A Review of the Impact of Exercise on Cholesterol Levels

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WHY HIGH-DENSITY LIPOPROTEIN, OR HDL, CHOLESTEROL LEVELS ARE ASSOCIATED WITH A REDUCED RISK OF HEART DISEASE—AND HOW EXERCISE CAN HELP.

Recently, the National Institutes of Health issued new criteria for the detection, categorization and treatment of unhealthy cholesterol levels (American Medical Association 2001). As a result of these new criteria, the number of Americans in the high-cholesterol category rose substantially. The revised guidelines recommend that individuals with elevated cholesterol levels undertake "therapeutic lifestyle changes" and, when needed, drug therapy. Consequently, fitness professionals can expect to see more and more clients wanting to lower their cholesterol levels through exercise and lifestyle modifications.

The link between cholesterol and coronary heart disease (CHD) has been well established through numerous long-term studies. What isn't as well established or understood is how to achieve and maintain optimal cholesterol levels. While dietary changes and certain medications can lower cholesterol, exercise is effective as well. But how much and what type of exercise is needed to positively change cholesterol levels? And do cholesterol levels in men and women respond differently to exercise?

This article gives an overview of what cholesterol is; explains how it functions in the body; and presents the latest research on how exercise impacts cholesterol levels.

By Chantal A. Vella, MS; Len Kravitz, PhD; and Jeffrey M. Janot, PhD

UNDERSTANDING CHOLESTEROL

Cholesterol is a waxy, fat-like substance found in all animal products (i.e., meats, dairy products and eggs). The human body makes cholesterol in the liver and absorbs cholesterol through the diet. Cholesterol is essential to the body and is used to build cell membranes, produce sex hormones and form bile acids, which are necessary for the digestion of fats; however, when cholesterol levels in the blood are too high, some of the excess is deposited in the artery walls, increasing the risk for CHD. (See "Glossary" on this page for a review of the terms used in this article.)

Cholesterol travels through the bloodstream as part of larger particles known as **lipoproteins.** Lipoproteins are special transporters that carry lipids—fatty substances such as cholesterol—in the bloodstream to the liver, the intestine and peripheral tissues. Lipoproteins are classified based on the thickness of the protein shell that surrounds the cholesterol. **Low-density lipoproteins** (LDL) are the primary transporters of cholesterol; they deposit excess cholesterol in the artery walls. **High-density lipoproteins** (HDL) are involved in the reverse transport of cholesterol to the liver (Durstine & Haskell 1994); they remove cholesterol from the blood and arteries (the reverse transport process). When LDL levels get too high or HDL levels get too low, cholesterol builds up in the blood, forming artery-clogging deposits.

Glossary

Cholesterol is a waxy, fat-like substance found in all animal products (i.e., meats, dairy products and eggs). The body absorbs cholesterol from the diet and makes cholesterol in the liver. Cholesterol is essential for building cell membranes, producing sex hormones and forming bile acids, which are necessary for the digestion of fats.

Coronary heart disease results from a decreased flow of blood to the heart, usually caused by atherosclerosis, an accumulation of fatty deposits in the arteries.

Dose-response relationship is a linear relationship between exercise volume (total kilocalories expended) and a particular health outcome.

HDL_2 is an HDL_3 molecule that has increased its cholesterol content, becoming less dense, and is then classified as HDL_2.

HDL_3 is a molecule produced in the liver and put into circulation to collect cholesterol. As an HDL_3 molecule increases its cholesterol content, it becomes less dense and is then classified as HDL_2.

High-density lipoproteins are involved in the reverse transport of cholesterol to the liver.

Lipids are fatty substances found in the diet and made in the body. Cholesterol is an example of a lipid.

Lipoproteins are special transporters that carry cholesterol and other substances through the bloodstream.

Low-density lipoproteins are the primary transporters of cholesterol; they deposit excess cholesterol in the artery walls.

