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Responses of Blood Lipids to Aerobic, Resistance, and Combined Aerobic With Resistance Exercise Training: A Systematic Review of Current Evidence

Konstantinos Tambalis, MSc, Demosthenes B. Panagiotakos, PhD, Stavros A. Kavouras, PhD, and Labros S. Sidossis, PhD

This review considers the effectiveness of aerobic exercise training with different intensities (moderate and high) as well as the type of exercise (aerobic, resistance, and combined aerobic with resistance) in altering the blood lipids. We reviewed various trials via a systematic search of PubMed, published reviews, and references from original articles. We selected studies that involved aerobic and/or resistance and/or combined exercise training in healthy adults over a limit of 12 weeks and had examined the response of training to one or more of the following: triglycerides, total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol. We selected a total of 84 studies, 58 were randomized controlled trials. Comparisons between intensities of aerobic exercise programs resulted in favorable effects only for high intensity. The most frequently observed alteration was an increase in the high-density lipoprotein cholesterol, whereas reductions in triglycerides, total cholesterol, and low-density lipoprotein cholesterol appeared less often. Moreover, the evidence of the positive effect of resistance exercise marks out a trend mainly for the low-density lipoprotein cholesterol levels, whereas for combined exercise, results extracted from a short list of published studies show improvements in values of both the high-density lipoprotein cholesterol and the low-density lipoprotein cholesterol. High-intensity aerobic training results in improvement in high-density lipoprotein cholesterol. For resistance and combined exercise, the results are inconsistent. The heterogeneity between the types of exercise did not allow reliable comparisons.

Keywords: exercise; aerobic; resistance; combined; lipids; lipoproteins

Introduction

There has been considerable progress in the understanding of the role of blood lipids in the pathogenesis of atherosclerosis and coronary heart disease (CHD).[1] Major risk factors for cardiovascular diseases include hypertension, smoking, serum total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and low levels of high-density lipoprotein cholesterol (HDL-C).[2,3] The potential independent association between plasma triglycerides (TG) and CHD is more controversial,[1,4] because the elevated levels of TG are associated with other risk factors (eg, lower HDL-C).[5] Physical inactivity and reduced cardiorespiratory fitness contribute to the risk of CHD,[6] whereas there is consistent, substantial, and strong evidence that physical activity is a deterrent for developing cardiovascular disease.[7] The preventive effects of physical activity on CHD are probably because of the decrease in known CHD risk factors such as hypertension, obesity,[8] and hyperlipidemia. Moreover, physical activity is a significant factor in insulin sensitivity.[9] Because of the varied exercise

From the Department of Nutrition Science–Dietetics, Harokopio University, Athens, Greece.

Address correspondence to: Labros S. Sidossis, Laboratory of Nutrition and Clinical Dietetics, Department of Nutrition Science–Dietetics, Harokopio University, 70 El Venizelou Str, Athens 17671, Greece; e-mail: lsidossis@ath.forthnet.gr.

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interventions, experimental designs, and participant characteristics, the influence of physical activity on lipid and lipoprotein levels remains elusive.[10,11] The optimal kind, intensity, or volume of exercise necessary for significant alterations in blood lipids or other risk factors is unknown. There are several longitudinal epidemiologic observational studies, as well as a growing number of clinical randomized trials that mainly involve aerobic and secondary resistance exercise and their effect on blood lipids.[12-89] As for combined exercise, there is limited data that have estimated the influence on risk factors for CHD and mainly focused on elderly people.[90-95] To the best of our knowledge, reviews that compared different intensities (moderate or high) of aerobic exercise according to American College of Sports Medicine's (ACSM) criteria or different kinds of exercise (aerobic, resistance, and combined) do not exist.

The main focus of this review is on the results of published clinical randomized trials that have evaluated supervised aerobic, resistance, and combined exercise and its influence on blood lipid and lipoprotein concentrations.

Evaluated Studies

Studies for this review article were identified via a systematic search of the electronic database of PubMed (www.pubmed.gov). In addition to computer investigation, we use previous review articles and references from original articles. Major keywords included aerobic, resistance, combined, exercise, lipids, and lipoproteins. We selected studies that involve aerobic, resistance, and combined exercise published in English from January 1990 to December 2006. Moreover, because the data for resistance exercise were limited, we included data from some previous trials (between 1994 and 2006). We chose the following inclusion criteria for our review: (1) exercise program of no less than 12 weeks, the least duration required to observe significant alterations in blood lipids,[96] (2) sedentary, apparently healthy adult humans aged 18 years and older, (3) both hyperlipidemic and normolipidemic humans, and (4) assessments of at least one of the lipids (TC, HDL-C, LDL-C, and TG) in the fasting state. We limited our search to these lipid variables because they are often incorporated in clinical studies. We also excluded trials with potential confounding variables such as exercise combined with dietary measures or hormone replacements. The studies are presented in chronological order. The main categories of information include study (first author and year), number of participants completing the intervention, sex, age and race of the participants, body mass index (BMI) group (overweight, obese), and classification of blood lipid status according to the National Cholesterol Education Program (NCEP) guidelines[97] and the presence of a no-exercise control group. Furthermore, it includes details of the exercise program (the type of exercise, length of training period, duration of session, frequency of session per week, intensity, and volume of exercise). Regardless of the purpose of exercise, it is performed with regard to the components of the exercise prescription such as mode, frequency, duration, intensity, rest, and progression; regarding involvement with acute and chronic responses, intensity is the most important.[98] This study used the modified classification of exercise intensities as recommended for healthy adults by ACSM and the Surgeon General.[98] Analytically, for aerobic exercise, we classified the studies as follows: (1) moderate intensity [$VO_{2max} \leq 60\%$ or heart rate reserve (HRR) $\leq 60\%$ or maximal heart rate (MHR) $\leq 60\%$] [] and (2) high intensity ($VO_{2max} > 60\%$ or HRR > 60% or MHR > 60%). Moreover, we classified as moderate intensity trials, those that used lactate or anaerobic threshold for the definition of intensity,[99] because for untrained individuals, lactate threshold appears between 40% and 60% of VO_{2max}.[100,101] The last columns of the tables (Tables 1-4) show the primary outcome of our study which are significant changes (%) and baseline to postintervention, in TC, HDL-C, LDL-C, and TG. Exercise-induced alteration in blood lipid profile was compared for statistical significance, with baseline levels in studies without control group or with control group in randomized controlled trials (RCT). The results of studies that included groups with different intensities (moderate and high) training programs are presented in the table.

