
ACSM	American College of Sports Medicine
ATP	Adenosine Tri-phosphate
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
BMR	Basal Metabolic Rate
CV	Coefficient of variation
ECG	Electrocardiogram
FEV ₁	Forced expiratory volume during the 1 st second
FEV ₁ %	FEV ₁ % of forced vital capacity
FRC	Functional Residual Capacity
FVC	Forced expiratory Vital Capacity
HR	Heart Rate
HR _{max}	Maximum Heart Rate
HRR	Heart Rate Reserve
IAAF	International Amateur Athletic Federation
LVD	Left Ventricular Diameter
LBM	Lean Body Mass
MEF ₂₅	Maximum Expiratory Flow at 25% of maximal VC
MEF ₅₀	Maximum Expiratory Flow at 50% of maximal VC
MEF ₇₅	Maximum Expiratory Flow at 75% of maximal VC
MMEF	Maximum Mid Expiratory Flow between 25% and 75% of FVC,
PEF	Peak Expiratory Flow
PIF	Peak Inspiratory Flow
PI _{max}	Maximum inspiratory pressure
RV	Residual Volume
TLC	Total Lung Capacity
TV	Tidal Volume
VO _{2max}	Maximum Oxygen Uptake
VO _{2peak}	Peak Aerobic Power

VC Vital Capacity

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Abstract

Important test components for performance evaluation, including assessment of body composition, maximum aerobic capacity, heart rate and pulmonary function evaluation are worth considering. The purpose of this study was to assess the influence of Skinfold thickness and some selected cardiopulmonary parameters in middle distance running performance. Twenty top-class middle distance runners (10 males, with Age = 18-26, Weight = 52-68kg, Height = 165-183cm, BMI (kg/m^2) = 17.63-20.90; and 10 females with Age = 18-26, Weight = 41-57kg, Height = 157-178cm, BMI (kg/m^2) = 14.53-19.99) from Ethiopian Athletics Federation volunteered to participate in the study. Skinfolds were measured at biceps, triceps, sub-scapular and supra-iliac regions. Vital capacity (VC), Forced expiratory vital capacity (FVC), Forced expiratory volume in the first second (FEV_1), FEV_1 %, Peak expiratory flow (PEF), Maximum expiratory flow at 25% of maximal VC (MEF_{25}), Maximum expiratory flow at 50% of maximal VC (MEF_{50}), Maximum expiratory flow at 75% of maximal VC (MEF_{75}), Maximum mid expiratory flow between 25% and 75% of FVC (MMEF), Peak Inspiratory Flow (PIF) and Peak Expiratory Flow (PEF) were measured by Spirometer. The maximal rate of oxygen consumption (VO_2max) was determined using a continuous, incremental exercise protocol conducted on an electronically braked treadmill. Cardiotester belt was used to measure heart rate at different level of treadmill testing. Correlation analyses were applied to each variables and run time (performance). Performance was rated by the scoring procedures of the International Amateur Athletic Federation (IAAF). In male athletes, significant negative correlations were observed between skinfold measurement at sub-scapular ($r = 0.676$, and $P = 0.046$), and supra-iliac ($r = 0.798$, $P = 0.01$) and IAAF score. High negative correlation were found between sum of four skinfold measures and IAAF score ($r = 0.800$, $P = 0.010$). In the female athletes, high negative correlations were found between skinfolds measurement at sub-scapular ($r = -0.639$, $P = 0.047$), supra-iliac ($r = -0.751$, $P = 0.012$), sum of four skinfolds measurement ($r = -0.778$, $P = 0.008$), body fat percentage ($r = -0.840$, $P = 0.002$) and IAAF score.

There was a negative significant correlation between IAAF score and Percent Sub Maximum Heart Rate ($\%HR_{\text{max}}$) at 0.01 level of significance ($r = -0.843$ in female and $r = -0.865$ in male) runners. VO_2max (measured as $\text{ml}/\text{min}/\text{kg}$) was positively correlated with IAAF score in male and female runners ($r = 0.805$, $P = 0.003$) ($r = 0.859$, $P = 0.001$). IAAF score was positively correlated ($p < 0.05$) in the male athletes with the following variables: VC ($r = 0.65$), FVC ($r = 0.70$), and FEV_1 ($r = 0.63$). In female athletes IAAF score was also positively correlated with VC ($r = 0.66$), FVC ($r = 0.85$) and FEV_1 ($r = 0.80$).

Results of this study suggested that lower skinfold thicknesses and sub maximal heart rate were correlated with faster race time; higher lung volume and VO_2max are associated with faster run time.

Key words: Pulmonary profiles, skinfold thickness, Heart Rate, maximum oxygen uptake, performance, IAAF scoring.

1. INTRODUCTION

The athletes of today, whether recreational or elite, run and swim faster, throw farther, and jump higher than their competitors from the past. These improvements have been attributed to several factors including better nutrition, a greater understanding of biomechanics of sport movement, better training techniques, advances in psychological support, and improvements in coaching education (Coyle, 1995).

Continuing efforts to extend laboratory research into the sport-specific field setting have resulted in the identification of several variables deemed necessary for successful performance in several sports (Schabert *et al.*, 2000). To be competitive, the key is to select tests that provide information specific to the particular sport, position, or event. Coaches should consider important test components including Maximal Oxygen Consumption (maximum aerobic capacity), body composition assessment, resting heart rate, heart rate during maximum exercise, pulmonary function evaluation, nutritional analysis, and total blood chemistry as adjuncts to the training regimen and weight room assessment (Muller *et al.*, 2000).

1.1. Maximal Oxygen Consumption (VO₂max)

The major components of physical fitness are cardiorespiratory endurance, muscular strength and endurance, flexibility, and body composition (Bassett & Boulay, 2000). These components provide a basis to predict the body's ability to sustain intense exercise. A measure of cardiorespiratory endurance, simply called aerobic fitness, is often used as an indicator of overall physical fitness. It is well documented that a good measure of aerobic fitness is the extent to which the body is able to take up and use oxygen (Mitchell & Blomquist, 1971). That is, aerobically fit individuals have higher cardiorespiratory and muscular endurance allowing them to deliver and offload oxygen to the skeletal muscle more efficiently as compared to individuals that are less aerobically fit.

When a person is subjected to increasing aerobic workloads, oxygen uptake will increase until a maximum quantity of oxygen uptake is reached. When the maximum oxygen uptake is reached, workload may be increased, but oxygen uptake will not increase beyond this point (Mitchell & Blomquist, 1971). This point is called the maximal oxygen uptake, or VO_2max . VO_2max is generally considered the best measure of aerobic fitness (Glassford *et al.*, 1965).

VO_2max varies due to physiological differences between people in age, body size and gender. That is, VO_2max tends to decrease as age increases (Wilson & Tanaka, 2000), and women tend to have lower VO_2max than men. Also, oxygen uptake tends to increase in proportion to body size because more energy and therefore oxygen is required to move a larger individual (Mitchell & Blomquist, 1971). VO_2max is most commonly expressed as milliliters of oxygen (O_2) consumed per kilogram (kg) of body weight per minute, ml/kg/min (Mitchell & Blomquist, 1971). Expressing VO_2max as ml/kg/min normalizes the data for body weight and enables VO_2max measurements to be comparable among people of different body sizes.

Heart rate (HR) is used to estimate VO_2max . Therefore, anything that affects HR would affect the results of a submaximal test. Numerous factors such as drugs, caffeine, eating, nicotine, amount of sleep, time of day, room temperature and humidity, and anxiety can alter HR. Caffeine increases, while nicotine decreases the HR response to exercise. Therefore, caffeine would tend to underestimate VO_2max and nicotine could overestimate VO_2max (Jackson & Ross, 1996). Direct measurement of VO_2max requires expensive equipment, and considerable time, indirect methods of estimating VO_2max are often used to assess aerobic fitness. Many of these tests measure heart rate during exercise and rely on a linear relationship between heart rate and oxygen consumption to estimate VO_2max (Astrand & Rhyning, 1954).

VO_2max is generally accepted to be the best indicator of endurance performance capacity (O'Toole and Douglas 1995; Sleivert and Rowlands 1996; Weltman *et al.*

1990). Consequently, this variable is frequently used to determine training intensities in numerous endurance sports. VO_2max is assumed to be highly dependent upon the mode of testing, with the highest values normally attained during treadmill running.

Therefore, to optimize the effectiveness of a training program, training activities need some specificity with regard to mode, duration and intensity (Kohrt *et al.* 1987). Training effects also appear to be specific to the mode of training used by an athlete; therefore differences between testing modes vary with training (Sharkey 1988). Because of this specific adaptation, runners are generally tested on a treadmill, and cyclists on a cycle ergometer.

The running speed associated with maximal O_2 uptake (VO_2max) and the time for which this speed can be maintained have been identified as training indices that may be used to achieve gains in performance (James and Doust 2000). Indeed, studies have now shown that increasing the time spent running at VO_2max through interval training may lead to substantial improvements in performance (Billat *et al.*, 2001).

Mechanisms believed to be responsible for the performance improvement associated with training at VO_2max are a reduction in oxygen deficit with less anaerobic contribution at the onset of exercise, an improvement in critical power or increases in ventilatory and lactate thresholds (Poole and Gaesser 1985). Indeed, a recent study showed that running speed at the lactate threshold was highly correlated with the improvement in running performance following a high-intensity training program (Billat *et al.* 2002).

In the 1950s, 1960s, and 1970s, classic studies were performed on the physiological determinants of VO_2max and on its key role in endurance performance (Farrell, *et al.*, 1979). During this time there was much debate on O_2 delivery versus O_2 extraction as the “limiting factor” for VO_2max (Saltin & Strange 1992). Observations during this era clearly established the role of maximal cardiac output

as a determinant of VO_2max , and very high maximal cardiac output values were seen in champion endurance athletes. In addition, the important role of blood volume and total body hemoglobin as determinants of VO_2max also emerged.

In an effort to better understand the physiological determinants of VO_2max , studies were then conducted that attempted to manipulate O_2 delivery using a variety of approaches including altered concentrations of inspired O_2 , drugs that speed or slow the heart, and, as discussed here, techniques that altered total body hemoglobin and hemoglobin concentration (Ekblom *et al.*, 1976). In general, by the 1970s it was clear that manoeuvres that increased total body hemoglobin increased VO_2max and vice versa. These changes in VO_2max appeared to be somewhat independent of total blood volume because volume loading per se had little impact on VO_2max , and likewise manoeuvres that cause haemoconcentration did not increase VO_2max . Therefore, the importance of total body hemoglobin as a primary determinant of VO_2max was emphasized (Kanstrup and Ekblom, 1984). In parallel with these mechanistic studies on the determinants of VO_2max , applied observations on athletic performance and the role of VO_2max , lactate threshold, and running economy emerged (Farrell *et al.*, 1979). As VO_2max was seen as a key determinant of performance, the next obvious question was whether or not manoeuvres that increased total body hemoglobin and VO_2max would also increase performance. A number of studies confirming the positive impact of increased total body hemoglobin on performance were then conducted. In addition; a variety of rumors and innuendo suggested that at least some endurance athletes were using this technique in an effort to gain a competitive advantage in international competition (Joyner, 2002).

The limiting factor of maximal oxygen consumption (VO_2max) has been a source of debate for many years. Proposed limiting factors include cardiac output, pulmonary ventilation, lung diffusion, and oxygen utilization (Warren & Cureton, 1989).

1.1.1. Limiting Factor of VO₂max

1.1.1.1. Cardiac Output:

Researchers sometimes increase the supply of oxygen to the working muscle to determine if oxygen supply or utilization is the limiting factor of maximal oxygen consumption. If maximal oxygen consumption does not change, it implies that the ability of the tissues to utilize oxygen is the limiting factor. On the other hand, if VO₂max increases with artificial increase in O₂ to the muscles, cardiac output probably is the limiting factor. Considerable evidence suggests that cardiac output is the limiting factor for maximal aerobic capacity (Warren & Cureton, 1989). VO₂max is increased if the rate of oxygen supply to the muscle is increased through induced erythrocythemia (blood doping) or breathing 100 percent oxygen during exercise (Warren & Cureton, 1989).

1.1.1.2. Pulmonary function:

Many exercisers use expressions that imply breathing limits for performance. There is little evidence that pulmonary function limits aerobic capacity at sea level in healthy people. Arterial oxygen content at maximal exercise is the same as at rest in most people. Also, maximum voluntary ventilation is much greater than maximum exercise ventilation (Dempsey, *et al.*, 1981). Maximum voluntary ventilation is a test that measures the ventilatory capacity of the lungs. The lungs have a very large reserve that enables them to meet most of the body's requirements for gas exchange and acid-base balance during heavy exercise (Dempsey, *et al.*, 1981).

Dempsey, *et al.* (1984) presented evidence that the lungs may be limiting in some elite male endurance athletes. No such evidence has been presented for elite female athletes. In their subjects, PaO₂ dropped as low as 65 mmHg. There was a significant widening in the difference between oxygen partial pressures in the alveoli and arteries. They hypothesized there was a diffusion limitation as well as increased airway impedance at high levels of ventilation in these athletes.

1.1.1.3. Cellular metabolism:

Other researchers have argued that oxygen supply does not limit either VO_2max or endurance. Rather, the limiting factors are biochemical (Gayeski *et al.*, 1987). Suggested limiting factors decrease the rate and force of myofibrillar cross-bridge cycle activity. Contributing factors may be failure of calcium transport mechanisms or decreased myofibrillar ATPase activity. The critical mitochondrial PO_2 is thought to be 1 mm Hg (i.e., PO_2 necessary for diffusion into the mitochondria) (Gayeski *et al.*, 1987). Indirect estimates of mitochondrial PO_2 during maximal exercise suggest that it is above the critical level. Mitochondrial oxygen availability is estimated from its redox state. This is the ratio of NAD^+ to NADH , which is partially controlled by oxygen availability. Mitochondrial PO_2 is also estimated from myoglobin-associated PO_2 (Green and Patla, 1992).

