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Effects of Running on Cardiovascular Health: Benefits, Risks, and Long-Term Adaptations – A Narrative Review

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Abstract

Background: Running is an accessible form of aerobic exercise associated with cardiovascular benefits. However, the long-term effects of high-volume endurance running remain uncertain.

Aim: To summarise evidence on cardiovascular adaptations and benefits of running, dose–response relationships, and potential risks of prolonged, intensive endurance training.

Materials and methods: A narrative review of PubMed/MEDLINE literature from database inception to October 7, 2026, was conducted. Adult studies examining running in relation to cardiovascular adaptations, risk factors, morbidity, mortality, or complications were considered. Only publications with legally accessible full text were included. Evidence was synthesised thematically without meta-analysis.

Results: Running was associated with improved cardiorespiratory fitness and lower all-cause and cardiovascular mortality, with benefits reported even at low running volumes. Aerobic exercise also showed beneficial effects on blood pressure, vascular function, and selected lipid parameters, although some findings were not running-specific. Potential concerns associated with high-volume endurance training included atrial fibrillation, coronary artery

calcification, and transient cardiac biomarker elevations after marathons. Their clinical significance and long-term consequences remain uncertain.

Conclusions: Regular recreational running is associated with substantial cardiovascular benefits and may support cardiovascular disease prevention. High training volumes are not necessary to obtain health benefits, while the long-term effects of extreme endurance running remain less certain. Training should be adapted to individual health status, fitness, and exercise tolerance.

Key words: running; cardiovascular health; cardiorespiratory fitness; cardiovascular mortality; endurance exercise; dose–response relationship; atrial fibrillation; coronary artery calcification.

1. Introduction

Running is a popular and convenient form of leisure-time physical activity, and participation in recreational running has increased over recent decades despite concerns relating to the possible negative effects of strenuous endurance exercise (Lee et al. 2014). More broadly, consistent physical exercise is well established as an important determinant of health and is associated with a lower risk of several chronic diseases and premature mortality. According to the 2022 Special Eurobarometer on Sport and Physical Activity, 55% of European Union citizens reported engaging in sport or exercise, with improving health and physical fitness as one of the main motivations for participation (European Commission 2022; Oja et al. 2024).

Running, as a predominantly aerobic form of exercise, may provide particularly important cardiovascular benefits. Recent systematic evidence indicates that recreational running is associated with lower risks of all-cause, cancer and cardiovascular mortality and may have favourable effects on body composition, cardiovascular function at rest and cardiorespiratory fitness (Oja et al. 2024). The results correspond with evidence from large prospective cohort studies showing substantially lower all-cause and cardiovascular mortality among recreational runners than non-runners (Lee et al. 2014).

Cardiorespiratory fitness (CRF) is an important determinant of cardiovascular health and is strongly associated with long-term prognosis. Extensive evidence accumulated over several decades indicates that low levels of CRF are associated with increased risks of cardiovascular disease and all-cause mortality, as well as mortality from several cancers. Furthermore, improvements in CRF are associated with reduced mortality risk, supporting the benefit of maintaining and improving aerobic fitness as part of cardiovascular disease prevention (Ross et al. 2016). Despite the well-established benefits of physical activity, questions remain regarding the optimal dose of running and whether very high volumes or intensities of endurance exercise may produce cardiovascular effects that differ from those observed with recreational running. Therefore, a balanced assessment of the cardiovascular benefits, physiological adaptations and possible risks related to running is warranted.

2. Aim

This review summarises current evidence regarding the effects of running concerning cardiovascular health, with particular emphasis on cardiovascular adaptations, potential health benefits, the dose–response relationship, and possible cardiovascular risks associated with high-volume and high-intensity endurance running. Additionally, it discusses differences between recreational and competitive running and provides practical considerations for safely incorporating running into cardiovascular disease prevention and health promotion.

3. Research materials and methods

3.1 Literature search

A literature search was conducted in the PubMed/MEDLINE database from database inception to October 7, 2026. The search strategy included combinations of terms linked to running and cardiovascular health, including “running”, “recreational running”, “endurance running”, “jogging”, “marathon”, “cardiovascular health”, “cardiovascular disease”, “cardiovascular mortality”, “cardiorespiratory fitness”, “VO2max”, “blood pressure”, “heart failure”, “stroke”, “atrial fibrillation”, “coronary artery disease”, “coronary artery calcification”, “cardiac remodelling”, and “sudden cardiac death”. Other relevant publications were identified by screening the reference lists of key reviews and primary studies. Only publications with legally accessible full text were considered.

