

5-1-2012

The Acute Effect of Endurance Exercise on Lipoproteins Measured by Nuclear Magnetic Resonance (NMR) in Healthy Men

Hanaa Adnan Shaheen
University of Nevada, Las Vegas

Follow this and additional works at: <https://digitalscholarship.unlv.edu/thesesdissertations>

 Part of the [Cardiovascular Diseases Commons](#), and the [Exercise Science Commons](#)

Repository Citation

Shaheen, Hanaa Adnan, "The Acute Effect of Endurance Exercise on Lipoproteins Measured by Nuclear Magnetic Resonance (NMR) in Healthy Men" (2012). *UNLV Theses, Dissertations, Professional Papers, and Capstones*. 1626.

<http://dx.doi.org/10.34917/4332607>

This Thesis is protected by copyright and/or related rights. It has been brought to you by Digital Scholarship@UNLV with permission from the rights-holder(s). You are free to use this Thesis in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/or on the work itself.

This Thesis has been accepted for inclusion in UNLV Theses, Dissertations, Professional Papers, and Capstones by an authorized administrator of Digital Scholarship@UNLV. For more information, please contact digitalscholarship@unlv.edu.

THE ACUTE EFFECT OF ENDURANCE EXERCISE ON
LIPOPROTEINS MEASURED BY NUCLEAR MAGNETIC
RESONANCE (NMR) IN HEALTHY MEN

By

Hanaa Adnan Shaheen

Bachelor of Science
University of Jordan
2004

**A thesis submitted in partial fulfillment
of the requirements for the**

Masters of Science Degree in Exercise Physiology

**Department of Kinesiology and Nutrition Sciences
School of Allied Health Sciences
The Graduate College**

**University of Nevada, Las Vegas
May 2012**

Copyright by Hanaa Adnan Shaheen 2012
All rights reserved



THE GRADUATE COLLEGE

We recommend the thesis prepared under our supervision by

Hanaa Adnan Shaheen

entitled

The Acute Effect of Endurance Exercise on Lipoproteins Measured by Nuclear Magnetic Resonance (NMR) in Healthy Men

be accepted in partial fulfillment of the requirements for the degree of

Master of Science in Exercise Physiology

Department of Kinesiology and Nutrition Sciences

Antonio Santo, Committee Chair

Richard Tandy, Committee Member

John Young, Committee Member

Patricia Alpert, Graduate College Representative

Ronald Smith, Ph. D., Vice President for Research and Graduate Studies
and Dean of the Graduate College

May 2012

ABSTRACT

The Acute Effect of Endurance Exercise on Lipoproteins Measured by Nuclear Magnetic Resonance (NMR) in Healthy Men

by

Hanaa Adnan Shaheen
Dr. Antonio Santo, Examination Committee Chair
Assistant Professor of Kinesiology
University of Nevada, Las Vegas

Background: Cardiovascular disease (CVD) represents a major cause of death in the United States, with abnormal levels of blood lipids and physical inactivity considered as major modifiable risk factors. The conventional lipid profile has been used to assess for CVD risk by directly measuring the concentrations of blood lipids. However, lipoprotein particle size and number obtained from a novel method, Nuclear Magnetic Resonance (NMR) may also assess for CVD risk with greater sensitivity. Exercise and increased physical activity has been shown to produce favorable effects on blood lipids and consequently reduce CVD risk. To understand this effect, it is important to understand the acute effects of an exercise session on these parameters. **Purpose:** The purpose of this study was to examine the effect of a 60-minute bout of dynamic exercise on lipoprotein particle number and size as measured by NMR, and compare it to the conventional lipid profile analysis. **Method:** Eight active healthy men between the ages of 19-34 years (age = 26 ± 5.17) participated in the study. After assessment of body composition and aerobic fitness, participants ran for 60 minutes at 70% of their aerobic fitness on a motor driven treadmill. Fasting blood samples were drawn immediately before, 5 minutes and 24 hours after exercise. Samples were sent to LipoScience, Inc. for the analysis of the lipoproteins by the NMR method and to Quest Diagnostics for the conventional lipid

profile analysis. **Results:** The conventional profile showed a significant change in triglycerides (TG), ($p=.019$) immediately after exercise with a significant increase of 22%, then a non significant decrease of 13% from baseline after 24 hours. The NMR profile showed a significant change in the large HDL particle concentration ($p=.046$) with an increase of 5.8% observed immediately after exercise, and a decrease of 6.7% observed 24 hours after exercise. However, none of these changes were significantly different from the baseline value. Both profiles did not show any significant changes in any of the other parameters. **Conclusion:** Changes were observed in blood lipids that might be attributed to the session of exercise. The conventional profile has detected a significant change in HDL-C and TG. However, these changes were not significant from baseline. Also, the NMR profile detected changes in the HDL particles through large HDL particle concentration and this change in large HDL particle concentration was not significant from baseline either. So, the NMR profile was not more sensitive in detecting acute exercise-induced changes on blood lipids, in terms of CVD risk.

TABLE OF CONTENTS

ABSTRACT	iii
LIST OF TABLES	vii
LIST OF FIGURES	viii
CHAPTER 1 INTRODUCTION	1
Purpose of the Study	5
Research Questions	5
Significance of the Study	5
Definition of Terms.....	5
CHAPTER 2 REVIEW OF RELATED LITERATURE.....	7
Cardiovascular disease.....	7
Lipoproteins	10
Relationship between Lipoproteins and CVD Using the Conventional Profile .	14
Relationship between Lipoproteins Sizes, Densities and CVD	19
The Effect of Exercise on Lipoproteins	23
The Effect of Training on Blood Lipids (Conventional Profile)	24
The Effect of Training on Blood Lipids (NMR Profile)	24
The Acute Effect of Exercise on Blood Lipids (Conventional Profile).....	28
The Acute Effect of Exercise on the Size and Density of Lipoproteins	33
CHAPTER 3 METHODOLOGY	35
Subject Characteristics.....	35
Collection of the Data	35
Statistical Analysis	39
Limitations	39
Delimitations.....	40
CHAPTER 4 RESULTS	41
Conventional Profile Results	41
NMR Profile Results.....	43
CHAPTER 5 DISCUSSION.....	48
Conventional Profile	48
NMR Profile.....	50
Conclusions and Recommendations for Further Study	53
APPENDIX I ANTHROPOMETRIC DATA	56
APPENDIX II CONVENTIONAL LIPID PROFILE DATA	57

APPENDIX II NMR PROFILE DATA.....	58
REFERENCES	60
VITA.....	64

LIST OF TABLES

Table 1	Characteristics of Plasma Lipids and Lipoproteins	11
Table 2	TC and LDL-C Levels and Association with CHD.....	15
Table 3	Subjects Physical Characteristics.....	41
Table 4	Serum Lipids and Lipoproteins before and after Exercise	42
Table 5	Percentage Change in Conventional Profile between Different Time Points .	43
Table 6	NMR Lipoprotein Subclasses Concentration RM ANOVA Results	44
Table 7	Percentage Change in Lipoprotein Subclasses	45
Table 8	NMR Lipoprotein Size Changes at different Time Points.....	46
Table 9	NMR Lipoprotein Percentage Size Changes at different Time Points	47

LIST OF FIGURES

Figure 1	Data from Framingham Study Showing that CHD Risk will Decrease with Increased HDL Concentrations at Various LDL Concentrations	16
Figure 2	Lipoprotein Subclasses Derived by NMR.....	20
Figure 3	Conventional Lipid Profile Results	42
Figure 4	The Positive Relationship between Running Mileage per Week and the Immediate Change in HDL-C.....	43
Figure 5	Percentage Changes in the NMR Lipoprotein Subclasses	45
Figure 6	Large HDL Concentration Changes across the Three Time Points	46

CHAPTER 1

INTRODUCTION

Cardiovascular disease (CVD) represents a group of diseases that are associated with atherosclerosis, which is a progressive disease in the large arteries that is characterized by the accumulation of lipids and other fibrous elements. It is one of the major causes of death in the United States that accounted for 34.3 % of deaths, or 1 of every 2.9 deaths in 2006. That means approximately 2,300 Americans die of CVD each day, or nearly 1 death every 38 seconds (AHA, 2010; Lusic, 2000).

Risk factors for developing CVD are divided into modifiable and non-modifiable factors. Factors that have a strong genetic component like, gender, and family history are considered non-modifiable. While hypertension, smoking, hyperlipidemia, type 2 diabetes mellitus, overweight and obesity, physical inactivity, increased average total energy consumption and low socioeconomical status are considered modifiable risk factors (AHA, 2010).

Among these modifiable risk factors, abnormal blood lipids such as elevated levels of low density lipoproteins (LDL), very low density lipoproteins (VLDL), triglycerides (TG), total cholesterol (TC), and decreased levels of high density lipoproteins (HDL), and physical inactivity are considered major risk factors for developing CVD. The first measures towards controlling these abnormalities should include the modification of diet and increased physical activity (AHA, 2010; Lusic, 2000).

The lipoproteins that have a direct association to atherosclerosis and consequently CVD are LDL and HDL. LDL is considered atherogenic and the primary factor that leads to the cascade of events in the process of atherosclerosis owing to its accumulation in the

subendothelial space of an injured blood vessel. The chance of this accumulation increases with higher levels of circulating LDL at the susceptible regions in the arteries such as bifurcations (Cziraky, Watson, & Talbert, 2008; Lusis, 2000; NCEP, 2002). However, HDL is considered anti-atherogenic and negatively associated with the development of CVD due to its role in reverse cholesterol transport (Lusis, 2000).

While evaluating the risk for developing CVD, blood lipid screening is of high importance. Conventional lipid profiles are used to directly measure the concentrations of TG, TC, LDL-C and HDL-C. Although this information is important in determining the lipid status, it was found that it is not only the concentrations of blood lipids and lipoproteins that affect the risk for developing CVD, but also the size and density of these particles that reflect the distribution of lipids in lipoproteins (Freedman et al., 1998; Otvos, 2002). Several techniques are available to directly measure the size and density of lipoprotein particles in circulation such as ultracentrifugation and gel electrophoresis (Ip, Lichtenstein, Chung, Lau, & MD, 2009). But recently, an innovative technique, Nuclear Magnetic Resonance (NMR), was introduced that enables the technician to quantify the number, the size of the particles, and how the cholesterol is distributed among particles. In addition to its accuracy, NMR is considered inexpensive and fast compared to the other methods (Otvos, JeyaraJah, Bennett, & Krauss, 1992; Otvos, Jeyarajah, & Bennett, 1991, 1996). The research that was done to compare the conventional lipid profile with the NMR profile, has shown that the NMR profile was more sensitive to detecting cardiovascular disease (CVD) risk in individuals who were considered low-risk according to the conventional lipid profile (Blake, Otvos, Rifai, & Ridker, 2002; Harchaoui et al., 2007). So, apparently healthy people with conventionally measured blood lipids, which

are within normal ranges, might be at high risk for developing CVD due to an abnormal distribution of lipids in the particles (Otvos, 2002). This abnormality is expressed by increased small, dense LDL particles and a decreased size of HDL particles. Also, participants with similar quantities of blood lipids might differ in their risks for developing CVD due to the same reason (Freedman et al., 1998; Otvos, 2002).

The effect of physical activity on longevity and the risk for CVD had gained attention as early as the 1950s, when it was observed that occupations with higher energy expenditures lived longer. Since then, the effect of physical activity on developing CVD, especially its effect on blood lipids and lipoproteins has been thoroughly investigated (Bruce & Grove, 1994; Peltonen, Marniemi, Hietanen, Vuori, & Ehnholm, 1981).

The favorable effects of exercise training on conventionally measured lipoproteins are well established, and these include reduced concentrations of total cholesterol (TC), LDL-cholesterol (LDL-C), and triglycerides (TG) and increased HDL-cholesterol (HDL-C) concentrations (Lippi et al., 2006; Peltonen et al., 1981; Sopko et al., 1985; Svedenhag, Lithe, Juhlin-Dannfelt, & Henriksson, 1983). Also, with the NMR method, it was found that positive effects of exercise training on lipoprotein densities and sizes were achieved (i.e. decreased small dense LDL, increased size of HDL) regardless of the diet or a change in body fat (Halverstadt, Phares, Wilund, Goldberg, & Hagberg, 2007; Karus et al., 2002).

To understand the cumulative effect of exercise on lipoproteins, it is important to understand the effect of a single bout of exercise on lipoproteins (Pronk, 1993). This topic gained the attention of scientists as early as the 1960s (Carlson & Mossfeldt, 1964). However, the majority of studies involved prolonged exercise programs (marathons,

triathlons) (Carlson & Mossfeldt, 1964; Kussi et al., 1984; Lamon-Fava, McNamara, Farber, Hill, & Schaefer, 1989; Thompson, Cullinane, Henderson, & Herbert, 1980), and the rest of the studies had variable, inconsistent results (Ferguson et al., 2003; Kantor, Cullinane, Sady, Herbert, & Thompson, 1987). The conventional lipid profile was used to analyze blood lipids in these studies, and in general, most of them revealed immediate increases in HDL-C and delayed increases in TG (Cullinane, Siconolfi, Saritelli, & Thompson, 1982; Park & Ranson, 2003).

The acute effect of exercise was investigated to determine any immediate changes in lipoproteins analyzed by the NMR method after completion of the 1995 World Championship Hawaii Ironman Triathlon (Yu et al., 1999). To my knowledge, that was the only study that examined the acute effect of exercise on lipoproteins using the NMR analysis. However, this kind of exercise cannot be achieved in the general population. In light of the previous, understanding the effect of acute exercise is of high importance. But, the information provided by the previous studies that used the conventional lipid profile might overlook favorable changes in lipoproteins due to exercise, because it will only provide information about the concentrations of TG, LDL-C, HDL-C and TC. However, changes related to the size and density of lipoproteins need to be studied, as these changes are critical in terms of CVD risk, regardless of whether these changes are accompanied with changes in the concentrations of blood lipids or not.

Purpose of the Study

Based upon the foregoing, the purpose of this study was to examine the acute effect of a 60-minute bout of dynamic exercise on lipoprotein particle number and size as measured by nuclear magnetic resonance (NMR), and to compare it with the conventional lipid profile analysis.

Research Questions (or Hypotheses)

Question #1 (or Hypothesis #1)

A 60-minute bout of exercise at 70% $\text{VO}_{2\text{max}}$ will affect the concentration, size and distribution of lipoproteins. The null hypothesis is that exercise has no effect on these parameters.