1.1.1.4. Age:

Maximal oxygen uptake (VO_2max) has been reported to decrease by about 10% per decade after the age of 25 years in healthy sedentary men (Rogers, *et al.*, 1990). Moreover, age-related decrements have been reported in respiratory capacity and submaximal exercise performance (Coggan *et al.*, 1993). Training status seems to have a significant effect on the age related decrements in aerobic fitness, by reducing the rate of decline in VO_2max by about 5% per decade (Heath *et al.*, 1981). Mattern and his colleagues (2003) reported a 3.3% decrease in sub-maximal aerobic performance per decade in well-trained subjects (cycling and triathlon). Since aerobic fitness has been shown to be related to physical performance, (Castagna *et al.*, 2002) we suggest that this age-related decline in aerobic fitness may affect elite athletes running performance.

1.2. Pulmonary Functions

Pulmonary ventilation is generally known to have a linear relationship with oxygen consumption at different levels of exercise. Oxygen consumption is also known to increase from resting state to intense exercise. Lung function parameters tend to

have a relationship with lifestyle such as regular exercise and non-exercise (Wasserman *et al.*, 1995). Due to regular exercise, athletes tend to have an increase in pulmonary capacity when compared to non-exercising individuals, especially when the exercise is strenuous (Twick *et al.*, 1998).

Many authors reported ethnic difference in lung function. Forced vital capacity (FVC) and Forced Expiratory Volume in the first second (FEV₁) have been shown to be lower in African blacks than in whites, whereas Indians and Chinese have intermediate FVC and FEV₁ values (Twick *et al.*, 1998).

According to Mengesha and Mekonnen (1985) in Ethiopians the lung function indices in particular FVC and FEV₁ increases with increasing stature in both sexes. The sex difference in all indices is apparent, although for FEV₁ % the mean values for women are unexpectedly low compared with those of the men. This may be due to poor cooperation or poor muscular effort of the women studied. In the women FVC and FEV₁ showed a significant regression against age and height (Mengesha & Mekonnen, 1985). When comparison is made using a standard age and height, FVC and FEV₁ measured in Ethiopians are found to be lower than in whites but higher than in other Africans, Chinese and Indians (Mengesha & Mekonnen, 1985). The difference observed in these indices among the ethnic groups may be attributable to genetic factors, physical make up inherent in the ethnic groups, altitude, environmental differences, physical activities and tobacco smoking (Mengesha & Mekonnen, 1985).

This Ventilatory adaptation to exercise may differ in different populations such as in Black and Caucasian subjects particularly under different climatic conditions i.e. it may be related to ethnic and environmental factors. A study done in Nigeria showed male athletes have significantly higher tidal volumes (TV) and forced vital capacities (FVC) than male non-athletes, while in females there was no difference (Olufeyi *et al.*, 2002). Hagberg (1988) reported that values for static lung volumes (TV and FVC) of accomplished marathoners and other endurance trained athletes were no different from those of untrained controls of comparable body size.

However, another study reported larger normal static lung volumes in swimmers and divers when compared to normal non-athletes (Cordain, 1990).

Another study showed that training induces a beneficial effect not only in skeletal muscles, but also in respiratory muscles (Powers *et al.* 1997). Coast *et al.* (1990) compared highly trained cross-country skiers and untrained subjects after performing maximal exhausting cycle ergometer exercise and showed that maximal inspiratory pressure decreased in the untrained subjects, but not in the trained athletes. They suggested that the endurance exercise training undertaken by the skiers had induced an adaptive change in the inspiratory muscles that protected them from the acute loss of strength seen in normal subjects following exercise. Similarly, Bender and Martin (1985) compared trained runners and non-runners after exhausting treadmill exercise lasting either 3–10 min or 60 min, and showed that respiratory muscle endurance assessed by maximal voluntary ventilation (MVV) was more significantly decreased in the non-runners than in the trained runners. Interestingly, the authors noted that during the 60 min run, the runners were ventilating similar to (mean of minute ventilation, V_E , measurements taken every 10 min) or relatively more (expression of mean exercise V_E as a percentage of body mass) than the non-runners. Hue and his colleagues (2000) reported significantly a higher ventilatory response during an experiment in which cycling was followed by running in competition triathletes, i.e. regionally- and nationally-ranked compared with elite triathletes, i.e. internationally-ranked. The authors concluded that the ventilatory response to exercise may have been related to the level of performance in the triathletes.

Respiratory muscle strength and endurance are improved with training regimens that specifically target the respiratory muscles (Powers, 1992). However, there is conflicting evidence as to whether respiratory muscle function is altered in response to whole-body endurance training. Respiratory muscle strength, expressed as the mouth pressure generated during maximal inspiratory efforts against a closed

airway, is not augmented in endurance athletes with a background of skiing, swimming, or running (Cordain *et al.*, 1990; Armour *et al.*, 1993).

Metabolic changes consistent with improved respiratory muscle endurance have been reported in animal studies following various types of endurance training although this does not seem to apply to the diaphragm's oxidative capacity (Okumoto *et al.*, 1996). In humans, improved ventilatory muscle endurance is reported after swimming, running or cycling training (O'Kroy & Coast, 1993). In contrast Thomas *et al.* (1998) found no functional adaptations of ventilatory muscles following cycle training, even when the training was performed at altitude.

One study demonstrates that although respiratory muscle strength was not different between sedentary subjects and highly trained marathon runners (Eastwood *et al.*, 2001), respiratory muscle endurance, as assessed from the Maximum inspiratory pressure (PI_{max}) developed during progressive threshold loading, was greater in the athletes. This increased capacity of the athletes to cope with respiratory loads appeared to be a consequence of differences in the breathing pattern adopted during loaded breathing, rather than to any functional differences in the respiratory muscles themselves. These findings suggest that a long-term background of endurance training may induce 'sensory' rather than respiratory muscle adaptations (Eastwood *et al.*, 2001).

Highly trained marathon runners had similar respiratory muscle strength PI_{max} to non-athletic sedentary subjects, despite having long-term training backgrounds (Cordain *et al.*, 1990). This finding is in agreement with most other retrospective studies which have demonstrated that, compared to untrained subjects, similar values of PI_{max} are seen in highly trained skiers, competitive swimmers and long-distance runners (Cordain *et al.*, 1990). Also, prospective studies in healthy humans generally report no changes in PI_{max} after running or cycling training, although one study has documented improvements after swimming training (Clanton *et al.*, 1987).

In contrast to respiratory muscle strength, which was similar in the athletes and non-athletes, respiratory muscle endurance, as defined by the maximum threshold pressure achieved during progressive threshold loading, was greater in the athletes. This increased endurance is consistent with results from animal experiments that demonstrate increased activity of oxidative metabolism in the diaphragm following various types of endurance training. However, it should be noted that other studies have been unable to detect such changes in diaphragmatic oxidative capacity after endurance training (Okumoto *et al.*, 1996).

Lung function tests provide qualitative and quantitative evaluation of pulmonary function and are therefore of definitive value in the diagnosis and therapy of patients with cardiopulmonary disorders as well as those with obstructive and restrictive lung diseases (Robinson & Kjeldgaard, 1982). The parameters used to describe lung function are lung volumes and capacities. While the various lung volumes reflect the individual's ability to increase the depth of breathing, lung capacities are simply a combination of two or more lung volumes (Olufeyi *et al.*, 2002).

Pulmonary function, and its relationship to athletic performance, has been a controversial topic among exercise researchers. While some have claimed that respiratory muscle fatigue did not influence submaximal exercise performance (Johnson *et al.*, 1996).

Others have found that respiratory training actually enhanced exercise tolerance (Boutellier *et al.*, 1992). It has been shown that running improved pulmonary muscle strength in recreational runners (Robinson & Kjeldgaard, 1982). It has also been reported that respiratory muscle fatigue limited performance in high intensity activities such as sprinting (Johnson *et al.*, 1996).

While numerous respiratory assessments have been performed on endurance athletes, and pulmonary adaptations to exercise have been defined, the question remains as to what degree these pulmonary parameters are related to exercise

performance. Furthermore, can the assessment of pulmonary function values in endurance athletes help to predict performance in an endurance event?

In longer running events, such as a Marathon, pulmonary function has also been studied, but not in terms of performance in a race. In a study of 11 male Marathon runners, researchers found no significant differences between the runners' actual lung function scores and their age predicted scores in forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), total lung capacity (TLC), and functional residual capacity (FRC) values (Kaufmann, 1974). Another study of 101 male runners found that running did not improve inspiratory muscular strength or FVC values (Cordain, 1987).

There is limited research examining pulmonary function as a predictor of running performance. In one study, it was found that respiratory function was related to performance in a 26.2-mile Marathon run. A significant relationship was found between race finish time and residual volume (RV), FRC, TLC, RV/TLC ratio and FEV₁ (Cordain, 1987). In another study, pulmonary measurements were obtained on subjects before, during, and after a 17 Km race; however, these values were not analyzed in terms of individual performance in the race (Nava *et al.*, 1992).

1.3. Body Composition

Health practitioners universally agree that too much body fat is a serious health risk. Problems such as hypertension, elevated blood lipids (fats and cholesterol), diabetes mellitus, cardiovascular disease, respiratory dysfunction, gall bladder disease, and some joint diseases are all related to obesity. Also, some research suggests that excessive accumulation of fat at specific body sites may be an important health risk factor (Wilmore *et al.*, 1986). For instance, it appears that extra fat around the abdomen and waist is associated with higher risk of diabetes, heart disease, and hyperlipidemia. Individuals who accumulate a lot of fat around the waist (apple-shaped) are worse off than those who tend to accumulate fat in the thighs and

buttocks (pear-shaped). The apple-shaped pattern of fat deposition is more commonly seen in men; whereas women tend to be pear-shaped (Abe *et al.*, 1998).

The human body is composed of water, protein, minerals, and fat. A two-component model of body composition divides the body into a fat component and fat-free component. Body fat is the most variable constituent of the body. The total amount of body fat consists of essential fat and storage fat. Fat in the marrow of bones, in the heart, lungs, liver, spleen, kidneys, intestines, muscles, and lipid-rich tissues throughout the central nervous system is called essential fat, whereas fat that accumulates in adipose tissue is called storage fat. Essential fat is necessary for normal bodily functioning. The essential fat of women is higher than that of men because it includes sex-characteristic fat related to child-bearing. Storage fat is located around internal organs (internal storage fat) and directly beneath the skin (subcutaneous storage fat). It provides bodily protection and serves as an insulator to conserve body heat. The relationship between subcutaneous fat and internal fat may not be the same for all individuals and may fluctuate during the life cycle (Abe *et al.*, 1998).

Lean body mass represents the weight of one's muscles, bones, ligaments, tendons, and internal organs. Lean body mass differs from fat-free mass. Since there is some essential fat in the marrow of bones and internal organs, the lean body mass includes a small percentage of essential fat. However, with the two-component model of body composition, these sources of essential fat are estimated and subtracted from total body weight to obtain the fat-free mass. Practical methods of assessing body composition such as skinfolds, bioelectrical impedance analysis (BIA), and hydrostatic weighing are based on the two-component (fat and fat-free mass) model of body composition (Brodie, 1988).

1.3.1. Standards of Body Fat

Our bodies require essential fat because it serves as an important metabolic fuel for energy production and other normal bodily functions. Essential fat requirements are

< 5% for men and < 8% for women. Normal body functions may be disrupted if body fat falls below the minimum level recommended for men (5%) and women (15%). The body fat ranges for optimal health (18%-30% for women and 10%-25% for men) are based on several epidemiological studies of the general population (Jackson & Pollock, 1985).

Body fat percentages for optimal fitness and for athletes tend to be lower than optimal health values because excess fat may hinder physical performance and activity (Stewart, 2001). When prescribing ideal body fat for a client, one should use a range of values rather than a single value to account for individual differences. After age 20, it is expected at least 1-3% fat gain per decade up to the age of 60; thereafter fatness declines gradually. In addition, there is approximately a 2% loss of bone mass per decade in older populations. As a result of these changes, men and women who weigh the same at age 60 as they did at age 20 may actually have double the amount of body fat unless they have been physically active throughout their life (Wilmore *et al.*, 1986).

1.3.2. Assessing Body Composition

Some practical methods of measuring body composition include skinfolds, circumference (girth) measures, hydrostatic weighing, bioelectrical impedance, and near-infrared interactance. Other advanced methods include isotope dilution, neutron activation analysis, magnetic resonance imaging, and dual-energy x-ray absorptiometry (Brodie, 1988). Most practical methods have a 3% to 4% error factor in their prediction of body fat. That is, if you were measured at 20% body fat you could be as low as 17% or as high as 23% (Brodie, 1988). This error factor may be increased dramatically due to the lack of skill of the technician taking the measurements. The following sections will focus on three body fat measurement techniques that are often accessible to fitness professionals: hydrostatic weighing, bioelectrical impedance, and skinfolds.

1.3.2.1. Hydrostatic Weighing

Hydrostatic weighing is a valid, reliable and widely used technique for assessing body composition. It has been labeled the "Gold Standard" or criterion measure of body composition analysis. It is based on Archimedes' principle. This principle states that an object immersed in a fluid loses an amount of weight equivalent to the weight of the fluid which is displaced by the object's volume. This principle is applied to estimate the body volume and body density of individuals. Since fat has a lower density than muscle or bone, fatter individuals will have a lower total body density than leaner individuals (Stewart, 2001).

1.3.2.2. Bioelectrical Impedance Analysis

Your total body water constitutes the largest component (72%) of your fat-free body weight. Bioelectrical Impedance Analysis (BIA) is based on the fact that the body contains intracellular and extracellular fluids capable of electrical conduction. Safe, low-level current flows through these intracellular and extracellular fluids. Since your fat-free body weight contains much of your body's water and electrolytes, it is a better conductor of the electrical current than the fat, which contains very little water. So this technique is essentially an index of total body water, from which fat-free mass is estimated.

The popularity of the BIA method has grown significantly over the last few years because it is painless, quick, and easy to administer the test. To take the test, one lie on a testing table or floor and electrodes are attached to one's hands and feet. You do not feel a thing as the current passes through your body. Average time for administering this test is about 10 minutes (Heyward, 1991).

1.3.2.3. Skinfold Method

The skinfold method of measuring body fat is a practical, economical, and administratively feasible field technique for body composition analysis. It involves measuring the skinfold (subcutaneous fat) thickness at specific sites of the body.

