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REVIEW ARTICLE

THE EFFECT OF AEROBIC AND RESISTANCE EXERCISE ON MARKERS OF ATHEROSCLEROSIS. A NARRATIVE REVIEW OF META-ANALYSES AND SYSTEMATIC REVIEW

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Abstract

Background: Atherosclerosis, a chronic inflammatory vascular disease with lipid metabolism abnormalities, serves as a major pathological foundation for ischemic coronary heart disease (CHD). As lifestyle-related habits transform to sedentarism and unhealthy eating, the incidence of atherosclerosis increases. The beneficial impact of physical activity on the cardiovascular system is well-documented and widely acknowledged. Major health organisations strongly recommend regular participation in aerobic exercise for individuals to reduce all-cause and cardiovascular disease mortality and morbidity, whereas resistance exercise is suggested with caution.

Method and Material: A literature search of the PubMed and Scopus databases was performed where 9 meta-analyses were retrieved, published in the English language from the past 10 years. This narrative review aims to evaluate the latest scientific evidence regarding the role of aerobic and/or resistance exercise in relation to atherosclerosis development, through the evaluation of its effect on lipids, and inflammatory markers.

Results: The findings of the studies summarised here are inconsistent concerning which type of exercise exerts the maximum effect on atherosclerotic biomarkers. There is a moderate level of evidence suggesting that a combination of aerobic and resistance exercise is likely to provide the greatest benefit.

Conclusions: Nevertheless, minimising sedentary behaviour on a population level, lowers the risk of several major chronic diseases, thereby decreasing healthcare costs. Thus, effective interventions to increase physical activity levels or reduce sedentary behaviour should be implemented.

Keywords: Exercise, aerobic exercise, resistance exercise, atherosclerosis, biomarkers.

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INTRODUCTION

Cardiovascular diseases (CVDs) are the leading cause of mortality worldwide. According to WHO, CVDs are responsible for an estimated 17.9 million deaths in 2019, representing 32% of all global deaths. Within Europe, cardiovascular diseases are also the leading cause of mortality representing 50% of all deaths.[1] Furthermore, in Europe, physical inactivity affects an estimated one out of three adults and is more common in high-income countries compared with middle-income countries.[2] The beneficial impact of physical activity on the cardiovascular system has been long proven.[3] Exercise has consistently been shown to improve cardiovascular health through mechanisms that include lowering blood pressure, reduction of body weight, increased insulin sensitivity, and a more favourable plasma lipoprotein profile.[2] This consolidating evidence has been summarised in several systematic reviews and meta-analyses. Although there are many randomised controlled exercise trials on cardiovascular health, exercise is known to improve the biomarkers of cardiovascular disease, the question remains whether which type (aerobic or resistance training) is superior for the treatment of atherosclerosis-related CVD. Thus, the aim of this narrative review of meta-analyses was to present a summary of the latest scientific evidence regarding the effect of aerobic and/or resistance exercise on atherogenic biomarkers, and specifically, lipid, lipoproteins, inflammatory markers and indices of atherogenesis.

METHODOLOGY

Literature search

This is a narrative review; however, the basic principles of systematic reviews, according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement, were followed.[4] Meta-analyses were identified by systematic online searches of MEDLINE (through PubMed), Scopus and Google Scholar databases, until June 30, 2024. The search terms were combined using Boolean operators "AND", "OR" and "NOT" to make the search specific. The following keywords, according to Medical Subject Headings (MeSH), were used to conduct the search: "Aerobic Exercise", "Exercise", "Endurance Training", "Aerobic Training", "Resistance Training", "Strength Training", "High-Intensity Interval Training", "Weightlifting", "Lipids", "Cholesterol", "Triglycerides", "Lipoproteins", "CRP", "Carotid Intima Media Thickness", "Inflammatory Response", "Atherosclerosis", "Arteriosclerosis", "Vascular diseases", "Cardiovascular Disease". A hierarchical approach, i.e., screening the title, reading the abstract followed by the full-text manuscript, was used to search for studies. The searches were focussed on the last 10 years.

After further examination, deletion of irrelevant articles and duplicates, 9 meta-analyses evaluating the role of different types of physical activity (aerobic, resistance) on atherosclerosis development, were retrieved, and discussed here.

RESULTS

The beneficial effects of exercise on cardiovascular health, together with the adverse effects of sedentary behaviour have been extensively reported in the literature within the past 20 years. For example, in a relatively recent, large-scale meta-analysis with a total of 148 randomised clinical trials and 36 prospective cohort studies, it was reported that long-term sedentary behaviour increases the risk of CVD by 34% in healthy adults, whereas long-term physical activity reduces the risk of CVD by 29% together with mildly improving indicators associated with CVD.[5] In line with the previous study, a more recent umbrella review including 23 meta-analyses found that higher physical activity levels, regardless of type, intensity and units of measurement, was associated with a lower risk of CVD ranging from 1% - 56%.[6] However, despite the extensive evidence regarding the impact of physical activity on CVD prevention, and atherogenic indicator enhancement, there are few epidemiological studies, randomised controlled trials (RCT), and consequently meta-analyses that have appraised the influence of the type of exercise, i.e., aerobic or resistance exercise, on atherogenic markers and cardiovascular health.

