TURKISH JOURNAL OF INTERNAL MEDICINE

ISSN:2687-4245

Review Article

Unravelling the Role of Physical Activity on Cardiovascular Health

Palak Gupta[1], Kamaljot Kaur Ahuja[2], Biswajyoti Das[3], Parth Munjal[4] Tanveer Shaik[5], Rohit Jain[6]

[1]. Maharishi Markandeshwar Institute of Medical Sciences and Research, Ambala, Haryana, India
[2]. Shri Guru Ram Rai Institute of Medical and Health Sciences, Dehradun, Uttarakhand, India
[3]. Maulana Azad Medical College, New Delhi, India
[4]. Rohilkhand Medical College and Hospital, Bareilly, India
[5]. Avalon University School Of Medicine, Willemstad, Curacao
[6]. Department of Internal Medicine, Penn State Milton S Medical Center, Pennsylvania, USA

ABSTRACT

Cardiovascular diseases (CVDs) are the leading cause of death globally, with physical inactivity being a significant risk factor. The intensity and volume of physical activity (PA) are critical in reducing CVD risk and improving primary and secondary prevention outcomes. We conducted a narrative review, searching electronic databases such as PubMed using relevant keywords and Google Scholar to identify relevant studies. This research utilized a comprehensive search to identify appropriate resources, such as university website links. We examine the impact of different PA intensities, including moderate-intensity continuous training (MICT) and vigorous physical activity (VPA), on CVD risk and mortality. It also evaluates the role of combined aerobic and resistance training in secondary prevention and explores potential risks associated with excessive VPA. MICT and VPA significantly reduce CVD risk, with VPA providing superior benefits by enhancing VO_2 max, endothelial function, and lipid profiles. For individuals with existing CVD, combining aerobic and resistance training substantially lowers mortality rates. While higher PA volumes reduce all-cause mortality, VPA intensity more effectively mitigates CVD risk. However, excessive VPA may increase oxidative stress and arrhythmia risk in susceptible individuals. Personalized PA plans that balance intensity and volume are essential for optimal cardiovascular health. Healthcare providers are pivotal in encouraging tailored PA regimens to maximize benefits while minimizing risks and supporting improved outcomes and longevity.

Turk J Int Med 2025;7(2):52-61
DOI: 10.46310/tjim.1592426

Keywords: *Physical activity, moderate intensity, vigorous intensity, resistance training, endurance training, aerobic exercise, cardiovascular disease, mortality risk*

INTRODUCTION

Cardiovascular diseases (CVDs) are a leading cause of death worldwide, with approximately 2,552 reported fatalities each day in the United States alone. Conditions such as coronary artery disease (CAD), hypertension, stroke, and heart failure contribute significantly to this burden. It has been determined that 48.6% of people over 20 have some form of CVD.[1] The primary risk factors for these conditions are lifestyle-related, including

Received: *November 27, 2024* ***Accepted:*** *March 16, 2025* ***Published:*** *April 29, 2025*

How to cite this article: *Gupta P, Ahuja KK, Daas B, Munjal P, Shaik T, Jain R. DUnraveling the Role of Physical Activity on Cardiovascular Health, Turk J Int Med 2025;7(2):52-61. DOI: 10.46310/tjim.1592426*

Address for Correspondence:
Kamaljot Kaur Ahuja, Shri Guru Ram Rai Institute of Medical and Health Sciences, Dehradun, Uttarakhand, India
Email:ahujakamal7@gmail.com

poor diets, physical inactivity, alcohol consumption, and smoking.[2] One of the important modifiable risk factors is physical inactivity. With the widespread use of technology, people often sit for extended periods without realizing it, leading to minimal physical activity. This results in elevated blood lipid and cholesterol levels and increased red blood cell aggregation, heightening the risk of CVD.[3] However, incorporating regular aerobic or strength training exercises into daily routines can mitigate the risk.[4] Physical activity (PA) is defined as any voluntary bodily movement produced by skeletal muscles that requires energy expenditure.[5] The different modes of PA include resistance/strength training and aerobic/endurance training. Strength training targets muscles in different ways, including isotonic contraction, which involves maintaining the same amount of muscle tension throughout the movement eg; Push-ups/Pull-ups/Bicep curls that build the strength of the muscle, isometric contraction, also known as static exercises, where no change in muscle length occurs but these help improving stability and maintaining strength for eg: Planks and isokinetic contraction which increases muscle strength by involving motion during the exercise while maintaining the same speed during the movement such as using a stationary bike or setting a target speed on the treadmill. Aerobic training includes walking, cycling, jogging, swimming, etc, which uses large muscle groups of the body and increases the heart rate and the amount of oxygen used by the body. In resistance and aerobic training, exercise volume can be explained as the total work done during a workout. It is commonly calculated by adding the number of sets, repetitions, and intensity (weight lifted) for resistance training, or the duration and intensity (pace) for aerobic activity. Exercise volume indicates "how much" exercise is done during a session.

According to intensity, PA can be high-intensity interval training (HIIT)/vigorous PA (VPA) and moderate-intensity continuous training (MICT).[6] The American Heart Association classifies both MICT and VPA based on the variations they produce in heart rate. MICT is defined as exercise performed at 50%-70% of an individual's maximum heart rate, while HIIT involves higher intensity, typically reaching 70%-85% of maximum heart rate, depending on the person.[7] Heart rate is used to evaluate the intensity of aerobic exercise, whereas the amount of resistance applied is used to gauge the intensity of resistance training. While it is well-established that some form of PA is known to be beneficial for preventing CVD and promoting longevity, a key question is whether exercise intensity or volume is more advantageous.[8]

MET (metabolic equivalent tasks) stands for metabolic equivalent, with 1 MET indicating the level of energy used while sitting still, which corresponds to an oxygen consumption of 3.5 mL per kilogram (kg) per minute, or a calorie expenditure of 1 kcal/kg/h.[9] Guidelines recommend using METs as reference thresholds for intensities of PA (moderate intensity 3.0–5.9 METs and vigorous-intensity ≥6.0 METs).[10]