Most equations use the sum of at least three skinfolds to estimate body density from which body fat may be calculated. Skinfold measurement does not require expensive equipment and it can be routinely incorporated into many health promotion settings. Skinfold technicians can be trained rather easily, but must practice on at least 50-100 clients before the skinfold technique is mastered (Rubiano *et al.*, 2000).

When using the skinfold method, it is assumed that the distribution of subcutaneous fat and internal fat is similar for all individuals. This assumption is not fully supported. It is now known that older subjects of the same body density and gender have proportionately less subcutaneous fat than their younger counterparts. There is considerable biological variation in the distribution of subcutaneous, intermuscular, intramuscular, and internal organ fat due to age, gender, and degree of fatness (Heyward, 1991). However, generalized skinfold equations have been developed to estimate the body fat of men and women varying greatly in age (18 to 61 yrs) and degree of body fatness (4 to 44% fat).

1.3.3. Accuracy of Skinfold Measurement

The accuracy of the skinfold method is dependent on the technician's skill as well as the type of caliper and the skinfold prediction equation used. When choosing a skinfold caliper for a health/fitness setting, the cost, durability, and degree of precision of the caliper are important considerations. Reasonably priced plastic calipers have a less precise measuring scale, and often provide variable pressure and a smaller range of measurement. Despite this, a number of researchers have reported only small differences between skinfolds measured with high quality calipers and plastic calipers for highly skilled technicians. However, plastic calipers are not recommended for use by untrained technicians.

To assure accuracy, the skinfold technician must follow standardized testing procedures:

1. Take all skinfold measurements on the right side of the body.

2. Carefully identify and mark the skinfold sites.
3. Place the thumb and index finger approximately 3 inches (8 cm) perpendicular to the skinfold, following the natural cleavage lines of the skin.
4. Grasp the skinfold firmly with the thumb and index finger just slightly less than 1/2 inch (1 cm) above the marked site to be measured.
5. Do not release the skinfold during the measurement.
6. Place the jaws of the caliper approximately 1/2 inch (1 cm) below the thumb and index finger. Always release the caliper jaw pressure slowly.
7. The skinfold measurement should be taken 4 seconds after the pressure is released.
8. Measure the skinfold to the nearest 1/2 to 1 mm.

One should take a minimum of two measurements at each site. It is advisable to take measurements in a rotational order rather than consecutive readings at the same site. If values differ by more than 1 mm, additional measurements are taken. The client's skin should be dry and free of any oils and lotions. Skinfold measurement should not be done immediately after exercise due to the shift of body fluid to the skin. Fortunately, the time of day or the phase of the menstrual cycle will have little effect on the skinfold measurement (Jackson & Pollock, 1985).

As with many skills, the more you practice the better you will become at measuring skinfolds. It always helps if you have another trained technician to compare your results. For severely obese clients (> 45% body fat) you will not be able to measure their skinfold thickness accurately. One alternative for obese clients would be to use fat-specific equations developed for the BIA method (Segal *et al.*, 1985).

1.3.4. Skinfold thicknesses and running performance

Early studies on general populations of subjects observed that physical performance measurements were negatively related to the amount of body fat and positively related to amounts of fat-free weight (Riendeau *et al.*, 1968). Studies have also indicated that appropriate sport-specific levels of relative fat and fat-free weight are beneficial to performance in most sports (Moffat *et al.*, 1984).

In spite of the introduction of new measurement techniques, such as dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA), the results of these studies suggest that surface anthropometry offers a valid field method of assessing body composition in athletes (Claessens *et al.*, 2000). Moreover, this examination can be easily performed in all circumstances. Differences in the distribution of subcutaneous fat around the body have already been reported (Stewart and Hannan, 2000). The above reports have described body fat values and some have reported the sum of skinfolds. However, it is notable that few studies have presented data for specific skinfold values in runners (Bosch *et al.*, 1990). Furthermore, despite an increasing amount of data from different scientific fields concerning important variables for performance capacity in distance running, to the best of our knowledge, very few studies have reported, the relationship between body fat or sum of skinfolds with running performance in homogeneous groups of elite athletes. Conley and Krahenbuhl (1980) reported no significant relationship between body fat or sum of skinfolds in an elite group of 10,000 m runners (average best time 32 min. 06 sec, Coefficient of Variance (CV)= 3.1%). Another study reported similar findings in a homogeneous group of elite 3000m steeplechase runners (average best time 8 min. 38 sec, CV = 1.2 %) (Kenney and Hudson 1985). Only occasionally have previous studies reported the expected significant associations in more heterogeneous groups (Tanaka *et al.* 1989). However, as far as our knowledge, no previous studies have reported correlations between specific skinfold measures and running performance. Therefore, the purpose of this study was to determine if the sum of skinfold thicknesses and specific single skinfold site were related to competitive running performance in male and female middle distance athletes.

1.4. Heart rate

In response to physical activity, HR increases in a predictable manner (Boulay *et al.*, 1997). In fact, the relationship between exercise intensity and HR is an extremely linear one—the greater the intensity, the higher the HR, with the relationship becoming more curvilinear (HR begins to plateau) at very high intensities (Wenger & Bell, 1986). Because of its predictability, one can use HR to prescribe running intensities.

It has been reported that the HR observed at slightly below the ventilatory threshold is a better indicator of the exercise intensity that can be sustained for prolonged periods than other physiological measures such as blood lactate concentration, work output, ventilation (liters of air breathed in or out per minute), and volume of expired carbon dioxide (Boulay, *et al.*, 1997). This is good news for the coach since determining athletes' heart rates is obviously much easier than determining their blood lactate concentrations or VO_2 max.

1.4.1. The Importance of Maximal Heart Rate

Measurement of heart rate is routinely used to assess the response of the heart to exercise, or the recovery from exercise, as well as to prescribe exercise intensities. Given that the increase in heart rate during incremental exercise mirrors the increase in cardiac output, maximal heart rate is often interpreted as the upper ceiling for an increase in central cardiovascular function. Indeed, research for the last 100 years has demonstrated that heart rate does in fact have a maximal value; one that cannot be surpassed despite continued increases in exercise intensity or training adaptations (Karvonen *et al.*, 1957).

HR is considered the standard for estimating exercise training intensity in the field based on its linear relationship to VO_2 max. The recommendations of the American College of Sports Medicine (ACSM) for moderate to hard relative exercise training intensities for cardiorespiratory fitness based on HR are 55%-90% of maximum

heart rate (HRmax) or 40%-85% of heart rate reserve (HRR) (American College of Sports Medicine, 1998). Although the use of heart rate to monitor exercise intensity is common practice, several drawbacks of this method has been noted. To be effective, an accurate determination of HR must be obtained, often requiring individuals to stop their activity temporarily to palpate their pulse rate (Dunbar *et al.*, 1994). In addition, many individuals experience difficulty palpating a pulse or accurately timing their pulse count which can result in subjective error. It has been suggested that individuals who use HR to monitor their exercise intensity may become overly preoccupied with the monitoring of their HR in order to avoid deviating from their targeted training range. This preoccupation and frequent pauses in activity to obtain an accurate HR are believed to have a negative effect on activity enjoyment and long-term compliance (White, 1977).

Use of a HR monitor would eliminate many of the problems associated with palpating a pulse and would provide an alternative means by which an individual could use HR as a guide to estimating exercise intensity. However, some individuals may perceive the need to wear a device during exercise as bothersome or the additional expense of a HR monitor a barrier to initiating an exercise regimen (Joseph *et al.*, 2001).

1.4.2. Heart rate variability and baroreceptor responsiveness

Chronic aerobic exercise elicits important cardio-protective adaptations that have been linked to decreased all-cause mortality (Blair *et al.*, 1989). Effects such as increased aerobic capacity (consequent to decreased peripheral vascular resistance and increased cardiac output and arteriovenous oxygen difference) are well documented (Blomqvist & Saltin, 1983), and characterize the physiological adaptation to endurance training. Surprisingly, despite important implications for cardiovascular health, the effects of aerobic exercise on autonomic cardiovascular regulation receive comparatively less attention. Effects such as significant resting

sinus bradycardia and increased heart rate variability are thought to be mediated through adaptations in autonomic cardiovascular control (Kenney, 1985).

Analyses of heart rate variability and baroreceptor responsiveness provide important information on exercise training effects. High heart rate variability is associated with increased parasympathetic cardiac control, and low heart rate variability is associated with decreased parasympathetic cardiac control and coronary heart disease (Hayano *et al.*, 1990). Heart rate variability was shown to be significantly higher in physically active, compared to non-physically active healthy humans (Dixon *et al.*, 1992). Conversely, decreased vagal outflow after myocardial infarction results in both decreased heart rate variability and baroreceptor responsiveness (Kleiger *et al.*, 1987). Although not consistently found, some have reported increased arterial baroreceptor sensitivity in active, compared to sedentary humans (Fiocchi *et al.*, 1985). Taken together, these data suggest that the autonomic nervous system adapts to chronic demands imposed by exercise or inactivity.

Many applied exercise physiology laboratories evaluate the effects of exercise on functional rather than autonomic adaptations despite being equipped to do both. Autonomic function tests, performed in conjunction with standard exercise tests, would more completely inform mechanisms of systemic-wide adaptations to exercise, and contribute importantly to the evaluation of physical fitness and cardiovascular health (Fiocchi *et al.*, 1985).

In this study we wanted to examine the accepted concept that additional adiposity contributes in a negative way to performance, Decline in VO_2max affect elite athletes running performance. Can the assessment of pulmonary function values in endurance athletes help to predict performance in an endurance event?

2. SIGNIFICANCE OF THE STUDY

The physiological characteristics and capabilities of the Olympic athlete developed from a combination of genetic predisposition and arduous physical training (Karlsson & Saltin, 1971). While it is our belief that these physiological factors represent some of the most important determinants of athletic success, it should be acknowledged that biomechanical, psychological, tactical, nutritional and environmental factors also have the potential to impact upon performance to a greater or lesser extent.

There are clearly a large number of both physiological and non-physiological factors that can determine the outcome of a running race such that the relationship between an athlete's physiological capacities and their likelihood of success is not straightforward (Fukuba & Whipp, 1999). Therefore, knowledge of the physiological demands and limitations to performance enables the exercise physiologist to assist in the construction of appropriate training programmes for athletes specializing in different events and to advise athletes on other (legal) performance enhancing strategies.

Identification of several variables is believed to be necessary for successful performance test in several sports. There is no adequate study carried out so far to analyze the affiliation between pulmonary parameters, VO_2 max, body fat percentage, heart rate and running performance in Ethiopia. This study evaluated the relationship of those parameters with running performance.

Sport science technology for performance testing is not well studied in Ethiopia. This study may offer starting inspiration for subsequent scientific study on sport science.

3. OBJECTIVES OF THE STUDY

3.1. General Objective

- To assess the influence of Skinfold thickness and some selected cardiopulmonary parameters in middle distance (800 and 1500 meters) running performance in male and female athletes.

3.2. Specific Objectives

- To determine if selected measures of pulmonary function correlate with middle distance running performance.
- To find out the correlation between selected cardiopulmonary parameters such as heart rate, and VO_2 max with middle distance athletic performance.
- To determine if skinfold thickness was related to competitive running performance in male and female middle distance athletes.

4. SUBJECTS AND METHODS

4.1. Study Design:

The study design appropriate for this study is cross-sectional. Selected study subjects have different performance (race run time). Their performances were obtained after consulting the official rankings recorded by Ethiopian Athletics Federation. The best performance for an athlete who involved in two events (800 and 1500 meters) was established using Scoring Tables of the International Amateur Athletic Federation (IAAF) (Spiriev, 1998). With the introduction of these tables the run time in athletics were converted to a number of points (typically between 0 and 1400). These tables assign a definite score to each performance (run time), which enable us to compare performances in different events for the same or different athletes. The person who took cardiopulmonary function and skinfold thickness measurements was blind about the performance of the athletes.

4.2. Study Setting:

Federal Sport Health Center Laboratory, National Olympic Gymnasium, Addis Ababa University, Faculty of Medicine Laboratories, and measuring instruments in those laboratories.

4.3. Study Subjects

Twenty volunteer elite middle distance runners participated in the study. All of them are member of Ethiopian National team. There were two groups of experimental subjects, elite middle distance male and female runners (since lung function parameters and VO_{2max} , are usually slightly lower in females than in males). The mean (Standard Deviation) of age is 20.42 (2.58) years for males and 19.67 (2.87) years for females, height is 178.25 (5.24) cm for males and 167.08 (5.49) cm for females, weight is 62.67 (5.00) kg for males and 49.25 (4.65) kg for females, Body Mass Index (BMI) is 19.70 (0.95) kg/m^2 for males and 17.78 (1.43) kg/m^2 for females. Subjects were healthy and nonsmokers.

4.4. Procedures

Health status of study subjects were evaluated by sport physician for any illness or disease that precluding them from participation in maximum aerobic capacity and pulmonary function testing. The objective of the study was explained to all study subjects. Then after, complete instruction was given on the testing procedure before signing a written informed consent.

4.4.1. Determination of VO_{2max}

Initially, subjects were familiarized with the experimental apparatus, which consisted of an electronically braked treadmill (Technogym HC 1200, Italy) and chest belt sensor (cardiotester) (Technogym, Italy). All subjects were familiarized with the test protocol prior to carrying out the actual test.