One of the older reviews that evaluated the type of exercise on cardiovascular health was published in 2009 by Tambalis et al.[7] In this work the effect of the type of exercise, i.e., aerobic, resistance, or combined aerobic with resistance, as well as different intensities of aerobic training (moderate and high) in altering blood lipids levels were evaluated. A total of 84 studies were selected, 58 of which were RCTs that involved over 12 weeks of aerobic and/or resistance and/or combined exercise training in healthy adults. In total, 6300 participants from the general population were studied. The meta-analysis demonstrated that high intensity aerobic training resulted in improvement in HDL-cholesterol, whereas for resistance and combined exercise the results were inconsistent. The heterogeneity between the types of exercise did not allow reliable comparisons as the authors concluded.

Almost 10 years following the previous review, Wewege et al.[8] examined the influence of aerobic, resistance and combined (aerobic and resistance) training on cardiovascular risk factors in 588 patients with Metabolic Syndrome. Randomised controlled trials > 4 weeks in duration were included, and intervention of exercise to the non-exercise controls were compared in Metabolic Syndrome without diabetes. Metabolic Syndrome criteria, cardiorespiratory fitness and cardiovascular risk factors [elevated fasting blood glucose, low high-density lipoprotein (HDL-C), high triglyceride (TG) levels, high blood pressure and increased waist circumference] were meta-analysed in a random effects model. It was concluded by 11 studies that engagement in aerobic exercise following current guidelines significantly improved HDL-cholesterol (mean difference = +0.90 mg/dL; 95% confidence interval [CI] [0.18- 1.44], p = 0.02) and triglycerides (mean difference = -5.23 mg/dL; 95%CI [-7.74, -2.52], p < 0.01) , while no significant effects were determined following resistance and combined exercise, possibly due to limited data. Sub-analyses suggested that when aerobic exercise was conducted 3 days/week for ≥ 12 weeks and progressed to vigorous intensity, it offered larger and more widespread improvements.

In a systematic review and meta-analysis of 26 studies, Wang et al. investigated the effectiveness of aerobic and resistance exercise in carotid intima–media thickness (cIMT) of 1370 participants.[9] The duration of the interventions ranged from 2 to 12 months, but lasted ≤ 6 months for the majority of studies. The effect of aerobic exercise was reported in 9 of the 32 study groups. Data analysis showed a decline in cIMT (mean difference = -0.02 mm; 95%CI [-0.03, -0.01], p < 0.01) in those who engaged in exercise, compared with control participants, while aerobic exercise (mean difference = -0.02 mm; 95%CI [-0.04, -0.01], p = 0.03) is associated with a greater decline in cIMT than resistance exercise (mean difference = -0.01 mm; 95%CI [-0.02, -0.00], p = 0.16). An exercise duration greater than 6 months was associated with a 0.02mm reduction in cIMT. However, in participants with low cIMT at baseline (< 0.7 mm), exercise alone was not associated with a change in cIMT (mean difference = -0.01 mm; 95%CI [-0.03, -0.00], p = 0.12).

A meta-analysis of randomized controlled trials conducted by Buzdagli et al.,[10] aimed to examine which type of exercise is best for improving blood lipid profile. High density lipoprotein (HDL-cholesterol), low density lipoprotein (LDL-cholesterol), total cholesterol (TC) and triglycerides (TG) were the lipid biomarkers measured and examined. In the 18 studies evaluated, with a total of 562 participants, and duration varying from 8 to 16 months, results showed that the high-intensity intermittent training (HIIT) was the most effective type of exercise compared with aerobic and resistance training. In particular, aerobic exercise significantly decreased total cholesterol (mean difference = -14.06 mg/dL; 95%CI [-27.33, -0.80], p = 0.04) and triglycerides (mean difference = -13.82 mg/dL; 95%CI [-34.38, -13.27], p < 0.01), HIIT decreased LDL-cholesterol (mean difference = -16.91 mg/dL; 95%CI [-32.34, -1.49], p = 0.03), total cholesterol (mean difference = -15.13 mg/dL; 95%CI [-29.57, -0.68], p = 0.04), and triglycerides (mean difference = -32.47 mg/dL; 95%CI [-37.05, -27.89], p < 0.01) and resistance exercise significantly decreased triglycerides (mean difference = -29.07 mg/dL; 95%CI [-49.05, -9.09], p = 0.03). Combined exercise had no significant effect on lipid markers. Neither type of exercise showed a significant effect on HDL-cholesterol.