Research on exercise intensity highlights the benefits of VPA, showing that it can significantly reduce the risk of all-cause mortality when it makes up 30-50% of total exercise duration. In fact, engaging in 60-90 minutes of VPA per week has been associated with a three-year increase in life expectancy and a 4% reduction in the risk of arrhythmogenic cardiomyopathy. This finding highlights the potential advantages of incorporating VPA into one's routine. While MICT is often recommended initially for fat loss and improving cardiorespiratory fitness, it requires a considerable time commitment (typically over 150 minutes per day or 1000 minutes per week) to achieve its full benefits.[11] In contrast, VPA/HIIT provides a more time-efficient way to achieve similar or even greater benefits. This approach alternates brief rest periods or light exercise (active recovery at around 70% of peak heart rate) with several short bursts of high-intensity activity (typically 85%-95% of peak heart rate for about three to four minutes). The entire workout can be finished in around forty minutes, and this method has been shown to improve cardiovascular function, blood pressure, and total peripheral resistance.[12] VPA boosts catecholamine synthesis, improving fat oxidation and visceral adipose tissue breakdown.[13] It has also been shown to improve the VO_2 max, which is the maximum amount of oxygen a person uses during PA. VO_2 max is the gold standard for assessing cardiorespiratory fitness and has been shown to improve significantly with VPA compared to MICT.[14] Although VPA seems more effective than moderate PA, the volume of PA is a factor to consider, as long-term negative effects of VPA, like coronary sclerosis and atrial fibrillation, continue to come forward.[15] The 2018 Physical Activity Guidelines for Americans and the 2020 WHO guidelines on PA recommend that adults should engage in at least 150-300 minutes of moderate-vigorous aerobic PA or 75-150 minutes of vigorous aerobic PA weekly or a combination of both, along with muscle-strengthening activity on 2 or more days per week. Children and adolescents aged 6–17 should participate in at least 60 minutes of moderate to vigorous PA (MVPA) daily to improve their overall well-being.[16,17] Understanding how

exercise intensity and volume influence health outcomes is important. Although VPA has emerged as a viable approach for improving cardiovascular function, the best option for each individual may depend on their health goals, fitness level, and personal preferences. Regular PA remains one of the most effective strategies for preventing cardiovascular diseases and enhancing overall well-being, whether focusing on intensity, volume, or a combination of both.[8] In this review, we aim to explore the relative benefits of exercise intensity versus volume in reducing the risk of cardiovascular diseases and improving overall cardiovascular health, focusing on how different exercise regimens may be tailored to individual needs and goals.

Pathophysiology

Physical activity plays a significant role in attenuating the mortality and morbidity associated with CVDs. It mediates its effects mainly by altering the risk factors of CVD, which include hypertension, hyperglycemia, dyslipidemia, and chronic inflammatory states. Different intensities and volumes of PA are associated with varied instances of risk reduction (Figure 1). Moderate PA (MPA) is associated with lowering blood pressure. This is caused by systemic vasodilation, mediated by increased endothelial nitric oxide production.[18] It also causes a reduction in vascular angiotensin II receptor expression, which in turn decreases Angiotensin II-mediated vasoconstriction.[19] MPA reduces the incidence of atherosclerosis and coronary artery disease (CAD). It increases ABCA1 (ATP binding cassette A1) gene transcription, increasing plasma high-density lipoprotein cholesterol (HDL-C) levels and reverse cholesterol transport[20], which reduces the risk of forming foam cells. Regular MPA is associated with reduced leptin signalling to hematopoietic stem cells and, hence, reduced output of inflammatory leukocytes.[21] These factors significantly reduce the chances of plaque formation. It also decreases platelet aggregation by increasing cGMP production and reducing intracellular calcium levels.[22] MPA also increases the translocation of GLUT 4, a glucose transporter, from the cytoplasm to the cell membrane in skeletal muscles. This leads to a reduction in plasma glucose levels, thereby improving insulin resistance.[23] MPA thus ameliorates coronary microvasculature complications associated with diabetes and also reduces the chances of clot formation in the coronary arteries. Furthermore, VPA is associated with an even greater reduction in the risk of most CVDs. It is associated with increased production of vascular endothelial growth factor (VEGF), which results in the development of collateral coronary blood supply, which limits the extension of an infarct in case of coronary artery blockage.[24] VPA leads to a reduction in the occurrence of arrhythmias. It does so by increasing the parasympathetic tone and reducing beta 2 adrenergic receptor sensitivity and expression, promoting better autonomic balance of the heart.[25] VPA is also cardioprotective against necrosis, mediated by the activation of delta opioid receptors and the release of adenosine and bradykinin in a dose-dependent manner.[26] However, excessive VPA is associated with increased