LDL CHOLESTEROL

The role of LDL cholesterol (LDL-C), sometimes called the "bad," "lousy" or "unhealthy" cholesterol, is to transport cholesterol to various body cells and deposit any excess cholesterol in the artery walls, which increases the risk of heart disease. (For a more detailed discussion of LDL-C, see "A Closer Look at LDL Cholesterol" on the next page.) A desirable level of LDL-C is below 130 milligrams per deciliter (mg/dl), with 100 mg/dl or less being optimal.

HDL CHOLESTEROL

HDL cholesterol (HDL-C), sometimes called the "good" or "healthy" cholesterol, is responsible for transporting cholesterol from the blood and artery walls to the liver, where it is converted to bile for digestion or disposed of by the body. This "reverse cholesterol transport process" is believed to be helpful in preventing or reversing heart disease. HDL molecules have two main subclasses: HDL_2 and HDL_3 (Durstine & Haskell 1994). HDL_3 molecules are produced in the liver and put into circulation to collect cholesterol. As they increase their cholesterol content, they become less dense and are classified as HDL_2. The HDL_2 molecules are then recycled in the liver, where the cholesterol is extracted and either converted to bile for digestion or disposed of by the body. Then HDL_3 molecules are again released into circulation (Durstine & Haskell 1994).

Because HDL molecules collect and remove cholesterol from the blood and artery walls, high HDL-C levels are associated with a reduced risk of CHD (Neiman 1998). In fact, for every 1 mg/dl decrease in HDL-C, the risk of CHD increases by 2 to 3 percent (%) (Durstine & Haskell 1994). HDL-C levels equal to or above 60 mg/dl are considered desirable, while HDL-C levels below 35 mg/dl are considered undesirable. See "Measuring Cholesterol Levels" on the next page.

While the current research clearly indicates that exercise does not *independently* affect LDL-C levels, some findings are promising on the connection between cardiovascular exercise and increases in HDL-C levels. Consequently, this article focuses on research into how exercise affects HDL-C levels, specifically.

EXERCISE AND HDL CHOLESTEROL

It is well established that a sedentary lifestyle contributes significantly to the development of CHD and that physical activity plays an important role in decreasing CHD mortality. Some studies have found that regular physical activity and a single exercise session can both have a positive effect on cholesterol metabolism (Durstine & Haskell 1994). Exercise is partly responsible for increasing the production of several enzymes that enhance the reverse cholesterol transport system (Durstine & Haskell 1994). The precise mechanisms for this action are unclear, but evidence indicates that factors like diet, body fat, weight loss, hormones and enzyme activity interact with exercise to alter the rates at which cholesterol is synthesized, transported and cleared from the blood (Durstine & Haskell 1994).

While exercise training has been associated with increased levels of HDL-C, the *volume* (amount) of exercise required to confer this benefit is still debatable. Research has provided inconsistent results, but it suggests that an exercise threshold must be met before significant changes in HDL-C are observed. Research also suggests that a dose-response relationship may exist between exercise volume and increases in HDL-C levels (Drygas et al. 2000).

The following sections describe studies involving men and women engaged specifically in cardiovascular activity. (While resistance training may be beneficial in improving HDL-C levels, little research exists to support that finding. See "Resistance Training and HDL Cholesterol" on the next page.) The studies indicate that the impact of exercise on HDL-C levels is different for men and women, partly because female hormones influence HDL-C levels. In addition, most of the research on HDL-C and exercise has involved male subjects, so the results are clearer for men. For this reason, the research on men and women is presented separately.