Findings of Reviewed Studies

Tables 1 to 4 show 84 studies, 58 were RCT, which included moderate intensity aerobic exercise (Table 1), high-intensity aerobic exercise (Table 2), and resistance training (Table 3), and combined exercise (Table 4). A total of 12 trials[13,21,23,26,28,30,32,33,35,36,37,38] compared the effects of moderate intensity and high-intensity aerobic exercise on the blood lipid profile,

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Table 1. Blood Lipid Responses to Moderate Intensity Aerobic Exercise

Literature Citation	Participants/Groups	Mode	Exercise Training Program: Length	Exercise Training Program: Intensity/Frequency Duration	Blood Lipids
Despres et al[12]	N = 13 women 33-50 year obese (no control)	Walk/jog/swim cycle	14 mo	55% VO_{2max}; 4-5×/wk; 90 min	TC-7%[a]; LDL-C-10%[a]; NS TG, HDL-C
Stein et al[13]	N = 49 men 44 ± 8 years ↑ TC 1. Moderate intensity 2. Intermediate intensity 3. High intensity 4. Control (RCT)	Cycle ergometer	12 wk	1. 65% MHR; 3×/wk; 30 min; 2. 75% MHR; 3×/wk; 30 min; 3. 85% MHR; 3×/wk; 30 min	NS (group 1); HDL-C-18%; LDL-C-11%[a]; NS TC, TG (group 2); NS TC, TG, LDL-CHDL-C-13%[b] (group 3)
Barr et al[14]	N = 24 men 18-22 years swimmer 1. Swim-high volume 2. Swim-moderate volume (no control)	Swim	25 wk	1. Moderate; 7×/wk.22-44 km/wk 2. Moderate; 7×/wk.22 km/wk	NS (groups 1 and 2)
Blumenthal et al[15]	N = 101 men + women ≥ 60 years 1. Exercise 2. Control (RCT)	Cycle ergometer	14 mo	50%-60% HRR; 3×/wk; 60 min	NS TC, LDL-C;HDL-C-7.5%[a]; TG-20%[a] (group 1)
Duncan et al[16]	N = 53 women 20-40 years 1. Aerobic walking 8 km/hr 2. Fast walking 6.4 km/hr 3. Strolling 4.8 km/hr 4. Control (RCT)	Walking	24 wk	Moderate; 5×/wk; 30-60 min	HDL-C-6%[b] (group 1); HDL-C-6%[b] (group 3); LDL-C-8%[a] (group 2); NS TC, TG
Lamarche et al[17]	N = 31 women 30-40 years obese 1. Fat loss 2. Fat gain (no control)	Walking/jogging	24 wk	1. 55% VO_{2max} 4-5×/wk; 90 min 2. 55% VO_{2max} 4-5×/wk; 90 min	TC-8%[a]; TG-18%[a]; LDL-C-11%[a]; NS HDL-C (group 1); NS (group 2)
Suter and Marti[18]	N = 33 women 25-55 years 1. Exercise 2. Control (RCT)	Walking/jogging	16 wk	Moderate; 2-6×/wk; 11 km/wk	NS
Hinkleman and Nieman[19]	N = 36 women 25-45 years obese 1. Exercise 2. Control (RCT)	Walking/jogging	15 wk	60% VO_{2max}; 5×/wk; 45 min	HDL-C-3%[a]; NS TC, TG, LDL-C
Nieman et al[20]	N = 32 women 67-84 years 1. Exercise 2. Control (RCT)	Walking	12 wk	60% HRR; 5×/wk; 30-40 min	NS
Suter et al[21]	N = 75 men mean age 41 years 1. Moderate intensity 2. High intensity 3. Control (RCT)	1. Walking 2. Jogging	6 mo	1. 50% VO_{2max}; 6×/wk; 30 min 2. 75% $VO_{2max;}$ 4×/wk; 30 min	NS (groups 1 and 2)
Kumagai et al[22]	N = 10 women 32-49 years ↑BMI 1. Exercise (no control)	Cycle ergometer	24 wk	Lactate threshold; 3×/wk; 60 min	HDL-C-8%[a]; NS TC, TG

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King et al[23]	N = 149 men + 120 women 50-65 years 1. Moderate intensity at home 2. High intensity at home 3. High intensity supervised 4. Control (RCT)	Walking/jogging	24 mo	1. 60%-70% MHR; 5×/wk; 30 min 2. 73%-88% MHR; 3×/wk; 40 min 3. 73%-88% MHR; 3×/wk; 40 min	NS (group 1); HDL-C 4.3%[b]; NS TC, TG, LDL-C (group 2); NS HDL-C,LDL-C, TC, TG (group 3)
Motoyama et al[24]	N = 30 men + women 75 ± 5 years 1. Exercise 2. Control (RCT)	Treadmill; walking	40 wk	Lactate threshold; 3-6×/wk; 30 min	NS
Ready et al[25]	N = 76 women 55-67 years ↑TC 1. Moderate volume 2. High volume 3. Control (RCT)	Treadmill; walking	24 wk	1. 60% $VO_{2max;}$ 3×/wk; 60 min 2. 60% $VO_{2max;}$ 5×/wk; 60 min	NS (groups 1 and 2)
el-Sayed[26]	N = 18 men 1. Low intensity 2. High intensity (no control)	Cycle ergometer	12 wk	1. 30% VO_{2max}; 3×/wk; 20 min 2. 80% $VO_{2max;}$ 3×/wk; 20 min	NS (group 1 and 2)
Leon et al[27]	N = 22 men 22-44 years ↑BMI 1. Exercise 2. Control (RCT)	Walking; stair climbing	12 wk	55%-82% MHR; 5×/wk; 45 min; ~19×/wk	NS
Crouse et al[28]	N = 26 men 37-57 years ↑TC 1. Moderate intensity 2. High intensity (no control)	Cycle ergometer	24 wk	1. 50% $VO_{2max;}$ 3×/wk; 350 kcal 2. 80% $VO_{2max;}$ 3×/wk; 350 kcal	NS (groups 1 and 2)
Stefanick et al[29]	N = 90 men + 177 women 30-64 years ↑LDL-C and ↓HDL-C 1. Exercise 2. Control (RCT)	Walking or jogging	12 mo	1. Moderate; 3×/wk; 60 min	NS (group 1)
Schuit et al[30]	N = 113 men + 116 women 60-80 years with ↑TC 1. Moderate intensity at home 2. High intensity supervised 3. Control (RCT)	Cycle ergometer; ball-games, dance	24 wk	1. Moderate; 3×/wk; 30 min 2. 70% VO_{2max}; 4×/wk; 45 min	NS (groups 1 and 2)
Vasankari et al[31]	N = 34 men + 70 women 31-58 years with ↑TC (no control)	Walking, ergometer dance, etc	40 wk	Moderate; HR 110-145 bpm; 209 min/wk (women); 257 min/wk (men)	NS
Dunn et al[32]	N = 116 men + 119 women Mean age 46 years with ↑TC 1. Structured exercise 2. Lifestyle exercise (no control)	Individual aerobic activities	24 mo	1. 50%-85% VO_{2max}; 3-5×/wk; 20-60 min 2. Moderate; 5-7×/wk; 30 min+	HDL-C-8%[b]; TC - 5%[b]; LDL-C - 6%[b]; NS TG (group 1); NS (group 2)