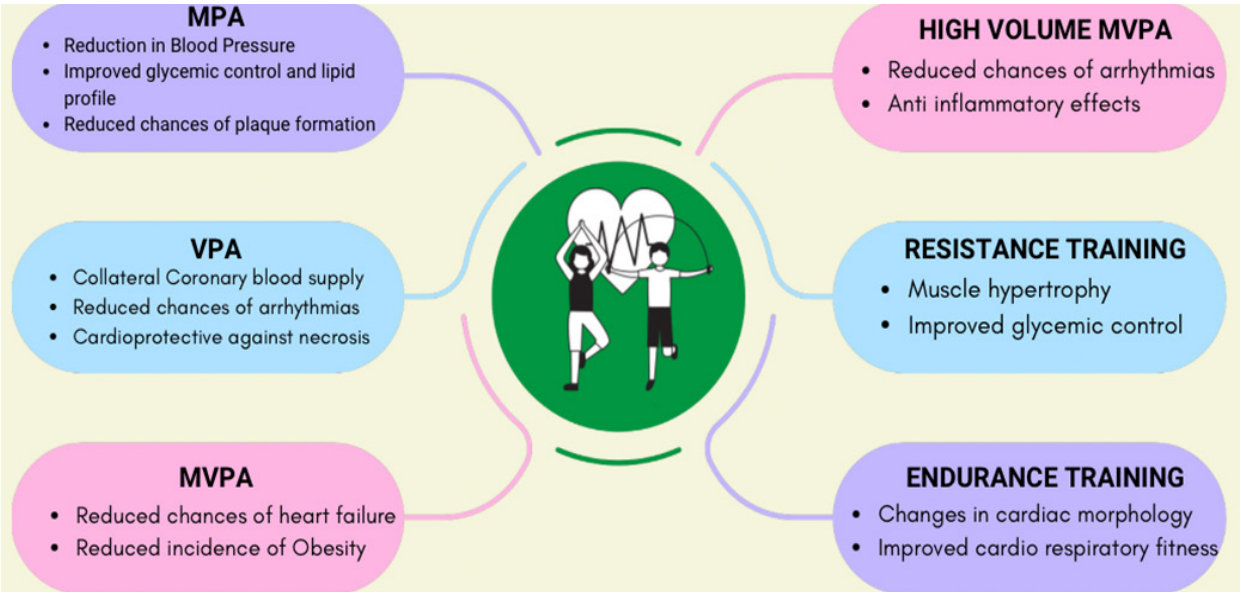

Figure 1. The figure highlights the cardiovascular health benefits of various types of physical activity, including MPA, VPA and endurance training. MPA: moderate physical activity, MVPA: moderate to vigorous physical activity, VPA: vigorous physical activity.

production of reactive oxygen species (ROS), which leads to increased susceptibility to ROS-mediated lipid peroxidation and membrane damage. This might negate the positive effects of VPA by exacerbating the risk for plaque formation, especially among those with pre-existing conditions.[27] Additionally, long-term MVPA is beneficial as it is associated with increased end-diastolic volume, ventricular mass, and left ventricular compliance, leading to increased stroke volume and greater perfusion, reducing the chances of heart failure.[28] MVPA also has an inverse relation with obesity, which is a strong risk factor for CVDs.[29] This is due to MVPA's correlation with improved glycemic control, lower insulin resistance, and lipid profiles. A higher volume of PA, combined with MVPA, is associated with a greater reduction in risk for CVDs. Regular high-volume PA normalizes the repolarisation of cardiac musculature. It also reduces calcium-handling abnormalities by changing the expression of calcium-handling genes, thereby reducing the chances of arrhythmias. It also reduces the expression of Toll-Like Receptors (TLRs), in particular TLR 4. This results in anti-inflammatory effects and thereby reduces the chances of atherosclerosis.[30] Resistance training is mostly associated with improved skeletal muscle function and hypertrophy. This muscle hypertrophy is achieved by the upregulation of mTOR (molecular target of rapamycin) expression, leading to increased protein synthesis. It is also associated with improved glycemic control by mechanisms similar to those pertaining to MPA.[31] Conversely, endurance training is associated with improved cardiorespiratory fitness and changes in cardiac morphology similar to MVPA.[32] A mixed regime of resistance training coupled with endurance training is associated with a reduction in the production of inflammatory mediators and expression of TLRs, in addition to producing changes seen in these forms of PA individually.[33]

DISCUSSION

Physical inactivity is one of the major preventable risk factors for CVD and early mortality worldwide.34 Various forms of CVD, including ischemic and hemorrhagic strokes, CAD, heart failure, and sudden cardiac death, can result from a decline in weekly PA and an increase in comorbidities and risk factors. In addition to lowering the incidence of CVD itself, PA and an increase of 500 steps daily are associated with a 7% decrease in CV mortality.[35] PA can vary in intensity and is classified as low, moderate, or high intensity, depending on an individual's maximum aerobic capacity (VO2max). The World Health Organization recommends 150–300 minutes of MPA or 75–150 minutes of VPA per week, based on the idea that the same amount of time spent engaging in VPA (≥6 metabolic equivalent tasks [METs], such as running) could provide twice the health benefits of MPA (3–5.9 METs, such as brisk walking.[16]

Several prospective cohort studies have examined the relationships between VPA, MPA, and all-cause mortality. VPA was associated with a 17% lower all-cause mortality rate compared to MPA, according to a prospective cohort analysis of 403,681 US adults.[36] Similarly, a cohort study of 64,913, using pooled data from 11 cohorts from England and Scotland, indicated that VPA was associated with a reduced risk of all-cause mortality compared to MPA.[37] A study exploring the associations of various combinations of aerobic and muscle-strengthening activities with all-cause mortality suggested that increasing VPA while maintaining any level of MPA, alongside recommended levels of muscle-strengthening activity (MSA), leads to a greater reduction in all-cause mortality risk.[38]

However, current studies on the association of VPA versus MPA with CVD, the leading cause of mortality worldwide, have produced inconsistent results. A US study identified a lower risk of CVD among individuals performing more than 50% to 100% of VPA relative to total MVPA.[36] A study examining the relationship between the proportion of VPA to MVPA and their combined effect on the occurrence of CVD found that having 0%-30% of VPA in relation to MVPA was linked to a 12% and 19% reduction in the risk of developing CVD and all-cause mortality, respectively, compared to no VPA. The greatest decrease in risks for both CVD and all-cause mortality was observed with around 30% VPA to MVPA. Participants who engaged in 150–300 minutes of MVPA and at least 150 minutes of VPA per week had the lowest risk of CVD and all-cause mortality compared to those with the least MVPA (0–150 min/week; VPA, 0–75 min/week).[39] In contrast, the UK study did not find a significant association between higher VPA and CVD mortality.[37] This difference could be attributed to variations in underlying factors such as population, lifestyle, and other influences. A meta-analysis involving 3,439,874 participants and 179,393 events over an average follow-up of 12.3 years indicated that moving from inactivity to achieving recommended PA levels (150 minutes of moderate-intensity aerobic activity per week) was associated with a 23% lower risk of CVD mortality and a 17% reduction in CVD incidence.[40]