Question #2 (or Hypothesis #2)

The NMR method of analysis will be more sensitive to the changes in lipoproteins particle size and number, compared with the conventional lipid profile. The null hypothesis is that there is no difference between the two methods

Significance of the Study

The significance of this study is to provide information about the acute, favorable changes in lipoproteins due to exercise that are related to the sizes and densities of lipoproteins detected by the NMR method that might reduce the risk for developing CVD. A secondary purpose is to detect the timeline of these changes over a 24-hour period.

Definition of Terms

The following definitions are given for the purpose of clarification:

NMR: Nuclear Magnetic Resonance. HDL: high density lipoprotein. HDL-C: the cholesterol part in HDL. LDL: low density lipoprotein. LDL-C: the cholesterol part within LDL. Acute exercise: a single session of exercise. High intensity exercise: an exercise with an intensity $\geq 70\%$ VO_{2max} . Heavy exercise: a marathon or a triathlon. Prolonged exercise: exercise sessions that last 1-3 hours.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Cardiovascular Disease

Definition of Cardiovascular Disease

Cardiovascular disease (CVD) is the group of diseases that affect the heart and the circulatory system. Total CVD includes high blood pressure (HBP) and coronary heart disease (CHD) which includes myocardial infarction (MI), angina pectoris (AP), heart failure, stroke, and congenital cardiovascular defects. Other cardiovascular diseases include; rheumatic fever/rheumatic heart disease, pulmonary embolism, bacterial endocarditis, valvular heart disease, aortic valve disorders, mitral valve disorders, arrhythmias, peripheral artery disease, and venous thromboembolism (AHA, 2010).

It is estimated that more than 1 of 3 American adults have one or more types of CVD, which is considered one of the major causes of death in the United States. In 2006, CVD accounted for 34.3 % of deaths, or 1 of every 2.9 deaths. That means approximately 2,300 Americans die of CVD each day, or nearly 1 death every 38 seconds. Since 1900, except 1918, CVD has been the primary cause of death over any other major cause of death in the United States (i.e. cancer, accidents, Alzheimer's disease, HIV/AIDS). For example, in 2006, 1 in 2.8 females died from cancer, whereas 1 in 4.5 died of CVD (AHA, 2010).

Pathophysiology of CVD

Atherosclerosis is a progressive disease in the large arteries that is characterized by the accumulation of lipids and other fibrous elements in the subendothelial space. The process begins with lesion initiation in which injury to the endothelial lining of the blood vessel occurs. The preferred sites for lesion initiation are areas with arterial branches or

curvatures, such as bifurcations. Those areas have an increased permeability to macromolecules, such as LDL particles, which will cross the endothelium, interact with the protein matrix, and then become trapped in the subendothelial space. The LDL accumulation increases with higher circulating LDL particles, especially at the preferred sites such as arterial bifurcations. The trapped LDL particles in these areas become minimally oxidized due to their exposure to vascular cell waste. The second stage will be the inflammation stage; where attraction of monocytes to the site of injury takes place, which cross the endothelium and then morph into macrophages. The third stage is foam cell formation; where macrophages release chemotactic factors that result in attracting more monocytes to the site of injury, engulf the oxidized LDL, become trapped and morph into foam cells. The surrounding tissue becomes necrotic, more debris begins to build up and fatty streaks are formed. This stage is followed by fibrous plaque formation, in which the blood vessel's lumen continues to narrow due to smooth muscle cell migration. The combination of foam cells, necrotic tissue and smooth muscle cells results in the development of a fibrous cap. The last stage will be complex lesions and thrombosis due to calcification of necrotic tissue and a weakened endothelial lining which will contribute to the instability of the plaque (which is weakest at the tail-end of the accumulation). This may result in rupture of the plaque to form a thrombus that may break loose and travel to other parts of the body. The most critical complication of a thrombus is an acute occlusion of smaller blood vessels that may result in a stroke or a myocardial infarction (Lusis, 2000).

Risk Factors for Developing CVD

The risk factors for developing CVD are divided into modifiable and non-modifiable risk factors. Modifiable risk factors include; hypertension/high blood pressure, tobacco use/smoking, high blood cholesterol and other lipids, type 2 diabetes mellitus, overweight and obesity, physical inactivity, increased average total energy consumption (especially diets rich in saturated fats), low socioeconomical status, alcohol consumption, certain medications (contraceptive pills and hormone replacement therapy) and left ventricular hypertrophy (LVH). Non-modifiable risk factors include factors with a strong genetic component such as: age (> 55 years), gender (males are at a higher risk, but after menopause women will have a similar risk as men), family history of CVD (a first degree male relative who had CHD or stroke before the age of 55 or a first degree relative female before the age of 65), and ethnicity (Asians and Africans have a higher risk for developing CVD than other ethnic groups. These factors have different effects on CVD risk and is in part, because of their effects on lipid and lipoprotein metabolism and subsequent composition (Durstine & Lysterly, 2007).

Blood Lipids as a Risk Factor

Abnormal levels of lipoproteins are considered strong and critical risk factors for developing CVD (AHA, 2010; Lusic, 2000). These include elevated levels of low density lipoproteins (LDL), very low density lipoproteins (VLDL), triglycerides (TG), cholesterol, and decreased levels of high density lipoproteins (HDL). These abnormalities might be due to a genetic disorder, or due to adopting certain lifestyle factors such as consumption of a high fat diet, physical inactivity and obesity (AHA, 2010; Lusic, 2000).

Lipoproteins

Definition of Lipoproteins

Lipoproteins are colloidal particles that consist of lipid-protein complexes that are responsible for transporting the non-soluble lipids (TG, cholesterol and phospholipids), within the blood, lymph and cerebrospinal fluid. The primary components of lipoproteins are apolipoproteins (the protein part), TG, phospholipids and free and esterified cholesterol (the lipid part) (German, Smilowitz, & Zivkovic, 2006; Shepherd, 1992).

Metabolism of lipoproteins takes place mainly in the liver and intestines. Lipid transport in the plasma is regulated by certain apolipoproteins, lipoprotein receptors, lipolytic enzymes and transfer proteins to maintain lipid homeostasis (Shepherd, 1992).

Lipoproteins have gained significant scientific attention in the medical and biological fields because it was found that deregulation of these particles (e.g., TG and cholesterol) is associated with high mortality and morbidity levels (German et al., 2006).

To provide further understanding of their structures and functions, several methods have been used to isolate lipoproteins based on density (i.e. ultracentrifugation), size (i.e. gradient gel electrophoresis, NMR), apolipoproteins separation, and composition (German et al., 2006). Generally, lipoproteins are divided into 4 classes: chylomicrons, VLDL, LDL and HDL (Durstine, Grandjean, Christopher, & Thompson, 2002). The lipoprotein classes differ in their composition based upon the percentage of lipids and protein they contain and the percentage of protein content (Table 1) (Durstine et al., 2002).

Table1: Characteristics of Plasma Lipids and Lipoproteins (Durstine et al., 2002)

Composition Percentage of Total Lipids								
Lipid/ Lipoprotein	Source	Protein	Total Lipid	TG	Chol	Phosph	Free Chol	Apolipoprotein
Chylomicron	intestine	1-2	98-99	88	8	3	1	Major: A-IV, B-48, H Minor: A-I, A-II, C-I, C-II, C-III, E
VLDL	Major: liver Minor: intestine	7-10	90-93	56	20	15	8	Major: B-100, C-III, E, G Minor: A-I, A-II, C-II, D
IDL	Major: VLDL Minor: chylomicron	11	89	29	26	34	9	Major: B-100
LDL	Major: liver Minor: intestine	21	79	13	28	48	10	Major: B-100 Minor: C-I, C-II, (a)
HDL ₂	Major: HDL ₃	33	67	16	43	31	10	Major: A-1, A-II, D, E, F Minor: A-IV, C-I, C-II, C-III
HDL ₃	Major: liver & intestine Minor: VLDL & chylomicron remnant	57	43	13	46	29	6	Major: A-1, A-II, D, E, F Minor: A-IV, C-I, C-II, C-III
Chol	Liver & diet	NA	100	NA	NA	70-75	25-30	
TG	Diet & liver	NA	100	100	NA	NA	NA	

VLDL, very low-density lipoprotein; LDL, low-density lipoprotein; HDL, high-density lipoprotein; Chol, cholesterol; TG, triglyceride; Phosp, phospholipid.

Physiology of Lipoproteins

Chylomicrons

Chylomicrons are the largest and least dense lipoproteins. Produced in the enterocytes after meals, their main function is to transport the absorbed TG from the intestine to the lymphatic system and secrete it into the circulation. In the skeletal muscles and adipose tissue, lipolysis of these particles takes place by the action of the enzyme lipoprotein lipase (LPL), where TG are hydrolyzed for storage or energy production. Chylomicron

remnants are formed as a result of TG removal, which become rich in cholesterol esters taken from HDL due to the action of the enzyme cholesteryl ester transfer protein (CETP). The amount of the acquired esters within chylomicron remnants depends mainly on the efficiency of chylomicron clearance and the action of LPL, where less cholesteryl ester is acquired with higher clearance of chylomicrons. Chylomicron remnants are degraded in the liver, where clearance of their cholesteryl esters takes place and they are used along with other components to make VLDL (Shepherd, 1992).

Very low density lipoproteins (VLDL)

Very low density lipoproteins (VLDL) are produced in the liver from chylomicron remnants and considered the main TG transporter in the post absorptive state. In the circulation, they undergo similar metabolism to chylomicrons, where LPL activity hydrolyzes the TG content that is transported to adipose tissue and cholesteryl esters are transported to the molecules from HDL. After TG removal, VLDL remnants or IDL are formed (German et al., 2006; Shepherd, 1992).

Intermediate density lipoprotein (IDL)

Intermediate density lipoprotein (IDL) is formed by the hydrolysis of TG within the VLDL particle due to the activity of lipoprotein lipase (LPL), which results in releasing fatty acids that are taken up by extrahepatic tissue. The remaining particle is a VLDL remnant or IDL which interacts with LPL and hepatic lipase to form LDL. But in the clinical practice, it is measured with LDL (Durstine et al., 2002).

Low density lipoproteins (LDL)

Low Density lipoproteins (LDL) are not produced in any organ or tissue, but certain activities and modifications to the VLDL remnant (IDL) take place that result in the production of LDL. These modifications take place when IDL particles reach the liver, and hepatic lipase acts on removing the remaining TG from those particles, resulting in altering the density of IDL which will lead to the production of LDL (German et al., 2006). LDL particles are the main carriers of cholesterol. They have a relatively simple structure compared with other lipoproteins which consists of the lipids remaining from VLDL, apo-B100, and a core of cholesteryl esters. The main function of LDL is to deliver cholesterol to the cells that require it for growth, hormone synthesis, and metabolism to bile. The cells receive LDL-cholesterol (LDL-C) by a receptor-mediated process, where these cells contain LDL-specific receptors on their surfaces and LDL-C is delivered as one package of free cholesterol and cholesteryl esters (German et al., 2006).

High density lipoproteins (HDL)

HDL is the lipoprotein that contains equal amounts of lipids and proteins. Its metabolism starts with the formation of apo A-I in the liver, which is the major protein in the HDL particle that is secreted into the plasma to form the discoidal HDL. After that, uptake of free cholesterol from the surrounding tissue and esterification of the free cholesterol takes place, which results in the formation of spherical or mature HDL. HDL has various subclasses due to different content of apolipoprotein, TG, lipid transfer enzymes and proteins. HDL is considered antiatherogenic because of its role in reverse cholesterol transport, promoting vasodilation and maintaining low blood viscosity, in

addition to its anti-inflammatory and antioxidant properties (Link, Rohatgi, & Lemos, 2007).

Relationship between Lipoproteins and CVD Using the Conventional Lipid Profile


LDL

In the process of atherosclerosis, the primary factor that leads to the subsequent events is the accumulation of LDL particles at the susceptible regions in the arteries such as bifurcations. The chance of this accumulation increases with higher levels of circulating LDL (Lusis, 2000). Normally, LDL is an important cholesterol carrier that is vital for many biological functions such as a precursor for the production of certain compounds (i.e. hormones). Normal LDL does not contribute directly in the initiation of atherosclerosis. Indeed, it was found that certain modifications to the native LDL particle take place before its uptake by macrophages. The “LDL modification theory” helps explain the relationship between LDL and CVD. This theory explains that what initiates the process of atherosclerosis in the arterial wall is not the uptake of the normal LDL particle, but modifications to that particle take place that result in a different-structured LDL. These modifications include oxidation, lipolysis, proteolysis and aggregation, and happen due to the LDL particle’s exposure to oxidative waste in the vascular cells. As a result, LDL uptake by the cells that contain receptors for LDL will be disrupted, and these modified LDL particles will be taken up by macrophages which contain scavenger receptors that can identify the oxidized LDL. This uptake of the oxidized LDL will lead to the subsequent events in the atherosclerotic process (Lusis, 2000).

LDL-C

LDL-C is the cholesterol part within the LDL particle. The National Cholesterol Education Program (NCEP) has identified LDL-C as the main target of cholesterol – lowering therapy (NCEP, 2002). In addition, most clinical interventions aim at reducing LDL-C to reduce CVD risk because it makes up to 60-70% of the total serum cholesterol, plays a significant role in CVD progression and is considered the most critical and abundant atherogenic lipoprotein (Cziraky et al., 2008; NCEP, 2002). TC and LDL-C levels are positively associated with CHD (Table 2) (NCEP, 2002).

Table 2: TC and LDL-C Association with CHD Risk (NCEP, 2002)

TC-levels	LDL-C Level	Description	
	< 100 mg/dL	Optimal	
< 200	100-129 mg/dL	Near optimal/ above optimal	
200-239	130-159 mg/dL	Borderline high	
> 240	160-189 mg/dL	High	
	> 190 mg/dL	Very high	

HDL

HDL is considered antiatherogenic or inversely related to CVD, because its main protective effect is due to its role in reverse cholesterol transport. In addition to reverse cholesterol transport, HDL has other mechanisms that contribute to the protection against CVD which include: promoting vasodilation and endothelial repair, providing

antioxidant, anti-inflammatory, antithrombotic, and antiapoptotic properties (Lusis, 2000).

HDL-C

HDL-C is considered an independent risk factor for developing CVD. For each 1 mg/dL decrease in HDL-C, there is 2-3% increase in CHD risk (NCEP, 2002). The Framingham Heart Study indicated that HDL-C was a more critical risk factor for recurrent CHD than LDL-C, TC or TG. Also, for each 5 mg/dL decrease in serum HDL-C below median ranges, there is a 25% increase in myocardial infarction (MI) risk for both men and women (Figure 1) (Link et al., 2007).