The maximal rate of oxygen consumption was determined using a continuous, incremental exercise protocol conducted on an electronically braked treadmill. Prior to exercise, subject's height without shoe nearest to 0.1 cm (Anthropometric Rod, Giant Germany), weight with minimum clothing and without shoe, nearest to 0.1 kg (Detecto Scales Inc. Brooklyn, N.Y. U.S.A) were measured and Body Mass Index

(BMI) was calculated using standard formula ($BMI = \text{weight (kg)} / \text{height (m)}^2$). The cardiometer belt was put on in contact with the skin. The belt was positioned just below the pectorals. The rubber contact was moistened with water before putting the belt on. The belt was adjusted so that it was tight enough to remain in stable position during exercise. The test administrator entered height, weight, sex and age data prior to the start of the test. The standard continuous graded exercise test protocol was given according to Astrand Protocol on treadmill. During the test, the speed and inclination of the treadmill was increased at a constant rate. After 3min of warming up with 10 km/hr and 0% slope, the inclination was increased by 2.5% in every 2 minutes. The initial speed of the incremental test performed on the treadmill was 14 km/h. In the test, the protocol was continued till the subject expressed his inability to continue further or attainment of the predicted maximal heart rate (age predicted maximum heart rate = $220 - \text{age}$) (Teresa *et al.*, 2004). The $VO_2\text{max}$ score was calculated by treadmill from five factors: age, heart rate, sex, weight and height. The program calculates and provides $VO_2\text{max}$ in ml/kg/min. Subjects visited the laboratory on two occasions. During the first visit, subject's performed an incremental exercise test to exhaustion on an electrically braked treadmill. The purpose of this first test was to familiarize the subjects to the testing and to allow optimization of the test protocol on the second visit. Each study subjects attended both sessions at the same place and time of day. All testing was performed with the subjects wearing t-shirts and shorts.

Heart rates were recorded using heart rate monitor on the treadmill and chest belt sensor during these tests. Heart rate was determined during the last 15 seconds of each level from suitably placed cardiometer. Resting heart rate was measured by using ECG machine (Fukuda Denshi Co. Ltd, Tokyo, Japan) prior to incremental exercise testing.

4.4.2. Determination of Pulmonary Variables

A pulmonary profile was obtained on each subject, which includes measures of Vital capacity (VC), Forced Expiratory Vital Capacity (FVC), Peak Inspiratory

Flow (PIF), Peak Expiratory Flow (PEF), Forced Expiratory Volume after 1 sec (FEV₁), FEV₁ in % of maximal vital capacity, Maximal expiratory flow at 25% of maximal VC (MEF25), Maximal expiratory flow at 50% of maximal VC (MEF50), Maximal expiratory flow at 75% of maximal VC (MEF75), Mean maximal expiratory flow between 25% and 75% of FVC (MMEF), Forced Expiratory volume after 6 seconds (FEV6). Subjects were asked to refrain from exercise for eight hours prior to testing since FVC values have been shown to decrease immediately following endurance exercise (Maron *et al.*, 1979).

Spirometric measurements were obtained from a SpiroPro pocket sized spirometer made by JAEGER, Germany. As important correction factors are calculated from ambient conditions; temperature, humidity and barometric pressure were checked. Because the predicted values are calculated from subject's anthropometric data, the subject's anthropometric data (sex, date of birth, height, and weight) were entered before recording starts.

All procedures were explained to the subjects prior to testing, and subjects received verbal encouragement throughout the testing. Usage of a disinfected pneumotach before starting the measurement was verified.

Subjects were seated and wearing nose clips during data collection. The test administrator checked the lips seal around the mouthpiece. Each subject faced the spirometer and performed a normal breathing. The test administrator informed the subject to inhale to maximum followed by a forceful exhalation into the tube until all air was expelled. The subject then performed a maximal inhalation to complete the maneuver. The best value of two trials was recorded for each subject. Calibration of the spirometer and all testing protocols was performed as outlined in the instruction manual.

4.4.3. Determination of Body fat Composition

Body fat content was estimated by measurements of skinfold thickness at four sites using a Harpenden caliper (British Indicators Ltd., St. Albans, UK), having an

accuracy of 0.2 mm. The skinfold sites were biceps, triceps, subscapula, and suprailiac. The landmarks were identified and measured according to Wilmore and Behnke (Wilmore & Behnke, 1969). The skinfold sites were marked with a surgical marking pen. All skinfolds were taken on the right side of the body, and the same person took a minimum of two measurements at each site in a rotational order. The average of two measurements within 10% of each other was recorded as the skin fold thickness for that site. Body fat percentages were determined according to Siri equation (Siri, 1956).

The skinfold caliper, electrodes of ECG machine, the belt of Cardiotester as well as the subject's skin were cleansed with a gauze pad and rubbing alcohol.

5. STATISTICAL ANALYSIS

Descriptive statistics was calculated for both male and female subjects for all variables and values are expressed as mean \pm Standard Deviation (SD). To determine if pulmonary function tests, VO₂max, heart rate and sum of four skinfold thicknesses serve as predictors of running performance, Pearson correlation analysis was performed on those variables based on the athlete's current performance. SPSS software version 12 was used for data analysis. Statistical significance was fixed at the $p < 0.05$ level.

6. ETHICAL CONSIDERATION

Ethical clearance was obtained from AAU-FM. Informed consent was obtained from the study participants prior to the interview and tests of the variables. Also the purpose of the study was explained to each of the study participants prior to commencement of various testes.

7. RESULTS

7.1. Anthropometric Measurements

The physical characteristics and performance of the athletes are summarized in Table 1.

Table 1 - Physical characteristics and performance of the male and female runners

	Males			Females		
	Min.	Max.	Mean \pm SD	Min.	Max.	Mean \pm SD
Age (years)	18	26	20.42 \pm 2.58	18	26	19.67 \pm 2.87
Weight (kg)	52	68	62.67 \pm 5.00	41	57	49.25 \pm 4.65
Height (cm)	165	183	178.25 \pm 5.24	157	178	167.08 \pm 5.49
BMI (kg/m ²)	17.63	20.90	19.70 \pm 0.95	14.53	19.99	17.78 \pm 1.43
Performance (IAAF scoring)	976	1113	1040.92 CV = 4.12 %	1008	1093	1050.75 CV = 2.79%

CV = Coefficient of variation

There was no significant statistical difference in age of male and female athletes. The female athletes were significantly shorter and lighter ($P < 0.01$) and possessed lower BMI ($P < 0.05$) than the males. According to WHO cut off points there is mild thinness in female athletes but average male athletes BMI fall in normal range (Table 2).

Table 2: The International Classification of adult underweight, overweight and obesity according to BMI

Classification	BMI (kg/m ²)	
	Principal cut-off points	Additional cut-off points
Underweight	<18.50	<18.50
Severe thinness	<16.00	<16.00
Moderate thinness	16.00 - 16.99	16.00 - 16.99
Mild thinness	17.00 - 18.49	17.00 - 18.49
Normal range	18.50 - 24.99	18.50 - 22.99
		23.00 - 24.99
Overweight	≥25.00	≥25.00

Pre-obese	25.00 - 29.99	25.00 - 27.49
		27.50 - 29.99
Obese	≥30.00	≥30.00
Obese class I	30.00 - 34.99	30.00 - 32.49
		32.50 - 34.99
Obese class II	35.00 - 39.99	35.00 - 37.49
		37.50 - 39.99
Obese class III	≥40.00	≥40.00

Source: Adapted from WHO 1995, WHO 2000 and WHO 2004.

7.2. Skinfold Thickness Measurements

Skinfolds measurements of the male and female athletes are summarized in Table 3

	Males		Females	
	Range	Mean ±SD	Range	Mean ±SD
Biceps skin fold (mm)	3-5	4.00 ±0.71	4-7	5.00 ±1.16
Triceps skin fold (mm)	5-8	6.33 ±1.00	7-12	8.40 ±1.43

	Sub-scapular skin fold (mm)	6-8	7.22 ±0.67	6-9	6.90 ±0.99	
	Supra-iliac skin fold (mm)	5-7	5.67 ±0.71	5-8	7.00 ±1.16	
Females	Sum of skinfolds (mm)	Skin fold thickness			Sum of	Body Fat
		Biceps	Triceps	Sub-	Supra-	Percentage
		20-27	23.22 ±2.22	24-35	27.30 ±1.03	
	Fat percentage (% body weight)	8.10-10.50	9.17 ±1.26	16.80-20.50	18.18 ±1.63	
IAAF	Pearson	-0.57	-0.51	-0.63*	-0.75*	-0.77**

Table 3 - Descriptive statistics of skinfolds measurement of the male and female athletes

In female runners the sum of four skinfolds was significantly greater compared to male runners ($P < 0.05$).

The relationship between skinfold measurements and IAAF score for the male and female runners is shown in Table 4.

Table 4 - Association between skinfold values, sum of skinfolds and IAAF scoring in male and female athletes

scoring	Correlation						
	P values	0.19	0.127	0.047	0.012	0.008	0.002
Males							
IAAF scoring	Pearson Correlation	-0.17	-0.58	-0.67*	-0.79**	-0.80**	-0.63*
	P values	0.671	0.098	0.046	0.010	0.010	0.047

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

In male athletes skinfold measurement at biceps and triceps were not significantly associated with running performance. Significant negative correlations were observed between skinfold measurement at sub-scapular ($r = -0.676$, $P = 0.046$), supra-iliac ($r = -0.798$, $P = 0.01$) and running performance. High negative correlation were found between sum of four skinfold measures and IAAF score ($r = -0.800$, $P = 0.010$).

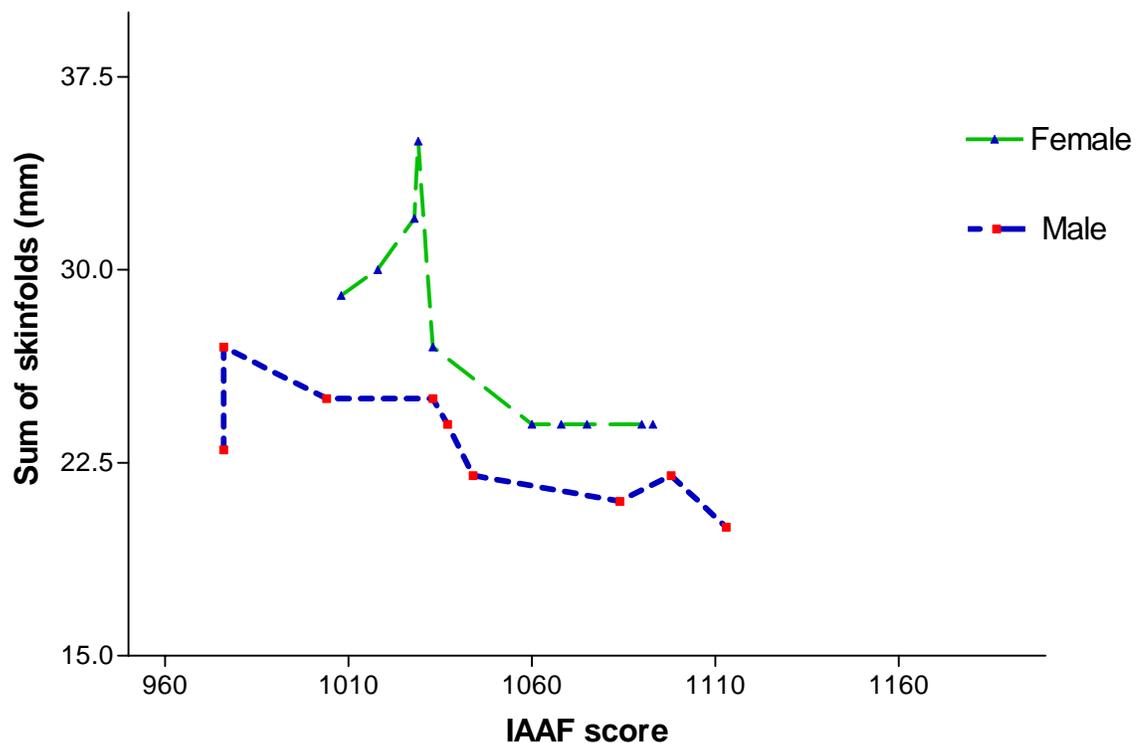


Figure 1 - Association between sum of four skinfold measurements and running performance in male and female athletes

In the female runners IAAF score was not significantly associated with skinfold measurement at biceps and triceps. High negative correlations were observed between skinfolds measurement at sub-scapular ($r = -0.639$, $P = 0.047$), supra-iliac ($r = -0.751$, $P = 0.012$), sum of four skinfolds measurement ($r = -0.778$, $P = 0.008$), body fat percentage ($r = -0.840$, $P = 0.002$) and running performance.

7.3. Heart Rate

Table 5 - Descriptive Statistics of heart rate at different level of treadmill testing for male and female athletes

	Males		Females	
	Range	Mean \pm SD	Range	Mean \pm SD
Resting Heart Rate	64-70	66.36 \pm 2.29	64-70	68.80 \pm 1.93
Heart Rate during warming up (V = 10 km/hr, S = 0%)	90-129	113.27 \pm 12.69	114-161	128.30 \pm 17.75
Heart Rate at level 1 (V = 14 km/hr, S = 0%)	128-172	147.55 \pm 12.38	124-174	151.50 \pm 18.05
Heart Rate at level 2 (V = 14 km/hr, S = 2.5%)	147-178	161.73 \pm 8.32	144-185	161.80 \pm 13.46
Heart Rate at level 3 (V = 14 km/hr, S = 5.0%)	158-178	169.64 \pm 5.48	153-188	170.80 \pm 11.90

Heart Rate at level 4 (V = 14 km/hr, S = 7.5%)	165-191	176.73 ± 6.72	165-196	179.90 ± 9.76
Heart Rate at level 5 (V = 14 km/hr, S = 10%)	165-195	180.09 ± 7.36	170-200	189.50 ± 9.62
Heart Rate at level 6 (V = 14 km/hr, S = 12.5%)	165-200	181.82 ± 8.92		
% Sub-Maximal HR	82-100	91.36 ± 4.72	85-103	94.90 ± 5.34

V = Treadmill Velocity

S = Inclination of the treadmill

In male athletes the heart rates required to run at a treadmill velocity of 10km/hr and 0% inclination ranged from 90 to 129 beats per minute, which correspond to 45 and 64 % of the individual's maximal heart rate, respectively. The heart rates required to run at a treadmill velocity of 14km/hr and 12.5% inclination ranged from 165 to 200 beats per minute, which correspond to 82 and 100 % of the individual's maximal heart rate, respectively.

In female athletes the heart rates required to run at a treadmill velocity of 10km/hr and 0% inclination ranged from 114 to 161 beats per minute, which correspond to 57 and 81 % of the individual's maximal heart rate, respectively. The heart rates required to run at a treadmill velocity of 14km/hr and 10% inclination ranged from 170 to 200 beats per minute, which correspond to 85 and 100 % of the individual's maximal heart rate, respectively.