A meta-analysis conducted by Makarewicz et al.,[11] compared the effects of endurance, strength, and combined training on inflammatory markers and adipokines in 1145 overweight and obese adults. The duration of the interventions ranged from 8 to 26 weeks and 24 randomised control trials were included. The inflammatory parameters accessed were C-reactive protein (CRP), interleukin 6 (IL-6) and tumour necrosis factor-alpha (TNF-α) levels and the adipokines levels evaluated were leptin, adiponectin and visfatin. The findings indicate that endurance training, compared to strength training, are more effective in lowering CRP (mean difference = -1.32 mg/L; 95%CI [-2.56, -0.07], p = 0.04), IL-6 (mean difference = -0.36 pg/mL; 95%CI [-0.65, -0.08], p = 0.01), and visfatin (mean difference = -0.62 ng/mL; 95%CI [-1.01, -0.22], p < 0.01) concentrations, while combined training was more beneficial in reducing TNF-α levels (mean difference = -0.89 pg/mL; 95%CI [-1.48, -0.30], p < 0.01) in overweight and obese adults.

A meta-analysis by Cheng et al.,[12] investigated the effect of exercise training on arterial stiffness in children. In total, 26 studies with 661 overweight or obese participants younger than 18 years of age were included in the meta-analysis. An exercise training program for at least 8 weeks in duration was implemented and flow-mediated dilatation (FMD), pulse wave velocity (PWV), and intima-media thickness (IMT) were evaluated. Results demonstrated that all types of training significantly improved FMD [aerobic exercise (mean difference = +1.04, 95%CI [0.44, 1.64], p < 0.05); high-intensity intermittent training (HIIT) (mean difference = +0,92, 95%CI [0,25, 1.58], p < 0.05); combined training (mean difference = +0,36, 95%CI [0.73, 1.45], p < 0.05)]. Aerobic exercise (mean difference = -0.23 m/s; 95%CI [-0.44, -0,03], p < 0.05) and HIIT (mean difference = -0.76 m/s; 95%CI [-1,31, -0,22], p < 0.05) reduced the PWV of the participants, and were more effective than resistance training (mean difference = -0.08 m/s; 95%CI [-0.46, 0,30], p > 0.05) and aerobic plus resistance training (mean difference = 0.02 m/s; 95%CI [-0.25, 0.29], p > 0.05). Only HIIT significantly reduced the IMT (mean difference = -1.32 mm; 95%CI [-1.91, -0.74], p < 0.05). Exercise training improved vascular endothelial function and vascular sclerosis in overweight and obese children, while aerobic exercise had a more favorable effect on arterial stiffness.

In a more recent meta-analysis aiming to determine the effects of aerobic exercise on lipids and apolipoproteins levels, 57 randomized controlled trials with 3194 participants were analyzed, with intervention duration ≥ 12 weeks of at least moderate intensity (>40% maximum oxygen consumption), and reporting pre/post measurements. The markers and ratios accessed were apolipoproteins (Apo-A1, Apo-A2, Apo-B100), high-density lipoproteins (HDL2, HDL3), very low-density lipoprotein-cholesterol (VLDL), total cholesterol (TC)/HDL-C, low-density lipoprotein-cholesterol (LDL-C)/HDL-C, Apo-B100/Apo-A1, HDL-C/TC, HDL-C/LDL-C and Apo-A1/Apo-B100. It was observed that aerobic exercise intervention significantly raised antiatherogenic (mean difference= + 0.05 mmol/L; 95%CI [0.01, 0.08], p = 0.01) and lowered atherogenic (mean difference = -0.08 mmol/L; 95%CI [-0.16, 0.00], p = 0.05) apolipoproteins and lipoprotein subfractions, and positively impacts atherogenic lipid ratios (mean difference = -0.20; 95%CI [-0.29, -0.11], p < 0.01). No associations were observed regarding resistance exercise.[13]