EXERCISE INTENSITY

Research has shown that men and women have different exercise intensity thresholds with regard to changes in HDL-C levels. Here's a look at the latest research based on gender differences:

Men. Data from exercise training and epidemiological studies involving male subjects support the need to reach an exercise intensity threshold in order to increase HDL-C levels. Although researchers have not yet conducted exercise studies specifically designed to quantify such a threshold, the literature gives a general idea of the threshold men must reach. Studies have suggested that the threshold for positive changes in HDL-C is an exercise intensity of 6 METs or more (Leclerc et al. 1985; Lakka & Salonen 1992). Leclerc et al. (1985) reported no further improvements in HDL-C levels when exercise intensity increased above 6 METs. Stein et al. (1990) reported significant increases in HDL-C levels in men who exercised at or above 75% of heart rate maximum (HRmax) three times a week for 12 weeks; because no changes in HDL-C were reported in subjects who exercised at 65% of HRmax, these researchers concluded that an intensity of 75% of HRmax or above is necessary to increase HDL-C levels

Measuring Cholesterol Levels*

LDL Cholesterol (in milligrams/deciliter, or mg/dl)

< 100	optimal
100-129	near or above optimal
130-159	borderline high
160-189	high

HDL Cholesterol (mg/dl)

< 35	low
35-59	desirable
≥ 60	optimal

Total Cholesterol (mg/dl)

< 200	desirable
200-239	borderline high
≥ 240	high

**Adapted from the American Medical Association. 2001.* Journal of the American Medical Association, 285 *(19), 2486-97.*

A Closer Look at LDL Cholesterol

Although both low-density lipoprotein (LDL) and high-density lipoprotein (HDL) levels affect risk for coronary heart disease, LDL levels get more attention because they are more clearly linked to this risk. LDL cholesterol (LDL-C) is often called the "bad," "lousy" or "unhealthy" cholesterol because its main function is to transport cholesterol to various cells throughout the body, including the artery walls. When LDL levels are elevated, cholesterol begins to accumulate in these vessel walls. LDL-C deposits can eventually reduce blood flow through the arteries (ACSM 1998).

Of the 65 million Americans now considered to have high cholesterol, roughly half should be able to reach their LDL-C goals through lifestyle changes alone. The National Institutes of Health recommends the following dietary changes:

- Reduce intake of saturated fats.
- Consume fewer than 200 milligrams of cholesterol per day.
- Consume 5 to 10 grams (g) of soluble fiber per day.
- Consider consuming about 2 g of plant sterols per day.
- Consider consuming about 25 g of soy protein per day.

The guidelines also recommend losing weight and exercising more. Exercise can increase HDL cholesterol levels, lower triglycerides and contribute to weight loss, which positively impacts LDL-C levels.

Resistance Training and HDL Cholesterol

There is little agreement in the literature as to whether resistance training positively influences high-density lipoprotein cholesterol (HDL-C) levels. In women, evidence supporting a positive effect is lacking. However, some studies indicate that high-volume resistance training may increase HDL-C levels in men (Wallace et al. 1991; Yeater et al. 1996). These studies suggest that a program of moderate resistance with high repetitions may be the most beneficial type of strength training protocol for increasing HDL-C levels in men. Kraemer et al. (1999) reported no changes in HDL-C levels in men following 12 weeks of periodized heavy resistance training. The inconsistent results reported in the literature may be due to the different types of resistance training protocols used in each study. Although it is presently unclear whether resistance training can positively influence HDL-C levels, strength training does provide many other benefits, including increased bone mass, muscle strength and endurance; improved glucose metabolism; increased resting metabolic rate; improved body composition; and improved psychological well-being.

in men. In addition, Kokkinos et al. (1995a) studied 2,906 men and reported that increases in HDL-C levels occurred in men who had established a long-term jogging routine at an exercise intensity of 10 to 11 minutes per mile. These studies suggest that moderate-intensity exercise is sufficient to raise HDL-C levels in men.

