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Optimal aerobic exercise regimens for improving HDL levels in older, healthy males

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Abstract

High-density lipoprotein levels are predictive of future cardiovascular events even in healthy individuals. Exercise has been found to improve HDL levels, but most of these studies focus on younger males or on older subjects with pre-existing cholesterol issues, and the findings offer conflicted results. Our aim in the present study was to distinguish the impact, if any, of various intensity, frequency, and duration combinations of aerobic exercise on HDL levels in healthy males 45 years and older, to the previous research on younger or diseased subjects. MEDLINE, EMBASE, and SCOPUS were searched for all articles containing the keywords, “aerobic training/exercise” and “HDL” and “healthy, older/elderly men/males.” A total of 38 studies were included in the review. The studies were classified by intensity and statistical change from baseline HDL, then compared by frequency and duration. Too few low intensity articles were retrieved to compare. High intensity exercise 4-5 times a week for 45 minutes for a training period of at least 12 weeks appeared most consistently effective in raising HDL. In conclusion, in healthy males, aged 45 and up, high intensity exercise for at a moderate frequency and duration prove most beneficial to HDL levels than more intense training programs or more conservative ones.

Keywords

Hyperlipidemia, Aerobic Exercise, Cardiovascular Disease, Healthy Aging

1. Introduction

Cardiovascular disease (CVD) contributes to over 600,000 deaths annually in the US, and in 2010, cost America $444 billion in lost productivity and sick leave [18]. In men over the age of 45, approximately 30% of all deaths are CVD-related; by the age of 65, this percentage rises dramatically to 50% [38]. The lipid profile is a common indicator of future atherosclerotic and cardiac risk [2], and dyslipidemia, a major predictor of future cardiac events, can be screened for with a simple blood test in both healthy and ailing individuals [23]. One component of the lipid profile, high density lipoprotein, or HDL, is of particular interest as it appears to correlate to absolute cardiac events in both subjects with and without baseline CVD [23; 16; 32]. A man’s HDL level at age 45 is predictive of events that can occur decades later, even if he shows no other risk factors.

Improving HDL levels, and thereby reducing CVD risk, can easily be attained through lifestyle modifications. Such aerobic exercise-based studies typically employ younger, college-aged athletes or older individuals already suffering from CVD. In the younger populations, studies typically report an exercise-driven increase in HDL [15; 33; 37; 44]. However, in older populations, of males aged 45 and up, most studies examine those in those with hypercholesterolemia or existing risk factors for CVD. These studies tend to find exercise less beneficial, if at all, and results are highly conflicted [4; 46-48].

Few have recruited healthy older men. Several recent studies have found exercise to enhance HDL levels in dyslipidemia men; however, for every study touting the beneficial effect of aerobic activity on lipid, another finds no effect. While much research has focused on the impact of exercise on CVD reduction through lipid modification in subjects suffering from diseases, exercise can improve measures of HDL and future cardiovascular events in healthy individuals [16; 32]. Furthermore, the optimal combination of aerobic frequencies, durations, and intensities is not well-defined. The World Health Organization recommends 30 minutes to 1 hour of moderate to high intensity aerobic exercise daily, with two days of strength training, but the evidence to support that this prescription is optimal is controversial, and may vary depending on age, sex, and healthy status. As older men are more susceptible to CVD than younger or female populations, elucidating the optimal intensity, frequency, and duration for an exercise regimen for this populace is of particular importance.

This systematic review assesses the available literature on HDL changes associated with various types of aerobic exercise in healthy males age 45 and older. We hypothesized that an optimal regimen for beneficial HDL changes in healthy, older males would require high intensity aerobic exercise, at least five times a week for 45+ minutes, for a period of 12 weeks or more.