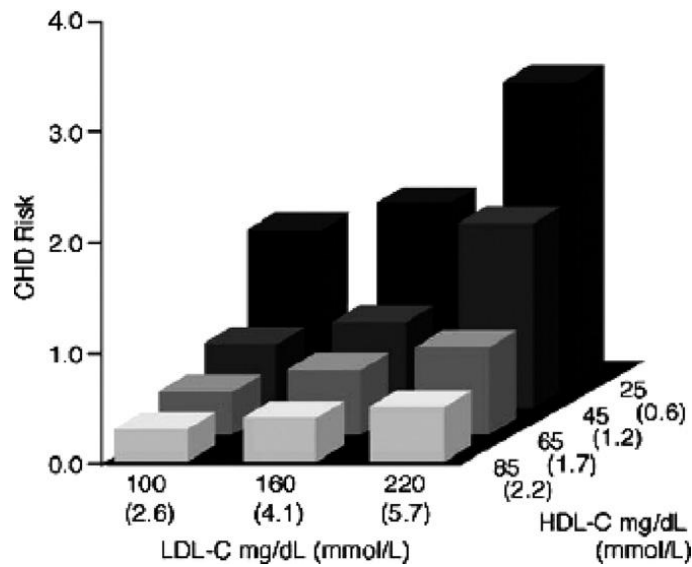


Figure 1: Data from Framingham Study Showing That CHD Risk Will Decrease With Increased HDL Concentrations at Various LDL Concentrations (Link et al., 2007).

In addition to genetic factors (which account for 50% in the variability of HDL-C in the general population), low HDL-C concentrations are mainly due to smoking, obesity,

physical inactivity, elevated serum TG, certain diseases like type 2 diabetes (T2DM) and certain medications like beta blockers. These factors are considered acquired factors and account for the remaining 50% variability in HDL-C. So to increase HDL-C, the first step taken should be towards smoking cessation, weight loss, diet and exercise. If these measures fail to increase HDL-C, medications like niacin, fibrates or cholesterol ester transfer protein (CETP) inhibitors might be initiated (NCEP, 2002).

Low levels of HDL-C are associated with other non-lipid risk factors such as increased insulin resistance and other metabolic risk factors. In addition, low HDL-C concentrations are also associated with higher serum TG, and an increased number of the small dense LDL particles. This relationship between low HDL-C, high TG and increased small LDL particles is called the lipid triad or atherogenic dyslipidemia, which usually appears in persons with immature CHD who show typical characteristics such as obesity, abdominal obesity, insulin resistance and physical inactivity. The best intervention to alleviate atherogenic dyslipidemia is weight reduction and increasing physical activity (NCEP, 2002). HDL-C concentrations that are below 40 mg/dL are considered low and concentrations above 60 mg/dL are considered high. The latter is considered a negative risk factor for CVD and if present, evokes the removal of one positive risk factor (NCEP, 2002).

TG

TG is considered an independent risk factor for coronary artery disease (CAD). When other risk factors associated with CAD are adjusted, each 88 mg/dL increase in TG, will increase CAD risk by 14% in men and 37% in women (Durstine & Lyerly, 2007).

Several factors lead to increased serum TG such as overweight and obesity, physical inactivity, cigarette smoking, excessive alcohol intake, a very high carbohydrate diet (> 60% of total energy), type 2 diabetes (T2DM), chronic renal failure, certain medications (like estrogens and corticosteroids) and genetic factors. Among the previously mentioned factors, the most common are obesity and physical inactivity (NCEP, 2002).

High TG is associated with high lipoprotein remnants like VLDL. These lipoproteins are high in TG and are called triglyceride-rich lipoproteins (TGRLP). Also high TG levels are associated with more atherogenic lipoproteins (such as an increased number of small LDL particles and a reduced number of HDL particles), and with other non-lipid risk factors such as elevated blood pressure, insulin resistance and glucose intolerance (NCEP, 2002). The National Cholesterol Education Program NCEP recommends that elevated TG should be first decreased by lifestyle changes (NCEP, 2002).

The Residual CVD Risk (Non-HDL-C)

Non- HDL-C includes all atherogenic lipoproteins (LDL-C, VLDL-C, IDL-C and lipoprotein (a). Studies have shown that even after using medications like statins (that lower LDL-C, but have a lesser effect on lowering TG or increasing HDL-C,) there was a residual risk for developing CVD that might be up to two thirds the risk before treatment (Fabbri & Maggioni, 2009). That remaining risk might be due to lower HDL-C concentrations, (which is associated with high TG and other lipoprotein remnants, like VLDL-C), high TG which is an indicator for other atherogenic lipoproteins like VLDL-C, or related to the particle size (Cziraky et al., 2008; Fabbri & Maggioni, 2009; Sharma, Singh, & Reddy, 2009). So, to decrease this residual CVD risk, some clinicians suggest adding other medications to the statin therapy that aim at increasing HDL-C like Niacin

(Cziraky et al., 2008). Because of this residual risk for developing CVD, the term non-HDL-C was introduced which refers to the combination between VLDL-C and LDL-C. It was found that non-HDL-C gives a more accurate prediction for CVD risk than LDL-C alone (Cziraky et al., 2008; Sharma et al., 2009). When TG levels are elevated (> 200 mg/dL), NCEP recommends that treatment should target non-HDL-C after reaching LDL-C goals (NCEP, 2002).

Relationship between Lipoproteins Sizes, Densities and CVD (What the Conventional Lipid Profile Might be Missing)

The conventional lipid profile provides information about the concentrations of LDL-C, HDL-C, TC and TG, which can predict Coronary Heart Disease (CHD). However, it was found that the risk for CVD and severity of CHD vary widely among patients with similar levels of these lipids. One reason for this variability is the difference in lipoprotein subclasses that have different relationships to CVD (Freedman et al., 1998). This variability is mainly due to the varying amounts of cholesterol per particle among persons with similar amounts of TC, LDL-C, and HDL-C, due to differences in particle size, and variable amounts of TG and cholesteryl esters (Otvos, 2002).

Each class of lipoprotein contains subfractions that differ in their particle size and density due to the difference in the apolipoprotein and lipid contents. For example, depending on the methodology used to determine particle size and density, LDL has three to seven subfractions, while HDL has two to five subfractions. These subfractions have different functions and different relationships to CVD risk (Durstine et al., 2002). The NCEP has identified emerging lipid risk factors for developing CVD, which include TG,

lipoprotein remnants (VLDL, IDL), lipoprotein (a), small LDL particles, HDL sub species (HDL₂, HDL₃), and the TC/HDL-C ratio. Several studies have found that certain LDL and HDL subclasses have stronger relationships to CVD than others (Cromwell & Otvos, 2004; Freedman et al., 1998; Gardner, Fortmann, & Krauss, 2002; Jeyarajah, Cormwell, & Otvos, 2006; Otvos et al., 2006).

Different methods are used to determine lipoprotein subclasses and measure size and density of particles, such as gel electrophoresis, ultracentrifugation and nuclear magnetic resonance (NMR) (Ip et al., 2009). Among these methods, NMR is considered an inexpensive and simple method compared with other methods. For example, gel electrophoresis is considered time-consuming, requires physical separation, and it's not possible to measure all lipoprotein subclasses in a single gel. However, using NMR, lipoprotein subclasses can be obtained rapidly and simultaneously using a moderate magnetic field strength and quantification of 5 HDL, 4 LDL and 6 VLDL subclasses can be obtained in less than one minute (Figure 2) (Otvos et al., 1992; Otvos et al., 1991, 1996). In addition, archived, frozen specimens at -70° C can be analyzed. Also, the method has been shown to be accurate and precise (Otvos, 2002).

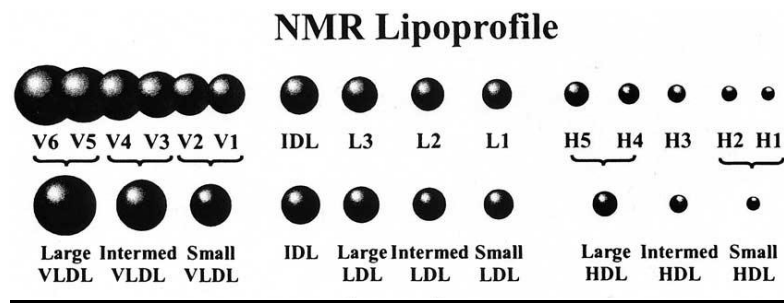


Figure 2: Lipoprotein Subclasses Derived by NMR (Otvos, Jeyarajah, & Cromwell, 2002).

NMR was introduced in the early 1990s by a group of researchers to quantify lipoprotein subclasses. Lipoproteins are exposed to a magnetic field, and then the signal emitted by the methyl groups within each lipid is measured. The amplitude of this signal reflects the concentration of a certain lipoprotein, and proprietary software is used to convert concentrations into subfractions. Additional calculations are done to determine sizes and patterns of lipoproteins (Otvos et al., 1991).

LDL Subfractions and Relationship to CVD

Several studies have found that small, dense LDL particles are strongly associated with CVD and more atherogenic than larger particles (Cromwell & Otvos, 2004; Freedman et al., 1998; Gardner et al., 2002; Otvos et al., 2006). During the process of atherosclerosis, small dense LDL particles are more susceptible to oxidation and more rapidly taken up by macrophages than larger, less dense particles (Ip et al., 2009).

Some studies found that small LDL particles can better predict CVD than LDL-C (Blake et al., 2002; Cromwell & Otvos, 2004; Harchaoui et al., 2007). Also, normocholesterolic persons are at higher risk for developing CHD if they have higher levels of small, dense LDL particles (Freedman et al., 1998). Blake et al (2002) conducted a nested-case control study among 28,263 healthy middle-aged women to determine the effect of LDL particle size and concentration determined by NMR on future CVD events (MI, stroke, and CAD). Blood samples were obtained at baseline and stored. All participants were flagged for developing MI, stroke or death due to CAD. For each reported case of CVD, a control participant was matched for age and smoking status that remained free of CVD. Blood samples for the affected and the control participants

were analyzed for LDL particles using NMR. Results showed that baseline LDL concentrations were higher in cases than controls. Also, LDL particle sizes were smaller in cases than controls (Blake et al., 2002). A similar case control study was conducted by El Harchaoui and colleagues (2007) in the UK that involved over 25,000 apparently healthy men and women. Blood samples were collected and stored at the time of enrolment. During six years of follow up, participants were flagged for death certificates or having CAD. During that period of time 1,003 cases of CAD were reported. The blood samples were analyzed for LDL-C using the conventional lipid profile, and for LDL particle size and both results were compared to see their relationship with the actual CAD events. Results showed that LDL size as determined by the NMR method was more strongly associated with CAD than LDL-C determined by the conventional lipid profile (Harchaoui et al., 2007).^{2d}

HDL Size and Density

It was found that HDL subclasses have a stronger relationship to CVD than HDL-C (Cromwell, 2007). Also, the subclasses have different relationships to CHD. Large and less dense HDL (HDL_{2a}, HDL_{2b}, HDL_{3a}) particles measured by GGE are negatively associated with the rate and progression of coronary atherosclerosis (Freedman et al., 1998; Johansson, LA Carlson, Landou, & Hamsten, 1991). While small, dense HDL particles (HDL_{3b}, HDL_{3c}) are positively associated with CHD (Freedman et al., 1998; Otvos et al., 1996).

Freedman et al (1998) examined the relationship between NMR derived subclasses of small HDL and large VLDL particles measured by NMR, and the severity of documented CAD by arteriography in 158 men. Patients with complaints of severe angina pectoris,

myocardial ischemia or occult chest pain were admitted to perform arteriography by a cardiologist. Fasting blood samples were obtained and analyses of lipoproteins using the conventional lipid profile and NMR profile were executed. Severity of CAD was determined according to the degree of occlusion in the coronary arteries. Results showed strong, positive relationships between the degree of occlusion (severity) of CAD and large VLDL and small HDL particles independent of age and lipid concentrations. Also, there was a negative relationship between intermediate HDL particles and the severity of CAD (Freedman et al., 1998).

The Effect of Exercise on Lipoproteins

According to the National Cholesterol Education Program (NCEP Report), physical inactivity is considered a major modifiable risk factor for developing CHD. The favorable effect of physical activity on CHD risk comes mainly from its effect on blood lipids and lipoproteins (i.e. increased HDL-C, decreased TG and LDL-C), and its effect on the non-lipid risk factors such as improving insulin sensitivity and lowering blood pressure (NCEP, 2002). Because of its favorable effects on several CVD risk factors, it was suggested to add regular physical activity as a negative risk factor (like elevated HDL-C). Although this suggestion has not been applied yet, history of physical inactivity is considered a major risk factor for developing CHD (NCEP, 2002).

From 1980 to 2000 there was a decrease in deaths associated with CVD. About 47% of that decrease was due to advanced medical care, while 44% was associated with modification of lifestyle (i.e. diet and exercise) and environmental risk factors.

One of the mechanisms by which exercise affects CVD risk, is its favorable effects on blood lipids and lipoproteins, which represent a major modifiable risk factor for developing CVD. The main lipoproteins that have a direct contribution in developing CVD are LDL and HDL, and exercise is considered an important method to achieve alterations in these lipoproteins that will reduce CVD risk (Pronk, 1993). Bruce & Grove, (Bruce & Grove, 1994) examined the effect of lipoprotein levels on CVD risk. Their study has investigated the effect of the Coronary Artery Risk Evaluation (CARE) program in 195 military participants on reducing CVD risk through screening and education about lifestyle modifications (i.e. diet and exercise). It consisted of 3 phases: The first phase was a screening phase to evaluate the participants' lipids concentrations (TC, LDL-C, and HDL-C). The second phase was a risk evaluation phase, where participants were divided into 3 levels of risk (low, moderate, high). The third phase was a 6- month education phase about reduction of cardiac disease risk by lowering lipids levels through lifestyle modifications (i.e. diet and exercise), follow up and referral. Results showed a significant reduction in TC (13%), LDL-C (17%), and HDL-C (5.8%). Also, coronary artery disease (CAD) risk categories changed: high risk individuals decreased from 59.5% to 23.1%, moderate risk individuals increased from 25.6% to 36.4% and low risk individuals increased from 14.9%- 40.5% (Bruce & Grove, 1994).