3.2. Eligibility criteria

Studies involving adults were considered eligible if they investigated recreational, competitive, marathon, or ultramarathon running in relation to cardiovascular health, cardiovascular adaptations, cardiovascular risk factors, morbidity, or mortality. Systematic reviews, meta-analyses, prospective cohort studies, intervention studies, and relevant observational and physiological studies were considered. Studies focusing exclusively on other forms of physical activity, predominantly pediatric populations, or outcomes unrelated to cardiovascular health were excluded. Conference abstracts, editorials, letters without relevant original data, and publications without freely accessible full text were also excluded.

3.3. Data synthesis

This study was conducted as a narrative review. The available evidence was synthesised thematically according to cardiovascular adaptations, cardiovascular benefits, the dose–response relationship, possible cardiovascular risks of high-volume endurance running, effects in different populations, and practical consequences. Due to the narrative structure design and methodological heterogeneity of the included studies, no formal meta-analysis was performed. Greater emphasis was placed on systematic reviews, meta-analyses, prospective cohort studies, and relevant intervention studies.

Generative artificial intelligence tools were used to organise the literature search, identify potentially relevant publications, and edit language. All sources and scientific information were independently verified for relevance and accuracy, and the author retained responsibility for the final selection, interpretation, and synthesis of the evidence.

4. Cardiovascular Adaptations to Running

4.1. Central cardiovascular adaptations

Regular endurance exercise induces functional and structural cardiovascular changes that improve the heart's ability to deliver blood and oxygen to exercising tissues. During dynamic aerobic exercise, cardiac output increases through elevations in both heart rate and stroke volume. With endurance training, achieving a high cardiac output becomes increasingly dependent on stroke volume, supported by adaptations in ventricular filling and cardiac structure (Joyner and Casey 2015).

A characteristic adaptation to endurance training is increased stroke volume. Regular endurance exercise promotes greater left ventricular filling and increased end-diastolic volume, which contributes to higher stroke volume through the Frank–Starling mechanism. Increased stroke volume allows the heart to maintain a high cardiac output during exercise without requiring a proportionally greater increase in heart rate (Joyner and Casey 2015; Schmitt et al. 2022).

Endurance training is also associated with physiological cardiac remodelling. Repeated exposure to increased volume loading may enlarge the left ventricular chamber and alter myocardial structure to facilitate ventricular filling and blood ejection during exercise. Such changes are generally accompanied by preserved cardiac function and contribute to the increased circulatory capacity characteristic of endurance-trained individuals (Janik et al. 2025; Schmitt et al. 2022).

Adaptations in circulating blood volume further support central cardiovascular function. Increased blood volume improves venous return and ventricular filling, helping maintain stroke volume during prolonged exercise. Together, increased blood volume, enhanced ventricular filling, and physiological cardiac remodelling allow the cardiovascular system to meet the increased circulatory demands of endurance exercise (Joyner and Casey 2015).

4.2. Peripheral vascular adaptations

The cardiovascular adaptations to endurance exercise go beyond the heart and involve substantial changes within the vascular system. Repeated increases in blood flow and shear stress during exercise provide important stimuli for vascular adaptation. These stimuli can promote functional and structural changes in the arterial wall and improve blood vessels' ability to regulate blood flow to active tissues (Green et al. 2017).

One of the most relevant functional adaptations is improved endothelial function, which can be assessed using flow-mediated dilation (FMD). Regular exercise training may increase endothelium-dependent vasodilation by mechanisms involving increased nitric oxide bioavailability and improved endothelial responsiveness. These

changes may occur even without major improvements in traditional cardiovascular risk factors, suggesting that exercise can directly benefit vascular function (Green et al. 2017).

Endurance exercise may additionally influence arterial structure and compliance. Repeated exposure to enhanced blood flow and pulsatile pressure can induce adaptations in arterial diameter, wall properties, and the distribution of vascular resistance. These changes help regulate blood flow and may improve the vascular system's capacity to meet the haemodynamic demands of exercise (Green et al. 2017).

Peripheral adaptations additionally occur within the skeletal muscle microcirculation. Regular endurance exercise promotes changes in the microvascular network and improves active skeletal muscle's capacity to receive and use oxygen. Enhanced peripheral oxygen extraction complements increased cardiac output and contributes to the improved aerobic exercise capacity associated with endurance training (Joyner and Casey 2015; Green et al. 2017).