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Table 1. (continued)

Literature Citation	Participants/Groups	Mode	Exercise Training Program: Length	Exercise Training Program: Intensity/Frequency Duration	Blood Lipids
Spate-Douglas and Keyser[33]	N = 25 women 40 years ↓HDL-C 1. Moderate intensity 2. High intensity (no control)	Treadmill walking	12 wk	1. 60% HRR; 3×/wk; 3.2 km 2. 80% HRR; 3×/wk; 3.2 km	HDL-C-25%[a]; NR TC, TG, LDL-C; HDL-C-20%[a]; NR TC, TG, LDL-C (group 2)
Sunami et al[34]	N = 20 men + 20 women 60-80 years with ↑TC 1. Exercise 2. Control (RCT)	Cycle ergometer	5 mo	50% VO_{2max}; 2-4×/wk; 60 min	HDL-C-10%[a]; NS TC, TG, LDL-C
Cox et al[35]	N = 126 women 40-65 years 1. Moderate intensity 2. High intensity (no control)	Walking and jogging	18 mo	1. 40%-55% HRR; 3×/wk; 30 min 2. 65%-80% HRR; 3×/wk; 30 min	NS (groups 1 and 2)
Kraus et al[36]	N = 111 men + women 40-65 years ↑LDL-C or ↓HDL-C 1. Moderate intensity–low volume 2. High intensity–low volume 3. High intensity–high volume 4. Control (RCT)	Jogging	8 mo	1. 40-55 VO_{2max}; 19 km/wk 2. 65-80 $VO_{2max;}$ 19 km/wk 3. 65-80 VO_{2max}; 32 km/wk	TG-25%[b]; NS TC, HDL-C,LDL-C (group 1); NS TC, HDL-C,LDL-C TG-10%[b] (group 2); NS TC, LDL-C; TG-9%[a] (group 3)
O'Donovan et al[37]	N = 64 men 30-45 years 1. Moderate intensity 2. High intensity 3. Control (RCT)	Treadmill Jogging	24 wk	1. 60% $VO_{2max;}$ 3×/wk; 400 kcal 2. 80% $VO_{2max;}$ 3×/wk; 400 kcal	NS (group 1); NS TG, HDL-C;LDL-C-12%[a]; TC-9%[b] (group 2)
Duncan et al[38]	N = 492 women + men 30-69 years 1. High intensity–high freq 2. High intensity–low freq 3. Moderate intensity–high freq 4. Moderate intensity–low freq 5. Control (RCT)	Walking	6-24 mo	1. 65%-75% HRR; 5-7×/wk; 30 min 2. 65%-75% HRR; 3-4×/wk; 30 min 3. 45%-55% HRR; 5-7×/wk; 30 min 4. 45%-55% HRR; 3-4×/wk; 30 min	NS (groups 1, 2, 3, and 4)
Frank et al[39]	N = 173 women 50-75 years ↑BMI 1. Exercise 2. Control (RCT)	Aerobic activity	12 mo	Moderate; 5×/wk; 45 min	NS TG NR TC, HDL-C, LDL-C

[a]$P < .05$, [b]$P < .01$

NOTES: BMI = body mass index; freq = frequency; HDL-C = high-density lipoprotein cholesterol; hr = hour; HRR = heart rate reserve; LDL-C = low-density lipoprotein cholesterol; MET = metabolic equivalent; MHR = maximum heart rate; min = minute; NR = not reported; NS = no significant differences between the changes with training in the treatment and control group or from baseline if there is no control group; RCT = randomized controlled trials; TC = total cholesterol; TG = triglycerides; wk = week; ↑ = increase; ↓ = decrease.

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Table 2. Blood Lipid Responses to High-intensity Aerobic Exercise