2. Methods

A systematic review of literature was performed using OVID (MEDLINE, EMBASE, and SCOPUS databases). The keyword searches were ‘aerobic exercise OR training,’ AND ‘lipid profile OR HDL’ AND ‘healthy [older OR elderly][men OR males]’. Abstracts from all articles that reported exercise as an independent variable and lipid levels as a dependent variable were reviewed, as were additional papers found through review of reference lists and related citations. Papers were excluded if they were not published in English, did not measure the impact of exercise on cardiovascular-related measures, included a diseased subject population or a population under the age of 45 years, or measured exercise in combination with a medication or a supplement. As the majority of the US population is now overweight or obese, we did include studies with such subject populations as long as they were otherwise noted as healthy (no hypertension, hypercholesterolemia, etc.). Due to the small amount of studies fitting our search criteria, we did include studies with mixed sex populations as long as sex-effects were controlled for in the analysis or men and women were separately analyzed.

The search identified 475 potentially relevant papers. Following application of the exclusion criteria (Figure 1), 38 articles were identified to include in the final analysis.

Of the original 475, 251 were excluded for consisting of subjects younger than 45 years old, and the remaining 192 did not employ the correct independent and dependent variables, used diseased subjects, or measured the effects of exercise with a prescription or over-the-counter supplement. Full-text copies of all remaining articles were obtained to determine intensity, duration, and statistical significance of the exercise(s).

Odds ratios and 95% confidence intervals for the likelihood of statistically significant benefit versus no benefit for each set of parameters (i.e., odds of 30 min causing a beneficial change / odds of 45 min causing a beneficial change, odds of 30 min causing a beneficial change / odds of 60 min causing a beneficial change, etc.) were calculated using the summed number of participants in each study employing the specific parameter.

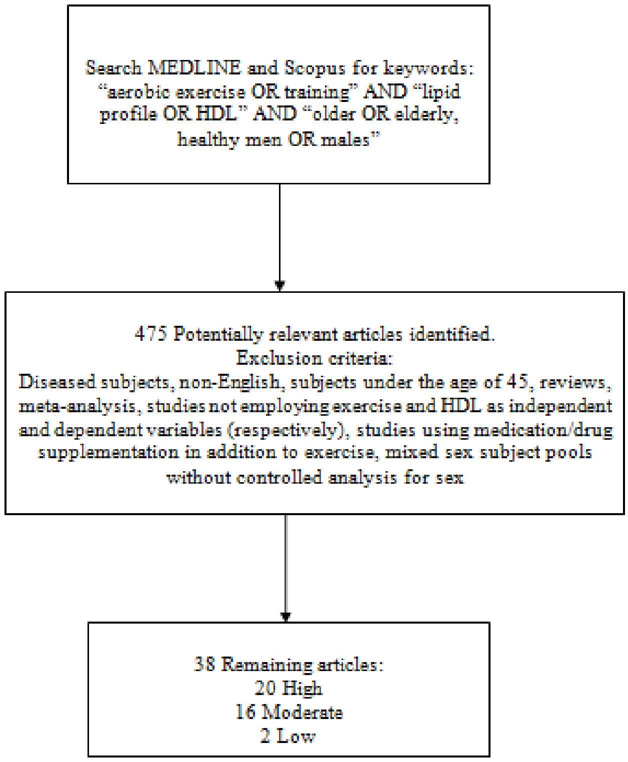

Figure 1. *Method of Article Retrieval and Selection*

3. Results

The literature classified aerobic exercise as continuous motion in the form of swimming, running, cycling or walking, at low, moderate, or high intensity (Table 1). Intensity was classified according to percentage of heart rate reserve, max heart rate, or peak VO2 as based on definitions from The American College of Sports Medicine Position Stand[1].

Each study was further categorized by the intensity and the statistical significance of the exercise intervention as compared to levels from baseline measures or sedentary controls (Table 2). If the study had multiple subject groups (i.e., one performing group exercise and one performing at-home exercise, or weight-stable and weight loss) or multiple time points (i.e., after 4 weeks of the intervention versus after 8 weeks), the significance from baseline/controls for each of these groups is noted.

Studies were not included in the analysis if upon review of the full-text information of statistical significance or aerobic intensity were not provided. A table of each study defined by frequency, intensity, and durations, as well as by statistical change was constructed (not shown) and the findings were visualized in Figure 2. As illustrated by Figure 2, there were no clear associations between frequency, intensity, or duration and impact on HDL changes from baseline levels. Due to the lack of low intensity studies, we did include the parameter in further analysis.