4.3. Cardiorespiratory fitness and VO_2max

Cardiorespiratory fitness (CRF), commonly expressed as maximal oxygen uptake (VO_2max), reflects the integrated capacity of the cardiovascular, respiratory, and muscular systems to transport and utilise oxygen. VO_2max is therefore an important indicator of aerobic exercise capacity and is affected by both central and peripheral cardiovascular adaptations. Regular endurance exercise, including running, can improve CRF by increasing maximal cardiac output, elevating oxygen delivery, and increasing peripheral oxygen extraction (Joyner and Casey 2015).

The importance of CRF reaches beyond physical performance. A systematic review of more than 20.9 million observations from 199 unique cohort studies showed that CRF is a strong and consistent predictor of morbidity and mortality in adults. Higher CRF levels were associated with lower risks of all-cause, cardiovascular, and cancer mortality. In contrast, low CRF was associated with an increased risk of developing several chronic conditions, including hypertension, heart failure, stroke, atrial fibrillation, and type 2 diabetes (Lang et al. 2024).

A 1 MET difference in CRF, corresponding to approximately 3.5 mL/kg/min of oxygen consumption, was associated with substantial reductions in the risks of all-cause, cardiovascular, and cancer mortality. Higher CRF was also associated with lower risks of incident hypertension, heart failure, stroke, atrial fibrillation, and type 2 diabetes (Lang et al. 2024). These data indicate that improvements in aerobic fitness may represent an important pathway through which regular running encourages long-term cardiovascular health.

Importantly, the relationship between CRF and health outcomes appears graded rather than limited to individuals reaching a particular fitness threshold. Consequently, even moderate improvements in cardiorespiratory fitness may have clinically relevant implications. For runners, the progressive improvement or maintenance of VO_2max may therefore represent an important marker of the long-term cardiovascular effects of regular endurance training (Lang et al. 2024).

5. Cardiovascular Benefits of Running

5.1. Cardiovascular mortality

Evidence from prospective cohort studies suggests that leisure-time running is associated with a lower risk of cardiovascular mortality. In a large prospective cohort study, runners had a 33% lower risk of cardiovascular mortality than non-runners. The association was even stronger among individuals who reported running both at baseline and at the five-year follow-up, who had a 56% lower risk of cardiovascular mortality compared with those who never ran. Among the leisure-time physical activity categories examined, individuals reporting 15–25 MET-hours per week showed the largest reduction in cardiovascular mortality. However, running was associated with the greatest risk reduction among the high-intensity workouts investigated (Bergwall et al. 2021).

Importantly, the cardiovascular benefits of running may be observed even at relatively low levels of activity. Lee et al. (2014) reported that running for only 5–10 minutes per day was associated with substantial reductions in mortality risk, including cardiovascular mortality, even at volumes below the minimum recommended duration of vigorous-intensity aerobic activity. This evidence indicates that regular running does not necessarily need to involve prolonged or high-volume training to be associated with meaningful health benefits.

Evidence from older populations also supports the benefits of leisure-time physical activity. Zhao et al. (2022) found that achieving 7.5 to less than 15 MET-hours per week of moderate-to-vigorous leisure-time physical activity was associated with a lower mortality risk among older adults. Although the magnitude of the association differed between activity types, all examined activities were associated with lower mortality risk. The results emphasise the potential value of encouraging previously inactive older adults to participate in physical activities they can sustain over time.

The relationship between exercise volume and cardiovascular health, however, may not remain linear indefinitely. A systematic review of prolonged strenuous physical activity found that most available evidence did not indicate cardiovascular harm from high levels of exercise. Nevertheless, some studies suggested that the additional benefits might plateau at higher activity volumes. Evidence supporting a U-shaped relationship, in which very high exercise volumes increase cardiovascular risk, was limited and affected by methodological concerns and possible bias. Overall, the findings support the cardiovascular benefits of physical activity while drawing attention to the necessity of additional research into the long-term effects of very high training loads (Saulicz et al. 2026).

Taken together, the available evidence indicates that running is associated with lower cardiovascular mortality and that benefits may occur even at relatively low volumes. Although greater amounts of physical activity can provide

additional benefits, the magnitude of these benefits may diminish at higher volumes. From a public health perspective, supporting regular, sustainable running and gradual increases in training load may therefore be more important for most individuals than encouraging very high-volume endurance exercise.