Secondary prevention of CVD involves strategies aimed at lowering the risk of heart attacks or strokes in individuals who have experienced a prior event or have a known history of CVD. Current guidelines recommend PA for secondary CVD prevention. Jeong et al.[41] found that the benefits for those in secondary prevention were more pronounced than in primary prevention; specifically, each 500 MET-min/week increase in activity correlated with a 14% reduction in mortality risk for the secondary prevention group, compared to 7% for the primary group. Additionally, a study investigating the association between PA and mortality according to the presence of specific CVDs in a nationwide elderly population found that the risk of mortality progressively reduced with increasing PA in patients with heart failure or myocardial infarction, but reached a plateau in patients with stroke or peripheral artery disease. Finally, the benefits of PA were greater in patients with stroke or heart failure.[42] These findings align with recommendations from the American College of Cardiology Foundation and American Heart Association, which suggest engaging in 30–60 minutes of moderate-intensity aerobic exercise at least 5 to 7 days per week for patients with stable ischemic heart disease.

VPA increases peak oxygen uptake, improves cardiorespiratory fitness, and thus provides greater cardiovascular benefits.[43] However, while VPA has beneficial effects, high levels of VPA have also been positively associated with oxidative stress, which may counteract some of the benefits of PA. For instance, a cohort study of 204,542 middle-aged and older Australians reported that engaging in 0%–30% VPA was associated with a 9% reduction in all-cause mortality, while no additional benefits were observed among those engaging in 30% or more of VPA.[27] Despite the significant health advantages of regular PA, intense exercise can unexpectedly trigger life-threatening ventricular arrhythmias (VAs) in individuals with existing CVD, with sudden cardiac death (SCD) being the primary cause of exercise-related fatalities among athletes.[44] In fact, odds ratios ranging from 1.9 to 8.8 have been reported in several literature reviews, evidencing an increased incidence of AF among endurance athletes compared with non-athletes.[45]

The volume of PA (measured in metabolic equivalent of task hours per week, METh/wk) and its intensity are crucial in influencing cardiovascular risk, with intensity playing a more significant role in minimizing CVD risk, independent of total PA volume. Increased PA volume is associated with a lower risk of all-cause mortality, but not specifically for cardiovascular disease.[8] However, a study found that compared to no exercise, any exercise volume (>0 METh/wk) was associated with lower risks of all-cause mortality and recurrent cardiovascular events. A reverse J-shaped relationship was identified for both outcomes, with the lowest risk at 29 METh/wk for all-cause mortality and recurrent vascular events. Factors, such as body mass index (BMI), insulin resistance, systolic blood pressure (SBP), systemic inflammation, and low-density lipoprotein cholesterol (LDL-C), accounted for 29% of the link between exercise volume and all-cause mortality, and 32% for recurrent cardiovascular events. Systemic inflammation and insulin resistance emerged as the primary mediators, contributing to 16% of the relationship with all-cause mortality and 17% for recurrent vascular events, while insulin resistance accounted for 5% and 8%, respectively.[33] Data from a study involving 88,412 UK Biobank middle-aged adults found that higher PA energy expenditure (PAEE) and a higher percentage of MVPA, adjusted for PAEE, were associated with lower rates of incident CVD. The study revealed that CVD rates were 14% lower when MVPA accounted for 20% rather than 10% of 15 kJ/kg/d PAEE, equivalent to converting a 14-minute stroll into a brisk 7-minute walk. Notably, CVD rates did not significantly differ between PAEE values when the percentage of MVPA was fixed at 10%. The lowest CVD rates were observed with combinations of higher PAEE and a higher percentage of MVPA.[46]

Resistance and endurance training offer valuable benefits, enhancing various aspects of physical fitness. Resistance training primarily offers musculoskeletal benefits while lowering the risk of CVD and certain cancers. It is especially recommended for enhancing physical function and glycemic control.31 Endurance training effectively improves cardiorespiratory fitness, decreases subcutaneous fat, and lowers CVD risk.[47] When compared to those who do not exercise, individuals engaging in resistance training experienced a lower risk of all-cause mortality and recurrent vascular events. Similarly, combining endurance and resistance training was associated with a reduced risk of all-cause mortality and recurrent vascular issues. These relations were driven by reduced risk of cardiovascular mortality and non-fatal stroke.[33]

Engaging in PA is essential for lowering the risk of CVD and mortality (Table 1). Both moderate and vigorous exercises offer considerable health advantages, highlighting the need to adhere to recommended activity levels. Different types and intensities of exercise provide unique benefits, but a mix of aerobic and resistance

Table 1. Studies investigating the relationship between PA, including its type, intensity, and volume, and cardiovascular disease outcomes and mortality risk. Statistical models like Cox regression quantify these associations, emphasizing thresholds for optimal health benefits. Key findings highlight that higher PA levels lead to lower mortality and disease risk.