The Effect of Training (Chronic Exercise) on Blood Lipids (Conventional Profile)

Most of the favorable effect of exercise on blood lipids is expressed by increased HDL-C and TG. Although little evidence exists about the effect of exercise on TC or LDL-C, (Trejo-Gutierrez & Fletcher, 2007), a study by Lippi and colleagues (2006)

found that after the analysis of blood samples from 60 sedentary, 80 cross-country skiers and 120 road cyclists that TC, TG, TC/LDL-C ratio were significantly lower in the two athletic groups compared to the sedentary group. In addition HDL-C in the athletic groups was higher than the sedentary group. These findings suggest that the favorable differences in the blood lipids and lipoproteins in the athletic groups might be due to physical activity, which subsequently reduce the risk for developing CVD (Lippi et al., 2006).

Several studies have examined the effect of exercise training on blood lipids and lipoproteins as a means to reduce CVD risk in sedentary and active people. Peltonin and colleagues (1981) examined the effect of 15 weeks of exercise training on blood lipids and lipoproteins of sedentary men. The exercise frequency was 3 times/week, with a duration of 30-60 minutes. Different kinds of exercise were used (jogging, cross country skiing and swimming), and the target was to raise the participants' heart rates (HR) to 140-160 beats per minute. Results showed a significant increase in HDL-C by 7%, an increase in the HDL/TC ratio by 11%, and a significant decrease in TC and LDL-C, with no significant change in body weight. Also, there was a significant increase in lipoprotein lipase (LPL) activity, which is responsible for the hydrolysis of TG in TG-rich lipoproteins, and a significant decrease in hepatic lipase (HL), which is involved in HDL catabolism (Peltonen et al., 1981).

Svedenhag et al. (1983) investigated the effect of 8 weeks of exercise training on LPL in sedentary participants. Exercise consisted of cycling on a cycle ergometer for 40 minutes, 4 times/week, at an intensity of 60-75% of VO_{2max} . Muscle biopsy specimens were taken before and after training. Results showed a significant increase in LPL

activity, which affects increasing HDL and decreasing TG-rich lipoproteins, by 47%. In addition, there was a significant increase in the muscular capillary density by 19% (Svedenhag et al., 1983).

Some studies have shown that changes in lipoproteins due to exercise training might be due to changes in body fat. Spoko et al. (1985) examined the effect of exercise training with and without weight loss on blood lipids and lipoproteins in obese men. Participants were divided into 4 groups according to weight loss and exercise during the program ; group 1: inactive with constant weight (no weight loss), group 2: exercise with constant weight where they exercised 5 times per week on a treadmill to expend 3,500 kcal/week and weight was maintained by increasing caloric intake, group 3: inactive weight loss where caloric intake was reduced by 3,500 kcal/week to lose 1 lb/week with no exercise, group 4: exercise –weight loss where they had the same exercise program as group 2 , but without increasing caloric intake. Results showed significant increases in HDL-C in groups 2, 3 and 4 with percentages of 2%, 2.4%, and 5.5%, respectively. Also, TG and VLDL-C increased in group 2 and decreased in group 4. These results indicate that exercise and weight loss might have independent and additive effects on lipids, especially HDL-C (Sopko et al., 1985). Other studies showed that exercise training had positive effects on conventionally measured blood lipids independent of changes in body weight (Halverstadt et al., 2007; Karus et al., 2002; Peltonen et al., 1981).

The Effect of Training (Chronic Exercise) on Blood Lipids (NMR Profile)

Halverstadt and colleagues (2007) investigated the effect of 24 weeks of exercise training on blood lipids in 100 sedentary healthy old men and women (age range 50-75

years) using the conventional and the NMR profiles. The exercise program consisted of different types of endurance exercise equipment (treadmill, cycling, stepping machines, and elliptical machines). The frequency was 3 sessions per week, and participants exercised for 20 minutes at 50% of their VO_{2max} at the beginning of the program, which increased to 40 minutes at 70% VO_{2max} for the last 12 weeks. Additionally, a low intensity exercise session of 45-60 minutes was added in the last 12 weeks. Blood samples before and after the exercise program were taken and analyzed using both the conventional lipid profile and the NMR method. Results showed a significant decrease in TG, TC, and LDL-C. Also, there was a significant increase in HDL-C. NMR analysis results showed a significant decrease in the particle concentrations for small dense LDL, small HDL, and VLDL. At the same time there was a significant decrease in VLDL particle size and a significant increase in HDL particle size. These changes in lipids and lipoproteins were independent of changes in body weight, composition or diet (Halverstadt et al., 2007).

A similar study by Kraus et al. (2002) that examined the effect of 6 months of exercise training on blood lipids and lipoproteins analyzed by both the conventional lipid profile and the novel NMR method. Results showed that exercise did not significantly reduce TC or LDL-C when analyzed by the conventional profile. However, NMR results showed significant changes in LDL subfractions by reducing the concentration of small dense LDL particles and increasing their average size. To test the accuracy of the NMR results, samples were analyzed using density-gradient ultracentrifugation, and the results were similar to those obtained by the NMR method. These results indicate that the NMR

method might be more sensitive to detect changes in lipoproteins due to exercise than the conventional lipid profile (Kraus et al., 2002).

The Acute Effect of Exercise on Blood Lipids (Conventional Profile)

Understanding the effect of exercise on blood lipids cannot be achieved without understanding the acute effects of one bout of exercise on these parameters (Pronk, 1993). The acute effects of a single bout of exercise might include a decrease in TC, TG, LDL-C and an increase in HDL-C, which is, according to literature, the most sensitive lipid to acute exercise.

Studies that investigated the effect of acute exercise on blood lipids showed highly inconsistent results. Some studies reported changes in lipoproteins at high energy expenditures. For example, (Ferguson et al., 2003) did not see any changes in lipoproteins before 800 kcal were expended at 70% VO_{2max} . In contrast, other studies (Kantor et al., 1987), found a significant increase in HDL-C in both trained and untrained men at lower levels of energy expenditure. The variability in the results in different studies might be due to different factors such as diet, plasma volume shifts, last bout of exercise, level of training, accuracy of measurement, age, percent body fat and alcohol consumption (Pronk, 1993). So these factors should be taken into consideration and controlled before designing any study.

The acute effect of exercise on blood lipids and lipoproteins gained researchers' attention as early as the 1960s. One of the first studies done was in 1964 by Carlson and colleagues to examine the effect of prolonged ski racing (8-9 hours) on blood lipids. Fasting blood samples were obtained before the race, and water with 30% sugar was

supplied during the race at certain distance points. Immediately after the race, post exercise blood samples were obtained and analyzed for VLDL, LDL, HDL, TG, phospholipids and TC. Results showed a significant decrease in TG, TC and phospholipids. Also, there was a significant decrease in the content of TG and phospholipids in VLDL, LDL and to a lesser extent in HDL. The decrease in TG was mainly due to a decrease of TG content in VLDL. Also, this study revealed an interesting linear relationship between the fasting levels of TG and the decrease in its concentration after exercise (Carlson & Mossfeldt, 1964).

The transient effect of exercise on lipoproteins starts as early as immediately after exercise and usually subsides between 24-48 hours after exercise (Annuzzi, Jansson, Kaijser, Holmquist, & Carlson, 1987; Cullinane et al., 1982; Park & Ranson, 2003; Pronk, 1993; Swank, Robertson, Deitrich, & Bates, 1987). Immediately, within 5-10 minutes after exercise, there will be an effect on HDL-C, while the effect on TG is usually delayed to about 24 hours post exercise (Cullinane et al., 1982; Park & Ranson, 2003).

The Acute Effect of Heavy Exercise (Marathon, Triathlon) on Lipoproteins

The acute effect of prolonged exercise (i.e. marathons, triathlons) on lipoproteins has been thoroughly investigated (Carlson & Mossfeldt, 1964; Kussi et al., 1984; Lamon-Fava et al., 1989; Thompson et al., 1980). Kussi and colleagues (1984) investigated the acute effect of a 42 km marathon in twenty men. Blood samples were obtained immediately before and within 15 minutes after the marathon and analyzed for blood lipids. Results showed no change in serum TC or TG. There was a significant decrease in VLDL-TG, LDL-TG and VLDL-C, while LDL-C remained unchanged after exercise

(Kussi et al., 1984). The effect of a 42 km marathon on lipoproteins was also examined in 12 men by Thompson et al. (1980). The average time for completing the marathon was 4 hours. Blood samples were obtained 24 hours and one hour before the race. The post race samples were taken at 5 minutes, 1, 4, 18, 42, and 66 hours. Samples were analyzed for TG, TC, HDL-C, and LDL-C. Results showed a significant delayed decrease in TG of 65%, 39%, and 32% at 18, 42, and 66 hours post exercise, respectively. Also there was a significant reduction in TC and LDL-C of 6%-10% from 4-66 hours after exercise. HDL-C increased significantly immediately (5 minutes) after exercise and remained elevated until 18 hours after exercise (Thompson et al., 1980). A similar study by Kantor and colleagues (1984) was conducted to determine the acute effects of a 42 km footrace on lipids and lipoproteins in trained men. Results showed a significant decrease in TG, TC, LDL-C and a significant increase in HDL-C and HDL₂ subfractions. Also there was a significant increase in lipoprotein lipase (LPL) activity after the race which might explain the decrease in TG and the increase in HDL-C (Kantor, Cullinane, Herbert, & Thompson, 1984). Lamon Fava et al. (1989) investigated the effect of triathlon (2.4 mile swim, 112 miles cycling, and 26.2 mile run) on TG, TC, LDL-C, and HDL-C in men and women. Blood samples were obtained 12 and 16 hours prior to exercise, and immediately after, 1, 2, 4 and 6 days of completion of the triathlon in the fasting state. For men, results showed a significant decrease of 60 % in TG. There was no significant change in TC or LDL-C. Also, there was a significant increase of 18% in HDL-C. A negative association was found between the change in HDL-C and TG, and an inverse relationship between baseline TG and the change in TG due to exercise (Lamon-Fava et al., 1989). These studies revealed a delayed effect of exercise on TG (Carlson & Mossfeldt, 1964; Kussi et

al., 1984; Thompson et al., 1980), and variable results regarding TC, LDL-C or HDL-C (Lamon-Fava et al., 1989).

The Acute Effect of Prolonged Bouts of Exercise

Most of the studies that investigated the effect of acute exercise on lipoproteins involved prolonged bouts of exercise that lasted between 1-3 hours (Annuzzi et al., 1987; Cullinane et al., 1982; Griffin, Skinner, & Maughan, 1988; Kantor et al., 1987; Magkos, Patterson, Mohammed, & Mittendorfer, 2006). Annuzzi and colleagues (1987) investigated the acute effects of two sessions of exercise at 50% of their maximum workload, determined on the cycle ergometer on TG removal in 10 healthy men. The durations for both sessions were 1.5 and 3 hours and the same participants exercised for both sessions that were 4-6 weeks apart. The exercise session consisted of 1 hour of cycling followed by 30 minutes of running at the same intensity. Results showed a significant decrease in plasma TC in both sessions and a significant increase in TG clearance in the 3-hour session (Annuzzi et al., 1987).

The effect of prolonged exercise has been shown to have favorable effects on blood lipids and lipoproteins, but such is not the case with short bouts of exercise. Cullinane et al. (1982) conducted a study to determine the effect of 30 minutes of cycling at 75% VO_{2max} on blood lipids in men. Results revealed no significant effect on any of those parameters. One year later, they designed a similar study with increased duration (60 minutes) and results revealed a significant decrease in TG. Also, there was a significant decrease in TC and LDL-C that disappeared after correction for plasma volume (Cullinane et al., 1982).

The effect of exercise sessions that lasted for 1 and 2 hours at 80% VO_{2max} on HDL-C was investigated in untrained and trained men, respectively. After the exercise sessions, there was a significant increase in HDL-C in both groups (after correcting for changes in plasma volume). The increase in HDL-C in trained men was mainly due to an increase in HDL₂-C subfractions, while in untrained men it was due to an increase in HDL₃-C subfractions (Kantor et al., 1987). Some studies found that the increase in HDL-C due to exercise is affected by the intensity of exercise, where more effect was seen with high intensity exercise sessions, even if similar energy expenditures were achieved (Gordon et al., 1994; Sgouraki, Tsopanakis, Kioussis, & Tsopanakis, 2004). Others tried to detect the amount of energy expenditure required to produce positive effects on HDL-C in trained men. They found that an energy expenditure of no less than 800 kcal (at 75% VO_{2max}) is required to produce favorable effects on HDL-C. This result is not consistent with other studies that found a significant increase in HDL-C at lower energy expenditures (400 kcal) at a similar intensity (Gordon et al., 1994). In spite of this variability, most of the studies revealed a positive effect of exercise on lipoproteins at intensities greater than 60% VO_{2max} (Gordon et al., 1994; Lira et al., 2009; Sgouraki et al., 2004; Visich et al., 1996).

In light of the previous studies, the acute effect of exercise that lasts up to 2 hours on conventionally measured lipids is established for HDL-C and TG. Usually, there will be a delayed decrease in TG (Cullinane et al., 1982; Park & Ranson, 2003) and an immediate increase in HDL-C (Gordon et al., 1994; Kantor et al., 1987; Park & Ranson, 2003; Swank et al., 1987; Visich et al., 1996). The variability in that effect is mainly with TC and LDL-C, where some studies revealed positive and favorable effects on these

parameters (Lira et al., 2009; McCarthy, Plowman, Looney, Kelly, & Manning, 2002; Sgouraki et al., 2004) while others showed no effect (Joshua, Kyle, Biggerstaff, & Ben-Ezra, 2009; Lamon-Fava et al., 1989).

The Acute Effect of Exercise on the Size and Density of Lipoproteins

The risk for developing CVD is not only related to the conventionally measured blood lipids, but also to the size and density of lipoproteins (Blake et al., 2002; Cromwell & Otvos, 2004; Harchaoui et al., 2007). As discussed previously, exercise training has favorable chronic effects on conventionally measured blood lipids. Also, plausible changes related to the size and density of lipoproteins were related to exercise training (Halverstadt et al., 2007; Karus et al., 2002). However, in order to understand the cumulative effect of exercise on the size and density of lipoproteins, the acute effect of an exercise session needs to be understood.