Women. Exercise training studies attempting to assess the role of exercise intensity on HDL-C in women are few and report conflicting results. In general, most of the research suggests that women (pre- and postmenopausal) with lower initial levels of HDL-C are more likely to respond positively to exercise training. Duncan, Gordon & Scott (1991) reported similar increases in HDL-C levels in women (ages 29-40) following 24 weeks of walking 4.8 kilometers (km) five days per week, regardless of exercise intensity; this finding suggests that moderate exercise will raise HDL-C levels as much as intense exercise. In addition, Spate-Douglas and Keyser (1999) reported that moderate-intensity training over a 12-week period was sufficient to improve HDL-C in female subjects, and high-intensity training appeared to provide no further advantage as long as training volume (total distance walked per week) was constant. Conversely, Santiago, Leon and Serfass (1995) reported no changes in HDL-C levels in women (ages 22-40) following 40 weeks of moderate endurance training. These subjects had higher initial HDL-C levels than the subjects in the Duncan, Gordon and Scott study (65 vs. 55 mg/dl); therefore, Santiago and colleagues' finding adds to the evidence that women with lower levels of HDL-C are more likely to see increases in HDL-C with exercise training.

Research specific to postmenopausal women is also limited, but it provides positive results. Lindheim et al. (1994) reported increased HDL-C levels in postmenopausal women who exercised at 70% of HRmax for 24 weeks *and* received hormone replacement therapy (HRT); interestingly, no increases in HDL-C levels were reported for the exercise-only group, suggesting a synergistic relationship between exercise and HRT. However, Seip et al. (1993) found significant increases in HDL-C levels in postmenopausal women *not* taking HRT after nine to 12 months of endurance training at 80% to 90% of HRmax. In addition, King et al. (1995) assessed the effects of both high- and low-intensity exercise programs on HDL-C levels in sedentary women not receiving HRT. Although this team observed no significant increases in HDL-C during the first year, by the end of the second year, subjects in both exercise groups had shown small but significant increases in HDL-C levels. Interestingly, the increases were higher for subjects in the low-intensity group, which exercised more days each week. The authors concluded that frequency of participation may be particularly important for increasing HDL-C levels in women. The results of these studies suggest that regular low- to moderate-intensity exercise may increase HDL-C levels in postmenopausal women with or without HRT.

Practical Application. Based on the research to date and depending on the individual client's health goals, men should exercise at a moderate intensity (70%-80% of HRmax) in order to improve their HDL-C levels. To achieve the same goal, pre- and postmenopausal women should exercise at a low to moderate exercise intensity (60%-80% of HRmax) (Kokkinos & Fernhall 1999).

EXERCISE VOLUME

Like exercise intensity, exercise volume may affect HDL-C levels differently in men and women.

Men. In research that used running as the exercise protocol, most of the studies involving male subjects have identified jogging/running seven to 10 miles per week as the threshold that must be reached to gain significant increases in HDL-C. Wood et al. (1983) suggested that running approximately eight miles per week over a one-year period is the exercise volume needed to increase HDL-C levels. In addition, Williams et al. (1982) found that HDL-C levels generally did not begin to change in subjects assigned to supervised running until they had maintained an exercise volume of 10 miles per week for at least nine months. Kokkinos et al. (1995a) reported significantly higher HDL-C levels in runners who averaged seven to 14 miles per week than in nonexercisers. In another study, Williams (1998) reported that weekly exercise volume correlated to HDL-C levels more strongly than exercise intensity did. Interestingly, in the same study Williams compared subjects' average weekly running mileages and found that a higher volume of exercise provided significant increases in

HDL-C in a shorter period of time. This indicates a possible relationship between exercise volume and the length of training required to improve HDL-C levels.

For nonrunners, Drygas et al. (2000) defined a caloric expenditure above 1,000 kilocalories (kcal) per week as an exercise volume threshold that must be met to increase HDL-C levels. This research team also noted that exercise energy expenditure of 2,000 or more kcal per week was associated with additional increases in HDL-C and that a dose-response relationship may exist between exercise and HDL-C levels. A dose-response relationship exists when there is a linear relationship between weekly exercise volume (total kcal expended) and HDL-C levels. The higher the weekly exercise volume, the higher HDL-C levels tend to be.