Study (year published)	Study design	Outcomes
Banach et al[35] (2023)	Seventeen cohort studies with a total of 226,889 participants and a median follow-up of 7.1 years were included in the meta-analysis to evaluate the relationship between step count, all-cause mortality, and cardiovascular mortality.	The study demonstrated that a 1,000-step increment was associated with a 15% decreased risk of all-cause mortality, while a 500-step increment was associated with a 7% decrease in cardiovascular mortality. Specifically, exceeding 3,867 steps per day is linked to reduced all-cause mortality, while exceeding 2,337 steps is linked to lower cardiovascular mortality.
Wang et al[36] (2021)	The cohort study included 403,681 adults from the 1997–2013 National Health Interview Survey, who provided data on self-reported PA and were linked to National Death Index records through December 31, 2015. Statistical analysis was conducted between May 15, 2018, and August 15, 2020, to assess the association between the proportion of VPA to total PA and all-cause mortality, cardiovascular disease mortality, and cancer mortality.	The study found that, among participants engaging in any MVPA, a higher proportion of VPA to total PA was associated with lower all-cause mortality, but not cardiovascular disease or cancer mortality. Compared with participants with 0% VPA, those performing greater than 50% to 75% VPA of total PA had a 17% lower risk of all-cause mortality, independent of total MVPA.
Lopez et al[37] (2019)	Data from 11 cohorts of the Health Survey for England and the Scottish Health Survey, collected from 1994 to 2011, were examined to assess whether, compared with moderate, vigorous activity was associated with larger mortality risk reductions.	Vigorous activities were associated with larger reductions in mortality risk than activities of moderate intensity.
López-Bueno et al[38] (2023)	A nationwide prospective cohort study was conducted to examine the associations between different combinations of MPA, VPA, and MSA with all-cause, CVD, and cancer mortality, utilizing data from the US National Health Interview Survey. The study included 500,705 eligible US adults, followed by a median duration of 10 years.	The study showed that balanced levels of MPA, VPA, and MSA combined were associated with optimal reductions in mortality risk.
Mu et al[39] (2022)	A prospective cohort study recruited 502,505 participants aged 40–69 years in the UK from 2006 to 2010, followed by a median of 11.8 years to examine the associations between the proportion of VPA to MVPA with incident CVD and all-cause mortality. Cox regression was used to calculate HRs and 95% CIs for the risks of these outcomes.	Compared with no VPA, 0%-30% of VPA to MVPA was associated with 12% and 19% lower risks of incident CVD and all-cause mortality, respectively.
Wahid et al[40] (2016)	A systematic review and meta-analysis created a single continuous PA metric for comparing its association with CVD and T2DM. The analysis included 36 studies (3,439,874 participants, 179,393 events, and an average follow-up of 12.3 years) from the MEDLINE and EMBASE databases, covering publications from January 1981 to March 2014. Of the studies, 33 focused on CVD and 3 on T2DM.	The study demonstrated that moving from inactivity to achieving the recommended PA levels (150 minutes of moderate-intensity aerobic activity per week) was associated with a 23% lower risk of CVD mortality, a 17% reduction in CVD incidence, and a 26% reduction in T2DM incidence.
Jeong et al[41] (2019)	From a population-based cohort, the study involved 131,558 individuals with CVD and 310,240 without. Physical activity was assessed using self-reported questionnaires. The study subjects were followed up for a median of 5.9 years, and the main study outcome was all-cause mortality.	An inverse relationship between PA levels and mortality risk was found in both groups. The benefit in the secondary prevention group was greater than that in the primary prevention group: every 500 MET-min/week increase in PA resulted in a 14% and 7% reduction in mortality risk in the secondary and primary prevention groups, respectively.

Kim et al[42] (2022)	The study was conducted to evaluate the effect of PA on mortality in older adults with specific CVD. From the Korean NHIS-Senior database, 68,223 participants (n: 23,871 with CVD, n: 44,352 without CVD), aged ≥65 years, with available PA data between 2005 and 2012, were enrolled in this study and followed for a median of 42 months.	The study showed that a 500 MET-min/week increase in PA resulted in an 11% and 16% reduction in mortality risk in the non-CVD and CVD groups, respectively. Concerning specific CVDs, the risk of mortality progressively decreased with increasing PA in patients with heart failure or myocardial infarction, but reached a plateau in patients with stroke or peripheral artery disease. Finally, the benefits of PA were greater in patients with stroke or heart failure.
Gebel et al[27] (2015)	The prospective cohort study analyzed activity data linked to all-cause mortality information from February 1, 2006, to June 15, 2014, involving 204,542 adults aged 45 to 75 years from the 45 and up population-based cohort in New South Wales, Australia to examine the relationship between various levels of VPA and mortality, adjusting for total MVPA as well as sociodemographic and health-related factors.	The study reported that engaging in 0%–30% VPA was associated with a 9% reduction in all-cause mortality, while no additional benefits were observed among those engaging in 30% or more VPA.
Bonekamp et al[33] (2023)	A prospective UCC-SMART cohort (n: 8,660) assessed the associations between clinical endpoints and physical exercise volume, type (endurance vs. endurance + resistance), and intensity (moderate vs. vigorous) using multivariable-adjusted Cox models, with a follow-up period of a median of 9.5 years.	The study found that, compared to no exercise, any exercise volume was associated with lower risks of all-cause mortality and recurrent cardiovascular events. A reverse J-shaped relationship was identified for both outcomes, with the lowest risk at 29 METh/wk for all-cause mortality and recurrent vascular events. Factors such as BMI, insulin resistance, SBP, systemic inflammation, and LDL-C accounted for 29% of the association between exercise volume and all-cause mortality and 32% for recurrent cardiovascular events. Systemic inflammation and insulin resistance emerged as the primary mediators, contributing to 16% of the relationship with all-cause mortality and 17% for recurrent vascular events, while insulin resistance accounted for 5% and 8%, respectively
Dempsey et al[46] (2022)	Data were collected from 88,412 middle-aged adults in the UK Biobank (58% women) without existing CVD, who wore accelerometers on their dominant wrist for 7 days. Total PAEE was estimated using population-specific validation. Cox proportional hazard models were used to assess the relationship between PAEE and PA intensity with incident CVD (ischemic heart disease or cerebrovascular disease), adjusting for potential confounding factors	The study revealed that CVD rates were 14% lower when MVPA accounted for 20% rather than 10% of 15 kJ/kg/d PAEE, which is equivalent to converting a 14-minute stroll into a brisk 7-minute walk. Notably, CVD rates did not significantly differ between PAEE values when the percentage of MVPA was fixed at 10%. The lowest CVD rates were observed with combinations of higher PAEE and a higher percentage of MVPA.