The effect of acute exercise was investigated to determine any immediate changes in lipoprotein size and density (Joshua et al., 2009; Lamon-Fava et al., 1989; Yu et al., 1999). Lamon fava et al. (1989) investigated the acute effect of triathlon in 34 men and six women, on blood lipids and lipoproteins measured by the conventional lipid profile and gradient gel electrophoresis (GGE). After the race, men showed a significant decrease in TG and a significant increase in HDL-C. GGE results showed a significant decrease in LDL size in seven out of the 34 men. Joshua and colleagues (2009) examined the effect of 3 days of 60 minute exercise sessions at 65% VO_{2max} and omega-3 supplements on lipoprotein size analyzed by GGE in sedentary normoglycemic men.

Results showed a significant increase in LDL particles size with no effect on HDL particle size. Also there was a significant decrease in TG and TC (Joshua et al., 2009).

Since NMR has advantages over the previously discussed method (GGE), it is plausible to study the acute effect of exercise on lipoproteins analyzed by this method (NMR). Yu and colleagues (1999) examined the effect of acute exercise on lipoproteins measured by NMR in triathletes after completion of the 1995 World Championship Hawaii Ironman Triathlon. Blood samples were collected immediately after the race and analyzed by NMR spectroscopy. Results showed a significant increase of 11% in large HDL subclasses, whose concentrations are inversely related to cardiovascular disease (CVD) risk, while small LDL particles, that are directly associated with increased CVD risk, declined by 62%. Also, the NMR profile showed a 2.7% average increase in HDL particle size (Yu et al., 1999). However, this kind of exercise cannot be achieved in the general population. Therefore, it is plausible that the NMR profile may be more sensitive to changes in lipoprotein particle number and size in normally active adults after an acute bout of dynamic exercise. Based upon the foregoing, the purpose of this study is to examine the effect of a 60-minute bout of dynamic exercise on lipoprotein particle number and size as measured by nuclear magnetic resonance (NMR) in comparison with the conventional lipid profile analysis.

CHAPTER 3

METHODS

This study was approved by the UNLV's office for the Protection of Research Participants and the UNLV's Institutional Review Boards (IRB).

Subject Characteristics

Selected participants were eight active males between the ages of 19 and 34 years. See Table 3 for subjects' physical characteristics. They were apparently healthy and at low risk for developing CVD according to the ACSM health screening questionnaire, which was used to assess any health problems that might exclude individuals from participation. Those include, but are not limited to, any metabolic, pulmonary or cardiac diseases.

In addition to the aforementioned criteria, the participants were nonsmokers, exercised six hours or more per week (their exercise training consisted of both endurance and strength training), and were not taking any medications or supplements that might affect lipids and lipoprotein metabolism.

Data Collection

Participants reported to the exercise physiology laboratory three times at mutually agreed-upon times.

The First Visit

On the day of the first visit, participants were given an overview of the project. Discussion of the procedure was provided along with the risks associated with participation. Also, consent forms were signed and the ACSM health screening form was

completed before the initiation of any procedure. Participants were assured about the privacy and confidentiality of their data.

Anthropometric measurements were taken which included height and weight and percent body fat. Also, aerobic fitness was determined (Table 3). To determine percent body fat, bioelectrical impedance (BIA, BioAnalgetics) was used. The participant was in a supine position and electrodes were placed on the right hand and foot and then the impedance was obtained in (ohms). This value was transferred to the software that calculates percent body fat. To determine aerobic fitness (VO_{2max}), indirect calorimetry was used where the participant was asked to wear a mask that covers his mouth and nose. (The participant was able to breathe normally while wearing this mask). The mask was connected to a metabolic cart that measures the amount of expired oxygen and carbon dioxide. In addition, respiratory gas exchange (RER) was measured. While wearing this mask, the participant was asked to run on a treadmill at a speed that he selected and was comfortable with. The first stage was a warm-up that consisted of walking for two minutes. The grade and speed were increased gradually every two minutes. Criteria for attainment of VO_{2max} included a < 5 ml/kg/min increase in VO_2 with an increase in workload, a respiratory exchange ratio (RER) greater than or equal to 1.15, when heart rate reached within 5 beats per minute of their maximum predicted heart rate, and/or volitional fatigue (the participant's inability to maintain work rate). Heart rate was monitored throughout the test. The total duration of this test was 8-12 minutes.

After completion of the tests, the participant was provided water and asked to rest. Instructions about the second visit were provided, which included:

1. Maintaining their diet habits.

2. Providing diet and exercise records for 3 days before the second visit.
3. Refraining from vigorous exercise 3 days before the second visit (to minimize any carryover effect from a previous exercise).
4. Refraining from alcohol consumption 72 hours before the second visit.
5. Fasting for ten hours the night before the second visit. Only water will be permitted while fasting.

The Second Visit (Experimental Exercise Protocol)

Participants returned to the lab 3-4 days after the first visit. The exercise procedure was explained. Then, 15 ml of blood were drawn from the participant's antecubital vein by a licensed nurse. Eight ml of blood were collected in serum tubes for the conventional profile analysis and 7 ml were collected in EDTA tubes for the NMR profile analysis. Tubes were kept in an ice bath. The Participants started running on the treadmill. The treadmill speed and grade were adjusted to exercise the participant at an intensity of 70% of their relative VO_{2max} for duration of 60 minutes. They ran at a speed of 6.5 -8.5 mph (174.2-227.8 m/min) and the grade was between 0%-2.5%. Water was provided throughout the exercise to maintain hydration. During that time, heart rate was monitored and the participants were closely observed for any abnormal signs and symptoms that indicate termination of the exercise such as chest pain, severe fatigue or inability to continue the exercise. After completing the exercise, the participants were asked to rest. Five to ten minutes after exercise completion, another 15 ml of blood were drawn from the antecubital vein using serum separator and EDTA tubes. Collected blood was kept in an ice bath. The participants were given instruction sheets regarding the third visit which included: refraining from any exercise, refraining from drinking alcohol and repeating the

diet they consumed on the day before the exercise session. Then they were asked to return to the lab the next morning after a 10-hour fast.

The Third Visit

The next morning and within the 24th hour of the exercise session, the participants reported to the lab after a 10-hour fast. Fifteen milliliters of blood were drawn from the antecubital and collected in serum tubes and EDTA tubes. The collected blood was kept in an ice bath.

After collection was completed, samples in the EDTA tubes were centrifuged at 3,000 rpm (1,875g) for 10-15 minutes to separate plasma from red blood cells (RBCs). NMR Analysis

Five hundred μ l transfer vials were labeled using a coding system, to protect participants' identities. Using a pipette, plasma was transferred to the transfer vials and sealed securely, and stored at -70°C . After all samples are collected, they were sent to LipoScience, Inc. (Raleigh, NC) for analysis of the lipoproteins subclasses (LDL, HDL, IDL, and VLDL) and their particle number. As recommended by Liposcience, Inc., frozen specimens were shipped by an overnight courier using a well-insulated container and an adequate amount of dry ice.

Serum tubes were labeled using a coding system, to protect participants' identities.. On the same day of the collection, samples were sent to Quest Diagnostics for analysis of the conventional lipid profile.

Statistical Analysis

Statistics

A Repeated Measures Analysis of Variance (ANOVA) was used for statistical analysis. A probability value of $\leq .05$ was considered significant. Calculations were performed with SPSS (Statistical Package for the Social Sciences) 17.0.

Dependent and Independent Variables

The independent variables were time (pre-exercise, 5 minutes post-exercise and 24 hours post exercise) and method (NMR profile vs. conventional profile). The dependent variables were lipoprotein concentrations, sizes and particle number.

Limitations and Delimitations

Limitations

The sample size of this study is small compared to the general population, which can interfere with the external validity. Also, the acute effect of exercise varies greatly among people which can affect the internal validity. These variations can be due to several factors, such as age, percent body fat, training level, previous bouts of exercise and diet. To avoid these variations we tried to control these factors as much as possible by choosing participants with similar characteristics in terms of percent body fat, age and training level. To avoid the effect of a previous bout of exercise, participants were instructed to refrain from exercise 3 days before the exercise session. To control the effect of diet, participants were asked to maintain a record of their diets in the 3 days that precede the exercise session. Also, after the exercise session, participants were asked to repeat the diet they consumed on the day before the exercise session to avoid the effect of diet on the 24-hour samples.

In addition, our procedure included an invasive procedure (blood draw) and that might have decreased participants' interest to participate in the study, however, we were able to obtain the required sample size.

Delimitations

The participating participants were moderately to highly active, and they represent a small percentage of the population in contrast to the majority of people which are either sedentary or mildly active. We chose this level of activity to ensure their ability to complete the high-intensity exercise session chosen. The intensity and duration of exercise used in the current study was selected because some studies concluded better results with high intensity exercise sessions (even with similar energy expenditures) than lower intensities using conventionally measured lipoproteins (Gordon et al., 1994; Karus et al., 2002). Although we expected the NMR method to be more sensitive in detecting changes in lipoproteins due to exercise, we started with a higher volume of exercise, and if positive results were obtained, we would suggest future studies with lower intensities and durations applied on participants with lower levels of activity (sedentary or mildly active). Also, to get the health benefits from exercise, the American College of Sports Medicine (ACSM) recommends exercise sessions that last for 15-60 minutes, at intensities between 40-85% of VO_{2max} . So, our exercise session falls within those recommendations.

CHAPTER 4

RESULTS

Subjects Physical characteristics

Table 3: Subjects Physical Characteristics and VO₂ max (avg±SD)

N	Age	Height(cm)	Mass (kg)	VO ₂ max(ml/kg/min)	% Fat
8	26±5.17	176±6.6	78.5±5.84	57.8±4.83	17.4±3.1

Conventional Lipid Profile Results

One participant was excluded from the conventional profile lipid analysis due to the nurse's inability to get the blood sample immediately after exercise, but the sample for the NMR profile was obtained. So the conventional profile data analysis was run using 7 participants, and the NMR analysis was run using 8 participants. The ANOVA test was significant for TG (F=5.59, p=.019) (Table 4), with a significant increase of 22% observed immediately after exercise (p=.028), followed by a significant decrease observed 24 hours after exercise (p=.043) from the immediate post exercise values; this reduction in TG concentration was 13% from the baseline values (Table 5). HDL-C significantly changed due to exercise (p=.05) with an increase of 8.1% immediately after exercise. This increase in HDL-C was positively associated with the weekly running mileage of participants (Figure 4).

A trend for TC to increase was observed (5%) immediately after exercise and (2%) 24 hours after exercise was observed. However, this decrease was not significant. (F=3.99, p=.081). Also, no statistically significant changes were observed in LDL-C (F=3.88,

p=.835) or the TC/HDL-C ratio (F=.836, p=.418). Table 4 shows the results of the conventionally measured blood lipids and lipoproteins immediately before, immediately after and 24 hours post exercise. Also, Figure 3 shows the conventional profile component changes across the three time points, and Table 5 shows the percentage changes in conventionally measured blood lipids and lipoproteins.

Table 4: Serum Lipids and Lipoproteins before and after Exercise (avg±SD)

Lpid/Lipoprotein	Time Point			F value	P value
	Pre	Post	24 hours post		
TC	167±11.1	175.4±18.7	163.3±22.6	3.99	.081
TG	90.6±57.9	110.3±49.4	78.9±37.7	5.59	.019
HDL-C	51.4±11.4	55.6±12.1	51.3±10.6	3.88	.05
LDL-C	97.4±17.3	97.9±22.5	96.1±22.4	.184	.835
TC/HDL-C ratio	3.42±0.92	3.34±0.87	3.31±0.88	0.836	.418

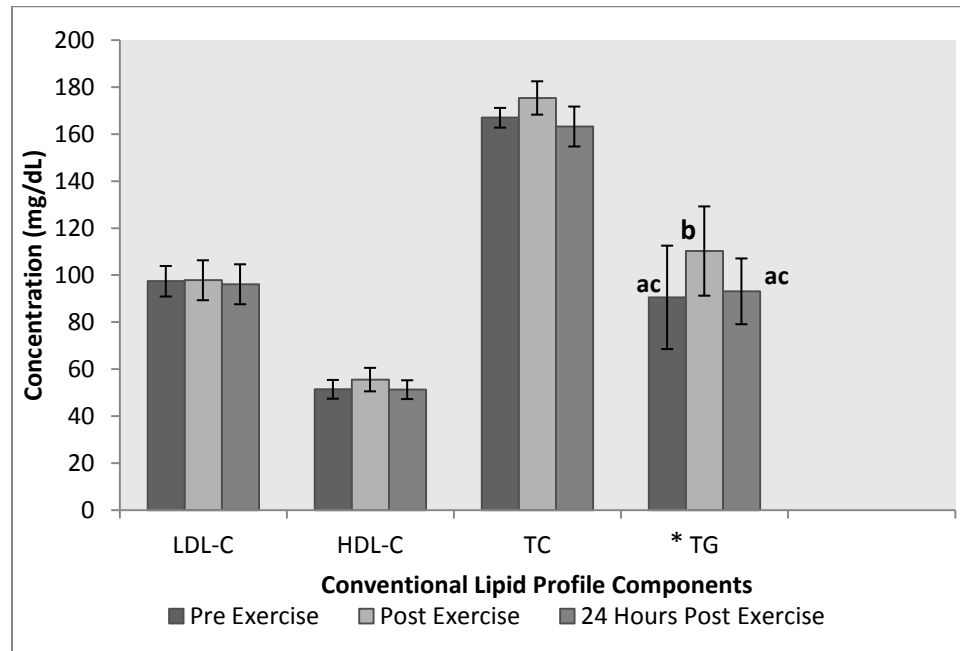


Figure 3: Conventional Lipid Profile Results

TC: Total cholesterol, TG: Triglycerides, LDL-C: Low density lipoprotein cholesterol, HDL-C: High density lipoprotein cholesterol

* Values with the same letters are not significantly different.