Another meta-analysis included RCT that compared exercise to a non-exercise intervention in patients with carotid atherosclerosis. The meta-analysis was composed of 34 RCTs, 20 on aerobic exercise, 6 on high-intensity interval exercise and 6 on aerobic exercise combined with resistance exercise, comprising 2420 participants in total. Changes in carotid intima–media thickness (cIMT), total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), and high-density lipoprotein-cholesterol (HDL-C) biomarkers were evaluated as outcomes. Results showed that cIMT decreased significantly. The main analyses featuring all types of exercise, showed pronounced differences on cIMT (mean difference = -0.06mm; 95%CI [-0.09, -0.04], p < 0.01), TC (mean difference = -7.39mg/dL; 95%CI [-10.45, -4.14], p < 0.01), LDL-C (mean difference = -5.58 mg/dL; 95%CI [-7.75, -3.60], p < 0.01) and HDL-C (mean difference = +1.98 mg/dL; 95%CI [0.72, 3.42], p < 0.01), which significantly reduced the risk factors of carotid atherosclerosis disease. The result of the subgroup analysis based on different exercise modes showed that aerobic exercise improved significantly cIMT (mean difference = -0.08 mm; 95%CI [-0.12, -0.05], p < 0.01), LDL-C (mean difference = -6.13 mg/dL; 95%CI [-9.00, -3.24], p < 0.01) and HDL-C (mean difference = +2.88 mg/dL; 95%CI [0.90, 4.86], p < 0.01), while high-intensity intermittent training significantly decreased cIMT (mean difference = -0.06 mm; 95%CI [-0.09, -0.02], p < 0.01) and LDL-C (mean difference = -8.47 mg/dL; 95%CI [-13.33, -3.78], p < 0.01). A significant effect was observed on HDL-C by aerobic exercise combined with resistance exercise (mean difference = +4.14 mg/dL; 95%CI [1.44, 6.85], p < 0.01).[14]

In their meta-analysis Khalafi M et al.[15], examined the influence of different modes of exercise training on inflammatory markers in older adults with and without chronic diseases. The analysis was composed of 40 studies within the duration of ≥ 12 weeks, involving 1898 older adults ≥ 65 years. Inflammatory markers including IL-6, TNF-α, and CRP were evaluated. The results highlighted that exercise training, regardless of exercise type, has small to moderate beneficial effects on markers of inflammation in older adults, particularly in those with chronic diseases. Overall, exercise reduced significantly IL-6 (mean difference = -0.17 pg/mL; 95%CI [-0.32, -0.02], p = 0.02), TNF-α (mean difference = -0.30 pg/mL; 95%CI [-0.46, -0.13), p < 0.01), and CRP (mean difference = -0.45 mg/L; 95%CI [-0.61, -0.29], p < 0.01) whereas combined training reduced significantly IL-6 (mean difference = -0.26 pg/mL; 95%CI [-0.52, -0.005], p = 0.04), aerobic training reduced TNF-α (mean difference = -0.44 pg/mL; 95%CI [-0.77, -0.11], p < 0.01), and aerobic (mean difference = -0.46 mg/L; 95%CI [-0.91, -0.01], p = 0.04), resistance (mean difference = -0.46 mg/L; 95%CI [-0.67, -0.25], p < 0.01), and combined training (mean difference = -0.38 mg/L; 95%CI [-0.59, -0.17], p < 0.01) reduced CRP. In addition, exercise training reduced IL-6 and TNF-α in older adults with chronic diseases, and CRP in older adults with and without chronic diseases.

The main characteristics regarding the design, and the major findings of the reviewed meta-analyses are summarised in Table 1.

DISCUSSION

It has been well documented in numerous studies that physical activity in general has a beneficial impact on the cardiovascular system through various mechanisms. The aim of this narrative review was to evaluate a selection of the most recent scientific evidence on the effect of exercise type, i.e., aerobic or resistance, on atherosclerosis markers. The latest evidence manifests great inconsistency of results, therefore no conclusion can be drawn as to which type of exercise, aerobic or anaerobic exercise, is superior in improving atherosclerotic markers. We can only rely on the previous assumption that exercise, regardless of type, helps to improve several indicators.

The latest 2021 guidelines of the European Society of Cardiology (ESC), vigorously endorses that all adults regularly engage in physical activity. This recommendation is supported by extensive evidence showing that there is an inverse relationship between the last and all-cause mortality and cardiovascular morbidity and mortality. Specifically, it is strongly recommended (Class I, Level A) for adults to perform at least 150 - 300 min a week of moderate- intensity or 75 - 150 min a week of vigorous-intensity aerobic physical activity, or an equivalent combination of both, spread throughout the week. Additional benefits are gained with even more physical activity. Individuals unable to meet the minimum physical activity, because of older age or chronic conditions, should be as active as their abilities and conditions allow. In sedentary individuals, gradually increasing activity levels and reducing sedentary time throughout the day is highly recommended. Performing resistance exercise together with aerobic exercise, is associated with lower risks of total cardiovascular events and all-cause mortality (Class I, Level B). The suggested prescription is one to three sets of 8-12 repetitions, at the intensity of 60-80% of the individual's maximal strength (1 repetition maximum), at a frequency of at least 2 days a week, in a variety of 8-10 different exercises involving each major muscle group. For older adults or deconditioned individuals, it is suggested to start with one set of 10-15 repetitions at 40-50% of their maximum strength. In addition, older adults are recommended to perform multicomponent physical activity that combines aerobic, muscle-strengthening, and balance exercises to prevent falls.[16]