5.2. Coronary artery disease

Regular running may play a role in a lower risk of coronary heart disease through improvements in cardiovascular fitness and modifiable risk factors. In a large prospective cohort, leisure-time runners had a lower risk of cardiovascular mortality than non-runners, including lower mortality from coronary heart disease (Lee et al. 2014). Evidence from a meta-analysis of running interventions in physically inactive adults also showed benefits for body mass, body fat, resting heart rate, and cardiorespiratory fitness, which may result in a more favourable cardiovascular risk profile (Hespanhol Junior et al. 2015). However, these outcomes should not be interpreted as direct evidence that running prevents incident myocardial infarction, as the studies assessed different outcomes and included observational results.

5.3. Blood pressure and hypertension

Regular exercise can help prevent and treat hypertension by reducing resting blood pressure. A network meta-analysis of 270 randomised controlled trials involving 15,827 participants found that aerobic exercise reduced systolic blood pressure by an average of 4.49 mmHg and diastolic blood pressure by 2.53 mmHg compared with control conditions. In secondary analyses comparing specific exercise submodes, running ranked highly for reducing diastolic blood pressure (Edwards et al. 2023). These results support using running as a potential component of a non-pharmacological approach to blood pressure management. However, the magnitude of the response may vary by baseline blood pressure, training characteristics, and individual factors. Evidence from running interventions also indicates improvements in cardiac fitness and resting heart rate, which may complement the wider benefits of regular aerobic exercise (Hespanhol Junior et al. 2015).

5.4. Heart failure

Higher levels of physical activity are associated with a lower risk of developing heart failure. A systematic review and dose–response meta-analysis of prospective studies found an inverse association between physical activity and heart failure incidence (Aune et al. 2021). Several mechanisms may contribute to this relationship, including improved body weight control and insulin sensitivity, lower blood pressure, a reduced risk of type 2 diabetes and coronary heart disease, and a lower resting heart rate. The association remained broadly similar in analyses that accounted for factors such as body mass index, diabetes, and hypertension, suggesting it may not be explained solely by differences in adiposity or these accompanying risk factors (Aune et al. 2021). Nevertheless, because the evidence primarily concerns physical activity in general, the magnitude of the association cannot be attributed specifically to running.

5.5. Stroke

Running may also be associated with a lower stroke risk. In a prospective analysis of the National Runners' Health Study, researchers followed 41,395 men and women for 7.7 years. After adjustment for age, smoking and other cardiovascular risk factors, each additional kilometre run per day was associated with an approximately 7% lower risk of incident stroke in the combined population (Williams 2009). Participants running more than 8 km per day had a 60% lower observed risk than those running less than 2 km per day. These data show a dose–response association between running distance and stroke risk, although the observational design does not demonstrate causality. The results also indicate that differences in hypertension, diabetes, hypercholesterolaemia, or body mass index did not fully explain the association.

5.6. Endothelial and vascular function

Regular exercise can influence vascular function through arterial wall adaptations and improved blood flow regulation. Repeated increases in blood flow and shear stress during exercise stimulate vascular responses, including changes in endothelial function and arterial properties (Green et al. 2017). A systematic review and meta-analysis of 42 randomised controlled trials involving 1,627 participants found that aerobic exercise significantly reduced pulse wave velocity (PWV) and augmentation index (AIx), two measures related to arterial stiffness and wave reflection. The reduction in PWV was greater within participants with higher arterial stiffness at baseline, while higher exercise intensity was associated with a larger reduction in AIx (Ashor et al. 2014). These outcomes support the potential vascular benefits of aerobic training. However, because the included interventions were not limited to running, the results should not be interpreted as evidence of a running-specific effect.

5.7. Lipid profile and metabolic risk factors

Running may improve selected lipid and metabolic risk factors associated with cardiovascular disease. A meta-analysis of habitual running interventions in physically inactive adults found statistically significant reductions in triglyceride concentrations and increases in high-density lipoprotein (HDL) cholesterol after one year of training. These effects were also observed in analyses of male participants. In contrast, results for total cholesterol were inconsistent across follow-up periods, and changes in low-density lipoprotein (LDL) cholesterol were not statistically significant (Hespanhol Junior et al. 2015). The analysis shows that running can improve some aspects of the lipid profile, but its effects are not uniform across all lipid parameters. In addition, changes in body composition and cardiorespiratory fitness may improve total metabolic risk. Running should therefore be considered one component of cardiovascular risk reduction rather than a substitute for dietary measures or indicated lipid-lowering treatment.