Table 6 - Pearson Correlation between heart rate and IAAF scoring for male and female athletes

	Pearson correlation coefficient	
	Males	Females
Resting Heart Rate	-0.335	-0.144
Heart Rate during warming up	-0.252	-0.210
Heart Rate at level 1	-0.345	-0.244
Heart Rate at level 2	-0.523*	-0.408

Heart Rate at level 3	-0.627*	-0.633*
Heart Rate at level 4	-0.929**	-0.947**
Heart Rate at level 5	-0.907**	-0.899**
Heart Rate at level 6	-0.896**	
% Maximum HR	-0.865**	-0.843**

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Figure 2 provides the relationship, for each individual, between sub-maximum heart rate and running performance in male and female athletes. This value of maximal heart rate was significantly related to IAAF score as shown in Table 6.

The Pearson correlation analysis showed that there was a significant negative correlation between IAAF score and Heart Rate at level 2 and 3 at 0.05 level of significance in male runners ($r = -0.523$ and $r = -0.627$ respectively), and there was also strong negative correlation between heart rate at level 4, 5 and 6 and performance at 0.01 level of significance ($r = -0.929$, $r = -0.907$ and $r = -0.896$) respectively.

The Pearson correlation analysis also showed that there was a significant negative correlation between IAAF score and Percent Maximum Heart Rate ($\%HR_{max}$) at 0.01 level of significance ($r = -0.865$) in male runners.

In females runners, the relationship between performance and heart rate at level 3, 4 and 5 was significant ($r = -0.633$, $P < 0.05$; $r = -0.899$, $P < 0.01$; $r = -0.947$, $P < 0.01$ respectively).

The Pearson correlation analysis also showed that there was a significant negative correlation between IAAF score and Percent Maximum Heart Rate ($\%HR_{max}$) at 0.01 level of significance in female athletes ($r = -0.865$).

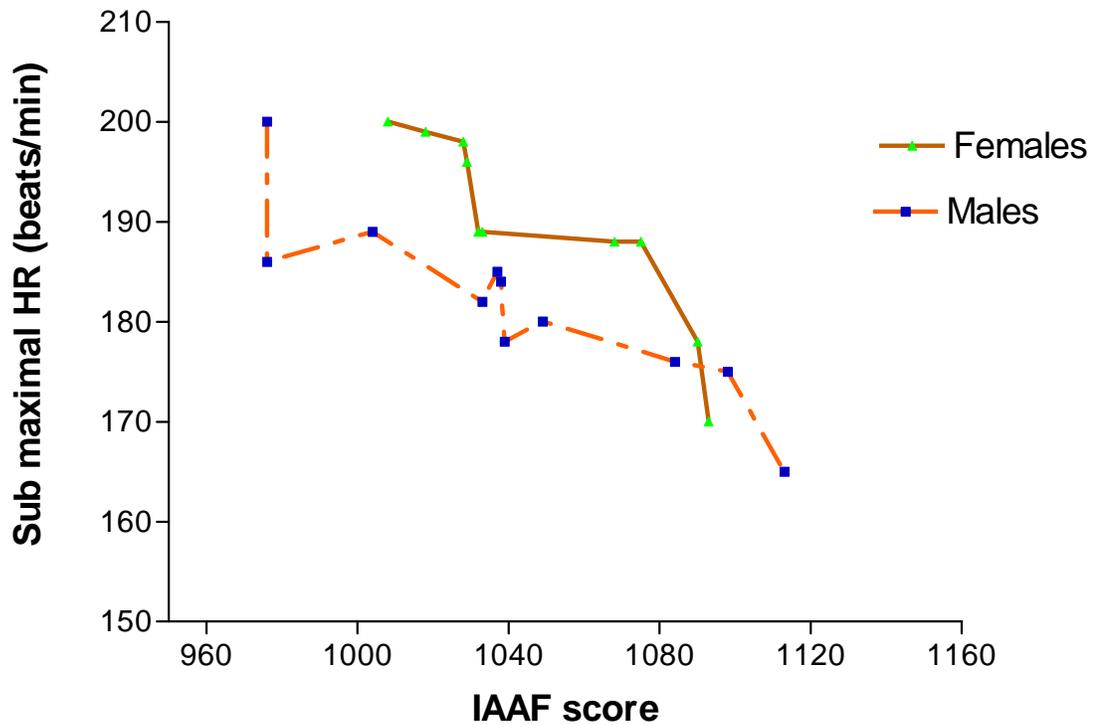


Figure 2 - The relationship between sub-maximal heart rate and performance for each subject in male and female athletes

7.4. Measurement of Maximal O₂ uptake

Table 7 - Descriptive Statistics of maximum O₂ uptake

VO ₂ max(ml/min/kg)			
	Min.	Max.	Mean (SD)
Males	56.00	71.00	67.18 (4.62)
Females	48.00	61.00	54.40 (5.32)
VO ₂ max (liters/min)			
	Min.	Max.	Mean (SD)
Males	3.46	4.83	4.19 (0.47)
Females	2.06	3.25	2.73 (0.40)

The maximum oxygen uptake (measured as ml/min/kg) of female runners was significantly lower than that of male runners ($P < 0.05$).

Table 8 - Pearson Correlation between maximum aerobic capacity and IAAF scoring

		Males	Females
VO ₂ max(ml/min/kg)	Pearson Correlation	0.805**	0.859**
	P value	0.003	0.001
VO ₂ max (liters/min)	Pearson Correlation	0.480	0.775**
	P value	0.135	0.008

** Correlation is significant at the 0.01 level (2-tailed).

Figure 3 shows that VO₂max increases with the IAAF scores in both male and female athletes. As shown in Table 8 VO₂max (measured as ml/min/kg) was significantly positively correlated with running performance in male runners ($r = 0.805$, $P = 0.003$). Correlation between VO₂max (measured as ml/min/kg and liters/min) and IAAF score was also highly significant in the female athletes ($r = 0.859$, $P = 0.001$).

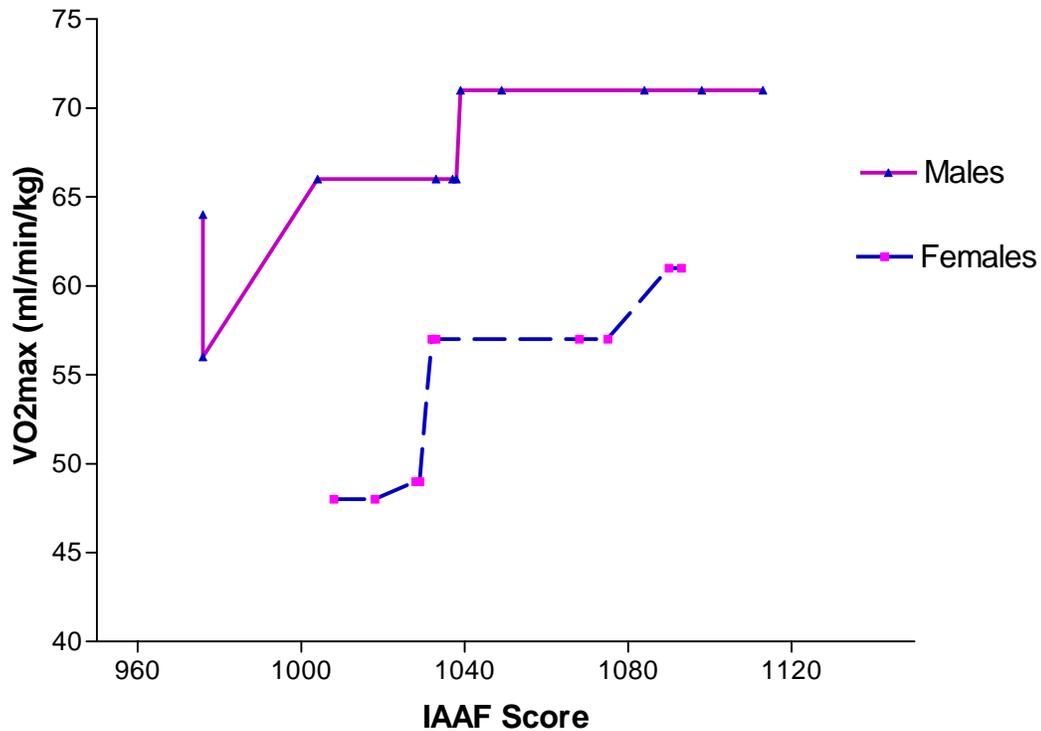


Figure 3 - Values of VO₂max as a function of IAAF scores for each individual in male and female runners

7.5. Pulmonary Function Measurements

Results of Spirometry testing are shown in Table 11. It was noted that for VC, FVC, FEV₁, and FEV₁% VC, all subjects had values higher than predicted norms for their age, height, and gender. We obtained percent predicted norms for their age, height, and gender for each variable from the Spirometer. But values for PIF were 70.4% of predicted value for women and 80.2% for men. And values of PEF were 93% of predicted value for men and 90% for women.

For FVC, the male subjects were at 103.6% of their predicted values, whereas the female subjects were at 111.4% of predicted values. The women performed at 110.6% of predicted values for FEV₁, while the men performed at 107.0% of predicted values.

The smallest difference between actual and predicted scores was noted in FEV₁% VC values for women. The actual scores were 102.3% of predicted scores. For the men, actual FEV₁% VC scores were 110.3% of predicted scores.

Table 9 - Descriptive Statistics of Pulmonary Parameters

	Females			Males		
	Min.	Max.	Mean ± SD	Min.	Max.	Mean ±SD
VC	3.43	4.29	3.86 ± 0.30	4.60	5.71	5.17 ± 0.40
FVC	3.44	5.78	4.65 ± 0.80	4.86	5.98	5.41 ± 0.44
FEV ₁	3.36	5.60	4.08 ± 0.73	4.16	5.32	4.73 ± 0.43
FEV ₁ % VC	79.00	98.00	88.18 ± 6.90	80.00	96.00	91.56 ± 5.20
PEF	6.19	7.57	6.95 ± 0.53	6.65	8.98	8.03 ± 0.78
MEF25	3.48	4.50	3.96 ± 0.30	6.08	8.64	7.01 ± 0.83
MEF50	2.93	5.45	3.97 ± 0.87	5.16	7.98	5.83 ± 0.91
MEF75	2.00	3.51	2.81 ± 0.56	1.88	5.95	4.33 ± 1.06
MMEF	2.40	3.99	3.29 ± 0.54	5.44	7.53	6.34 ± 0.58
PIF	4.74	5.51	5.14 ± 2.00	5.92	7.93	6.82 ± 0.75

It was noted that PIF values for men and women were below age predicted norms. Actual mean scores for men were 6.82 L/sec. and predicted values were 8.50 L/sec with a difference of 1.68 L/sec. Actual mean scores for women were 5.14 L/sec and predicted values were 7.35 L/sec with a difference of 2.2 L/sec. It was noted that PEF values for men and women were below age predicted norms. Actual mean scores for men were 8.03 L/sec. and predicted values were 8.64 L/sec with a difference of 0.61 L/sec. Actual mean scores for women were 6.95 L/sec and predicted values were 7.70 L/sec with a difference of 0.76 L/sec.

Table 10 consists of the Pearson correlation coefficients of all independent variables with 800 and 1500meters run time. All variables used in correlation analysis were corrected by height. IAAF score was significantly positively correlated ($p < 0.05$) with the following variables in the male athletes: VC ($r = 0.66$), FVC ($r = 0.70$), and FEV₁ ($r = 0.63$).

In female athletes running performance was also significantly positively correlated with VC ($r = 0.65$) at 0.05 level of significance and highly correlated with FVC ($r = 0.85$) and FEV₁ ($r = 0.80$) at 0.01 level of significance.

Table 10 - Pearson Correlation between Pulmonary parameters and IAAF scoring

	Females	Males
VC	0.66*	0.65*
FVC	0.85**	0.70*
FEV ₁	0.80**	0.63*
FEV ₁ % VC	-0.03	0.05
PEF	0.43	0.58
MEF ₂₅	0.37	0.57
MEF ₅₀	0.53	0.62
MEF ₇₅	0.11	0.61
MMEF	0.22	0.51
PIF	0.53	0.56

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

8. DISCUSSION

A variety of physiological variables have been found to be of importance for the performance level in middle-distance running events. The majority of research relating physiological parameters to middle-distance running performance has dealt primarily with well-trained males heterogeneous ($CV > 5\%$) in performance (Legaz *et al.* 2007).

8.1. Skinfold

This study tried to investigate association between sum of four skinfolds thickness, each skinfold thickness and running performance in male and female middle distance athletes with different running performance. In particular, we wanted to examine the accepted concept that additional adiposity contributes in a negative way to performance.

In the present study, a sum of four skinfolds and percent body fat have been found to be associated with 800 and 1500meters running performance. This study showed that a lower sum of skinfolds and percent body fat facilitates the individual's running performance and a reduction to minimal optimal levels would seem desirable. Despite the fact that it is very risky to compare skinfolds values from different studies, given the variability in technique, equipment and site location, the sum of skinfolds of these athletes is significantly lower than that reported among groups of runners showing lower performances (Bosch *et al.*, 1990). This leanness is probably the result of both a genetic predisposition to leanness and probably higher volume of training in our runners.

It is important to point out that the majority of studies regarding association between percent fat and/or sum of skinfolds with running performance were based on heterogeneous samples. Hartung and Squires (1982) found a significant correlation between percent fat and marathon race time, (average best time 3 hours 26 min. 54 s, CV = 17.5%, $r = -0.38$); Ready (1984) established that body fat in 10 top-class middle-distance female runners was significantly correlated with provincial ranking, $r = -0.98$. In a study of sixty male distance runners, classified into three homogeneous groups in accordance with their best performance capabilities in 10 km races, Bale and his colleagues (1986) observed that the best runners showed significantly smaller skinfolds values. Similar study also reported a weak but statistically significant association between percent fat and 10000 m race time in female runners (average best time 38 min. 26.7 s, CV = 6.8%, $r = 0.33$) (Tanaka *et al.* 1989). Kenney and Hodgson (1985) observed no significant associations between percent fat and 3000 m steeplechase race time (average best time 8 min. 38 s, CV = 1.2%) and 5000 m race time (average best time 14 min. 05 s, CV = 0.6%). The higher level of performance and the lack of variability exhibited by these runners may be the most likely explanations for these low correlations.