Literature Citation	Participants/Groups	Mode	Exercise Training Program		Blood Lipids
			Length	Intensity/Frequency Duration	
Whitehurst and Menendez[40]	N = 34 men 61-81 years 1. Exercise 2. Control (RCT)	Walking	12 wk	70%-80% MHR; 3×/wk; 25-40 min	HDL-C-7%[a]; TG-4%[a]; NS TC, LDL-C
Schwartz et al[41]	N = 27 men 28-68 years 1. Young 2. Older (no control)	Walking/jogging cycle	24 wk	50%-85% HRR; 5×/wk; 45 min	NS TC, TG, LDL-C HDL-C-13% (group 1); HDL-C-14%[a] TG-20%[a] NS TC, LDL-C (group 2)
Hellenius et al[42]	N = 157 men 30-60 years ↑TC 1. Exercise 2. Exercise + diet 3. Control (RCT)	Walking/jogging	6 months	75%-85% HRR; 4×/wk; 30-50 min	NS (group 1)
Lindheim et al[43]	N = 95 women 42-59 years ↑TC and ↑HDL-C 1. Exercise 2. Exercise + estrogen 3. Control (RCT)	Cycle ergometer/ treadmill walking	6 months	1. 70% MHR; 3×/wk; 30 min	LDL-C-10%[b]; TC-5%[a]; TG-2%[a]; NS HDL-C (group 1)
Houmard et al[44]	N = 13 men 45-50 years (no control)	Stair master	14 wk	70%-85% VO_{2max}; 3×/wk; 30-45 min	HDL-C-8.5%[a]; TG-20%[a]; NS TC, LDL-C
Williams et al[45]	N = 155 men 30-59 years ↑BMI 1. Exercise 2. Diet 3. Control (RCT)	Running or jogging	12 months	1. 60%-80% MHR; 4×/wk; 40-50 min	HDL-C-7%-13%[a]; NR TC, TG, LDL-C (group 1)
Santiago et al[46]	N = 27 women 22-40 years 1. Exercise 2. Control (RCT)	Treadmill walking	40 wk	72% MHR; 4×/wk; 53-56 min	NS
Katzel et al[47]	N = 21 men 46-80 years obese with ↓HDL-C 1. Exercise 2. Control (RCT)	Cycle ergometer/ treadmill walking	9 months	1. 70%-80% HRR; 3×/wk; 30-40 min	NS (group 1)
Grandjean et al[48]	N = 37 men 30-45 years 1. Exercise 2. Control (RCT)	Walking/jogging cycle	24 wk	60%-70% VO_{2max}; 3×/wk; 20-60 min	HDL-C-11%[a]; LDL-C-21%[a]; TC-10%[a]; NS TG
Binder et al[49]	N = 71 women 60-72 years 1. Exercise 3. Exercise + estrogen 4. Control (RCT)	Walking/jogging Stair climbing	11 months	1. 60%-70% VO_{2max}; 3-5×/wk; 30 min+	HDL-C-7.5%[a]; TC-6%[a]; NS TG, LDL-C (group 1)
Ponjee et al[50]	N = 23 men + 14 women 67 ± 7 years 1. Exercise 2. Control (RCT)	Running	9 months	Increasing intensity and volume; 3-4×/wk (marathon training program)	LDL-C-12%[a]; TC-12%[a]; NS TG, HDL-C (men); NS TC, TG, LDL-C, HDL-C (women)

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Table 2. (continued)

Literature Citation	Participants/Groups	Mode	Exercise Training Program		Blood Lipids
			Length	Intensity/Frequency Duration	
Fonong et al[51]	N = 34 men + women 27-49 years 1. Exercise 2. Control (RCT)	Walking	2 months	60%-75% VO_{2max}; 3×/wk; 200-300 kcal per session	NS
Thompson et al[53]	N = 17 men 30-50 years ↑TC (no control)	Walking/jogging	12 months	60%-80% MHR; 4×/wk; 50 min	HDL-C-9%[b]; TG-8%[a]; NS TC, LDL-C
Nicklas et al[54]	N = 46 men 46-72 years 1. Normal (BMI 22-26) 2. Overweight (BMI 27-30) 3. Obese (BMI 31-37) (no control)	Treadmill walking/ski machine	9 months	70%-80% HRR; 3×/wk; 60 min	HDL-C-13%[b]; TG-10%[a]; NS TC, LDL-C (group 1); HDL-C-6%[a]; TG-10%[a]; NS TC, LDL-C (group 2); TG-20%[a]; TC-7%[b]; NS HDL-C, LDL-C (group 3)
Leaf et al[55]	N = 137 men 23-68 years ↑TC 1. Exercise (no control)	Running/cycle/ rowing	12 months	60%-80% HRR; 30 min 1500-2000 kcal/wk	HDL-C-8%[a]; NS TG, LDL-C, HDL-C
Woolf-May et al[56]	N = 49 men + women 40-71 years 1. Long walking 2. Repetitive short walking 3. Control (RCT)	Walking	18 wk	1. 68% VO_{2max}; 20-40 min/d (average 139 min/wk) 2. 65% VO_{2max}; 3× 10-15 min/ d (average 135 min/wk)	NS (groups 1 and 2)
Zmuda et al[57]	N = 17 men 26-49 years ↑TC 1. Exer HDLC <40 mg/dL 2. Exer HDL-C > 44 mg/dL (no control	Walking/jogging or cycle ergometer	12 months	60%-90% MHR; 4×/wk; 50 min	NS TC, TG, LDL-C; HDL-C-12%[b] (group 1); NS (group 2)
Tikkanen et al[58]	N = 17 men 37 ± 4 years 1. Exercise 2. Control (RCT)	Leisure physical activity	12 months	4-10 MET; 3-5×/wk; 1000-2000 kcal/wk	HDL-C-21%[b]; LDL-C-8%[b]; NS TC, TG
Leon et al[59]	N = 299 men + 376 women 17-65 years (black and white) (no control)	Cycle ergometer	20 wk	55%-75% VO_{2max}; 3×/wk; 30-50 min	HDL-C 3.6%[b]; NS TG, TC, LDL-C
Bergeron et al[60]	N = 200 white men 36 ± 15 years 69 black men 33 ± 11 years (no control)	Cycle ergometer	20 wk	55%-75% VO_{2max}; 3×/wk; 30-50 min	HDL-C-2%[a]; TC-2%[a]; TG-10%[a]; NS LDL-C (white); NS (black)
Verissimo et al[61]	N = 63 men + women 65-94 years 1. Exercise 2. Control (RCT)	Walking/ergometer/ rowing	8 months	60%-80% MHR; 3×/wk; 50 min	Decrease TC, TG, LDL-C; HDL-C 4.5[b]

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Nieman et al[62]	N = 121 women 25-75 years 1. Diet 2. Exercise 3. Diet + exercise 4. Control (RCT)	Walking	12 wk	78% MHR; 5×/wk; 45 min	NS (group 2)
Wilund et al[63]	N = 17 men + 22 women .57 years with ↑TC or ↓HDL-C 1. Exercise 2. Control (RCT)	Ergometer; treadmill walking; ski	6 months	70% MHR; 3×/wk; 40 min	HDL-C-10%[a]; TG-10%[a]; NS TC, LDL-C
Halverstadt[64]	N = 83 men 50-75 years ↑TC or ↓HDL-C or ↑TG 1. Exercise 2. Control (RCT)	Walking/cycle ergometer	24 wk	50%-70% VO_{2max}; 3×/wk; 20-40 min	HDL-C-7%[a]; TG-11%[a]; NS TC, LDL-C
Thompson et al[65]	N = 126 men + women 39 ± 11 years Recruited according to AρoE genotype E2/3, E 3/3, E 3/4	Treadmill walking/ cycle/ski machine	6 months	60%-85% VO_{2max}; 4×/wk; 50 min	HDL-C-2%[a]; TG-11%[b]; NS TC, LDL-C (for the entire cohort)

[a]$P < .05$, [b]$P < .01$.