Odds, odds ratios and confidence intervals are given in Tables 3A and 3B. As shown in Table 3B, high intensity had greater odds of significantly increasing HDL than moderate. For frequency, 4-5 times a week was significantly superior to the other frequencies, though surprisingly 2-3x/week was over ten times as likely to raise HDL levels as 6-7. For session duration, 45 minutes was significantly more beneficial than both 30 and 60 minutes of exercise, while 30 minutes was significantly better than 60. For duration of training intervention, 25+ weeks was slightly more beneficial to 13-24 weeks, though the difference was not significant. Both elicited nearly 11x the positive changes that less than 12 weeks did (Table 3B).

Table 1. *Classification of Aerobic Exercise Studies by Intensity*

Intensity	Definition	Studies	N
Low Intensity	35-60% of Heart Rate Max (Max HR), 50-60% of Heart Rate Reserve 9 (HRR), OR < 45% VO2peak	1, 2	2
Moderate	60-80% of Max HR 60-70% of HRR, OR 45-60% of VO2 peak	3, 4, 5,6, 7,8, 9, 10, 11,12,13-15,16,17	16
High	80-90% of Max HR, 70-85% of HRR, OR 60-80% of VO2 peak	18,6, 19,20, 21, 22, 23-29, 30,31, 32,27, 28, 33, 34, 35-37	20

Table 2. *Impact of Intensity on HDL Benefits*

	Significance	No change	P<0.05	P<0.01	P<0.001
Low Intensity	Number of Studies	N=1		N=1	
	References	1		2	
Moderate Intensity	Number of Studies	N=8	N=5	N=4	N=1
	References	3, 4, 5, 6, 7,8, 1, 9	10,11,12 13, 14	15,2, 16	17
High Intensity	Number of Studies	*N=16*	*N=6*	*N=2*	*N=4*
	References	18,6, 17, 19,20, 21, 22,23-29	30,31, 32, 27, 28, 33	17,28	34, 35-37

Table 3A. *Odds of Eliciting Benefits on Serum Lipids*

	Intensity		*Frequency (times/week)*			*Exercise Duration (mins/session)*			*Duration of Training Intervention (weeks)*		
	Mod	**High**	**2--3**	**4--5**	**6--7**	**30**	**45**	**60**	**1--12**	**13--24**	**25+**
NS	531	935	880	652	83	449	796	341	233	522	641
P < 0.05	220	599	427	445	21	207	474	128	18	428	542
Odds	0.41	0.64	0.49	0.68	0.25	0.46	0.6	0.38	0.08	0.82	0.85

Table 3B. *Odds Ratios and Confidence Intervals*

	Intensity	*Frequency*			*Exercise Duration*			*Intervention Duration*		
Ratio Details	**Mod vs. High**	**2-3 vs. 4-5**	**2-3 vs. 6-7**	**4-5 vs. 6-7**	**30 vs. 45**	**30 vs. 60**	**45 vs. 60**	**≤12 vs. 13-24**	**≤12 vs. 25+**	**13—24 vs. 25+**
Odds Ratio	0.64	0.72	1.96	2.72	0.77	1.21	1.57	0.1	0.09	0.96
95% Min	0.53	0.60	6.60.	1.64	0.63	0.94	1.26	0.06	0.06	0.82
95% Max	0.78	0.84	16.31	4.42	0.95	1.60	2.00	0.15	0.15	1.15

4. Discussion

The aim of our review was to clarify the interrelationship of aerobic exercise intensity, duration, and frequency on lipid profile measures in non-diseased older male populations. Specifically, we wished to find an optimal prescription for lipid profile benefits in this population.

The picture that emerged from our literature search was that low intensity exercise, which is below 60% of the max HR/HRR, or below 45% of VO2peak, was understudied in our particular population of interest. This may be a consequence of the existing research supporting higher intensities of exercise as more beneficial on health, thus leading most researchers to employ a higher level of exertion in their studies to maximize statistics. Both moderate and high intensity exercise, or that which is 60-80% of max HR, 60-70% of HRR, or 45-60% VO2peak, were found to elicit a variety of changes for each combination of frequency, duration of session, and duration of training. Despite the conflicting findings and majority of studies yielding no beneficial effects of endurance exercise, the odds of high intensity exercise improving HDL levels were superior to those odds of moderate intensity. This is consistent with several studies that found the greater the intensity, the greater the benefits [7; 20; 35].