VPA: vigorous physical activity, MVPA: moderate to vigorous physical activity, MPA: moderate physical activity, CVD: cardiovascular disease, MSA: muscle-strengthening activity, HR: hazard ratio, CI: confidence interval, PA: physical activity, T2DM: type 2 diabetes mellitus, MET: metabolic equivalent task, BMI: body mass index, SBP: systolic blood pressure, LDL-C: low-density lipoprotein cholesterol, PAEE: physical activity energy expenditure.

training is crucial for optimal heart health. Healthcare providers should promote active lifestyles among patients with cardiovascular conditions, as they can achieve even greater health improvements than those without such issues. It's important to address obstacles to PA, offer personalized exercise plans, and create supportive environments to improve patient outcomes and encourage lasting cardiovascular health.

CONCLUSIONS

Physical inactivity remains a significant modifiable risk factor for CVD and all-cause mortality. The evidence supports that regular PA, whether moderate or vigorous, plays a pivotal role in improving cardiovascular outcomes. While VPA offers the greatest benefits, even a modest increase in PA can yield substantial benefits compared to no activity. Both intensity and volume of PA are important for enhancing cardiovascular

function; however, the most effective approach is a balanced combination tailored to individual capabilities. Further research is needed to clarify the most effective combinations of intensity and volume for distinct populations. Addressing barriers to PA, such as time constraints, access to safe exercise environments, and comorbidities, is crucial for promoting long-term cardiovascular health. Incorporating regular PA into daily life is essential not only for primary prevention but also for secondary prevention in individuals with a history of CVD. Healthcare professionals should continue to advocate for personalized exercise regimens, address barriers to PA, and create supportive environments that help individuals of all ages lead active lifestyles.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding Sources

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Authors' Contribution

Study Conception: RJ, PM, TS, KK, PG, BD; Study Design: RJ, PM, TS, KK, PG, BDC; Literature Review: PB; Critical Review: TS, PM; Writer: KK, BD, PG.

REFERENCES

1. Tsao CW, Aday AW, Almarzooq ZI, Allen NB, Armstrong PW, Bittencourt MS, Bozkurt B, Burch AE, Das SR, Deen JF, Elkind MSV, Evenson KR, Eze-Nliam CM, Ferguson JF, Generoso G, Ho JE, Kalani R, Khan SS, Kissela BM, Knutson KL, Levine DA, Lewis TT, Liu J, Loop MS, Ma J, Mussolino ME, Navaneethan SD, Perak AM, Poudel R, Rezk-Hanna M, Roth GA, Schroeder EB, Shah NS, Thacker EL, VanWagner LB, Virani SS, Voecks JH, Wang NY, Wong ND, Yancy CW, Martin SS. Heart Disease and Stroke Statistics—2023 Update: A Report From the American Heart Association. Circulation. 2023 Apr 18;147(8). doi: 10.1161/cir.0000000000001123.
2. Mokdad AH. Actual Causes of Death in the United States, 2000. JAMA. 2004 Mar 10;291(10):1238. doi: 10.1001/jama.291.10.1238.
3. Mury P, Faes C, Millon A, Mura M, Renoux C, Skinner S, Nicaise V, Joly P, Della Schiava N, Lermusiaux P, Connes P, Pialoux V. Higher Daily Physical Activity Level Is Associated with Lower RBC Aggregation in Carotid Artery Disease Patients at High Risk of Stroke. Front Physiol. 2017 Dec 12;8:1043. doi: 10.3389/fphys.2017.01043.
4. Stensvold D, Viken H, Steinshamn SL, Dalen H, Støylen A, Loennechen JP, Reitlo LS, Zisko N, Salvesen Ø, Ingul CB, Slørdahl SA, Wisloff U. Higher Daily Physical Activity Level Is Associated with Lower RBC Aggregation in Carotid Artery Disease Patients at High Risk of Stroke. Front Physiol. 2017 Aug 21;8:1043. doi: 10.3389/fphys.2017.01043.
5. World Health Organization: WHO. Physical activity. Published May 17, 2019. Available from: https://www.who.int/health-topics/physical-activity#tab=tab_1.
6. Miko HC, Zillmann N, Ring-Dimitriou S, Dorner TE, Titze S, Bauer R. [Effects of Physical Activity on Health]. Gesundheitswesen. 2020;82(S 03):S184-S195. doi: 10.1055/a-1217-0549.
7. Mayo Clinic. Exercise intensity: How to measure it. Mayo Clinic. Published June 17, 2021. Available from: https://www.mayoclinic.org/healthy-lifestyle/fitness/in-depth/exercise-intensity/art-20046887.
8. Schwendinger. Intensity or volume: the role of physical activity in longevity. Eur J Prev Cardiol. Published online 2024. doi: 10.1093/eurjpc/zwae295.
9. Shelley J, Boddy LM, Knowles ZR, Stewart CE, Dawson EA. Physical activity and associations with clinical outcome measures in adults with cystic fibrosis; a systematic review. J Cyst Fibros. 2019 Sep;18(5):590-601. doi: 10.1016/j.jcf.2019.03.003.
10. Mendes MA, da Silva I, Ramires V, Reichert FF, Martins RC, Ferreira RW, Tomasi E, Hallal PC. Metabolic equivalent of task (METs) thresholds as an indicator of physical activity intensity. PLoS One. 2018 Jul 19;13(7):e0200701. doi: 10.1371/journal.pone.0200701.
11. Guo Z, Li M, Cai J, Gong W, Liu Y, Liu Z. Effect of High-Intensity Interval Training vs. Moderate-Intensity Continuous Training on Fat Loss and Cardiorespiratory Fitness in the Young and Middle-Aged: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2023 Mar 25;20(6):4741. doi: 10.3390/ijerph20064741.
12. Sharman JE, La Gerche A, Coombes JS. Exercise and Cardiovascular Risk in Patients With Hypertension. Am J Hypertens. 2014 Feb;28(2):147-158. doi: 10.1093/ajh/hpu191.
13. Boutcher SH. High-Intensity Intermittent Exercise and Fat Loss. J Obes. 2011;2011:868305. doi: 10.1155/2011/868305.
14. Cao M, Tang Y, Li S, Zou Y. Effects of High-Intensity Interval Training and Moderate-Intensity Continuous Training on Cardiometabolic Risk Factors in Overweight and Obese Children and Adolescents: A Meta-Analysis of Randomized Controlled Trials. Int J Environ Res Public Health. 2021 Nov 18;18(22):11905. doi: 10.3390/ijerph182211905.