NOTES: BMI = body mass index; d = day; exer = exercise; HDL-C = high-density lipoprotein cholesterol; HRR = heart rate reserve; LDL-C = low-density lipoprotein cholesterol; MET = metabolic equivalent; MHR = maximum heart rate; min = minute; NR = not reported; NS = no significant differences between the changes with training in the treatment and control group or from baseline if there is no control group; RCT = randomized controlled trials; TC = total cholesterol; TG = triglycerides; wk = week; ↑= increase; ↓= decrease.

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Table 3. Blood Lipid Responses to Resistance Exercise

Literature citation	Participants/Groups	Mode	Exercise Training Program: Length	Exercise Training Program: Intensity/Frequency Duration	Blood Lipids
Goldberg et al[66]	N = 6 men + 8 women; 27-33 years sedentary; (no control)	Resistance training	16 wk	3×/wk; 8 exer; ×3 sets; ×3-8 reps (2 min rest)	NS TC, TG, HDL-C;LDL-C-16%[a] (men); TC-11%[a]; TG-28%[a]; LDL-C-19%[a] (women)
Ullrich et al[67]	N = 25 men 18-35 years (no control)	Resistance training	8 wk	100% 15-18 RM 3×/wk; 9 exer; ×1 set; ×15-18 reps	LDL-C-8%[a];HDL-C-14%[b]; NS TG
Hurley et al[68]	N = 11 men 44 ± 3 years 1. Exercise 2. Control (RCT)	Resistance training	16 wk	3-4×/wk; 14 exer; ×1 set; ×8-20 reps (cycle training-short intervals)	HDL-C-10%[a]; LDL-C-5%[a]; NS TC, TG
Kokkinos et al[69]	N = 37 men 21 ± 1 years 1. Low repetitions 2. High repetitions 3. Control (RCT)	Resistance training	10 wk	1. 3×/wk; ×10 exer; ×3 sets; ×4-6 reps 2. 3×/wk; ×10 exer; ×1-2 sets; ×14-16 reps	NS (groups 1 and 2)
Kokkinos et al[70]	N = 16 men 46 ± 11 years 1. Exercise 2. Control (RCT)	Resistance training	20 wk	100% 12-15 RM 3×/wk; ×11 exer; ×2 sets; ×12-15 reps (90 s rest)	NS
Blumenthal et al[71]	N = 46 women 45-57 years 1. Resistance exercise 2. Aerobic exercise 3. Control (RCT)	Resistance training; walking or jogging	12 wk	1. 3×/wk cycle resistance train 2. 70% HRR; 3×/wk; 35 min	NS (groups 1 and 2)
Manning et al[72]	N = 16 women 30-56 years 1. Exercise 2. Control (RCT)	Resistance training	12 wk	60%-85% 1 RM 3×/wk; 3 sets; ×6-8 reps	NS
Smutok et al[73]	N = 37 men 50 ± 9 years 1. Resistance exercise 2. Aerobic exercise 3. Control (RCT)	Resistance training; walking or jogging	20 wk	1.100% 12-15 RM 3×/wk; 11 exer; ×2 sets; ×12-15 reps (90 sec rest) 2. 75%-85% HRR; 3×/wk; 30 m.	NS (groups 1 and 2)
βoyden et al[74]	N = 88 women 28-39 years 1. Exercise 2. Control (RCT)	Resistance training	5 months	70% 1 RM 3×/wk; 12 exer; ×3 sets; × 12 reps	LDL-C-12%[a]; TC-8%[a]; NS TG, HDL-C
Hersey et al[75]	N = 42 men + women 1. Resistance exercise 2. Aerobic exercise 3. Control (RCT)	Resistance training; walking or jogging	6 months	1. 100% 12 RM 3×/wk; 10 exer; ×1 set; ×12 reps 2. 75%-85% HRR; 3×/wk; 35-45 min	NS (groups 1 and 2)
Joseph et al[76]	N = 35 men + women 1. Exercise 2. Control (RCT)	Resistance training	12 wk	80% 1 RM 3×/wk; 5 exer; ×3 sets; ×12 reps	HDL-C-6%[a] (men); HDL-C-6%[a] (women); NS TC, TG, LDL-C
Prahbakaran et al[77]	N = 27 women 27 years 1. Exercise 2. Control (RCT)	Resistance training	14 wk	85% 1 RM 3×/wk; 45-50 min	LDL-C-15%[a]; TC-9%[a]; NS TG, HDL-C
Hagerman et al[78]	N = 18 men 60-75 years 1. Exercise 2. Control (RCT)	Resistance training	16 wk	85%-90% 1 RM 2×/wk; 3 exer; ×3 sets; ×8 reps	NS
Volek et al[80]	N = 19 men 25 ± 5 years 1. Creatine 2. Placebo	Resistance training	12 wk	3-4×/wk; ×7-8 exer; ×2-4 sets ×3-12 reps	NS (groups 1 and 2)