6. Dose–Response Relationship Between Running and Cardiovascular Health

6.1. Running volume

The cardiovascular benefits of running may depend partly on training frequency, duration, distance, and total weekly volume. However, the relationship between exercise volume and health outcomes is not necessarily linear. Evidence from a large prospective cohort study indicated that running was associated with lower cardiovascular mortality, including among individuals reporting relatively low activity levels (Lee et al. 2014). Similarly, a prospective study examining different leisure-time activities found that running was associated with a substantial reduction in cardiovascular mortality. However, the results were observational and cannot prove causality (Bergwall et al. 2021).

Evidence from broader physical activity research supports the benefits of increasing activity from low levels. In a pooled analysis of 661,137 adults, leisure-time physical activity below the recommended minimum was associated with lower mortality than inactivity. The greatest overall benefit was observed at approximately three to five times the recommended minimum, while additional benefits at higher levels were comparatively modest (Arem et al. 2015). Another large pooled cohort analysis found that mortality risk decreased with increasing moderate-to-vigorous physical activity, although the magnitude of additional benefit diminished at higher activity levels (Moore et al. 2012).

These data suggest that regular running at a manageable volume may provide meaningful health benefits, particularly among previously inactive individuals. However, the evidence does not establish a single optimal weekly running distance or duration for cardiovascular protection. Individual responses likely vary with baseline fitness, age, health status, and training history. Furthermore, findings from studies of general physical activity should not be interpreted as defining a running-specific dose–response relationship.

6.2. Running intensity

Running intensity is another important component of training exposure. Moderate-intensity activity can improve cardiovascular fitness, while vigorous activity may provide substantial health benefits even when performed for relatively short periods. In a pooled analysis of prospective cohorts, vigorous-intensity leisure-time physical activity was associated with lower mortality even at levels below the recommended minimum volume (Arem et al. 2015). This evidence supports the potential value of vigorous activities, including running, but does not establish that vigorous exercise is universally superior to moderate-intensity activity for every cardiovascular outcome.

The relationship between intensity and cardiovascular mortality may also depend on activity type and the population studied. In the Malmö Diet and Cancer cohort, running was among the activities associated with a marked reduction in cardiovascular mortality, although differences between activity types should be interpreted in the context of the observational study design (Bergwall et al. 2021). Regular participation and the ability to sustain a training routine are therefore important considerations alongside intensity.

High-intensity endurance exercise places greater acute demands on the cardiovascular system than lower-intensity activity. Nevertheless, evidence on long-term strenuous exercise does not consistently indicate increased

cardiovascular mortality at high activity levels. A systematic review found that most included studies did not show cardiovascular harm from prolonged strenuous physical activity, although methodological weaknesses and potential bias limited the certainty of the evidence (Saulicz et al. 2026). Consequently, high-intensity running should be considered in the context of an individual's health, fitness, and training progression rather than treated as inherently beneficial or harmful.

6.3. Is more always better?

Although greater physical activity is generally associated with lower mortality, additional benefits may diminish beyond a certain volume. In a pooled analysis of prospective cohorts, the greatest observed mortality benefit occurred at approximately three to five times the recommended minimum level of leisure-time physical activity. Activity levels substantially above this range provided comparatively modest additional benefits, and the analysis found no clear evidence of increased mortality even among individuals reporting very high activity levels (Arem et al. 2015). Similar patterns of diminishing returns were observed in another large pooled analysis (Moore et al. 2012).

Evidence specific to running also suggests that considerable benefits can occur without very high training volumes. Lee et al. (2014) reported lower all-cause and cardiovascular mortality among runners, including those who ran relatively little. These results support the benefit of regular participation rather than assuming that high weekly mileage is necessary to achieve cardiovascular benefits.

The possibility that very high endurance-training volumes may have adverse cardiovascular effects remains under investigation. A systematic review of prolonged strenuous physical activity concluded that most available evidence did not show clear cardiovascular harm, while some studies suggested benefits may plateau at high exercise levels. Evidence for a U-shaped relationship, in which very high volumes increase cardiovascular risk, was limited and affected by methodological concerns (Saulicz et al. 2026). Therefore, researchers cannot define a universal threshold beyond which running becomes harmful.