Red= High Intensity Orange= Medium Intensity Green= Low Intensity

Study	Frequency (times/week)	Session Duration (minutes)	Training duration (weeks)	0.001	0.01	0.05	NS	P <
Blumenthal 89	3	60	16				X	NS
Blumenthal 91 a	3	60	16				X	NS
Blumenthal 91 b	3	60	40			X		0.05
Brinkley	3	40	24	X				0.001
Coon	3	40	12				X	NS
Dengel 94	3-4.	40	24		X			0.01
Dengel	3	45	40				X	NS
Desouza	5-6.	30-45	12				X	NS
Evans	2-3.	58	36				X	NS
Finucare	3	60	12				X	NS
Halvershadt	4	40	24		X			0.01
Halvershadt 03	3 high, 1 low	40 (3x), 45-60 (1x)	24			X		0.05
Halverstadt 07	3 high, 1 low	40 (3x), 45-60 (1x)	24				X	NS (0.09)
Katzel[a]	3	30-45	36			X[2]	X[1]	NS(1), 0.05 (2)
King 91	3	40	52				X	NS
King 91	5	30	52				X	NS
King 95	3	40	104		X			0.01
King 95	5	30	104				X	NS
Lira	3	60	24				X	NS
Lockard	3	40	24	X				0.001
McCrone	2	40	24				X	NS
Nicklas[b]	3	45-60	36		X[1]	X[2]	X[3]	0.01 (1), 0.05 (2), NS (3)
Riede	5	60	6			X		0.05
Riedl	5	60	6			X		0.05
Schwartz	3	40	12				X	NS
Schwartz et al 92	5	45	24	X				0.001
Sillanpau	2	30	21		X			0.01
Sunami	2-4.	60	20		X			0.01
Takeshima	3	30	12			X		0.05
Tamara	3	48	20			X		0.05
Tanka	3-4.	30	12				X	NS
Wilund	3	40	24		X			0.01

Figure 2. *Efficacy of Various Studies in Eliciting Beneficial HDL Changes*

[a] For Ketzel, et al., 1= Aerobic exercise with maintenance of baseline weight, 2= Aerobic exerise with weight loss
[b] For Nicklas, et al., 1= Lean men, 2= overweight, 3=obese

However, existing studies on younger or female populations document that while HDL increases result from both moderate and high intensity, high intensity elicits no more benefits than moderate [41; 42]. As we only found two low intensity exercise studies meeting our criteria, we are unable to make any conclusive observations about the effects of low versus moderate. In the existing literature on other subject populations, low intensity exercise repeatedly does not elicit beneficial changes in HDL[8; 13; 17; 25]. However, there are other studies suggesting that lower intensity may be more beneficial than higher intensities. In a study by Ledoux and colleagues, only the low-intensity group showed a significant rise in HDL and HDL2[29], while Stubbe et al. obtained a significant negative correlation between changes in HDL cholesterol and training intensity (expressed as percentage of maximal heart rate)[43].

For frequency, a more moderate approach appears superior as 4-5 times a week was more beneficial than either 2-3 or 6-7 times. Moreover, 2-3 times was more likely to elicit benefits that 6-7 times, contrary to our expectations. This is consistent with a study on diabetic children that found an exercise frequency of 4 times a week superior to 2 times[3] and other studies showing enhanced HDL benefits with higher frequencies in mixed sex populations or male populations with heart disease[3; 24]. However, to our knowledge, no existing studies have specifically examined the impact of aerobic frequency on HDL levels in healthy males over 45 years of age. Thus, our findings that 6-7 times is not more beneficial than 4-5 or even 2-3 cannot be compared.

Likewise, the more moderate duration elicited greater lipid benefits: 45 minutes were more likely to raise HDL levels than either 30 or 60, and 30 minutes was more beneficial than 60. The benefits of longer than 30 minutes are supported by existing research [6; 26]; however, we are again unable to find literature comparing both shorter durations to the 60 minute frame in our healthy, older male population.