The impact of aerobic exercise on the cardiovascular system has been thoroughly researched. The evidence strongly suggests that aerobic exercise according to the guidelines improves the blood lipid profile by reducing total cholesterol, low-density lipoprotein cholesterol, as well as triglycerides, and increasing high-density lipoprotein levels. However, underlying mechanisms by which exercise exerts its effects on blood lipids have not been fully delineated.[17-19] Cardiorespiratory fitness is a strong predictor of all-cause and/or CVD mortality in patients with established CVD. Low cardiorespiratory fitness is an independent risk factor for CVD and all-cause mortality.[20,21] The greatest benefit of aerobic exercise training can be attributed to improvements in cardiorespiratory fitness. Within at-risk populations, such as overweight, obese and older adults, aerobic exercise training typically increases cardiorespiratory fitness in a clinically meaningful magnitude. Aerobic exercise also reduce arterial stiffness, measured by pulse wave velocity in at-risk populations, and arterial blood pressure in people with hypertension.[18,22,23,24] Additionally, long-term aerobic exercise training typically leads to modest weight loss. While it doesn't significantly reduce overall body weight, it leads to significant reduction of harmful visceral and hepatic fat, which are strongly associated with a higher risk of cardiovascular disease.[18] Aerobic exercise, when combined with a balanced diet, consistently proves effective for controlling body weight and reducing fat accumulation. Therefore, following a healthy diet should always be recommended along with regular exercise.[17,23]

There are relatively few studies that have shown benefits of engagement in resistance exercise for the reduction of surrogate risk markers for CVD. Muscle-strengthening activities including either the use of weight machines or one's own body weight, such as resistance/ weight/ strength training, may affect incidence and mortality from CVD via various biomarkers and mechanisms.[25] Various biological mechanisms could explain the inverse association between muscle-strengthening activities and CVD. Randomised controlled trials indicate that resistance training can reduce CVD by decreasing body fat, particularly visceral fat, which improves glucose control, metabolic function, and reduces inflammation. Additionally, resistance exercise leads to elevated resting metabolic rate (RMR) by increasing lean body mass, therefore enhancing energy expenditure. Consequently, these physiological changes aid in weight management and diminish the risk of obesity, a significant risk factor for CVD.[25] Furthermore, patients with cardiovascular disease often have complex causes for lean mass abnormalities, which are exacerbated by physical inactivity. The resulting muscle loss (sarcopenia) further accelerates the progression of CVD, creating a vicious cycle between muscle loss and heart disease. Incorporating resistance exercise can help improve muscle health and potentially break this cycle.[26] Exercise training alone exerts clinically relevant reductions in blood pressure, by improving blood vessel function and reducing arterial stiffness. However, the addition of diet and weight loss may further reduce blood pressure and CVD risk.[18,24] Clinical trials have demonstrated that participation in resistance exercise improves the lipid profile by increasing HDL-cholesterol levels and reducing LDL-cholesterol and triglycerides. Resistance training has also been shown to enhance insulin sensitivity, thereby enabling cells to respond more effectively to insulin and regulate blood glucose levels. Additionally, it decreases levels of inflammatory markers, which are strongly associated with the development and progression of atherosclerotic cardiovascular disease.[17,27] Nevertheless, high-intensity resistance training may have some adverse effects, such as increased arterial stiffness and cardiac hypertrophy. Additionally, high-level resistance training can cause a significant rise in blood pressure, which could be harmful for individuals with uncontrolled hypertension. The current evidence supports the use of moderate-level resistance exercise complementary to the recommended levels of aerobic moderate-to-vigorous physical activity (MVPA) for maximal benefit.[25]

In conclusion, engagement in regular exercise is strongly recommended by the recent guidelines of ESC and other scientific organisations for adults of all ages, as exercise lowers risks of total CV events and all-cause mortality. The guidelines of ESC recommend that physical activity should be individually assessed and prescribed in terms of frequency, intensity, duration, type (aerobic and/or resistance), and progression. Specific training plans typically begin with moderate aerobic training, followed by resistance training at increasing intensity. Implementation of effective approaches, including behavioural theory-based interventions, such as goal-setting, re-evaluation of goals, self-monitoring, and feedback and other supportive means such as using a wearable activity tracker, could be leveraged to reassure the achievement and retention of the recommendations. Encouraging activities that people find enjoyable or can easily fit into their daily routines is crucial, as these activities are more likely to be maintained over time. However, exercise alone is not enough to effectively reduce the biomarkers of atherosclerosis and CVD risk. Clinicians should provide a personalised presentation of guidelines to improve understanding and encourage lifestyle changes. Motivation improvement, reduction of sedentary behaviour and moderation of alcohol consumption should also be encouraged along with exercise. Moreover, a healthy diet is recommended as a cornerstone of CVD prevention in all individuals and its efficiency should not be underestimated.