Women. In women, also, the volume of exercise seems to be more important than the intensity of exercise for positively influencing HDL-C levels. And while most studies suggest that a large volume of exercise is necessary to bring about significant HDL-C changes in women, the exercise volume threshold has not yet been defined. Generally, physically active women exhibit higher levels of HDL-C than their sedentary counterparts (Kokkinos & Fernhall 1999). When Kokkinos et al. (1995b) categorized female subjects according to their fitness level (assessed by an exercise tolerance test), the women in the moderate- and high-fitness categories exhibited higher HDL-C levels than those in the low-fitness category. Additionally, researchers have reported elevated HDL-C levels in women who have undergone a high-volume training program (Williams 1996; Williams 1998) but not in women who have undergone a low-volume training program (Brownell, Bachorik & Ayerle 1982). Williams (1996) reported that in pre- and postmenopausal women, HDL-C concentrations increased significantly in relation to the number of km run per week, whether the women were receiving HRT or not; substantial increases in HDL-C were also noted in women who ran more than 64 km per week compared to those who ran less than 48 km per wk. These findings suggest a dose-response relationship between exercise and HDL-C levels.

In studies specific to postmenopausal women, the research is limited and conflicting. Sunami et al. (1999) reported a positive correlation between total weekly exercise duration and HDL-C levels in postmenopausal subjects who exercised at 50% of VO_2max for 60 minutes two to four times a week. This finding suggests that moderate-intensity exercise is sufficient to increase HDL-C levels in postmenopausal women as long as exercise duration and frequency are sufficient. In contrast, however, Ready et al. (1996) found that walking at 60% of VO_2peak for 60 minutes had no influence on HDL-C levels in postmenopausal women, regardless of frequency.

Practical Applications. Based on the current literature, a weekly caloric expenditure of 1,000 or more kcal should be the goal for clients interested in improving HDL-C levels. Begin sedentary clients with 10 to 20 minutes of cardiovascular exercise per session and work up to 30 to 60 minutes. Encourage your clients to exercise at least three times a week, preferably five times per week.

A Sample Exercise Program to Increase HDL Cholesterol

When you are developing a cardiovascular exercise program to increase levels of high-density lipoprotein (HDL), or "good," cholesterol, individualize the program based on the health and/or fitness level of the client. If the client is relatively sedentary and/or overweight, progress the exercise program gradually, working up to a weekly caloric energy expenditure of ≥1,000 kilocalories as a general goal.

Exercise Intensity & Duration. The exercise program should involve continuous cardiovascular activities targeting the large muscle groups. The client should begin at a low to moderate level of intensity, depending on fitness level. As the client gains aerobic endurance, progressively increase the intensity. The American College of Sports Medicine (ACSM) (1998) recommends an exercise intensity of 55 to 90 percent of heart rate maximum or 40 to 85 percent of heart rate reserve. The duration of activity will depend on the client's initial fitness level and preferred exercise intensity. Begin with approximately 20 minutes of continuous exercise and progress to 60 minutes (ACSM 1998).

Exercise Frequency The optimal training frequency is three to five times per week (ACSM 1998). If a dose-response relationship is clearly established between exercise and HDL cholesterol, exercising up to five days per week is likely to be the recommendation.

IN SUMMARY

The response of HDL-C levels to exercise will differ for each of your clients, depending on the intensity, duration and frequency of the activities performed; the initial HDL-C level; and the length of the training period. Keep in mind, too, that clients may need to reach an exercise threshold with regard to exercise intensity, weekly amount of exercise and length of training before changes in HDL-C become evident.

As fitness professionals, we should not only help our clients meet their exercise goals but also educate clients about the health benefits of a diet low in fat and high in carbohydrates and high-fiber foods. Weight loss also plays an important role in lowering unhealthy cholesterol levels. From a practical point of view, performing moderate-intensity cardiovascular exercise three to five days per week (expending 1,000-1,600 kcal per week) is a winning-edge cardiorespiratory exercise program for clients committed to pursuing health and battling chronic disease.

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