An explanation for why the more moderate levels of exercise frequency and duration were better at eliciting positive HDL changes is that the exercise-induced stress response for longer duration/ greater frequency may surpass the "optimal" levels of stress and, instead of fostering a benefit, lead to a deterioration of positive physiological responses. In individuals who suffer from overtraining syndrome, the excess cortisol can lead to impaired metabolism, which in turn, could negate any potential benefits, or even cause a negative change in HDL levels [12; 14]. In a study that examined overtraining syndrome in rodents, researchers found that the overtraining state actually increased levels of total cholesterol and triglycerides [30].

The duration of the training program was key in eliciting beneficial lipid profile responses. Programs shorter than 12 weeks appear to elicit no response; the most significant changes in lipid levels occurred after 24 weeks of training. This is likely explained by the gradual process of physiological and behavioral adaptations. With longer periods of training, participants may increase caloric intake, overtime, counter-acting the initial benefits [40], or plateau, a common training problem in which the body adjusts to the exercise and no longer beneficially adapts until the routine is altered and enhanced [45]. On the contrary, shorter periods of training may not allow the body sufficient time for physiological adaptations such as altered fat metabolism [19; 31]. However, a higher frequency and longer session duration may compensate for a shorter training period—Riedl's 6 week study employed moderate intensity exercise for 60 minutes, 5 times week and elicited beneficial changes [39].

The importance of frequency and duration in raising HDL is supported by many claiming that an exercise training stimulus must be sufficient in both components in order to plasma HDL cholesterol levels[5]. One group of researchers found a positive correlation between miles run per week and the increase in HDL levels [27; 28]. Essentially, the more often and longer the participants ran at a "mild to moderate intensity" the higher their levels were for "good" cholesterol. When examining the combined impact of frequency and duration by intensity, it is intriguing that at a moderate intensity, longer duration and higher frequencies elicited greater benefits than those at a high intensity. This may simply reflect the small number of studies we analyzed, or perhaps it suggests that subjects who exercise at a high intensity for longer periods of time may enter the overtraining state, or overcompensate with calories.

It is important to note that in our review, the majority of studies that did not find a significant response of HDL to aerobic exercise prevented participants from losing weight. In studies that allowed for weight loss, the participants more often experienced a significant raise in HDL levels. It has been suggested that weight-loss, in addition to exercise, is what leads to raised HDL [11; 36], or even that weight-loss alone, and not exercise is responsible [10; 22]. Indeed, Katzel and colleagues found that healthy, obese men who participated in high intensity exercise for 45 minutes, three times a week and were weight-stabilized [meaning complete caloric compensation for burned calories] displayed no significant changes in any lipid measures [21]. In the comparison weight-loss group, which performed the same aerobic training but also shed pounds, the men displayed significantly beneficial changes in all lipid profile levels. Dengel and colleagues found that high intensity aerobic exercise plus weight loss caused the same degree of HDL level increase as weight loss alone in obese healthy men [9]. This may explain the number of studies that found no change in HDL levels following an exercise intervention—without weight loss, obese individuals may not be able to obtain the benefits. Interestingly, another complication is that older, obese men and older, lean men appear to respond differently to exercise. Nicklas and colleagues compared lean, overweight, and obese men who each exercised for 45-60 minutes at 70-80% of their heart rate reserve for 9 months [34]. The lean men's HDL levels were altered more by training compared to overweight men, whom in turned saw a greater increase than obese men. We included obese and overweight, healthy men in our review as now two–thirds of the US population is overweight or obese; however, such inclusion may not have been appropriate as BMI appears to affect the lipid-profile response to aerobic exercise.

5. Conclusion

As shown by our results, longer, more frequent bouts of high intensity exercise appear to elicit significantly greater positive alterations in high density lipoprotein levels, compared to moderate intensity efforts. Due to a lack of literature concerning low intensity exercise, we were unable to examine whether or not such exercise is effective in altering serum cholesterol markers. However, our data clearly demonstrates that for optimal high density lipoprotein benefits, older, healthy men should aim to workout 4-5days a week, at a high intensity, for 45 minutes per session. The benefits will be evident in serum levels of the lipoprotein after 13 weeks of such a regimen.

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