Overall, the available evidence supports a dose–response relationship in which moving from inactivity to habitual physical activity is associated with substantial health benefits. In contrast, additional benefits may become smaller at higher volumes. For most recreational runners, a sustainable training routine and gradual progression are reasonable priorities. Very high-volume endurance training may require more individualised assessment, specifically in individuals with cardiovascular symptoms or known cardiovascular disease.

7. Possible Cardiovascular Risks of High-Volume Endurance Running

7.1. Athlete’s heart and cardiac remodelling

Regular endurance training induces structural and functional adaptations together referred to as the athlete's heart. These changes may include enlargement of the cardiac chambers, increased left ventricular mass, and alterations in ventricular filling and function. In most trained individuals, such adaptations represent a physical response to repeated haemodynamic demands instead of evidence of cardiac disease (Janik et al. 2025).

However, distinguishing physiological remodelling from pathological changes can be challenging, particularly in athletes undertaking prolonged, high-volume endurance training. Some studies have reported myocardial fibrosis, right ventricular dysfunction, or other abnormalities in selected endurance athletes exposed to substantial cumulative exercise loads. The results have elicited questions about whether repeated extreme exercise may contribute to adverse cardiac remodelling in susceptible individuals (Patil et al. 2012).

Cardiac enlargement or increased ventricular mass alone does not establish pathology. Interpretation requires consideration of training history, clinical symptoms, family history, electrocardiographic findings, and cardiac imaging. Although physiological adaptation is the predominant response to endurance training, persistent dysfunction or unexplained abnormalities call for further clinical evaluation.

7.2. Atrial fibrillation

Atrial fibrillation (AF) is one of the cardiovascular conditions most frequently discussed in relation to long-term endurance exercise. Although consistent physical exercise is generally associated with favourable cardiovascular outcomes, several studies have reported a higher prevalence of AF among some endurance athletes, particularly men with prolonged exposure to intensive training (Li et al. 2018; Lobo et al. 2023).

Potential mechanisms include atrial enlargement, repeated increases in atrial pressure, changes in autonomic regulation, and structural remodelling. Repeated exposure to high exercise loads may contribute to an electrophysiological substrate that facilitates AF initiation or maintenance in susceptible individuals. Nevertheless, the relative contribution of the mechanisms are still incompletely established, and the relationship between exercise volume and AF risk is inconsistent across populations.

The available evidence does not indicate that recreational running generally causes AF. Instead, the possible association appears more relevant to selected individuals with prolonged exposure to high-volume endurance training. Differences in age, sex, training history, underlying cardiovascular risk, and study methodology complicate comparisons between athletes and the general population (Li et al. 2018; Lobo et al. 2023). Persistent palpitations, an irregular heartbeat, unexplained exercise intolerance, or episodes of dizziness should therefore prompt appropriate medical assessment, particularly in athletes with substantial endurance-training histories.

7.3. Acute cardiac stress after marathon running

Marathon running imposes substantial acute demands on the cardiovascular system. Studies assessing athletes before and after marathon events have reported transient increases in circulating cardiac biomarkers, including

cardiac troponins and N-terminal pro-B-type natriuretic peptide (NT-proBNP), as well as transient changes in selected echocardiographic parameters (Laily et al. 2026).

Troponin concentrations may rise after prolonged strenuous exercise, but this finding should not automatically be interpreted as evidence of an acute myocardial infarction. Exercise-associated biomarker elevations differ from those observed in clinical myocardial infarction in their context and time course. Similarly, changes in cardiac function measured immediately after a marathon may reflect temporary fatigue, altered loading conditions, and acute physiological stress rather than permanent myocardial injury.

Nevertheless, the clinical significance of these responses remains under investigation. The extent of biomarker elevation and functional changes may vary according to exercise duration, intensity, training status, environmental conditions, and personal susceptibility. Current evidence does not establish that transient post-marathon changes inevitably lead to chronic cardiac damage (Laily et al. 2026). Persistent chest pain, disproportionate breathlessness, syncope, or other concerning symptoms after prolonged exercise require prompt medical evaluation rather than being automatically attributed to normal post-exercise fatigue.

7.4. Coronary atherosclerosis and coronary artery calcification

Coronary artery calcification (CAC) has received increasing attention in studies of athletes with long histories of endurance training. Some investigations have identified a higher prevalence or greater extent of coronary artery calcification in selected endurance athletes than in less active comparison groups. These data have prompted discussion about whether prolonged high-volume exercise may be associated with coronary atherosclerosis in certain individuals (Celeski et al. 2024; Patil et al. 2012).