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LeMura et al[79]	N = 48 women 20.4 ± 1 years 1. Aerobic exercise 2. Resistance exercise 3. Aerobic + resistance 4. Control (RCT)	Cycle ergometer/walking; resistance training	16 wk	1. 70%-75% VO_{2max}; 3×/wk; 50 min 2. 60%-70% VO_{2max} 3×/wk 6 exer; ×2 sets; ×8-10 reps 3. 2×/wk; × programs 1 + 2	HDL-C-28%[b] (group 1); NS (group 2); TG-14%[a] (group 1); NS (group 2); NS TC, LDL-C (groups 1 and 2)
Fahlman et al[81]	N = 45 women 70-87 years 1. Resistance exercise 2. Aerobic exercise 3. Control (RCT)	Resistance training; walking	10 wk	1. 80% 1 RM 3×/wk; 8 exer; ×1-3 sets; ×8 reps 2. 70% MHR; 3×/wk; 50 min	HDL-C-8%[a]; LDL-C-23%[a]; TC-5%[a]; TG-11%[a] (group 1); HDL-C-25%[a]; TG-38%[a]; NS TC, LDL-C (group 2)
Elliot et al[82]	N = 15 women 49-62 years 1. Exercise 2. Control (RCT	Resistance training	8 wk	80% 10 RM 3×/wk; 5 exer; ×3 sets; ×8 reps	NS
Banz et al[83]	N = 26 men 47 ± 8 years 1. Resistance exercise 2. Aerobic exercise (no control)	Resistance training; running or walking	10 wk	1. Submax intensity 3×/wk; 8 exer; ×3 sets; ×10 reps 2. 60%-85% MHR; 3×/wk; 40 min	HDL-C-13%[a]; NS TC, TG, LDL-C (group 1); NS (group 2)
Vincent et al[84]	N = 43, men + women 70 years 1. Exercise high intensity 2. Exercise moderate intensity 3. Control (RCT)	Resistance training	6 months	1. 80% 1 RM; 3×/wk; 13 exer; ×1 set; ×8 reps 2. 50% 1 RM 3×/wk; 13 exer; ×1 set; ×5 reps	NS HDL-C, TC (groups 1 and 2); NR TG, LDL-C
Behall et al[85]	N = 10 premenopausal + 13 postmenopausal 18-77 years 1. Resistance exercise 2. Aerobic exercise (no control)	Resistance training;-treadmill walking	12 wk	1. 70% 1 RM 3×/wk; 14 exer; ×3 sets; ×8-15 reps 2. 60%-65% HRR; 3×/wk; 30-50 min	LDL-C-20%; TC-14%[a]; NS HDL-C, TG (group 1); LDL-C-26%[b]; TC-18%[a]; NS HDL-C, TG (group 2)
Vincent et al[86]	N = 49 men + women 60-72 years 1. Exercise normal weight 2. Exercise overweight 2. Control (RCT)	Resistance training	6 months	50%-80% 1 RM 3×/wk; 13 exer; ×1 set; ×8-13 reps	NS HDL-C, TC (groups 1 and 2); NR TG, LDL-C
Fenkci et al[87]	N = 60 women obese 1. Resistance exercise 2. Aerobic exercise 3. Control (RCT)	Resistance training; walking/cycle	12 wk	1. Resiatance training 2. Increasing duration and frequency	Decrease TC, TG (groups 1 and 2); decrease LDL-C (group 1)
Olson et al[88]	N = 28 women 25-44 years 1. Exercise 2. Control (RCT	Resistance training	12 months	Moderate intensity 2×/wk; 9 exer; ×1-3 set; ×8-10 reps	NS

[a]$P < .05$, [b]$P < .01$.

NOTES: exer = exercise; HDL-C = high-density lipoprotein cholesterol; HRR = heart rate reserve; LDL-C = low-density lipoprotein cholesterol; MHR = maximum heart rate; NR = not reported; NS = no significant differences between the changes with training in the treatment and control group or from baseline if there is no control; RCT = randomized controlled trials; RM = repetition maximum; rep = repetitions; TC, total cholesterol; TG = triglycerides; min, minute; s = second; wk = week.

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Table 4. Blood Lipid Responses to Combined Exercise

Literature Citation	Participants/Groups	Mode	Exercise Training Program		Blood Lipids
			Length	Intensity/Frequency Duration	
LeMura et al[79]	N = 48 women 20.4 ± 1 years; 1. Aerobic exercise 2. Resistance exercise 3. Aerobic + resistance 4. Control (RCT)	Cycle ergometer/walking; resistance training	16 wk	1.70%-75% VO_{2max}; 3×/wk; 50 min; 2. 60%-70% VO_{2max} 3×/wk; 6 exer; ×2 sets; ×8-10 reps; 3. 2×/wk; X programs 1 + 2	NS (group 3)
Park et al[90]	N = 30 women 40-45 years obese 1. Aerobic exercise 2. Aerobic + resistance 3. Control (RCT)	Walking/dance/exercise; resistance training	24 wk	1. 60%-70% HR max; 6×/wk; 60 min 2. 60%-70% HR max; 3×/wk; 60 min and 60%-70% 1 RM 3×/wk; ×10 exer; 60 min	HDL-C-20%[b]; TC-20%[b]; TG-30%[b]; LDL-C-29%[b] (group 1) HDL-C-23%[b]; TG-42%[b]; TC-25%[b]; LDL-C-34%[b] (group 2)
Tokudome et al[91]	N = 244 elderly men + women 1. Exercise 2. Control (RCT)	Walking and resistance training	12 wk	Walking; 5-7×/wk and 3×/wk; 11exer; ×1 set; ×10 reps	HDL-C-3.5%[b]; TG-8%[a]; NS TC, LDL-C
Lee[92]	N = 85 women 40-60 years 1. Exercise 2. Control (RCT)	Folk dance and resistance training	9 months	55%-80% MHR; 3×/wk; 60-90 min; combined exercise	NS
Stewart et al[93]	N = 115 men + women 55-75 years with ↑BP 1. Exercise 2. Control (RCT)	Walking and resistance training	6 months	60%-90% MHR; 3×/wk; 45 min and 50% 1 RM 3×/wk; 7 exer; ×1-2 sets; ×10-15 reps	HDL-C-10%[b]; NS TC, TG, LDL-C
Verney et al[94]	N = 10 men 73 ± 4 years 1. Exercise (no ccontrol)	Cycle and resistance training	14 wk	75%-95% HR max; 3×/wk; 12 min and 10-12 RM 3×/wk; 3 exer; ×3 sets; ×10-12 reps	TC-10%[a]; LDL-C-14%[a]; NS HDL-C, TG
Boardley et al[89]	N = 131 men + women 74.6 ± 6 years 1. Aerobic exercise 2. Resistance exercise 3. Aerobic + resistance 4. Control (RCT)	Walking; resistance training	16 wk	1. 70% MHR; 3×/wk; 50 min 2. 80% 1 RM 3×/wk; 8 exer; ×1-3 sets; × 8 reps 3. Combined exercise	NS (groups 1, 2, and 3)
Kodama et al[95]	N = 14 men + 64 women 64 ± 6 years 1. Exercise 2. Control (RCT)	Walking and resistance training	12 wk	50% VO_{2max}; 3×/wk; 30 min 2×/wk; 7 exer; ×3 sets; ×10 reps	LDL-C-4%[a]; NS TG, HDL-C

[a]$P < .05$, [b]$P < .01$

NOTES: BP = blood pressure; exer = exercise; HDL-C = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol; MHR = maximum heart rate; NR = not reported; RCT = randomized controlled trials; RM = repetition maximum; rep = repetitions; NS= no significant differences between the changes with training in the treatment and control group or from baseline if there is no control; TC = total cholesterol; TG = triglycerides; wk = week.