To our knowledge, no literature is available regarding the association between each skinfold measurement and running performance. In this study, the CV of performance in both male and female runners is small and thus high correlation between each skinfold value and running performance is not expected. However, as shown in Tables 4, although performance was not influenced by biceps and triceps skinfolds, there were negative correlations between Sub-scapular and Supra-iliac skinfolds and running performance in male and female athletes. An excess of subcutaneous adipose tissue means a greater muscular effort is required to accelerate the legs and therefore, increased energy expenditure is required.

Previous studies highlight the importance of the assessment of skinfolds values. Graves and his colleagues (1987) found that, out of 27 anthropometric variables studied, only the medial calf skinfold value were statistically lower among a group of 15 elite female distance runners compared to 12 good runners. Bosch and his colleagues (1990) found significant differences in triceps, front thigh and medial calf skinfolds when black and white runners were compared. It is probable that lower extremity skinfolds facilitate an individual's running performance due to the fact that a higher relative body mass quantity distributed in the lower limbs would most likely require a bigger muscular effort to accelerate the legs while running. Also, in theory, energy expenditure would be higher. It is important to point out that the relationship between sub-scapular and supra-iliac skinfolds with running performance observed in the present study cannot exclude the possibility that some athletes excelled in an event. Therefore, the association between performance and skinfolds thicknesses described in our investigation may not reflect entirely a causal effect of athletic training on skinfolds. It remains to be determined if this association is determined genetically, by diet and intensive training, or by a combination of these factors. Therefore, longitudinal study to assess the influence of skinfolds thicknesses on performance is recommended.

8.2. Heart rate

Despite the possible effect of some non-physiological variables on HR and the fact that HR measurement is an indirect estimation of the cardiorespiratory responses, it is widely admitted that this variable is a good indicator of exercise performance. It has been shown that the HR expressed as a percentage of HR_{max} is a good indicator of exercise performance than the absolute HR value (Gilman and Wells, 1993). At submaximal workloads, a higher HR has been associated with the additional oxygen cost and anaerobic energy resulting from more inefficient work (Legaz *et al.*, 2006). Possibly, a lower submaximal heart rate can be associated with the higher Left Ventricular Diameter (LVD) found in the better runners (Legaz *et al.*, 2006). Higher LVD increased, in submaximal exercise, the capacity of the athlete to pump unusually large volumes of blood and oxygen to the muscles with a lower HR. This allows the muscles to achieve higher work rates before they outstrip the available oxygen supply, developing skeletal muscle anaerobiosis. Furthermore, a higher LVD can determine a lower heart rate in processes such as the removal of products derived from metabolism, and the thermoregulation (Legaz *et al.*, 2006). However, researches have paid little attention to the heart rate measured during an incremental treadmill test (Legaz *et al.*, 2006). The present study showed that there was a negative correlation between the IAAF score and heart rate measured during an incremental treadmill test in both male and female athletes. That means a positive correlation exist between the race run time and HR. To our knowledge, only three studies have reported the association between the heart rate measured during an incremental treadmill test and running performance (Costill *et al.*, 1973, Pate *et al.*, 1987, Legaz *et al.*, 2006). Like the present study these authors found high positive correlations between submaximal heart rate and race run time in a homogeneous group of marathon (Legaz *et al.*, 2006) in heterogeneous groups of middle distance (Pate *et al.*, 1987) and long distance runners (Costill *et al.*, 1973).

8.3. Maximum Oxygen Uptake

This part of the present study shows VO_{2max} values of male and female runners of different performance levels (IAAF scores) to give other researchers and coaches a valid reference to compare their athletes and a better understanding of VO_{2max} as a performance determinant. Results of the present study showed that, in runners with

the different performance level in 800 and 1500meters, the VO_2 max increase progressively with running performance (IAAF score).

The energy for 800-m running is available in over 60–70% of the aerobic metabolism (Duffield *et al.*, 2005). Nevertheless, the success in 800 m running depends on an integrative contribution from aerobic and anaerobic systems (Spencer & Gastin, 2001). Thus, a successful runner may be capable of running at a relatively rapid speed while obtaining much of the necessary energy from the aerobic system, relying on a high VO_2 max and conversely, other runners can obtain the same performance sustaining major contributions from the anaerobic system while having lower VO_2 max. Aerobic metabolism contributes the greatest part of energy for 1500-m running (77–86%) (Spencer & Gastin, 2001). In agreement with the previous studies, for our athletes the race performance on this distance is greater for greater VO_2 max; therefore the aerobic metabolism is more important for the success in these distances.

The involvement of the aerobic metabolism in the energy production is progressively increases from the 100 m to 1500 and 3000 m event. Therefore, it will be necessary that the VO_2 max is increased at the same rate. This supposition has been confirmed by Legaz and his colleagues (2007). Hence, if an athlete wants to cover a distance superior to the appropriate one according to her/his physiologic condition and to achieve an equivalent performance in order to keep the same speed as a top-level athlete in that distance, he/she would have to achieve the greatest energy production of anaerobic way from the first seconds of the event. This would cause an excessively quick accumulation of lactate in muscle and blood, having to reduce the speed drastically before finishing the competition.

Many researchers have attempted to explain how the variable VO_2 max can account for the vast majority of the variance in distance running performances. Similar to the present study a significant relationship between VO_2 max and running performance has been found in heterogeneous groups of runners. Nevertheless,

different studies indicated that VO_2max was found not to be a good predictor of performance in more homogeneous groups of runners, for example Bassett and Howley (2000) have reported that VO_2max does not relate to endurance performance within groups that are homogeneous in terms of performance. Other studies highlighted a significant relationship between VO_2max and middle and long distance running performance in homogeneous groups (Billat *et al.*, 2001). A critical point of many of these studies concerns the interval of several weeks or months that elapsed from the measurement of the VO_2max to the completion of the best track performance of the subject. Such delays are too long to obtain a considerable amount of meaningful performance data. These results were based on cross-sectional studies and, as such, the relationships were influenced by interindividual factors. This means that it could not be ascertained from these studies whether the VO_2max in athletes was due to physical training or, conversely, if the propensity to athletic activity was secondary to the genetic predisposition to a high VO_2max . Longitudinal studies showed that regularly performed aerobic exercise results in significant improvements in VO_2max in sedentary subjects, in runners with low competitive levels and in elite runners during short term training and during one training season (Wilcox & Bulbulian, 1982).

8.4. Pulmonary functions

Measures of respiratory muscle strength and endurance, as well as selected lung capacities, were examined for correlation with performance in 800 and 1500 meters race. In the present study, significant negative relationships were found in 800 and 1500 meters race times and values for VC, FVC and FEV_1 , in female and male runners. This suggested that higher lung volumes are negatively correlated with faster run times. There is one study in which running performance was correlated with pulmonary function measures (Kaufmann *et al.*, 1974). In that study, 11 marathon runners were measured for FVC, FEV_1 , TLC, FRC, RV, and RV/TLC ratio following a 26.2-mile marathon race. A significant negative relationship was found between marathon race finish and measures of FRC, RV, and RV/TLC ratio. This result suggests higher lung volumes are negatively related to running times.

Research on pulmonary function and endurance event performance has yielded conflicting results. For example, Griffiths and McConnell (2007) reported inspiratory muscle training was largely associated with an improvement in rowing performance being accompanied by improvements in factors such as heart rate, and effort perception. In contrast, despite improvements in maximum expiratory pressure (PE_{max}) there were no discernable changes in any of the performance or physiological parameters measured in response to expiratory muscle training. Expiratory muscle training does not appear to result in any improvements in rowing performance

It was further reported that inspiratory muscle training improved cycling time-trial performance to a greater extent than that observed in a sham training placebo group, and that this was accompanied by an increase in anaerobic work capacity (Johnson *et al.*, 2007). Another study reported that pulmonary function improvements occurred in well-trained athletes after targeted respiratory training, and that these changes caused a 50% increase in cycle endurance time (Boutellier *et al.*, 1992). In contrast, another study performed on well-trained athletes found that respiratory muscle training did not affect performance on a graded exercise challenge test (Inbar *et al.*, 2000).

In this study it was hypothesized that there would be a significant negative relationship between 800 and 1500 meters run time and measures of VC, FVC, FEV₁, FEV₁ % VC, PEF and PIF. There was a significant negative relationship between VC and race run time ($r = -0.66$ and -0.65) in female and male athletes respectively, FVC and running performance ($r = -0.85$ and $r = -0.70$) in female and male athletes respectively, and FEV₁ and running performance ($r = -0.80$ and $r = -0.63$) in female and male athletes respectively. The implication is that athletes may potentially improve their lung volumes and capacities and their running performance by targeted respiratory muscles training. This finding may be of interest to competitive athletes and coaches.

Additional longitudinal research is needed to determine if respiratory training improves running times. The current study has shown that higher VC, FVC and FEV₁ values are associated with faster times in an 800 and 1500 meters run. Furthermore, which respiratory training programs would best improve VC, FVC, FEV₁ values?

FVC values were 103.6% of predicted norms in men and 111.4% of predicted norms in women. These findings are consistent with a study performed on 101 male runners. In these subjects observed values were significantly ($p < 0.05$) higher than predicted values for FVC, with the runners scoring at 104.5% to 113.8% of predicted scores. (Cordain *et al.*, 1987).

PEF values in the current study were found to be below age predicted norms for all subjects. Actual values for the men were 8.03 L/sec, which is 93% of the predicted value of 8.64 L/sec. In the women, actual values (6.95 L/sec) were 90% of predicted values (7.70 L/sec). These findings suggest that in these subjects, running may be associated with decreases in maximal expiratory flow.

9. CONCLUSIONS AND RECOMMENDATIONS

This study has assessed the relationship between skinfold thicknesses and running performance. It demonstrates that taking into account the sum of four skinfolds may provide a general assessment of the athlete. The sum of four skinfolds was related to performance. An important observation from the study is the apparent divergent association between upper limb, supra-iliac and sub-scapular skinfolds with running performance. On the basis of these findings, we believe it is essential that the anthropometric assessment of top- class athletes provides an evaluation of all skinfolds. The assessment of skinfolds values in the supra-iliac and sub-scapular regions may be a useful predictor of athletic performance. A longitudinal study is recommended to verify the influence of skinfolds thicknesses on running performance.

The current study showed that there was a significant negative relationship between 800 and 1500 meters run time with VC, FVC and FEV₁ which indicated that the higher lung volumes are associated with faster 800 and 1500 meters run times. Results from the present study strongly suggest that the intensity or severity of the sports engaged in by the athletes probably determines the extent of strengthening of the respiratory muscles with a resultant increase in the lung volumes.

Differences in VO₂max of runners with the different level of performance (IAAF scores) on these distances clearly indicate a contribution of VO₂max or aerobic requirement on running performance. For 800 and 1500 meters distance, performances are proportional to VO₂max. Furthermore, when comparing data from different studies, variation between performance and VO₂max may also depend on the protocol and metabolic equipment used to assess VO₂max. Then, with homogeneous groups of runners, VO₂max alone generally may not be sufficient to categorize athlete's performances. A future analysis with more data of VO₂max in

relation with the running performance level is considered necessary to verify these conclusions.

Longitudinal assessments of physiological variables, including VO_2max , pulmonary parameters, body composition, cardiac function, and distance running performance in the principal part of the season are necessary to determine the factors that contribute to successful running performance in elite athletes.

This study illustrates and revisits some scientific areas and tools of cardiopulmonary function and body composition. There is significant relationship between selected lung functions, sum of skinfold thicknesses, heart rate, VO_2max , and running performance. Coaches should add these variables in their present series of tests, to evaluate athlete's performance.

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Annex I: INFORMED CONSENT FORM

ADDIS ABABA UNIVERSITY, FACULTY OF MEDICINE

1. Title of the project: A Study of the Correlation of Middle Distance athletics Performance with Cardiopulmonary Functions and Skinfold Thickness

2. Significant of the study: There is no study carried out so far to analyze the affiliation between pulmonary parameters, maximum aerobic capacity (VO₂max), body fat percentage, heart rate and running performance.

This study will:

- ✎ Evaluate the relationship of those parameters with middle distance running performance.

✎ Revisits previous findings of cardiopulmonary functions and skinfold thickness of middle distance runners and compare with my findings.

3. Procedure: If the client agrees with the purpose of the project, a brief explanation will be offered by the principal investigator about the procedure of the recording. A pulmonary profile, Skinfold thickness, resting heart rate, heart rate for different exercise intensities will be compared with athlete's current performance. In addition to that maximum aerobic capacity (VO_2max) will be compared with athlete's current performance.

4. Period of data collection: The experiment will be conducted from April to July 2007.

5. Possible risks linked with this study: This study has no known unfavorable effect on your health and performance. Subjects will be checked to persuade they do not have an illness or disease precluding them from participation in pulmonary function testing.

6. Compensations

All client transportation and other expenses for the study will be covered by the investigator.

7. Anonymity of participant's information: anonymity shall be maintained and that every information will be kept confidential.

Subjects are free to withdraw from the study at any time.

This study is approved by the research committee of the Faculty of Medicine, Addis Ababa University.