15. Wernhart S, Dinic M, Pressler A, Halle M. Prävention kardiovaskulärer Erkrankungen durch Sport und körperliche Aktivität. Herz. 2015 Mar;40(3):361-368. doi: 10.1007/s00059-015-4216-4.
16. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, Carty C, Chaput JP, Chastin S, Chou R, Dempsey PC, DiPietro L, Ekelund U, Firth J, Friedenreich CM, Garcia L, Gichu M, Jago R, Katzmarzyk PT, Lambert EV, Leitzmann M, Milton K, Ortega FB, Ranasinghe C, Stamatakis E, Tiedemann A, Troiano RP, van der Ploeg HP, Wari V, Willumsen JF. World Health Organization 2020 Guidelines on Physical Activity and Sedentary Behaviour. Br J Sports Med. 2020 Dec;54(24):1451-1462. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7719906/.
17. Azar AM II, U.S. Department of Health and Human Services, Olson RD, et al. Physical Activity Guidelines for Americans. 2nd ed. U.S. Department of Health and Human Services; 2018. Available from: https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf.
18. Tsukiyama Y, Ito T, Nagaoka K, Eguchi E, Ogino K. Effects of exercise training on nitric oxide, blood pressure and antioxidant enzymes. J Clin Biochem Nutr. 2017 Dec;60(3):180-186. doi: 10.3164/jcbn.16-108.
19. Oliveira V, Akamine EH, Carvalho MH, Michelini LC, Fortes ZB, Cunha TS, Franco MC. Influence of aerobic training on the reduced vasoconstriction to angiotensin II in rats exposed to intrauterine growth restriction: possible role of oxidative stress and AT2 receptor of angiotensin II. PLoS One. 2014 Nov 18;9(11):e113035. doi: 10.1371/journal.pone.0113035.
20. Tofighi A, Rahmani F, Jamali Qarakhanlou B, Babaei S. The effect of regular aerobic exercise on reverse cholesterol transport A1 and apo lipoprotein a-I gene expression in inactive women. Iran Red Crescent Med J. 2015 Apr 25;17(4):e26321. doi: 10.5812/ircmj.17(4)2015.26321.
21. Frodermann V, Rohde D, Courties G, Severe N, Schloss MJ, Amatullah H, McAlpine CS, Cremer S, Bode C, Subramanian A, Iwamoto Y, Tricot B, Kohler RH, Arnal-Estapé A, Hulsmans M, Honold L, Wojtkiewicz GR, Masson GS, Kuppe C, Schloss MJ, Libby P, Swirski FK, Nahrendorf M. Exercise reduces inflammatory cell production and cardiovascular inflammation via instruction of hematopoietic progenitor cells. Nat Med. 2019 Nov;25(11):1761-1771. doi: 10.1038/s41591-019-0633-x.
22. Heber S, Volf I. Effects of Physical (In)activity on Platelet Function. Biomed Res Int. 2015;2015:165078. doi: 10.1155/2015/165078.
23. McGee SL, Hargreaves M. Exercise performance and health: Role of GLUT4. Free Radic Biol Med. 2024 Sep 6. doi: 10.1016/j.freeradbiomed.2024.09.004.
24. Fiuza-Luces C, Santos-Lozano A, Joyner MJ, Carrera-Bastos P, Picazo O, Zugaza JL, Izquierdo M, Ruilope LM, Lucia A. Exercise benefits in cardiovascular disease: beyond attenuation of traditional risk factors. Nat Rev Cardiol. 2018 Dec;15(12):731-743. doi: 10.1038/s41569-018-0065-1.
25. Besnier F, Labrunée M, Pathak A, Pavy-Le Traon A, Sénard JM, Galès C. Exercise training-induced modification in autonomic nervous system: An update for cardiac patients. Ann Phys Rehabil Med. 2017 Jan;60(1):27-35. doi: 10.1016/j.rehab.2016.07.002.
26. Miller LE, McGinnis GR, Peters BA, Biela LM, Whittaker P, Walker LA, Hollander JM, Angelos MG, Stowe DF, Downey JM, Headrick JP, Camara AK. Involvement of the δ-opioid receptor in exercise-induced cardioprotection. Exp Physiol. 2015 Apr;100(4):410-421. doi: 10.1113/expphysiol.2014.083436.
27. Gebel K, Ding D, Chey T, Stamatakis E, Brown WJ, Bauman AE. Effect of Moderate to Vigorous Physical Activity on All-Cause Mortality in Middle-aged and Older Australians. JAMA Intern Med. 2015 Jun;175(6):970-977. doi: 10.1001/jamainternmed.2015.0541.
28. Martinez MW, Kim JH, Shah AB, Thompson PD, Reiffel JA, Baggish AL. Exercise-Induced Cardiovascular Adaptations and Approach to Exercise and Cardiovascular Disease: JACC State-of-the-Art Review. J Am Coll Cardiol. 2021 Oct 5;78(14):1453-1470. doi: 10.1016/j.jacc.2021.08.003.
29. Mekary RA, Grøntved A, Després JP, De Moura LP, Willett WC, Hu FB. Weight training, aerobic physical activities, and long-term waist circumference change in men. Obesity (Silver Spring). 2015 Feb;23(2):461-467. doi: 10.1002/oby.20949.
30. Qin R, Murakoshi N, Xu D, Sato H, Li H, Zhang Y, Horie M. Exercise training reduces ventricular arrhythmias through restoring calcium handling and sympathetic tone in myocardial infarction mice. Physiol Rep. 2019 Apr;7(4):e13972. doi: 10.14814/phy2.13972.
31. 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. 2021 Oct;290(4):789-805. doi: 10.1111/joim.13344.
32. Hu J, Zhou S, Ryu S, Adams K, Gao Z. Effects of Long-Term Endurance Exercise on Cardiac Morphology, Function, and Injury Indicators among Amateur Marathon Runners. Int J Environ Res Public Health. 2023 Jan 31;20(3):2600. doi: 10.3390/ijerph20032600.
33. Bonekamp NE, May AM, Halle M, Dorresteijn JAN, van der Meer MG, Ruigrok YM, de Borst GJ, Geleijnse JM, Visseren FLJ, Koopal C. Physical exercise volume, type, and intensity and risk of all-cause mortality and cardiovascular events in patients with cardiovascular disease: a mediation analysis. Eur Heart J Open. 2023 Jun 13;3(3):oead057. doi: 10.1093/ehjopen/oead057.
34. Lavie CJ, Ozemek C, Carbone S, Katzmarzyk PT, Blair SN. Sedentary Behavior, Exercise, and Cardiovascular