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8 trials[71,73,75,79,81,83,85] included in their training intervention aerobic and resistance exercise, whereas only in 2 trials[79,89] aerobic, resistance, and combined exercise were involved. The study participants who completed training programs were approximately 6300 (51% men), predominately whites, ranging from 18 to 80 years old. According to the NCEP criteria, the pretraining TC levels were classified as elevated in 17 studies of aerobic exercise, andoverweight or obese individuals participated in 14 studies.

Aerobic Exercise—Moderate Intensity

In Table 1, we have shown 28 trials that met the inclusion criteria to moderate intensity aerobic exercise. Eighteen studies were RCT, whereas 10 studies have no control group. Ten trials included participants of both sexes, 10 trials included only women, and 8 trials included only men. The total number of participants was 2809 (57% women), and the ages of the participants varied from 18 to 84 years. Seven trials[12,17,19,22,27,36,39] included overweight or obese participants and 11 trials involved participants with abnormal lipid status.[13,24,25,28,29,30,31,32,33,34,36]

The greater part of the exercise programs (25 trials) used walking, treadmill walking, jogging, or cycle ergometer whereas 2 trials[32,39] used individual aerobic activities and 1 trial[14] swimming. The duration of the training program ranged from 12 weeks to 24 months and the frequency of training varied from 2 to 7 sessions per week. Only 3 of the reported studies[14,25,38] compared the effects of different volumes of exercise on the lipidemic profile.

According to the data of Table 1, the influence of moderate intensity aerobic training on blood lipids is not supported with strong evidence. The lipid alteration was recorded mostly in HDL-C. There was a significant ($P < .05$) increase in 6 of 28 (21.4%) studies[15,16,19,22,33,34] including men (2 studies) and women (6 studies) of all ages (20-80 years old). These 6 training groups involving 260 participants (189 women) reported an increase of 3% to 25% in HDL-C with a mean improvement in 9.8% across these studies. From those, 2 studies[19,22] involved overweight or obese individuals whereas 2 studies,[33,34] initially reported abnormal blood lipid values. Finally, we must point out that those studies[14,25,38] that used groups with different volumes but the same intensity (moderate) of exercise did not show significant alterations in any of the lipid levels.

We recorded only a few trials with significant decreases in LDL-C, TC, and TG. Of the 26, 2 studies[12,17] involving 25 women aged between 20 and 50 years presented significant reductions of 7% to 8% in TC after interventions with increased volume (360-450 min/wk). Additionally, the same studies showed significant decreases of 10%[12] and 11%[17] in LDL-C in relation to initial values of the participants. Reductions in TG (ranged from 18% to 25%) were observed in 3[15,17,36] of the 27 trials involving 245 participants (138 women) aged between 30 and 80 years.

Aerobic Exercise—High Intensity

Table 2 shows 37 studies (22 RCT) involving 1600 men (66%) and 753 women aged between 20 and 82 years. In 15 trials the participants had abnormal lipid values (primarily elevated TC), whereas in 4 trials,[45,47,54,36] the participants were overweight or obese. Moreover, in 20 studies only men participated and in 6 studies only women participated.

The mode of exercise included mainly walking, jogging, or cycle ergometer whereas ski machine, stair climbing, or ball games were used less frequently. The length of the training program varied between 12 weeks and 24 months, and the frequency of sessions was 3 times per week in most studies. The influence of different volumes of exercise (with the same intensity) on blood lipids was investigated in 2 studies,[36,38] with inconsistent results.

When aerobic exercise programs were performed with high intensity, favorable alterations in blood lipids, mainly in HDL-C and secondarily in TC, TG, and LDL-C, were observed. Significantly ($P < .05$) increased HDL-C was seen in 22[13,23,32,33,36,40,41,44,45,48,49,53-55,57-61,63-65] of 37 (60%) trials involving 1177 men (19 trials) and 955 women aged between 20 and 80 years. Women had significant increases in 10 trials ranging from 3.6% to 20%, although in 4 trials, the initial values of lipids were abnormal (mainly elevated TC). Men had a significant increase in 19 trials ranging from 2% to 18%, whereas in 8 of the above trials, they began an exercise program with increased TC or decreased HDL-C levels. In relation to the weekly volume of exercise (minute per week), we observed that significant alterations occur in a wide volume ranging from 90 min/wk[13] to 200 min/wk.[36] Significant decreased values of TG, TC, and LDL-C with high-intensity exercise were not included very often. Reductions

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in TG ranged from 2% to 20%, noted in 12 of 35 (34%) trials, affected mainly (11 trials) the male participants aged 28 to 80 years with elevated TC (5 trials), whereas in female participants, this was observed less frequently (5 trials). Lower TC values observed in 8 of the 35 (22%) publications were similar in both men and women aged 20 to 80 years, ranging from 2% to 12%; only 2 interventions[32,43] had increased baseline levels of TC. Likewise, the reductions in LDL-C levels have been reported in 7 of 35 studies in both genders of all ages (27-84 years) and ranged from 6% to 21%.

Resistance Exercise

In Table 3, we present 23 studies that included resistance training (n = 15) or resistance and aerobic training (n = 8) in their exercise program,[71,73,75,79,81,83,85,87] involving 768 men and women, aged 17 to 87 years. The main finding derived from Table 3 in relation to the influence of resistance training on blood lipids is a marked reduction in the LDL-C levels. In fact, 9 of 23 (39%) trials, affecting 191 women and 42 men aged 17 to 87 years, declared significant reductions ranging from 5% to 23%. Furthermore, the levels of TC in 6 of 23 trials (23%) were significantly reduced (by 5%-14%) only in women, although the previous finding was incorporated in 1 of 5 studies that involvedboth sexes. Similarly, reductions in the TG levels (3 of 23 trials) appeared to affect only women. Finally, HDL-C was significantly increased from 6% to 14% in 4 of 23 trials for both genders. Studies that compared the influence of different kinds of exercise (aerobic and resistance) on the lipid profile presented inconsistent results. Analytically, Blumenthal et al,[71] Smutok et al,[73] and Hersey et al[75] did not find significant alterations in blood lipids in their interventions with aerobic and resistance training in both the groups. In contrast, Fahlman et al,[81] Behall et al,[85] and Fenkci et al[87] reported improvements in both groups, whereas LeMura et al[79] found significant differences only for participants in aerobic training and Banz et al[83] only for those who used resistance training.