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REFERENCES

1. Cardiovascular diseases (CVDs) [Internet]. [cited 2024 Mar 22]. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)
2. Timmis A, Vardas P, Townsend N, Torbica A, Katus H, De Smedt D, et al. European Society of Cardiology: cardiovascular disease statistics 2021. Eur Heart J [Internet]. 2022 Feb 21 [cited 2024 Mar 22];43(8):716–99. Available from: https://doi.org/10.1093/eurheartj/ehab892
3. DHULI K, NAUREEN Z, MEDORI MC, FIORETTI F, CARUSO P, PERRONE MA, et al. Physical activity for health. J Prev Med Hyg [Internet]. 2022 Oct 17 [cited 2024 May 19];63(2 Suppl 3):E150–9. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9710390/
4. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ [Internet]. 2021 Mar 29 [cited 2024 May 22];372:n71. Available from: https://www.bmj.com/content/372/bmj.n71
5. Liang Z de, Zhang M, Wang C zhi, Yuan Y, Liang J hong. Association between sedentary behavior, physical activity, and cardiovascular disease-related outcomes in adults—A meta-analysis and systematic review. Front Public Health [Internet]. 2022 Oct 19 [cited 2024 May 19];10:1018460. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9632849/
6. Gower B, Blacket C, Girard D, Boyle T, Davison K. Prospective associations between systolic blood pressure, serum cholesterol, and physical activity behaviour and the development of cardiovascular disease. Prev Med [Internet]. 2024 Jun 1 [cited 2024 May 21];183:107958. Available from: https://www.sciencedirect.com/science/article/pii/S0091743524001130
7. Tambalis K, Panagiotakos DB, Kavouras SA, Sidossis LS. Responses of Blood Lipids to Aerobic, Resistance, and Combined Aerobic with Resistance Exercise Training: A Systematic Review of Current Evidence. Angiology [Internet]. 2009 Nov [cited 2024 May 29];60(5):614–32. Available from: http://journals.sagepub.com/doi/10.1177/0003319708324927
8. Wewege MA, Thom JM, Rye KA, Parmenter BJ. Aerobic, resistance or combined training: A systematic review and meta-analysis of exercise to reduce cardiovascular risk in adults with metabolic syndrome. Atherosclerosis. 2018 Jul;274:162–71.
9. Wang Y, Wu H, Sun J, Wei M, Wang J, Li H, et al. Effect of Exercise on Carotid Artery Intima–Media Thickness in Adults: A Systematic Review and Meta-Analysis. J Phys Act Health [Internet]. 2022 Oct 18 [cited 2024 Mar 30];19(12):855–67. Available from: https://journals.humankinetics.com/view/journals/jpah/19/12/article-p855.xml
10. Buzdagli Y, Tekin A, Eyipinar CD, Öget F, Siktar E. The effect of different types of exercise on blood lipid profiles: A meta-analysis of randomized controlled studies. Sci Sports [Internet]. 2022 Dec 1 [cited 2024 May 29];37(8):675–87. Available from: https://www.sciencedirect.com/science/article/pii/S0765159722001861
11. Makarewicz A, Jamka M, Geltz J, Śmidowicz A, Kokot M, Kaczmarek N, et al. Comparison of the Effect of Endurance, Strength, and Endurance-Strength Training on Inflammatory Markers and Adipokines Levels in Overweight and Obese Adults: Systematic Review and Meta-Analysis of Randomised Trials. Healthcare [Internet]. 2022 Jun 13 [cited 2024 Jul 7];10(6):1098. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9222976/
12. Cheng Y, Sun Z, Ya X, Zhou L, Wang M, Wang X, et al. Effect of exercise training on arterial stiffness in obese and overweight children: a meta-analysis. Eur J Pediatr [Internet]. 2022 Jul 1 [cited 2024 Jul 7];181(7):2633–42. Available from: https://doi.org/10.1007/s00431-022-04489-6
13. Wood G, Taylor E, Ng V, Murrell A, Patil A, van der Touw T, et al. Estimating the Effect of Aerobic Exercise Training on

Novel Lipid Biomarkers: A Systematic Review and Multivariate Meta-Analysis of Randomized Controlled Trials. Sports Med Auckl Nz [Internet]. 2023 [cited 2024 May 19];53(4):871–86. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10036419/