However, clinicians must interpret CAC findings in context. Calcification indicates coronary atherosclerotic plaque burden, but the amount of calcium alone does not fully describe plaque composition, the degree of luminal obstruction, or an individual's overall cardiovascular risk. Some studies suggest that athletes may have a different distribution of plaque characteristics from less active individuals, including a greater proportion of calcified plaques. The possible effects of these differences for long-term cardiovascular outcomes remain uncertain (Celeski et al. 2024).

The available evidence does not establish that endurance running directly causes coronary atherosclerosis, nor does it demonstrate that high-volume runners generally experience greater cardiovascular event rates than less active individuals. Age, sex, smoking, blood pressure, lipid concentrations, family history, and other established risk factors remain important when interpreting coronary imaging findings. Further prospective research is needed to clarify whether cumulative endurance-training exposure influences plaque development or clinical outcomes in specific populations.

7.5. Sudden cardiac death

Sudden cardiac death during or shortly after exercise is a rare but serious event. Although exercise can transiently increase the risk of an acute cardiac event in susceptible individuals, consistent physical exercise is associated with considerable long-term cardiovascular benefits. The absolute risk of sudden cardiac death during exercise remains low, and its causes vary according to age and the underlying cardiovascular condition (Wasfy et al. 2016).

In younger athletes, sudden cardiac death may be associated with inherited cardiomyopathies, congenital coronary artery abnormalities, or primary electrical disorders. In older athletes, coronary artery disease is an important cause. Exercise may act as a trigger for a fatal arrhythmia in an individual with a latent structural or electrical abnormality, rather than being the sole cause of the event (Wasfy et al. 2016; Ferreira et al. 2010).

The rarity of these events makes risk estimation difficult, and published incidence rates vary according to the population studied, the definition of sudden cardiac death, and the methods used to identify cases. Consequently, the occurrence of sudden cardiac death in endurance athletes should not be interpreted as evidence that running is generally unsafe. Instead, it draws attention to the importance of recognising potentially relevant symptoms and assessing individual risk.

Exertional syncope, unexplained chest discomfort, disproportionate breathlessness, or palpitations associated with dizziness warrant medical evaluation. A personal history of cardiovascular disease or a family history of premature sudden cardiac death may likewise influence the need for further assessment before undertaking high-intensity endurance training. Preventive approaches should be individualised, balancing the considerable benefits of frequent physical activity against the uncommon but potentially serious risks associated with underlying cardiovascular disease.

8. Running in Different Populations

8.1. Healthy adults

For healthy adults, regular running is an accessible form of aerobic exercise associated with improved cardiorespiratory fitness and lower all-cause and cardiovascular mortality. Evidence suggests that health benefits may occur even at relatively low running volumes, making running a potential component of long-term cardiovascular prevention (Lee et al. 2014; Oja et al. 2024). Training frequency, duration, and intensity must match individual fitness and increase gradually to support adherence and reduce the risk of exercise-related injury.

8.2. Older adults

Running may provide cardiovascular benefits in older adults who remain physically capable of participating safely. However, age-related alterations in physical capacity, musculoskeletal function, and the prevalence of cardiovascular risk factors should be considered when planning training. Evidence from older populations indicates that regular leisure-time physical activity is associated with lower mortality, although these outcomes are

not specific to running (Zhao et al. 2022). For previously inactive individuals, gradual progression and the selection of a sustainable form of exercise are particularly important.

8.3. Individuals with hypertension

Running can be part of a non-pharmacological strategy for controlling hypertension. Aerobic exercise training has been shown to reduce resting blood pressure, although the magnitude of the response varies by individual and exercise modality (Edwards et al. 2023). Individuals with hypertension should consider their baseline blood pressure, overall cardiovascular risk, treatment status, and exercise tolerance when initiating or intensifying running. Those with poorly controlled hypertension or symptoms suggestive of cardiovascular disease may require clinical assessment before undertaking vigorous training.

8.4. Individuals with cardiovascular disease

Running is not universally appropriate for all individuals with established cardiovascular disease; however, selected patients may incorporate it into an individualised exercise programme. The suitability of running depends on the underlying diagnosis, disease stability, functional capacity, symptoms, and the risk of exercise-related complications. For many patients, structured cardiac rehabilitation provides a framework for safely improving physical fitness and progressively increasing exercise intensity. High-intensity or high-volume endurance training should not be presumed safe for every patient and may require specialist assessment. The possible benefits of exercise should be balanced against individual clinical risks.