Table 5 : Percentage Changes in Conventional Profile between Different Time Points

Lipid/ Lipoprotein	Pre & Post	Pre & 24 hrs. post
TC	5%	-2%
TG	22%	-13%
LDL-C	0.4%	-1.3%
HDL-C	8.1%	0.3%
TC/HDL-C Ratio	-2%	-3%

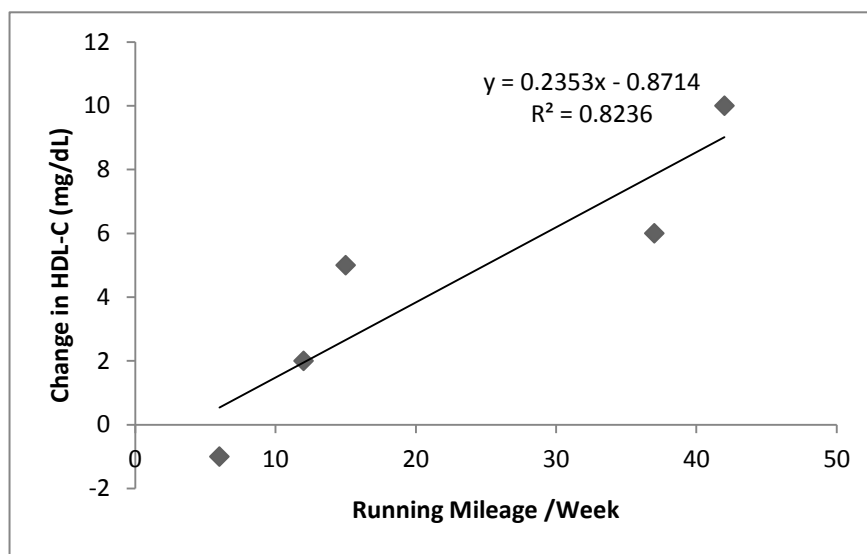


Figure 4: The Positive Relationship between Running Mileage Per Week and the Immediate Change in HDL-C

NMR Profile Results

Lipoprotein Subclasses Concentration Results

Table 6 summarizes the NMR lipoprotein subfraction concentration changes due to exercise across the three time points. Also, the percentages of these changes are represented in Table 7 and Figure 5.

There was a significant change in the large HDL subfraction concentration ($F=3.865$, $p=.046$), with an increase of 5.8% immediately after exercise, then a decrease of 6.8% observed 24 hours after exercise. See Figure 4 which shows the change in the large HDL particle concentration across the three time points of the exercise session. No significant changes were observed in the other HDL, IDL and LDL, or chylomicron and VLDL subfractions across the three time points (Table 6).

Table 6: NMR Lipoprotein Subclasses Concentration RM ANOVA Results (Avg \pm SD)

Lipoprotein	Subclasses	Pre Exercise	Post Exercise	24 hours Post	F	P
VLDL (nmol/L)	VLDL & Chylomicron (total)	49.9 ± 23.5	52 \pm 27.1	48.1 \pm 24.2	.486	.625
	Chylomicron & large VLDL	1.9 ± 3.5	1.4 \pm 2.6	0.8 \pm 1.2	1.780	.223
	Medium VLDL	16.7 ± 11	14 \pm 13.5	13 \pm 11.4	1.044	.378
	Small VLDL	31.3 ± 15.3	36.7 \pm 19.8	34.2 \pm 15.8	1.370	.286
LDL (nmol/L)	LDL (total)	969 ± 201	1050 \pm 256	984 \pm 285	1.507	.260
	IDL	27 ± 31.3	19.3 \pm 16.7	25.5 \pm 29.7	.597	.564
	Large LDL	279 ± 125	308 \pm 112	301 \pm 176	.626	.531
	Medium small LDL	142.6 ± 58.2	154.4 \pm 66.8	136.4 \pm 71.6	1.092	.362
	Small LDL	662 ± 251	772 \pm 293	658 \pm 354	1.092	.362
	Very small LDL	520 ± 69	568 \pm 80	522 \pm 100	.742	.494
HDL (μ mol/L)	HDL (total)	30 \pm 6	31 \pm 5	29 \pm 5	1.566	.243
	Large HDL	6.9 \pm 3.2	7.3 \pm 3.3	6.4 \pm 2.8	3.865	.046
	Medium HDL	4.3 \pm 2.8	3.8 \pm 2.2	3.7 \pm 2.9	.189	.690
	Small HDL	18.7 \pm 6.8	19.8 \pm 6.2	19.1 \pm 6.2	.266	.684

Table 7: Percentage Change in Lipoprotein Subclasses at Different Time Points

Lipoprotein		Pre & Post	Pre& 24 hours post
VLDL	VLDL & chylomicron (total)	4.2%	-3.7%
	Chylomicron & large VLDL	-29.7%	-57.4%
	Medium VLDL	-16%	-21%
	Small VLDL	17%	-9.20%
LDL	LDL (total)	8.4%	1.6%
	IDL	-28.7%	-5.6%
	Large LDL	10.3%	7.7%
	Medium small LDL	8.2%	-4.4%
	Small LDL	9%	-0.7%
	Very small LDL	9.3%	0.4%
HDL	HDL (total)	3.5%	-2%
	Large HDL	5.8%	-6.7%
	Medium HDL	-11.7%	-14.1%
	Small HDL	6.1%	-2.6%

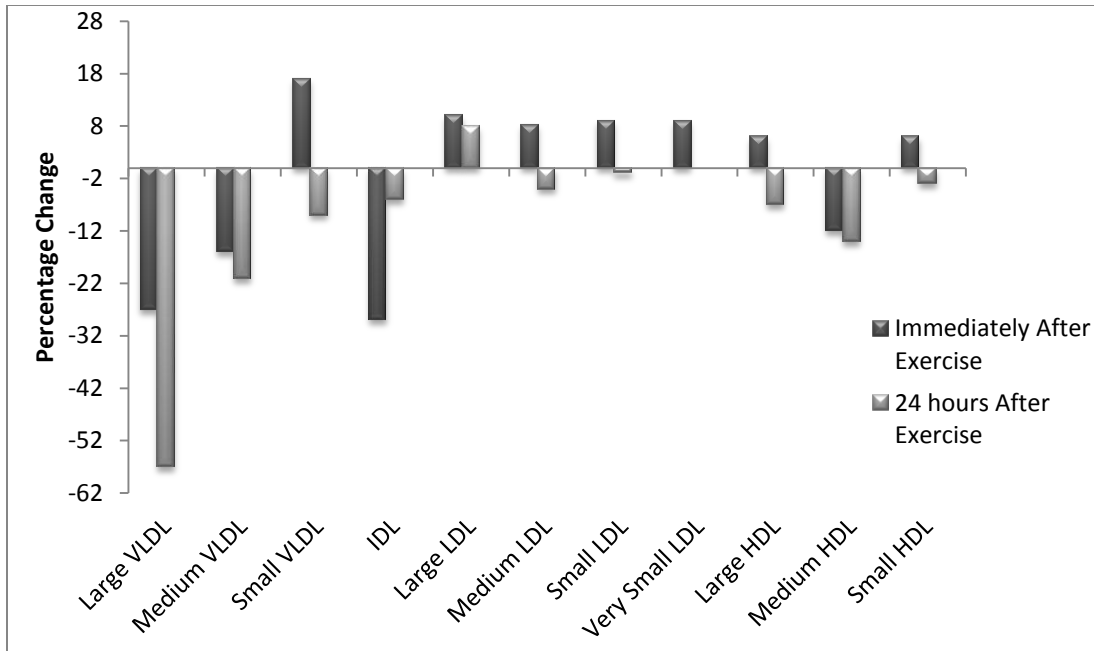


Figure 5: Percentage Changes in the NMR Lipoprotein Subclasses

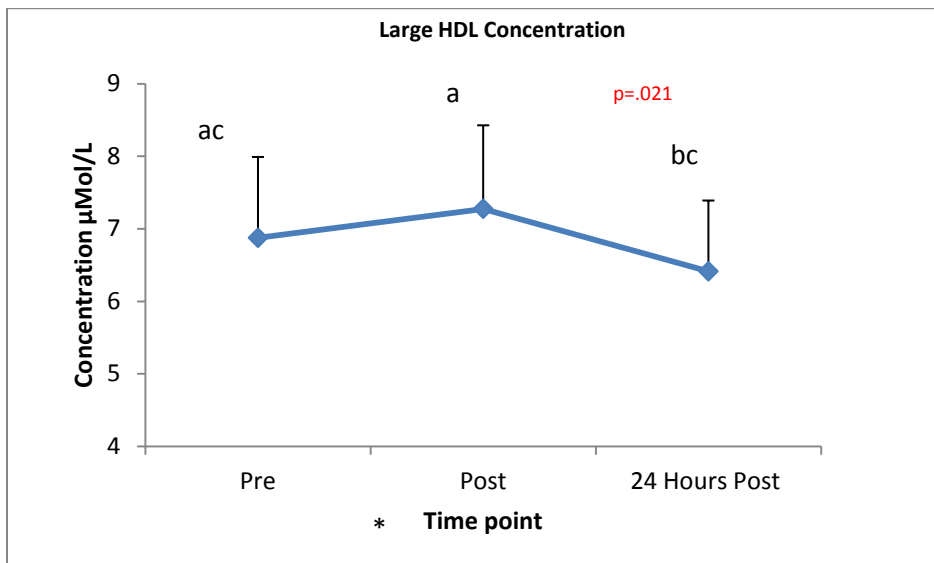


Figure 6: Large HDL Concentration Changes across the Three Time Points

* Values with the same letters are not significantly different.

Lipoprotein Subclasses Size Results

No significant changes in the three subfractions average size (VLDL, LDL and HDL) were observed. See Table 8, which shows the changes in the average size across the three

time points, and Figure 8 which illustrates the mean changes in VLDL, LDL and HDL mean particle size. Also, Table 9 shows the percentages of the mean size changes between the three time points pre exercise, post exercise and 24 hours post exercise.

Table 8: NMR lipoprotein Size Changes at different Time Points (nm) Avg±SD

Lipoprotein	Pre	Post	24 Hours Post	F	P value
VLDL	52±8.4	48.5±7.4	49.2±7.2	1.503	.256
LDL	20.76±0.7	20.79±0.56	20.86±0.83	.236	.793
HDL	8.95±0.43	9.01±0.44	8.93±0.41	2.416	.154

Table 9: NMR Lipoprotein Percentage Size Changes at different Time Points

Lipoprotein	Pre& Post	Pre & 24 Hours Post
VLDL	-6.9%	-5.5%
LDL	0.12%	0.5%
HDL	0.7%	-0.3%

CHAPTER 5

DISCUSSION

The Conventional Profile

Long duration exercise sessions increase the utilization of lipids compared with carbohydrates (Annuzzi et al., 1987), which might explain the significant increase of 22% in TG that was observed immediately after exercise in the current study. This increase is not consistent with Cullinane et al. (1982) who did not observe any immediate effects of 1 and 2 hours of cycling on TG (Cullinane et al., 1982). Delayed decrease in TG might be attributed to several factors such as a delayed increase in the activity of lipoprotein lipase (LPL) that increases at least 8 hours after the end of exercise, which in turn increases the removal capacity in TG.(Annuzzi et al., 1987). Other factors like replenishment of adipose and intramuscular stores that were depleted during the exercise might also explain this decrease in TG .The 24 hours values in the current study showed a non significant decrease of 13% from baseline but was significant from the values obtained immediately after exercise (Figure 3). This finding is consistent with a study done by Cullinane and colleagues in 1982, who reported a non significant decrease of 17% in TG after 1 hour of cycling (Cullinane et al., 1982).

HDL-C is negatively associated with CVD and for each 1 mg/dL decrease in its concentration, there is a 2-3% increase in coronary heart disease (NCEP, 2002). In the current study, HDL-C significantly changed due to exercise. However, the post hoc test did not show any significant differences between any two time points. A non significant average increase of 4.1 mg/dL (8%) in HDL-C was observed immediately after exercise that might be attributed to the increased activity of lipoprotein lipase (Kantor et al., 1984;

Kussi et al., 1984; Svedenhag et al., 1983). The increase in LPL activity results in an increased hydrolysis of TG and tissue uptake of TG. This in turn decreases the TG-rich lipoproteins and remodeling of these lipoproteins results in an indirect increase of HDL-C. Other possible mechanisms such as synthesis of new HDL or reverse cholesterol transport might have contributed to this increase (Skinner, Black, & Maughan, 1985). Exercise acutely increases the concentration of HDL-C (Cullinane et al., 1982; Kantor et al., 1987; Park & Ranson, 2003). In the present study, six out of eight participants responded by an immediate increase in HDL-C between 5-10 mg/dL, while one showed a decrease by 1 mg/dL and the other showed an increase of 2 mg/dL. This variability in response might be attributed to several factors such as age, percent body fat, last bout of exercise, constituents of diet that the participant usually consumes (high in fat versus high in carbohydrates diets) and the average running training mileage. Griffin et al. (1988) investigated the effect of a high fat diet versus a high carbohydrate diet on acute exercise induced changes in plasma lipoproteins. In their study, participants consumed 75% fat diet or 85% carbohydrate diet and performed a 37 km walking test over 4 consecutive days. Results showed a decrease in HDL-C in the participants who consumed the high carbohydrate diet. On the contrary, participants who consumed the high fat diet revealed a significant increase in HDL-C after exercise (Griffin et al., 1988). The results of this study however cannot be related to our study because our participants did not consume any of these diets. Variability in HDL-C responses might also be related to the weekly average running mileage (Skinner et al., 1985). In the current study, a positive relationship between the number of running miles per week and the change in HDL-C immediately after exercise was observed ($r=.908$, $p=.033$) (Figure 4). Participants with

higher training mileage were observed to have higher HDL-C concentrations immediately after exercise.

The other conventionally measured lipoproteins (TC, and LDL-C) did not show any statistically significant changes across any of the time points. There was a non significant increase in TC after exercise. This transient and non significant increase in TC immediately after exercise is consistent with a study conducted by Cuilinane and colleagues (1982) that investigated the effect of 60 minutes of cycling on the conventional lipid profile (Cullinane et al., 1982). In contrast, our results are not consistent with Park et al. (2003) who reported a significant transient increase in TC after running at 70% of the lactate threshold (LT) (Park & Ranson, 2003).

The NMR Profile

Previous studies have shown that the lipoprotein particle size and number measured by the NMR method were more sensitive predictors of cardiovascular disease than the lipids concentrations measured by the conventional profile (Blake et al., 2002; Cromwell & Otvos, 2004; Harchaoui et al., 2007). Also, other studies have shown that chronic exercise will produce favorable effects on these subfractions, such as an increased size of the LDL and HDL particles and a reduced number of small LDL and HDL particles (Halverstadt et al., 2007; Kraus et al., 2002). In addition, similar favorable changes were observed in athletes after a triathlon (Yu et al., 1999). However, the exercise session in the current study did not significantly alter these subfractions, except in the large HDL particle concentration (Table 6, Table 7, and Figure 6), which are known for their cardioprotective effect. Some studies reported a negative relationship between these

particles and the rate and progression of coronary artery disease (Freedman et al., 1998; Johansson et al., 1991). So an increase in the concentration of this particle that is induced by exercise is considered a favorable effect. The transient increase in the concentration of large HDL particles in the current study was not significant from baseline (Figure 6). These results are not in agreement with Yu et al. (1999) who reported a significant increase of 11% in large HDL subclasses after a triathlon (Yu et al., 1999). This inconsistency might be due to the difference in the intensity and duration of the exercise between the two studies. While Yu and colleagues (1999) investigated the effect of a triathlon, our study investigated the effect of 60 minutes of running at 70% $\text{VO}_{2\text{max}}$. So the difference in the exercise intensity and duration might explain the difference in the results. Also, a study (Durstine et al., 1987) reported an interesting relationship between the habitual time spent in training and the increase in large HDL particles. Our participants were recreational runners with an average of 8 hours of training per week, while in the other study they were endurance athletes with an average of 21 hours of training per week. So this might explain the significant increase in large HDL particles in their study that was not observed in our study.