Research Committee

Name

Signature

1. _____

2. _____

3. _____

Principal Investigator

Name

Signature

Participant

Name

Signature

አዲስ አበባ ዩኒቨርሲቲ ህክምና ፋኩልቲ

የምርምር ጥናት ስምምነት ቅፅ

1) የፕሮጀክቱ ርዕስ:

የመከከለኛ ርቀት ሯጮች የልብ፡ የአተነፋፈስ ስርዐትና የሩጫ ብቃት

2) የጥናቱ ጥቅም:

ከዚህ ቀደም እንዲህ አይነት ጥናት በአገራችን አልተካሄደም። ይህ ጥናት የልብና የአተነፋፈስ ስርዐትን ከሩጫ ብቃት ጋር በማወዳደር ለአሰልጣኞችና ለአትሌቶች የብቃት መገምገሚያ ዘዴዎችን ያሳውቃል።

3) የጥናቱ አካሄድ (ቅደም ተከተል):

አትሌቶች በጥናቱ ለመሳተፍ ፍቃደኛ ከሆኑ በኋላ ስለ ጥናቱ ቅደም ተከተል (አካሄድ) በተመራማሪው አጭር ገለጻ ይሰጣል። የአተነፋፈስ ስርዐት፣ የሰውነት የስብ ክምችት፣ የልብ ምት በአረፍት ጊዜ፣ የልብ ሞት በከፍተኛ ስፖርታዊ እንቅስቃሴ ጊዜ፣ እና ከፍተኛ የኤሮቢክ ብቃት ከአትሌቱ የሩጫ ብቃት ጋር ይወዳደራል።

4) መረጃ በሚሰበሰብበት ጊዜ:

ጥናቱ የሚከናወነው ከ ሚያዚያ እስከ ሐምሌ ወር 1999ዓ.ም ነው። ከእያንዳንዱ የመረጃ ምንጭ ስድስት ጊዜ ምዝገባ ይከሄዳል ይህ የሚሆነው በተለያየ ቀን ነው።

5) ጥናቱ ሊያስከትል የሚችለው አደጋ:

ይህ ጥናት በአትሌቱ/ቷ ጤናና ብቃት ላይ የሚያስከትለው ምንም አደጋ የለም። ከጥናቱ በፊት አትሌቱ/ቷ በጥናቱ እንዳይሳተፉ የሚከለክላቸው የጤና ችግር እንደሌለባቸው በባለሙያ ይረጋገጣል።

6) ማከከሻ:

የጥናቱ ተሳታፊዎች፣ የመጓጓዣና እና ሌሎች ተያያዥ ወጪዎች በሙሉ በተመራማሪው ይሸፈናል።

7) የጥናቱ ተሳታፊዎች መረጃ ሚስጥራዊነት:

የማንኛውም የጥናቱ ተሳታፊ መረጃ በሚስጥር የሚጠበቅ ይሆናል።

ይህ ጥናት በአዲስ አበባ ዩኒቨርሲቲ ሕክምና ፋኩልቲ የምርምር ኮሚቴ ተገምግሞ የተፈቀደ ነው።

ከዚህ ጥናት ጋር በመተባበርዎ እናመሰግናለን።

ጥናቱን በተመለከተ ጥያቄ ካለዎት በማናቸውም ሰዓት መጠየቅ ይችላሉ።

የምርምር ኮሚቴ አባላት ስም

ፊርማ

1. _____

2. _____

3. _____

የተመራማሪው ስም

ፊርማ

የጥናቱ ተሳታፊ ስም

ፊርማ

Annex II: QUESTIONNAIRE AND FORMAT DESIGN FOR DATA COLLECTION

Height

Weight

Body mass Index (BMI)

2. Body Fat

Skin-fold thickness measurements at

Biceps

Triceps

Sub-scapular

Supra-iliac

Calculated body fat percentage

3. Pulmonary profile

Vital capacity, VC	
Forced expiratory vital capacity, FVC	
Forced expiratory volume after 1 sec, FEV ₁	
FEV ₁ in % of maximal vital capacity, FEV ₁ % VC	
Maximum expiratory flow, PEF	
Maximum expiratory flow at 25% of maximal VC, MEF ₂₅	
Maximum expiratory flow at 50% of maximal VC, MEF ₅₀	
Maximum expiratory flow at 75% of maximal VC, MEF ₇₅	
Mean maximum expiratory flow b/n 25% and 75% of FVC, MMEF	
Maximum inspiratory flow, PIF	

4. Heart rate

Resting Heart Rate	
Heart Rate during warming up (V = 10 km/hr, S = 0%)	
Heart Rate at level 1 (V = 14 km/hr, S = 0%)	
Heart Rate at level 2 (V = 14 km/hr, S = 2.5%)	
Heart Rate at level 3 (V = 14 km/hr, S = 5.0%)	
Heart Rate at level 4 (V = 14 km/hr, S = 7.5%)	
Heart Rate at level 5 (V = 14 km/hr, S = 10%)	
Heart Rate at level 6 (V = 14 km/hr, S = 12.5%)	
% Maximum HR	

5. Maximum aerobic capacity (VO₂max)

_____ (L/min)

_____ (ml/min/kg)

6. Current Performance _____

Perf.	Points								
3:22.23	1250	3:28.29	1200	3:34.47	1150	3:40.78	1100	3:47.21	1050
3:22.35	1249	3:28.42	1199	3:34.60	1149	3:40.90	1099	3:47.34	1049
3:22.47	1248	3:28.54	1198	3:34.72	1148	3:41.03	1098	3:47.47	1048
3:22.59	1247	3:28.66	1197	3:34.85	1147	3:41.16	1097	3:47.60	1047
3:22.71	1246	3:28.78	1196	3:34.97	1146	3:41.29	1096	3:47.73	1046
3:22.83	1245	3:28.91	1195	3:35.10	1145	3:41.41	1095	3:47.86	1045
3:22.95	1244	3:29.03	1194	3:35.22	1144	3:41.54	1094	3:48.00	1044
3:23.07	1243	3:29.15	1193	3:35.35	1143	3:41.67	1093	3:48.13	1043
3:23.19	1242	3:29.27	1192	3:35.47	1142	3:41.80	1092	3:48.26	1042
3:23.31	1241	3:29.40	1191	3:35.60	1141	3:41.93	1091	3:48.39	1041
3:23.43	1240	3:29.52	1190	3:35.72	1140	3:42.05	1090	3:48.52	1040
3:23.56	1239	3:29.64	1189	3:35.85	1139	3:42.18	1089	3:48.65	1039
3:23.68	1238	3:29.77	1188	3:35.97	1138	3:42.31	1088	3:48.78	1038
3:23.80	1237	3:29.89	1187	3:36.10	1137	3:42.44	1087	3:48.91	1037
3:23.92	1236	3:30.01	1186	3:36.22	1136	3:42.57	1086	3:49.04	1036
3:24.04	1235	3:30.13	1185	3:36.35	1135	3:42.69	1085	3:49.17	1035
3:24.16	1234	3:30.26	1184	3:36.48	1134	3:42.82	1084	3:49.30	1034
3:24.28	1233	3:30.38	1183	3:36.60	1133	3:42.95	1083	3:49.43	1033
3:24.40	1232	3:30.50	1182	3:36.73	1132	3:43.08	1082	3:49.57	1032
3:24.52	1231	3:30.63	1181	3:36.85	1131	3:43.21	1081	3:49.70	1031
3:24.64	1230	3:30.75	1180	3:36.98	1130	3:43.33	1080	3:49.83	1030
3:24.76	1229	3:30.87	1179	3:37.10	1129	3:43.46	1079	3:49.96	1029
3:24.88	1228	3:31.00	1178	3:37.23	1128	3:43.59	1078	3:50.09	1028
3:25.01	1227	3:31.12	1177	3:37.36	1127	3:43.72	1077	3:50.22	1027
3:25.13	1226	3:31.24	1176	3:37.48	1126	3:43.85	1076	3:50.35	1026
3:25.25	1225	3:31.37	1175	3:37.61	1125	3:43.98	1075	3:50.48	1025
3:25.37	1224	3:31.49	1174	3:37.73	1124	3:44.11	1074	3:50.62	1024
3:25.49	1223	3:31.62	1173	3:37.86	1123	3:44.24	1073	3:50.75	1023
3:25.61	1222	3:31.74	1172	3:37.99	1122	3:44.36	1072	3:50.88	1022
3:25.73	1221	3:31.86	1171	3:38.11	1121	3:44.49	1071	3:51.01	1021
3:25.86	1220	3:31.99	1170	3:38.24	1120	3:44.62	1070	3:51.14	1020
3:25.98	1219	3:32.11	1169	3:38.37	1119	3:44.75	1069	3:51.28	1019
3:26.10	1218	3:32.23	1168	3:38.49	1118	3:44.88	1068	3:51.41	1018
3:26.22	1217	3:32.36	1167	3:38.62	1117	3:45.01	1067	3:51.54	1017
3:26.34	1216	3:32.48	1166	3:38.75	1116	3:45.14	1066	3:51.67	1016
3:26.46	1215	3:32.61	1165	3:38.87	1115	3:45.27	1065	3:51.80	1015
3:26.58	1214	3:32.73	1164	3:39.00	1114	3:45.40	1064	3:51.94	1014
3:26.71	1213	3:32.85	1163	3:39.13	1113	3:45.53	1063	3:52.07	1013
3:26.83	1212	3:32.98	1162	3:39.25	1112	3:45.66	1062	3:52.20	1012
3:26.95	1211	3:33.10	1161	3:39.38	1111	3:45.79	1061	3:52.33	1011
3:27.07	1210	3:33.23	1160	3:39.51	1110	3:45.92	1060	3:52.47	1010
3:27.19	1209	3:33.35	1159	3:39.63	1109	3:46.04	1059	3:52.60	1009
3:27.32	1208	3:33.48	1158	3:39.76	1108	3:46.17	1058	3:52.73	1008
3:27.44	1207	3:33.60	1157	3:39.89	1107	3:46.30	1057	3:52.86	1007
3:27.56	1206	3:33.72	1156	3:40.01	1106	3:46.43	1056	3:53.00	1006
3:27.68	1205	3:33.85	1155	3:40.14	1105	3:46.56	1055	3:53.13	1005
3:27.80	1204	3:33.97	1154	3:40.27	1104	3:46.69	1054	3:53.26	1004
3:27.93	1203	3:34.10	1153	3:40.39	1103	3:46.82	1053	3:53.39	1003
3:28.05	1202	3:34.22	1152	3:40.52	1102	3:46.95	1052	3:53.53	1002
3:28.17	1201	3:34.35	1151	3:40.65	1101	3:47.08	1051	3:53.66	1001

Perf.	Points								
3:53.79	1000	4:00.53	950	4:07.42	900	4:14.50	850	4:21.77	800
3:53.93	999	4:00.66	949	4:07.56	899	4:14.64	849	4:21.92	799
3:54.06	998	4:00.80	948	4:07.70	898	4:14.79	848	4:22.06	798
3:54.19	997	4:00.93	947	4:07.84	897	4:14.93	847	4:22.21	797
3:54.33	996	4:01.07	946	4:07.98	896	4:15.07	846	4:22.36	796
3:54.46	995	4:01.21	945	4:08.12	895	4:15.22	845	4:22.51	795
3:54.59	994	4:01.34	944	4:08.26	894	4:15.36	844	4:22.65	794
3:54.73	993	4:01.48	943	4:08.40	893	4:15.50	843	4:22.80	793
3:54.86	992	4:01.62	942	4:08.54	892	4:15.65	842	4:22.95	792
3:54.99	991	4:01.75	941	4:08.68	891	4:15.79	841	4:23.10	791
3:55.13	990	4:01.89	940	4:08.82	890	4:15.94	840	4:23.25	790
3:55.26	989	4:02.03	939	4:08.96	889	4:16.08	839	4:23.40	789
3:55.39	988	4:02.17	938	4:09.10	888	4:16.23	838	4:23.54	788
3:55.53	987	4:02.30	937	4:09.24	887	4:16.37	837	4:23.69	787
3:55.66	986	4:02.44	936	4:09.39	886	4:16.51	836	4:23.84	786
3:55.80	985	4:02.58	935	4:09.53	885	4:16.66	835	4:23.99	785
3:55.93	984	4:02.71	934	4:09.67	884	4:16.80	834	4:24.14	784
3:56.06	983	4:02.85	933	4:09.81	883	4:16.95	833	4:24.29	783
3:56.20	982	4:02.99	932	4:09.95	882	4:17.09	832	4:24.44	782
3:56.33	981	4:03.13	931	4:10.09	881	4:17.24	831	4:24.59	781
3:56.47	980	4:03.26	930	4:10.23	880	4:17.38	830	4:24.73	780
3:56.60	979	4:03.40	929	4:10.37	879	4:17.53	829	4:24.88	779
3:56.74	978	4:03.54	928	4:10.51	878	4:17.67	828	4:25.03	778
3:56.87	977	4:03.68	927	4:10.65	877	4:17.82	827	4:25.18	777
3:57.00	976	4:03.81	926	4:10.80	876	4:17.96	826	4:25.33	776
3:57.14	975	4:03.95	925	4:10.94	875	4:18.11	825	4:25.48	775
3:57.27	974	4:04.09	924	4:11.08	874	4:18.25	824	4:25.63	774
3:57.41	973	4:04.23	923	4:11.22	873	4:18.40	823	4:25.78	773
3:57.54	972	4:04.37	922	4:11.36	872	4:18.54	822	4:25.93	772
3:57.68	971	4:04.51	921	4:11.50	871	4:18.69	821	4:26.08	771
3:57.81	970	4:04.64	920	4:11.65	870	4:18.84	820	4:26.23	770
3:57.95	969	4:04.78	919	4:11.79	869	4:18.98	819	4:26.38	769
3:58.08	968	4:04.92	918	4:11.93	868	4:19.13	818	4:26.53	768
3:58.22	967	4:05.06	917	4:12.07	867	4:19.27	817	4:26.68	767
3:58.35	966	4:05.20	916	4:12.21	866	4:19.42	816	4:26.83	766
3:58.49	965	4:05.34	915	4:12.36	865	4:19.57	815	4:26.98	765
3:58.62	964	4:05.47	914	4:12.50	864	4:19.71	814	4:27.13	764
3:58.76	963	4:05.61	913	4:12.64	863	4:19.86	813	4:27.28	763
3:58.90	962	4:05.75	912	4:12.78	862	4:20.01	812	4:27.43	762
3:59.03	961	4:05.89	911	4:12.93	861	4:20.15	811	4:27.58	761
3:59.17	960	4:06.03	910	4:13.07	860	4:20.30	810	4:27.74	760
3:59.30	959	4:06.17	909	4:13.21	859	4:20.44	809	4:27.89	759
3:59.44	958	4:06.31	908	4:13.35	858	4:20.59	808	4:28.04	758
3:59.57	957	4:06.45	907	4:13.50	857	4:20.74	807	4:28.19	757
3:59.71	956	4:06.59	906	4:13.64	856	4:20.89	806	4:28.34	756
3:59.85	955	4:06.73	905	4:13.78	855	4:21.03	805	4:28.49	755
3:59.98	954	4:06.86	904	4:13.93	854	4:21.18	804	4:28.64	754
4:00.12	953	4:07.00	903	4:14.07	853	4:21.33	803	4:28.79	753
4:00.25	952	4:07.14	902	4:14.21	852	4:21.47	802	4:28.95	752
4:00.39	951	4:07.28	901	4:14.36	851	4:21.62	801	4:29.10	751