14. Gao P, Zhang X, Yin S, Tuo H, Lin Q, Tang F, et al. Meta-Analysis of the Effect of Different Exercise Mode on Carotid Atherosclerosis. Int J Environ Res Public Health [Internet]. 2023 Jan 25 [cited 2024 Mar 30];20(3):2189. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9914982/
15. Khalafi M, Akbari A, Symonds ME, Pourvaghar MJ, Rosenkranz SK, Tabari E. Influence of different modes of exercise training on inflammatory markers in older adults with and without chronic diseases: A systematic review and meta-analysis. Cytokine. 2023 Sep;169:156303.
16. Visseren FLJ, Mach F, Smulders YM, Carballo D, Koskinas KC, Bäck M, et al. 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice: Developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies With the special contribution of the European Association of Preventive Cardiology (EAPC). Eur Heart J [Internet]. 2021 Sep 7 [cited 2024 Mar 22];42(34):3227–337. Available from: https://doi.org/10.1093/eurheartj/ehab484
17. Enkhmaa B, Surampudi P, Anuurad E, Berglund L. Lifestyle Changes: Effect of Diet, Exercise, Functional Food, and Obesity Treatment on Lipids and Lipoproteins. In: Feingold KR, Anawalt B, Blackman MR, Boyce A, Chrousos G, Corpas E, et al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2000 [cited 2024 Jul 13]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK326737/
18. Tucker WJ, Fegers-Wustrow I, Halle M, Haykowsky MJ, Chung EH, Kovacic JC. Exercise for Primary and Secondary Prevention of Cardiovascular Disease: JACC Focus Seminar 1/4. J Am Coll Cardiol [Internet]. 2022 Sep 13 [cited 2024 Mar 30];80(11):1091–106. Available from: https://www.sciencedirect.com/science/article/pii/S0735109722055401
19. Wang Y, Xu D. Effects of aerobic exercise on lipids and lipoproteins. Lipids Health Dis [Internet]. 2017 Jul 5 [cited 2024 Jul 13];16:132. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5498979/
20. Elagizi A, Kachur S, Carbone S, Lavie CJ, Blair SN. A Review of Obesity, Physical Activity, and Cardiovascular Disease. Curr Obes Rep [Internet]. 2020 Dec 1 [cited 2024 Jul 13];9(4):571–81. Available from: https://doi.org/10.1007/s13679-020-00403-z
21. Ezzatvar Y, Izquierdo M, Núñez J, Calatayud J, Ramírez-Vélez R, García-Hermoso A. Cardiorespiratory fitness measured with cardiopulmonary exercise testing and mortality in patients with cardiovascular disease: A systematic review and meta-analysis. J Sport Health Sci [Internet]. 2021 Dec [cited 2024 Jul 12];10(6):609–19. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8724619/
22. Edwards JJ, Deenmamode AHP, Griffiths M, Arnold O, Cooper NJ, Wiles JD, et al. Exercise training and resting blood pressure: a large-scale pairwise and network meta-analysis of randomised controlled trials. Br J Sports Med [Internet]. 2023 Oct 1 [cited 2024 Jul 13];57(20):1317–26. Available from: https://bjsm.bmj.com/content/57/20/1317
23. Oppert J, Bellicha A, van Baak MA, Battista F, Beaulieu K, Blundell JE, et al. Exercise training in the management of overweight and obesity in adults: Synthesis of the evidence and recommendations from the European Association for the Study of Obesity Physical Activity Working Group. Obes Rev [Internet]. 2021 Jul [cited 2024 Jul 13];22(Suppl 4):e13273. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8365734/
24. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA, et al. Exercise and Hypertension. Med Sci Sports Exerc [Internet]. 2004 Mar [cited 2024 Jul 13];36(3):533. Available from: https://journals.lww.com/acsm-msse/fulltext/2004/03000/exercise_and_hypertension.25.aspx
25. Giovannucci EL, Rezende LFM, Lee DH. Muscle-strengthening activities and risk of cardiovascular disease, type 2 diabetes, cancer and mortality: A review of prospective cohort studies. J Intern Med [Internet]. 2021 [cited 2024 Jul 13];290(4):789–805. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/joim.13344

26. Kirkman DL, Lee D chul, Carbone S. Resistance Exercise for Cardiac Rehabilitation. Prog Cardiovasc Dis [Internet]. 2022 [cited 2024 Jul 13];70:66–72. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8930531/
27. Muscella A, Stefàno E, Marsigliante S. The effects of exercise training on lipid metabolism and coronary heart disease. Am J Physiol-Heart Circ Physiol [Internet]. 2020 Jul [cited 2024 Jul 14];319(1):H76–88. Available from: https://journals.physiology.org/doi/full/10.1152/ajpheart.00708.2019

ANNEX

TABLE 1. Summary of design, and meta-analyses findings regarding the effect of exercise type on atherosclerosis markers.