Factors such as the constituents of the consumed diet and level of training affect HDL particle change after exercise (Griffin et al., 1988; Kantor et al., 1987). This might explain the variability found in the participants in our study that some participants revealed a decrease in their large HDL particle concentrations while others showed an increase with varying degrees. The training level of the participants affects their large HDL particle change after exercise (Kantor et al., 1987). In their study, it was found that trained participants demonstrated a greater increase in the large HDL particles, while

untrained participants had a greater increase in small HDL subfractions after exercise. The other factor that might have lead to this variability is the consumed diet (Griffin et al., 1988). A study designed by Griffin and colleagues (1988) investigated the effect of 4 days of walking on HDL subfractions measured by gradient gel electrophoresis. In their results, they reported that participants who consumed a high fat diet (75% of kilocalories obtained from fat) demonstrated a greater increase in large HDL particles, while participants who consumed a high carbohydrate diet (85% of kilocalories obtained from carbohydrates) expressed a greater increase in small HDL particle concentrations. In our study, participants had the same level of training, so this variability might have been caused by the constituents of their diets. However, the diet data that we obtained from participants on the three days that preceded the exercise session does not relate to any of these diets. Our participants consumed more of a mixed diet with an average of 33%, 49% and 18% of kilocalories from fat, carbohydrates and protein respectively.

VLDL, LDL and HDL subfractions size and number measured by the NMR method have different relationships to CVD. For example large VLDL, small LDL and small HDL particle concentrations are positively associated with CVD, while large LDL particle concentrations are negatively associated with CVD (Blake et al., 2002; Freedman et al., 1998; Gardner et al., 2002; Jeyarajah et al., 2006). These subclasses concentrations did not show any significant change due to exercise in the current study, and this finding is not consistent with Yu et al. (1999) who reported a significant decrease in small LDL and small HDL particles and a significant increase in the HDL mean particle size by 2.8% immediately after exercise (Yu et al., 1999). Also, total HDL particle concentration has increased, but not significantly, immediately after exercise by 3.5%. This immediate

increase in total HDL is attributed to the increase in both large and small HDL particle concentrations (Table 6). These results, although temporally different, are consistent with results from Gordon et al. (1998) who showed a delayed non-significant increase in total HDL particles as measured by gradient gel electrophoresis in trained women after exercising at 75% VO₂ max. In their study, This increase was due to increased levels of both HDL₂ (large) and HDL₃ (small) subfractions (Gordon et al., 1998). However, this contrasts the work of Park et al. (2003) who observed a significant delayed increase from baseline values (Park & Ranson, 2003).

Conclusion and Recommendations for Future Study

The acute effect of one 60-minute session of exercise at an intensity of 70% VO₂ max on blood lipids measured by the conventional and the NMR profile was investigated in eight active and apparently-healthy men. Exercise produced a significant effect on TG and HDL-C in the conventional profile (Tables 4 and Table 5) and on the large HDL particle concentration in the NMR profile (Table 6 and Table 7). So the first null hypothesis, that exercise has no effect on conventionally and NMR measured lipids and lipoproteins was rejected. The change in the large HDL particle concentration that was detected by the NMR profile was not significant from baseline (Table 6, Table 7 and Figure 6). In addition, the conventional profile has detected significant change in TG and HDL-C that were not significant from baseline either. So the NMR method was not more sensitive in detecting changes in lipoproteins due to exercise, and we failed to reject the null for the second hypothesis.

One session of endurance exercise for 60 minutes at 70% VO₂max, might produce favorable effects on blood lipids and lipoproteins that might reduce CVD risk. In the current study, the NMR method of analysis did not show a greater sensitivity in detecting those changes than the conventional assay. These induced changes in both profiles were detected in TG, HDL-C in the conventional and in the large HDL particle concentration in the NMR profile. The other conventionally measured lipid (TC, LDL-C) and the rest of the NMR subclasses did not show any changes after one bout of exercise. This might indicate that one bout of strenuous exercise had no significant effect on all the lipid profile parameters measured by either methods. This is in agreement with previous studies which indicated that a single bout of exercise might produce significant effects on HDL-C, and TG in the conventional profile (Cullinane et al., 1982; Gordon et al., 1994; Kantor et al., 1987; Park & Ranson, 2003; Swank et al., 1987; Visich et al., 1996). without any significant effect on TC and LDL-C (Joshua et al., 2009; Lamon-Fava et al., 1989). For the effect of exercise on particle size and number, two studies investigated this effect using gradient gel electrophoresis as an analysis method (Griffin et al., 1988; Joshua et al., 2009). Although these studies showed significant effect on LDL and HDL particle size, they used exercise tests that were done over three days. Since the current study did not show any significant changes on lipoprotein subclasses after exercise (except large HDL particle concentration), we conclude that one bout of exercise might not be sufficient to produce effects on these subclasses. So, future studies might investigate the acute effect of exercise over a number of days on lipoproteins measured by the NMR method. Also, the participants in the current study were active men and

follow up studies might benefit from using sedentary participants, women or people with hyperlipidemia at lower intensities or duration of exercise.

APPENDIX I
ANTHROPOMETRIC DATA

Subject	Age	Height(cm)	Weight(kg)	VO2 max	BIA Resistance(ohms)	Percent Body Fat
1	22	166.5	64.62	62.4	470	15.7
2	32	171.5	76.97	57.3	427	16.6
3	28	183.5	81.94	64.9	421	13.7
4	23	181.5	80.00	56.0	426	14
5	24	182.0	85.37	51.7	434	16.7
6	32	173.5	82.37	52.5	471	22
7	19	171.0	79.08	63.6	455	20.2
8	34	183.5	77.45	54.2	523	20.4
Average	26.8	176.6	78.5	57.8	453.4	17.4
SD	5.5	6.7	6.2	5.2	34.4	3.1

APPENDIX II

CONVENTIONAL LIPID PROFILE DATA

Conventional Blood Lipids (mg/dL)					
Subject ID	Timepoint	TC (mg/dL)	TG(mg/dL)	HDL-C(mg/dL)	TC/HDL-C
1	Pre exercise	158	208	41	3.85
1	Post exercise	151	205	40	3.78
1	24 hours post exercise	141	127	41	3.44
2	Pre exercise	156	39	63	2.48
2	Post exercise	156	65	65	2.4
2	24 hours post exercise	139	39	60	2.32
3	Pre exercise	182	59	48	3.79
3	Post exercise	205	72	58	3.83
3	24 hours post exercise	204	53	60	3.40
4	Pre exercise	172	90	34	5.06
4	Post exercise				
4	24 hours post exercise	167	72	36	4.64
5	Pre exercise	172	75	56	3.07
5	Post exercise	172	86	58	2.97
5	24 hours post exercise	151	59	51	2.96
6	Pre exercise	179	102	55	3.25
6	Post exercise	188	124	60	3.13
6	24 hours post exercise	173	127	51	3.39
7	Pre exercise	155	45	64	2.42
7	Post exercise	172	84	70	2.46
7	24 hours post exercise	163	49	62	2.63
8	Pre exercise	167	106	33	5.06
8	Post exercise	184	136	38	4.84
8	24 hours post exercise	172	98	34	5.06

APPENDIX III

NMR PROFILE DATA

LIPOSCIENCE NMR PROFILE DATA									
	Concentrations				LDL Particle Concentrations				
	VLDL & Chylomicron Particles (total) nmol/L	Large VLDL & Chylomicrons Particles nmol/L	Medium VLDL Particles nmol/L	Small VLDL Particles nmol/L	LDL Particles (total) nmol/L	IDL Particles nmol/L	Large LDL Particles nmol/L	Small LDL Particles (total) nmol/L	Medium Small LDL Particles nmol/L
Sample ID	VLDLCP	VLCP	VMP	VSP	LDLP	IDLP	LLP	LSP	LMSP
1A	69.7	10.3	35.6	23.8	794	16	268	509	118
2A	17.1	0.1	2.2	14.7	950	0	231	720	162
3A	38.6	0.6	7.5	30.5	954	15	521	418	88
4A	33.8	1.0	15.4	17.5	1233	44	301	888	191
5A	51.7	0.5	12.8	38.4	905	9	293	603	137
6A	64.5	2.5	21.3	40.7	1166	93	170	904	199
7A	34.3	0.1	10.8	23.5	627	0	345	282	41
8A	89.4	0.4	27.6	61.4	1119	39	104	975	205
1B	67.4	7.6	39.8	19.9	859	10	268	580	125
2B	12.3	0.1	0.0	12.2	960	9	194	758	186
3B	41.2	0.2	2.8	38.3	1086	20	488	578	126
4B	43.2	0.4	5.5	37.3	1441	35	342	1064	221
5B	52.2	0.3	13.6	38.3	900	3	336	561	114
6B	64.8	1.6	20.4	42.9	1135	47	300	789	176
7B	32.0	0.1	5.6	26.3	672	0	400	271	39
8B	102.8	0.6	24.2	78.0	1343	30	136	1177	248
1C	54.3	3.5	23.2	27.6	834	12	290	532	125
2C	15.9	0.1	1.1	14.7	810	6	196	609	134
3C	35.6	0.1	3.4	32.0	1126	16	633	478	81
4C	30.4	0.6	7.0	22.8	1298	39	272	986	204
5C	51.5	0.1	3.9	47.5	634	0	445	188	49
6C	87.4	1.6	33.1	52.7	1034	45	194	796	169
7C	33.1	0.2	12.5	20.4	708	0	325	383	70
8C	76.2	0.4	20.0	55.9	1428	86	50	1292	259

LIPOSCIENCE NMR PROFILE DATA Continued

Sample ID	HDL Particle Concentrations					Mean Particle Sizes		
	Very Small LDL Particles	HDL Particles (total)	Large HDL Particles	Medium HDL Particles	Small HDL Particles	VLDL Size	LDL Size	HDL Size
	nmol/L	µmol/L	µmol/L	µmol/L	µmol/L	nm	nm	nm
	LVSP	HDLP	HLP	HMP	HSP	VZ	LZ	HZ
1A	391	24.9	8.4	7.2	9.3	65.0	20.9	9.1
2A	558	34.4	8.7	7.7	18.0	51.5	20.6	9.1
3A	330	31.0	5.1	7.0	18.9	53.4	21.7	9.1
4A	697	21.6	4.2	3.2	14.2	61.4	20.5	8.6
5A	465	31.8	9.1	3.5	19.2	49.6	20.9	9.1
6A	705	40.8	5.3	3.3	32.2	52.0	20.1	8.5
7A	241	26.7	11.9	0.0	14.8	44.5	21.6	9.7
8A	770	27.2	2.3	2.2	22.6	38.9	19.8	8.4
1B	455	24.7	7.7	6.7	10.3	60.2	20.8	9.1
2B	572	34.4	9.8	5.2	19.4	57.5	20.5	9.2
3B	452	34.1	6.4	4.6	23.0	45.1	21.3	9.1
4B	843	25.6	4.8	3.1	17.6	47.9	20.4	8.7
5B	447	30.5	8.8	3.7	18.0	43.2	21.0	9.2
6B	612	39.6	4.9	5.2	29.6	48.5	20.7	8.5
7B	232	27.4	13.0	0.0	14.4	47.8	21.7	9.8
8B	930	30.4	2.8	1.6	26.0	37.4	19.9	8.5
1C	407	26.1	6.3	5.5	14.3	55.0	21.0	8.9
2C	475	31.2	8.9	1.9	20.4	52.6	20.6	9.2
3C	397	35.6	6.4	0.0	29.2	46.2	21.6	8.8
4C	783	22.2	4.2	6.5	11.5	58.7	20.4	8.7
5C	139	30.6	7.3	5.3	18.0	41.2	22.1	9.1
6C	627	35.0	4.4	7.6	23.1	46.3	20.3	8.6
7C	313	24.1	11.2	0.2	12.6	54.8	21.4	9.7
8C	1033	28.9	2.6	2.3	23.9	38.7	19.5	8.4

REFERENCES

- AHA. (2010). Heart Disease and Stroke Statistics--2010 Update : A Report From the American Heart Association. *Circulation*, *121*, e46-e215.
- Annuzzi, G., Jansson, E., Kaijser, L., Holmquist, L., & Carlson, L. A. (1987). Increased removal rate of exogenous triglycerides after prolonged exercise in Man: time course and effect of exercise duration. *Metabolism*, *36*(5), 438-443.
- Blake, G., Otvos, J., Rifai, N., & Ridker, P. M. (2002). Low-density lipoprotein particle concentration and size as determined by nuclear magnetic resonance spectroscopy as predictors of cardiovascular disease in women. *Circulation*, *106*, 1930-1937.
- Bruce, S., & Grove, S. (1994). The effect of a coronary artery risk evaluation program on serum lipid values and cardiovascular risk levels. *Applied Nursing Research* *7*(2), 67-74.
- Carlson, L., & Mossfeldt, F. (1964). Acute effects of prolonged, heavy exercise on the concentration of plasma lipids and lipoproteins in man. *Acta Physiologica Scandanavica*, *62*(2), 51-59.
- Cromwell, W. (2007). High-density lipoprotein association with coronary heart disease: does measurement of cholesterol content give the best result? *Journal of Clinical Lipidology*, *1*, 57-64.
- Cromwell, W., & Otvos, J. (2004). Low-density lipoprotein particle number and risk for cardiovascular disease. *Current Atherosclerosis Reports*, *6*, 381-386.
- Cullinane, E., Siconolfi, S., Saritelli, A., & Thompson, P. (1982). Acute decrease in serum triglycerides with exercise: is there a threshold for an exercise effect? *Metabolism*, *31*(8), 844-847.
- Cziraky, M., Watson, K., & Talbert, R. (2008). Targeting low HDL-cholesterol to decrease residual cardiovascular risk in the managed care setting. *Manag Care Pharm*, *14*(8), S1-S28.
- Durstine, Grandjean, P., Christopher, & Thompson, P. (2002). Lipids, lipoproteins, and exercise. *Journal of Cardiopulmonary Rehabilitation* *2002;22:385-398*, *22*, 385-398.
- Durstine, & Lysterly. (2007). No physical activity or exercise is not an option. *Journal of Applied Physiology*, *103*, 417-418.
- Durstine, Pate, R., Sparling, B., Wilson, G., Senn, M., & Bartoli, W. (1987). Lipid, lipoprotein and iron status of elite women distance runners *Int J Sport Med*, *8*.
- Fabbri, G., & Maggioni, A. (2009). Cardiovascular risk reduction: what do Recent trials with rosuvastatin tell us? *Adv Ther*, *26*(5), 469-487.
- Ferguson, M., Alderson, N., Trost, S., Davis, P., Mosher, P., & Durstine, J. (2003). Plasma lipid and lipoprotein responses during exercise. *Scand J Clin Lab Invest*, *63*, 73-80.
- Freedman, D., Otvos, J., Jeyarajah, E., Barboriak, J., Anderson, A., & Walker, J. (1998). Relation of lipoprotein subclasses as measured by proton nuclear magnetic resonance spectroscopy to coronary artery disease *Arterioscler Thromb Vasc Biol*, *18*, 1046-1053.
- Gardner, C., Fortmann, S., & Krauss, R. (2002). Association of small low-density lipoprotein particles with the incidence of coronary artery disease in men and women. *Jama*, *276*(11), 875-881.