Perf.	Points								
4:29.25	750	4:36.96	700	4:44.94	650	4:53.20	600	5:01.78	550
4:29.40	749	4:37.12	699	4:45.10	649	4:53.36	599	5:01.95	549
4:29.55	748	4:37.28	698	4:45.26	648	4:53.53	598	5:02.13	548
4:29.71	747	4:37.44	697	4:45.42	647	4:53.70	597	5:02.31	547
4:29.86	746	4:37.59	696	4:45.59	646	4:53.87	596	5:02.48	546
4:30.01	745	4:37.75	695	4:45.75	645	4:54.04	595	5:02.66	545
4:30.16	744	4:37.91	694	4:45.91	644	4:54.21	594	5:02.83	544
4:30.32	743	4:38.06	693	4:46.08	643	4:54.38	593	5:03.01	543
4:30.47	742	4:38.22	692	4:46.24	642	4:54.55	592	5:03.18	542
4:30.62	741	4:38.38	691	4:46.40	641	4:54.72	591	5:03.36	541
4:30.77	740	4:38.54	690	4:46.57	640	4:54.89	590	5:03.54	540
4:30.93	739	4:38.70	689	4:46.73	639	4:55.06	589	5:03.71	539
4:31.08	738	4:38.85	688	4:46.89	638	4:55.23	588	5:03.89	538
4:31.23	737	4:39.01	687	4:47.06	637	4:55.40	587	5:04.07	537
4:31.39	736	4:39.17	686	4:47.22	636	4:55.57	586	5:04.25	536
4:31.54	735	4:39.33	685	4:47.38	635	4:55.74	585	5:04.42	535
4:31.69	734	4:39.49	684	4:47.55	634	4:55.91	584	5:04.60	534
4:31.85	733	4:39.65	683	4:47.71	633	4:56.08	583	5:04.78	533
4:32.00	732	4:39.80	682	4:47.88	632	4:56.25	582	5:04.96	532
4:32.15	731	4:39.96	681	4:48.04	631	4:56.42	581	5:05.13	531
4:32.31	730	4:40.12	680	4:48.20	630	4:56.59	580	5:05.31	530
4:32.46	729	4:40.28	679	4:48.37	629	4:56.76	579	5:05.49	529
4:32.61	728	4:40.44	678	4:48.53	628	4:56.93	578	5:05.67	528
4:32.77	727	4:40.60	677	4:48.70	627	4:57.10	577	5:05.85	527
4:32.92	726	4:40.76	676	4:48.86	626	4:57.27	576	5:06.03	526
4:33.08	725	4:40.92	675	4:49.03	625	4:57.44	575	5:06.20	525
4:33.23	724	4:41.08	674	4:49.19	624	4:57.62	574	5:06.38	524
4:33.39	723	4:41.24	673	4:49.36	623	4:57.79	573	5:06.56	523
4:33.54	722	4:41.40	672	4:49.52	622	4:57.96	572	5:06.74	522
4:33.69	721	4:41.56	671	4:49.69	621	4:58.13	571	5:06.92	521
4:33.85	720	4:41.72	670	4:49.86	620	4:58.30	570	5:07.10	520
4:34.00	719	4:41.88	669	4:50.02	619	4:58.48	569	5:07.28	519
4:34.16	718	4:42.04	668	4:50.19	618	4:58.65	568	5:07.46	518
4:34.31	717	4:42.20	667	4:50.35	617	4:58.82	567	5:07.64	517
4:34.47	716	4:42.36	666	4:50.52	616	4:58.99	566	5:07.82	516
4:34.62	715	4:42.52	665	4:50.69	615	4:59.17	565	5:08.00	515
4:34.78	714	4:42.68	664	4:50.85	614	4:59.34	564	5:08.18	514
4:34.94	713	4:42.84	663	4:51.02	613	4:59.51	563	5:08.36	513
4:35.09	712	4:43.00	662	4:51.19	612	4:59.69	562	5:08.54	512
4:35.25	711	4:43.16	661	4:51.35	611	4:59.86	561	5:08.73	511
4:35.40	710	4:43.32	660	4:51.52	610	5:00.03	560	5:08.91	510
4:35.56	709	4:43.48	659	4:51.69	609	5:00.21	559	5:09.09	509
4:35.71	708	4:43.64	658	4:51.85	608	5:00.38	558	5:09.27	508
4:35.87	707	4:43.80	657	4:52.02	607	5:00.56	557	5:09.45	507
4:36.03	706	4:43.97	656	4:52.19	606	5:00.73	556	5:09.63	506
4:36.18	705	4:44.13	655	4:52.36	605	5:00.90	555	5:09.82	505
4:36.34	704	4:44.29	654	4:52.52	604	5:01.08	554	5:10.00	504
4:36.49	703	4:44.45	653	4:52.69	603	5:01.25	553	5:10.18	503
4:36.65	702	4:44.61	652	4:52.86	602	5:01.43	552	5:10.36	502
4:36.81	701	4:44.77	651	4:53.03	601	5:01.60	551	5:10.55	501

Perf.	Points								
5:10.73	500	5:20.10	450	5:29.96	400	5:40.41	350	5:51.57	300
5:10.91	499	5:20.29	449	5:30.16	399	5:40.62	349	5:51.80	299
5:11.09	498	5:20.48	448	5:30.37	398	5:40.84	348	5:52.03	298
5:11.28	497	5:20.68	447	5:30.57	397	5:41.06	347	5:52.26	297
5:11.46	496	5:20.87	446	5:30.77	396	5:41.27	346	5:52.50	296
5:11.64	495	5:21.06	445	5:30.98	395	5:41.49	345	5:52.73	295
5:11.83	494	5:21.25	444	5:31.18	394	5:41.71	344	5:52.96	294
5:12.01	493	5:21.45	443	5:31.39	393	5:41.93	343	5:53.20	293
5:12.20	492	5:21.64	442	5:31.59	392	5:42.14	342	5:53.43	292
5:12.38	491	5:21.84	441	5:31.80	391	5:42.36	341	5:53.67	291
5:12.57	490	5:22.03	440	5:32.00	390	5:42.58	340	5:53.90	290
5:12.75	489	5:22.22	439	5:32.21	389	5:42.80	339	5:54.14	289
5:12.94	488	5:22.42	438	5:32.41	388	5:43.02	338	5:54.37	288
5:13.12	487	5:22.61	437	5:32.62	387	5:43.24	337	5:54.61	287
5:13.31	486	5:22.81	436	5:32.82	386	5:43.46	336	5:54.84	286
5:13.49	485	5:23.00	435	5:33.03	385	5:43.68	335	5:55.08	285
5:13.68	484	5:23.20	434	5:33.24	384	5:43.90	334	5:55.32	284
5:13.86	483	5:23.39	433	5:33.44	383	5:44.12	333	5:55.56	283
5:14.05	482	5:23.59	432	5:33.65	382	5:44.34	332	5:55.79	282
5:14.24	481	5:23.78	431	5:33.86	381	5:44.56	331	5:56.03	281
5:14.42	480	5:23.98	430	5:34.06	380	5:44.78	330	5:56.27	280
5:14.61	479	5:24.18	429	5:34.27	379	5:45.00	329	5:56.51	279
5:14.80	478	5:24.37	428	5:34.48	378	5:45.22	328	5:56.75	278
5:14.98	477	5:24.57	427	5:34.69	377	5:45.44	327	5:56.99	277
5:15.17	476	5:24.77	426	5:34.90	376	5:45.67	326	5:57.23	276
5:15.36	475	5:24.96	425	5:35.11	375	5:45.89	325	5:57.47	275
5:15.54	474	5:25.16	424	5:35.31	374	5:46.11	324	5:57.71	274
5:15.73	473	5:25.36	423	5:35.52	373	5:46.34	323	5:57.95	273
5:15.92	472	5:25.56	422	5:35.73	372	5:46.56	322	5:58.19	272
5:16.11	471	5:25.75	421	5:35.94	371	5:46.78	321	5:58.44	271
5:16.30	470	5:25.95	420	5:36.15	370	5:47.01	320	5:58.68	270
5:16.48	469	5:26.15	419	5:36.36	369	5:47.23	319	5:58.92	269
5:16.67	468	5:26.35	418	5:36.57	368	5:47.46	318	5:59.16	268
5:16.86	467	5:26.55	417	5:36.78	367	5:47.68	317	5:59.41	267
5:17.05	466	5:26.75	416	5:37.00	366	5:47.91	316	5:59.65	266
5:17.24	465	5:26.95	415	5:37.21	365	5:48.14	315	5:59.90	265
5:17.43	464	5:27.15	414	5:37.42	364	5:48.36	314	6:00.14	264
5:17.62	463	5:27.34	413	5:37.63	363	5:48.59	313	6:00.39	263
5:17.81	462	5:27.54	412	5:37.84	362	5:48.82	312	6:00.63	262
5:18.00	461	5:27.75	411	5:38.05	361	5:49.04	311	6:00.88	261
5:18.19	460	5:27.95	410	5:38.27	360	5:49.27	310	6:01.13	260
5:18.38	459	5:28.15	409	5:38.48	359	5:49.50	309	6:01.38	259
5:18.57	458	5:28.35	408	5:38.69	358	5:49.73	308	6:01.62	258
5:18.76	457	5:28.55	407	5:38.91	357	5:49.96	307	6:01.87	257
5:18.95	456	5:28.75	406	5:39.12	356	5:50.19	306	6:02.12	256
5:19.14	455	5:28.95	405	5:39.33	355	5:50.42	305	6:02.37	255
5:19.33	454	5:29.15	404	5:39.55	354	5:50.65	304	6:02.62	254
5:19.52	453	5:29.35	403	5:39.76	353	5:50.88	303	6:02.87	253
5:19.71	452	5:29.56	402	5:39.98	352	5:51.11	302	6:03.12	252
5:19.91	451	5:29.76	401	5:40.19	351	5:51.34	301	6:03.37	251

Perf.	Points								
6:03.62	250	6:16.84	200	6:31.70	150	6:49.08	100	7:11.24	50
6:03.87	249	6:17.12	199	6:32.02	149	6:49.46	99	7:11.77	49
6:04.13	248	6:17.40	198	6:32.34	148	6:49.85	98	7:12.30	48
6:04.38	247	6:17.68	197	6:32.66	147	6:50.24	97	7:12.84	47
6:04.63	246	6:17.97	196	6:32.98	146	6:50.63	96	7:13.39	46
6:04.89	245	6:18.25	195	6:33.30	145	6:51.02	95	7:13.94	45
6:05.14	244	6:18.53	194	6:33.63	144	6:51.41	94	7:14.49	44
6:05.39	243	6:18.81	193	6:33.95	143	6:51.81	93	7:15.06	43
6:05.65	242	6:19.10	192	6:34.28	142	6:52.20	92	7:15.62	42
6:05.91	241	6:19.38	191	6:34.60	141	6:52.60	91	7:16.20	41
6:06.16	240	6:19.67	190	6:34.93	140	6:53.00	90	7:16.78	40
6:06.42	239	6:19.95	189	6:35.26	139	6:53.41	89	7:17.37	39
6:06.68	238	6:20.24	188	6:35.59	138	6:53.81	88	7:17.96	38
6:06.93	237	6:20.52	187	6:35.92	137	6:54.22	87	7:18.56	37
6:07.19	236	6:20.81	186	6:36.25	136	6:54.63	86	7:19.17	36
6:07.45	235	6:21.10	185	6:36.59	135	6:55.04	85	7:19.79	35
6:07.71	234	6:21.39	184	6:36.92	134	6:55.46	84	7:20.41	34
6:07.97	233	6:21.68	183	6:37.26	133	6:55.87	83	7:21.05	33
6:08.23	232	6:21.97	182	6:37.60	132	6:56.29	82	7:21.69	32
6:08.49	231	6:22.26	181	6:37.93	131	6:56.71	81	7:22.34	31
6:08.75	230	6:22.56	180	6:38.27	130	6:57.14	80	7:23.00	30
6:09.01	229	6:22.85	179	6:38.61	129	6:57.56	79	7:23.67	29
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6:09.54	227	6:23.44	177	6:39.30	127	6:58.42	77	7:25.05	27
6:09.80	226	6:23.73	176	6:39.64	126	6:58.85	76	7:25.76	26
6:10.06	225	6:24.03	175	6:39.99	125	6:59.29	75	7:26.47	25
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6:10.59	223	6:24.62	173	6:40.68	123	7:00.17	73	7:27.95	23
6:10.86	222	6:24.92	172	6:41.03	122	7:00.62	72	7:28.71	22
6:11.12	221	6:25.22	171	6:41.38	121	7:01.06	71	7:29.49	21
6:11.39	220	6:25.52	170	6:41.73	120	7:01.51	70	7:30.28	20
6:11.66	219	6:25.82	169	6:42.09	119	7:01.97	69	7:31.10	19
6:11.93	218	6:26.12	168	6:42.44	118	7:02.42	68	7:31.93	18
6:12.19	217	6:26.42	167	6:42.80	117	7:02.88	67	7:32.78	17
6:12.46	216	6:26.73	166	6:43.15	116	7:03.34	66	7:33.66	16
6:12.73	215	6:27.03	165	6:43.51	115	7:03.81	65	7:34.56	15
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6:13.54	212	6:27.95	162	6:44.60	112	7:05.23	62	7:37.45	12
6:13.82	211	6:28.26	161	6:44.96	111	7:05.71	61	7:38.49	11
6:14.09	210	6:28.57	160	6:45.33	110	7:06.19	60	7:39.57	10
6:14.36	209	6:28.87	159	6:45.70	109	7:06.68	59	7:40.70	9
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Declaration

This thesis is my original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged

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