Combined Aerobic and Resistance Exercise

There are limited studies, focused mainly in elderly people,[89-95] which have investigated the probable effect of combined exercise on lipids and lipoproteins. Table 4 shows a remarkable improvement in the LDL-C levels in 3[90,94,95] of 8 trials including men and women, which ranged from 4% to 34%. The values of HDL-C showed significant increase (from 3.5% to 23%) in 3[90,91,94] studies involving both sexes. Regarding TC and TG, significant decreased levels were found only in 2 trials involving middle-aged[90] and elderly[94] individuals. Finally, we must mention that studies of LeMura et al[79] and Boardley et al,[89] which examined aerobic, resistance, and combined exercise in their intervention, did not find significant alterations on the lipid profile in relation to the control group.

Discussion

Table 1 shows that, when endurance exercise training is performed with moderate intensity, there is no favorable influence on the lipid profile independently of the total volume of exercise. Analytically, regarding TG, TC, and LDL-C, only a small percentage (about 7%-10%) of trials report significant reductions. The results for HDL-C values are more hopeful (21% of trials), although most trials indicate small improvements ranging from 3.5% to 10%. The only meta-analysis (in 1999)[102] that compared the influence of different intensities aerobic exercise training reports that programs at intensities lower than 70% $VO_{2\ max}$ modified the TG and HDL-C levels, whereas in our review, intensity is considered moderate when the $VO_{2\ max}$ is lower than 60%. Large observational studies[103] in 537 men aged 20 to 60 years and in 2492 men aged 42 to 60 years[104] show that it needs an intensity threshold greater than 7 kcal/min[103] or 6 metabolic equivalent (MET)[104] to produce beneficial effects of physical activity on serum lipids, intensities according to the latest ACSM classification for healthy adults include hard intensity[Is the edit ok?].

In contrast, the high-intensity aerobic exercise (Table 2) provides stronger indications for improvement in HDL-C levels, a protective factor against CHD,[5] but changes in TG, TC, and LDL-C levels were observed less frequently. Our results for HDL-C are in accordance with the latest meta-analyses for healthy men and women,[11,105,106] whereas significant observational studies[103,104,107,108] report that physical activity with increased intensity was associated positively with HDL-C values. From the trials that we reviewed, it could be concluded that adult men and women, independent of age

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(young or old), respond almost in the same way to aerobic training in relation to HDL-C changes. On the basis of restricted data from trials[13,28,30,32,33,36,42,43,46,47,52,53,55,57,63,64] that have been performed on participants with abnormal lipid profile, it shows that the initial lipid values notably influence the lipid alterations. A noteworthy number of studies (n = 12) directly examined the response of blood lipids related to different intensities (moderate and high) of the endurance exercise program with conflicting results. Half of them did not show significant alterations in any group,[21,26,28,30,35,39] whereas 4 trials[13,23,32,37] reported significant changes only for participants in the high-intensity group, and another 2 trials[33,38] foundfavorable effects in both groups. Is the response of blood lipids dependent on the weekly volume of energy expenditure? In our review, we noted that for moderate intensity aerobic training, significant alterations on lipids were seen only when the weekly volume is over 150 minutes per week, whereas the high-intensity changes were observed in an extensive range of weekly volume ranging from 90 to over 200 minutes per week. Trials[14,25] that used moderate intensity but different weekly volume (moderate and high) did not show significant results for both groups, whereas Kraus et al[36] who examined groups with the same high intensity but different volumes of exercise showed a significant decrease in TG for both and an additional increase in HDL-C only for those who had exercised more. Finally, Duncan et al[38] compared moderate and high intensity in 4 groups with low and high volume, respectively, and did not result in significant alterations in lipids for all groups.

The positive effect of resistance exercise on lipids and lipoproteins appears (Table 3) as a trend primarily for LDL-C because a number of studies[66-68,74,77,81,85,87] report significant reductions for both genders and secondarily for TC[66,74,77,81,85,87] but only for women. Significant epidemiological studies (eg, Kohl et al[109]) analyzed the association between muscular strength and serum lipid-lipoprotein levels in 1193 women and 5460 men and did not find a relationship between muscular strength and serum total or LDL-C in both sexes, whereas they reported a direct association between the upper and lower body strength and the TG levels in men, and an inverse association between muscular strength and HDL-C. In contrast, Tucker and Silvester[110] examined 8499 men and observed a decreased risk of hypercholesterolemia among participants using the strength training. Although the results of the relation between resistance training and serum lipid and lipoprotein levels are inconsistent,[111] Halbert et al[11] in their meta-analysis and Szarapy et al[112] in a recent review suggest that this type of physical activity may reduce LDL-C. To compare the influence of aerobic and resistance exercise on lipidemic profile, 8 trials included both types of training in their intervention with conflicting results. The failure of our review to classify significant differences between exercise programs is almost certainly because of the heterogeneity of the exercise programs.

Although the combined exercise is proposed as effective in eliciting improvements in cardiovascular and functional fitness for older adults[113] as for preventing and confronting against diabetes mellitus,[114] to the best of our knowledge, studies that examined its influence on lipid status are restricted. Based on the results of our review (8 trials), it seems that there is a trend for significant improvements primarily in LDL-C and HDL-C. Observations for LDL-C are in accordance with recently incorporated results excluding from an epidemiological study of our laboratory (under publishing) affecting young and middle-aged men and women. Asikainen et al[115] in their review based on limited evidence concluded that, this type of exercise might improve dyslipidemia in early postmenopausal women.

Limitations

According to our literature search, this is the first review that compares aerobic exercise with different intensities based on the ACSM criteria and also includes all types of exercise training. Although our conclusions are useful, there are several limitations when interpreting these findings. For example, we include trials with and without control groups, whereas other methodological differences including lipid levels, exercise protocols, and sample size may confound the conclusions. Furthermore, the heterogeneity between changes in blood lipids, differences in initial levels of lipids, cigarette smoking, and alcohol consumption may considerably influence the final results.

Conclusions

In conclusion, aerobic exercise training when performed with high intensity increases the HDL-C levels in adults independently of sex and age. In

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addition, there is noteworthy evidence that resistance and combined exercise mainly lowers LDL-C levels.

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