Health. Circ Res. 2019 Mar 1;124(5):799-815. doi: 10.1161/CIRCRESAHA.118.312669.
35. Banach M, Lewek J, Surma S, Penson PE, Sahebkar A, Martin SS, Bajraktari G, Henein MY, Reiner Ž, Bielecka-Dąbrowa A, Bytyçi I. The association between daily step count and all-cause and cardiovascular mortality: a meta-analysis. Eur J Prev Cardiol. 2023 Dec 21;30(18):1975-1985. doi: 10.1093/eurjpc/zwad229. Erratum in: Eur J Prev Cardiol. 2023 Dec 21;30(18):2045. doi: 10.1093/eurjpc/zwad263.
36. Wang Y, Nie J, Ferrari G, Rey-Lopez JP, Rezende LFM. Association of Physical Activity Intensity With Mortality: A National Cohort Study of 403 681 US Adults. JAMA Intern Med. 2021 Feb 1;181(2):203-211. doi: 10.1001/jamainternmed.2020.6331.
37. Rey Lopez JP, Gebel K, Chia D, Stamatakis E. Associations of vigorous physical activity with all-cause, cardiovascular and cancer mortality among 64 913 adults. BMJ Open Sport Exerc Med. 2019 Aug 12;5(1):e000596. doi: 10.1136/bmjsem-2019-000596.
38. López-Bueno R, Ahmadi M, Stamatakis E, Yang L, Del Pozo Cruz B. Prospective Associations of Different Combinations of Aerobic and Muscle-Strengthening Activity With All-Cause, Cardiovascular, and Cancer Mortality. JAMA Intern Med. 2023 Sep 1;183(9):982-990. doi: 10.1001/jamainternmed.2023.3093.
39. Mu X, Liu S, Fu M, Luo M, Ding D, Chen L, Yu K. Associations of physical activity intensity with incident cardiovascular diseases and mortality among 366,566 UK adults. Int J Behav Nutr Phys Act. 2022 Dec 13;19(1):151. doi: 10.1186/s12966-022-01393-y.
40. Wahid A, Manek N, Nichols M, Kelly P, Foster C, Webster P, Kaur A, Friedemann Smith C, Wilkins E, Rayner M, Roberts N, Scarborough P. Quantifying the Association Between Physical Activity and Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis. J Am Heart Assoc. 2016 Sep 14;5(9):e002495. doi: 10.1161/JAHA.115.002495.
41. Jeong SW, Kim SH, Kang SH, Kim HJ, Yoon CH, Youn TJ, Chae IH. Mortality reduction with physical activity in patients with and without cardiovascular disease. Eur Heart J. 2019 Nov 14;40(43):3547-3555. doi: 10.1093/eurheartj/ehz564.
42. Kim MH, Sung JH, Jin MN, Jang E, Yu HT, Kim TH, Pak HN, Lee MH, Lip GYH, Yang PS, Joung B. Impact of Physical Activity on All-Cause Mortality According to Specific Cardiovascular Disease. Front Cardiovasc Med. 2022 Feb 4;9:811058. doi: 10.3389/fcvm.2022.811058.
43. Swain DP, Franklin BA. Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. Am J Cardiol. 2006 Jan 1;97(1):141-7. doi: 10.1016/j.amjcard.2005.07.130.
44. Margolis G, Cohen O, Roguin A. Vigorous physical activity and atrial fibrillation in healthy individuals: What is the correct approach? Clin Cardiol. 2024;47(3):e24237. doi: 10.1002/clc.24237.
45. Pelliccia A, Sharma S, Gati S, Bäck M, Börjesson M, Caselli S, Collet JP, Corrado D, Drezner JA, Halle M, Hansen D, Heidbuchel H, Myers J, Niebauer J, Papadakis M, Piepoli MF, Prescott E, Roos-Hesselink JW, Graham Stuart A, Taylor RS, Thompson PD, Tiberi M, Vanhees L, Wilhelm M; ESC Scientific Document Group. 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease. Eur Heart J. 2021 Jan 1;42(1):17-96. doi: 10.1093/eurheartj/ehaa605. Erratum in: Eur Heart J. 2021 Feb 1;42(5):548-549. doi: 10.1093/eurheartj/ehaa835.
46. Dempsey PC, Rowlands AV, Strain T, Zaccardi F, Dawkins N, Razieh C, Davies MJ, Khunti KK, Edwardson CL, Wijndaele K, Brage S, Yates T. Physical activity volume, intensity, and incident cardiovascular disease. Eur Heart J. 2022 Dec 7;43(46):4789-4800. doi: 10.1093/eurheartj/ehac613.
47. Yarizadeh H, Eftekhar R, Anjom-Shoae J, Speakman JR, Djafarian K. The Effect of Aerobic and Resistance Training and Combined Exercise Modalities on Subcutaneous Abdominal Fat: A Systematic Review and Meta-analysis of Randomized Clinical Trials. Adv Nutr. 2021 Feb 1;12(1):179-196. doi: 10.1093/advances/nmaa090.