- German, J., Smilowitz, J., & Zivkovic, A. (2006). Lipoproteins: When size really matters. *Current Opinion in Colloid and Interface Science*, *11*, 171-183.
- Gordon, P. M., Fowler, S., Warty, V., Danduran, M., Visich, P., & Keteyian, S. (1998). Effects of acute exercise on high density lipoprotein cholesterol and high density lipoprotein subfractions in moderately trained females. *Br J Sports Med* *32*, 63-67.
- Gordon, P. M., Goss, F., Visich, P., Warty, V., Denys, B., Metz, K., et al. (1994). The acute effects of exercise intensity on HDL-C metabolism. *Medicine and Science in Sports and Exercise*, *26*(6), 671-677.
- Griffin, B., Skinner, E. R., & Maughan, R. (1988). The acute effect of prolonged walking and dietary changes on plasma lipoprotein concentrations and high-density lipoprotein subfractions. *Metabolism*, *37*(6), 535-541.
- Halverstadt, A., Phares, D., Wilund, K., Goldberg, A., & Hagberg, J. (2007). Endurance exercise training raises high-density lipoprotein cholesterol and lowers small low-density lipoprotein and very low-density lipoprotein independent of body fat phenotypes in older men and women. *Metabolism Clinical and Experimental*, *56*, 444-450.
- Harchaoui, K. E., Steeg, W., Stroes, E., Kuivenhoven, J., Otvos, J., Wareham, N., et al. (2007). Value of low-density lipoprotein particle number and size as predictors of coronary artery disease in apparently healthy men and women. *Journal of the American College of Cardiology*, *49*(5), 547-553.
- Ip, S., Lichtenstein, A., Chung, M., Lau, J., & MD, E. B. (2009). Systematic review: association of low-density lipoprotein subfractions with cardiovascular outcomes. *Ann Intern Med*, *150*, 474-484.
- Jeyarajah, E., Cormwell, W., & Otvos, J. (2006). Lipoprotein particle analysis by nuclear magnetic resonance. *Clin Lab Med*, *26*, 847-870.
- Johansson, J., LA Carlson, Landou, C., & Hamsten, A. (1991). High density lipoproteins and coronary atherosclerosis. A strong inverse relation with the largest particles is confined to normotriglyceridemic patients. *Arteriosclerosis, Thrombosis, and Vascular Biology*, *11*, 174-182.
- Joshua, S., Kyle, W., Biggerstaff, D., & Ben-Ezra, V. (2009). Responses of LDL and HDL particle size and distribution to omega-3 fatty acid supplementation and aerobic exercise. *Journal of Applied Physiology*, *107*, 794-800.
- Kantor, M., Cullinane, E., Herbert, P., & Thompson, P. (1984). Acute increase in lipoprotein lipase following prolonged exercise. *Metabolism*, *Vol 33, No 5 (May), 1984*, *33*(5), 454-457.
- Kantor, M., Cullinane, E., Sady, S., Herbert, P., & Thompson, P. (1987). Exercise acutely increases high density lipoprotein-cholesterol and lipoprotein lipase activity in trained and untrained men. *Metabolism Vol 36, No 2 (February). 1987: pp 188-192*, *36*(2), 188-192.
- Karus, W., Houmard, J., Duscha, B., Knetzger, K., Wharton, M., McCarthy, J., et al. (2002). Effects of the amount and intensity of exercise on plasma lipoproteins. *N Engl J Med*, *347*(19), 1483-1492.
- Kraus, W., Houmard, J., Duscha, B., Knetzger, K., Wharton, M., McCarthy, J., et al. (2002). Effects of the amount and intensity of exercise on plasma lipoproteins. *N Engl J Med*, *347*(19), 1483-1492.

- Kussi, T., Ella Kostiaainen, Vartiainen, E., Pitklnen, L., Ehnholm, C., Korhonen, H., et al. (1984). Acute effects of marathon running on levels of serum lipoproteins and androgenic hormones in healthy males *Metabolism, Vol 33, No 6 (June), 33(6), 527-531.*
- Lamon-Fava, S., McNamara, J., Farber, H., Hill, N., & Schaefer, E. (1989). Acute changes in lipid, Lipoprotein, apolipoprotein, and low-density lipoprotein particle size after an endurance triathlon *Metabolism, 38(9), 921-925.*
- Link, J., Rohatgi, A., & Lemos, J. d. (2007). HDL cholesterol: physiology, pathophysiology, and management. *Curr Probl Cardiol, 32, 268-314.*
- Lippi, G., Schena, F., Luca, G., Salvagno, Montagnana, M., Ballestreri, F., et al. (2006). Comparison of the lipid profile and lipoprotein(a) between sedentary and highly trained subjects. *Clin Chem Lab Med 44(3), 322–326.*
- Lira, F., Zanchi, N., Lima-Silva, A., Pires, F. v., Bertuzzi, R. m., Santos, R., et al. (2009). Acute high-intensity exercise with low energy expenditure reduced LDL-c and total cholesterol in men. *European Journal of Applied Physiology, 107, 203-210.*
- Lusis, A. (2000). Atherosclerosis. *Nature, 407, 233-241.*
- Magkos, F., Patterson, B., Mohammed, S., & Mittendorfer, B. (2006). A single 1-h bout of evening exercise increases basal FFA flux without affecting VLDL-triglyceride and VLDL-apolipoprotein B-100 kinetics in untrained lean men *Am J Physiol Endocrinol Metab 292: , 2007., 292, E1568–E1574.*
- McCarthy, K., Plowman, S., Looney, M., Kelly, G., & Manning, T. (2002). Acute effects of high and low intensity exercise on selected blood lipids in women. *Human Kinetics, Clinical Exercise Physiology, 4(1), 29-27.*
- NCEP. (2002). Third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III) final report. *Circulation, 106, 3143-3421.*
- Otvos, J. (2002). Measurement of lipoprotein subclass profile by nuclear magnetic resonance spectrophy. *Clinical Laboratory, 48(3-4), 171-180.*
- Otvos, J., Collins, D., Freedman, D., Shalaurova, I., Schaefer, E., McNamara, J., et al. (2006). Low-density lipoprotein and high-density lipoprotein particle subclasses predict coronary events and are favorably changed by gemfibrozil therapy in the veterans affairs high-density lipoprotein intervention trial. *Circulation, 113, 1556-1563.*
- Otvos, J., Jeyarajah, E., Bennett, D., & Krauss, R. (1992). Development of a proton nuclear magnetic resonance spectroscopic method for determining plasma lipoprotein concentrations and subspecies distributions from a single, rapid measurement. *Clinical Chemistry, 38(9), 1632-1638.*
- Otvos, J., Jeyarajah, E., & Cromwell, W. (2002). Measurement issues related to lipoprotein heterogeneity. *Am J Cardiol 90, 22i–29i.*
- Otvos, J., Jeyarajah, J., & Bennett, W. (1991). Quantification of plasma lipoproteins by proton nuclear magnetic resonance spectroscopy. *Clinical Chemistry, 37(3), 377-386.*
- Otvos, J., Jeyarajah, J., & Bennett, W. (1996). A spectroscopic approach to lipoprotein subclass analysis. *Journal of Clinical Ligand Assay, 19(3), 184-189.*
- Park, H., & Ranson, W. (2003). Effects of submaximal exercise on high-density lipoprotein -cholesterol subfractions *Sports Medicine, 24(4), 245-251.*

- Peltonen, P., Marniemi, J., Hietanen, E., Vuori, I., & Ehnholm, C. (1981). Changes in serum lipids, lipoproteins, and heparin releasable lipolytic enzymes during moderate physical training in man: a longitudinal study. *Metabolism*, *30*(5), 518-526.
- Pronk, P. (1993). Short term effects of exercise on plasma lipids and lipoproteins in humans. *Sports Medicine*, *16*(6), 431-448.
- Sgouraki, E., Tsopanakis, A., Kioussis, A., & Tsopanakis, C. (2004). Acute effects of short duration maximal endurance exercise on lipids, phospholipids and lipoprotein levels. *Journal of Sports Medicine and Physical Fitness*, *44*(4), 444-450.
- Sharma, R., Singh, V., & Reddy, H. (2009). Thinking beyond low-density lipoprotein cholesterol: strategies to further reduce cardiovascular risk. *Vascular Health and Risk Management*, *5* 793-799.
- Shepherd, J. (1992). Lipoproteins metabolism: an overview. *Annals of the Academy of Medicine*, *21*(1), 106-113.
- Skinner, E. R., Black, D., & Maughan, R. (1985). Variability in the response of different male subjects to the effect of marathon running on the increase in plasma high density lipoprotein. *European Journal of Physiology*, *54*, 6.
- Sopko, G., Leon, A., Jacobs, D., Foster, J. N., Moy, J., Kuba, K., et al. (1985). The effects of exercise and weight loss on plasma lipids in young obese men. *Metabolism*, *34*(3), 227-236.
- Svedenhag, J., Lithe, H., Juhlin-Dannfelt, A., & Henriksson, J. (1983). Increase in Skeletal Muscle Lipoprotein Lipase Following Endurance Training in Man. *Atherosclerosis*, *49*, 203-207.
- Swank, A., Robertson, R., Deitrich, R., & Bates, M. (1987). The effect of acute exercise on high density lipoprotein-cholesterol and the subfractions in females. *Atherosclerosis*, *63*, 187-192.
- Thompson, P., Cullinane, E., Henderson, O., & Herbert, P. (1980). Acute effects of prolonged exercise on serum lipids. *Merabolism*, *29*(7).
- Trejo-Gutierrez, J., & Fletcher, G. (2007). Impact of exercise on blood lipids and lipoproteins. *Journal of Clinical Lipidology*, *1*, 175-181.
- Visich, P., Goss, F., Gordon, P., Robertson, R., Warty, V., Denys, B., et al. (1996). Effects of exercise with varying energy expenditure on high-density lipoprotein-cholesterol. *European Journal of Applied Physiology*, *72*, 242-248.
- Yu, H., Ginsburg, G., Mary O'Toole, James Otvos, Douglas, P., & Rifai, N. (1999). Acute changes in serum lipids and lipoprotein subclasses in triathletes as assessed by proton nuclear magnetic resonance spectroscopy. *Arterioscler Thromb Vasc Biol*, *19*, 1945-1949.

VITA

Graduate College
University of Nevada, Las Vegas

Hanaa Adnan Shaheen

Degrees

Bachelor of Science, Physical Therapy, 2004

University of Jordan

Teaching Experience:

Teaching Assistant, Exercise and Sports Injury, University of Nevada Las Vegas,
(September 2010 – December 2011)

Teaching Assistant, Introduction to Athletic Training, , University of Nevada Las
Vegas, (January 2010-August 2010).

Research Experience:

Research Assistant, Exercise Physiology Laboratory, University of Nevada Las
Vegas, (August 2011-present)

Research Assistant, Biomedical Research Center, University of Nevada Las Vegas
Shadow Lane campus (August-December 2009).

Clinical Experience:

Physical Therapist, Physical Medicine Speciality Center, Amman-Jordan, (January
2005-June 2005).

Physical Therapist, Al-Khalidi Physical Therapy Center, Amman-Jordan, (June
2004-December 2004).

Grants and Research Support

Graduate and Professional Students Association. \$1500 in Research Support, (Spring
2012). Funds that covered in part the expenses of the research study (The Acute
Effect of Exercise on Lipoproteins Measured by Nuclear Magnetic Resonance).

Department of Kinesiology and Nutrition Sciences, \$1000 in Research Support,
(Spring 2012). Funds that covered in part the expenses of the research study (The
Acute Effect of Exercise on Lipoproteins Measured by Nuclear Magnetic
Resonance).

Students' Symposiums and Forums

Shaheen, H (March 17th, 2012). "The Acute Effect of Exercise on Lipoproteins
Measured by Nuclear Magnetic Resonance (NMR)", The UNLV Graduate &
Professional Student Association Research Forum, University of Nevada Las Vegas,
Las Vegas, NV.

Shaheen, H (April 10th, 2012). “The Acute Effect of Exercise on Lipoproteins Measured by Nuclear Magnetic Resonance (NMR)”, The Fifth Annual Interdisciplinary Research Scholarship Day (IRSD), University of Nevada Las Vegas, Las Vegas, NV.

Memberships

American College of Sports Medicine (ACSM), member since November, 2011.

Certificates

Heart Saver CPR/ AED, American Heart Association, February, 2012.

Thesis Title

The Acute Effect of Endurance Exercise on Lipoproteins Measured by Nuclear Magnetic Resonance in Healthy Men

Thesis Examination Committee

Chair, Antonio Santo, Ph.D., RD, CSSD.

Committee Member, John Young, Ph.D.

Committee Member, Richard Tandy, Ph.D.

Graduate College Representative, Patricia Alpert, DrPH, MSN, APN, FNP.