Study	Year	Studies Subjects	Effects	Comments
Wewege et al.	2018	11 studies N=588	**aerobic:** HDL +0.90 (0.18, 1.44) mg/dL, p=0.02 TG -5.23 (-7.74, -2.52) mg/dL, p<0.01 **resistance:** HDL +0.00 (-2.70, 2.70) mg/dL, p=0.97 TG -2.70 (-10.45, 5.04) mg/dL, p=0.69	Engagement in aerobic exercise following current guidelines significantly improved HDL-cholesterol and triglycerides. No significant effects were determined following resistance and combined exercise, possibly due to limited data.
Wang et al.	2022	26 studies N=1370	**aerobic:** cIMT -0.02 (-0.04 ,-0.01)mm, p=0.03 **resistance:** cIMT -0.01 (-0.02, -0.00) mm, p=0.16 **combined:** cIMT -0.02 (-0.03, -0.01) mm, p<0.01	Exercise was associated with reduced cIMT in adults. Aerobic exercise was associated with a greater decline in cIMT than other forms of exercise.
Buzdagli et al.	2022	18 studies N=562	**aerobic:** TC -14.06 (-27.33, -0.80) mg/dL, p=0.04 TG -13.82 (-34.38, -13.27) mg/dL, p<0,01 **HIIT:** LDL -16.91 (-32.34, -1.49) mg/dL, p=0.03 TC -15.13 (-29.57, -0.68) mg/dL, p=0.04 TG -32.47 (-37.05, -27.89) mg/dL, p<0.01 **resistance:** TG -29.07 (-49.05, -9.09) mg/dL, p=0.03 **combined:** -	The high-intensity interval training was the most effective type of exercise by developing more biomarkers. Neither type of exercise showed a significant effect on HDL-cholesterol.
Makarewicz et al.	2022	24 studies N=1145	**aerobic vs resistance:** CRP -1.32 (-2.56, -0.07) mg/L, p=0.04 IL-6 -0.36 (-0.65, -0.08) pg/mL, p=0.01 visfatin -0.62 (-1.01, -0.22) ng/mL, p<0.01 **combined vs resistance:** TNF-α -0.89 (-1.48, -0.30) pg/mL, p<0.01	Endurance training, compared with strength training, was more effective in lowering CRP, IL-6 and visfatin concentrations, while combined training was more beneficial from resistance training in reducing TNF-α levels in overweight and obese adults.
Cheng et al.	2022	26 studies N=661	**aerobic:** FMD +1.04, (0.44, 1.64), p<0.05 PWV -0.23 (-0.44, -0.03) m/s, p<0.05 **resistance: -** **HIIT:** FMD +0,92 (0,25, 1.58], p<0.05 PWV -0.76 (-1.31, -0.22) m/s, p<0.05 IMT -1.32 (-1.91, -0.74) mm, p<0.05 **combined:** FMD +0,36 (0.73, 1.45), p<0.05	Exercise training improved vascular endothelial function and vascular sclerosis in overweight and obese children, while aerobic exercise had a more favourable effect on arterial stiffness.
Wood et al.	2023	57 studies N=3194	**aerobic:** antiatherogenic apolipoproteins and lipoprotein subfractions +0.05 (0.01, 0.08) mmol/L, p=0.01 atherogenic apolipoproteins and lipoprotein subfractions -0.08 (-0.16, 0.00) mmol/L, p=0.05 atherogenic lipid ratios -0.20 (-0.29, -0.11), p<0.01) **resistance: -**	Aerobic exercise intervention significantly raised antiatherogenic and lowered atherogenic apolipoproteins and lipoprotein subfractions, and positively impacts atherogenic lipid ratios. No associations were observed regarding resistance exercise.

Gao et al.	2023	34 studies N=2420	**aerobic:** cIMT -0.08 (-0.12, -0.05) mm, p<0.01 LDL-C -6.13 (-9.00, -3.24) mg/dL, p<0.01 HDL-C +2.88 (0.90, 4.86) mg/dL, p<0.01 **HIIT:** cIMT -0.06 (-0.09, -0.02) mm, p<0.01 LDL-C -8.47 (-13.33, -3.78) mg/dL, p<0.01 **combined:** HDL-C +4.14 (1.44, 6.85) mg/dL, p<0.01	Aerobic exercise and HIIT can improve carotid atherosclerosis. Aerobic exercise has a more comprehensive improvement effect.
Khalafi et al.	2023	40 studies N=1898	**aerobic:** TNF-a -0.44 (-0.77, -0.11) pg/mL, p<0.01 CRP -0.46 (-0.91, -0.01) mg/L, p=0.04 **resistance:** CRP -0.46 (-0.67, -0.25) mg/L, p<0.01 **combined:** IL-6 -0.26 (-0.52, -0.005) pg/mL, p=0.04 CRP -0.38 (-0.59, -0.17) mg/L, p<0.01	Exercise training, regardless of exercise type, has small to moderate beneficial effects on markers of inflammation in older adults.

Abbreviations: HIIT; high-intensity intermittent training, TG; triglycerides, TC; total cholesterol, LDL-C; low density lipoprotein cholesterol, HDL-C; high density lipoprotein cholesterol, TNF-a; tumour necrosis factor-alpha, CRP; C-reactive protein, IL-6; interleukin-6, cIMT; carotid intima media thickness, FMD; flow-mediated dilation, PWV; pulse wave velocity