8.5. Recreational versus competitive runners

Recreational and competitive runners differ in their typical training volume, intensity, and cumulative exposure to endurance exercise. Recreational running may provide substantial cardiovascular benefits without requiring high weekly mileage, whereas competitive endurance training involves greater and more sustained physiological demands. Some studies have reported an association between long-term endurance training and atrial fibrillation or coronary artery calcification in selected athletic populations, although the clinical significance of these conclusions is still unclear (Lobo et al. 2023; Celeski et al. 2024). These observations should not be interpreted as evidence that competitive running is generally harmful. Rather, they highlight the relevance of considering training history, symptoms, and individual cardiovascular risk when evaluating athletes exposed to high-volume endurance exercise.

9. Practical Implications

The available evidence supports adopting regular running into cardiovascular health promotion, while emphasising the importance of individualisation and gradual training progression. Even relatively low volumes of running may

be associated with health benefits, and individuals do not necessarily need to undertake high-volume endurance training to improve their cardiovascular risk profile (Lee et al. 2014).

For previously inactive individuals, training should start at a manageable intensity and increase progressively based on fitness, tolerance, and recovery. Regularity and long-term adherence may be more important for general health than achieving high running speeds or weekly mileage. Aerobic exercise, including running, may also support blood pressure management, although it needs to complement rather than replace prescribed treatment when medication is indicated (Edwards et al. 2023).

Individuals with known cardiovascular disease, poorly controlled hypertension, exertional chest pain, unexplained syncope, or disproportionate breathlessness should seek appropriate clinical assessment before undertaking vigorous training. Exercise recommendations should account for the individual's clinical status, functional capacity, and cardiovascular risk. Cardiorespiratory fitness assessment may also help inform clinical risk evaluation and exercise counselling (Ross et al. 2016).

Finally, approach high-volume endurance training with awareness of individual tolerance, recovery, and potential warning symptoms. Persistent palpitations, chest discomfort, syncope, or an unexplained decline in exercise capacity warrant medical evaluation. These precautions should not discourage recreational running; rather, they support a moderate approach that pursues the established benefits of physical activity while appropriately considering individual risks.

10. Discussion

This review indicates that regular running is associated with important cardiovascular benefits, including improved cardiorespiratory fitness and lower cardiovascular and all-cause mortality. These benefits may occur even at relatively low running volumes, suggesting that high training loads are not necessary to preserve cardiovascular health (Lee et al. 2014; Lang et al. 2024). Running may also help manage cardiovascular risk factors, including elevated blood pressure and an unfavourable lipid profile.

The relationship between running volume and cardiovascular health is complex. Although increasing physical activity from low levels generally provides considerable benefits, the evidence does not establish a single optimal running dose for all individuals. Probable concerns associated with prolonged, high-volume endurance training include atrial fibrillation, coronary artery calcification, and exercise-related cardiac stress. However, these outcomes require prudent interpretation, as physiological cardiac adaptations and transient biomarker changes do not necessarily indicate clinically significant disease. The available evidence does not support discouraging recreational running but points to the importance of individual risk assessment.

Several limitations affect how we interpret current research. Studies differ in how they define running exposure, follow-up periods, and cardiovascular outcomes, and many rely on cohort data that cannot verify causality. Furthermore, findings from competitive endurance athletes may not apply directly to recreational runners, and

evidence on physical activity in general does not always reflect the specific effects of running. As this is a narrative review, the findings constitute a thematic synthesis rather than a quantitative assessment of pooled effects.

Future research has to use longer follow-up periods, objective measurements of running volume and intensity, and consistent cardiovascular outcome definitions. Greater inclusion of women, older adults, and individuals with established cardiovascular disease would also improve the evidence's applicability. Overall, regular running appears to serve as a valuable component of cardiovascular health promotion, provided that training is adapted to individual capacity and health status and that potential hazards connected with intensive endurance exercise are appropriately considered.

11. Conclusions

Regular recreational running is associated with substantial cardiovascular benefits, including improved cardiorespiratory fitness and lower cardiovascular and all-cause mortality. These benefits may be achieved without high training volumes, making running a valuable component of cardiovascular disease prevention. However, the long-term cardiovascular consequences of extreme endurance running remain less certain, notably regarding atrial fibrillation and coronary artery changes. Running recommendations should therefore reflect individual health status, training history, and exercise tolerance.

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