TURKISH JOURNAL OF INTERNAL MEDICINE

ISSN:2687-4245

Cardiovascular Medicine and Haematology

Physical therapy and the arrhythmias: The potential benefits and challenges of their kinship

FNU Anamika[1], Vaidehi Mendpara[2], Sakshi Sachdeva[3], Kinna Parikh[4], Sai Gautham Kanagala[5], Shreya Garg[6], Nikita Garg[7], Rohit Jain[8]

[1]MBBS, University college of Medical Sciences, New Delhi, India
[2]MBBS, Government Medical College, Surat, Gujarat, India
[3]MPT Neurology, Jamia Hamdard Deemed to be University, New Delhi, India
[4]MD, Western Reserve Health Education, Ohio, United States
[5]MD, NYC Health + Hospitals/Metropolitan, New York, United States
[6]MBBS, Dayanand Medical College and Hospital, Ludhiana, India
[7]MD, Children's Hospital of Michigan, Detroit, USA
[8]MD, Penn State Health Milton S. Hershey Medical Center, Pennsylvania, United States

ABSTRACT

Cardiovascular disease is the primary cause of mortality in the United States, and cardiac arrhythmias are a common cause of hospital admission with significant mortality and morbidity. Cardiovascular diseases significantly burden the healthcare system, with high costs associated with hospitalization, medication, and ongoing management. By finding cost-effective methods to prevent and treat cardiovascular diseases, healthcare resources can be allocated more efficiently, ultimately improving health outcomes and reducing the burden on the healthcare system. Exercise therapy is a low-cost intervention that can be done without expensive equipment or medical procedures. Exercise therapy can help decrease risk factors for heart disease, including high blood pressure, obesity, and high cholesterol, by improving overall fitness and reducing chronic inflammation. Over time, there have been concerns about exercise-induced arrhythmia because it can reduce physical activity among patients with arrhythmia. In this review, we emphasized the beneficial effects of physical activity on arrhythmia patients.

Turk J Int Med 2024;6(3):114-120
DOI: 10.46310/tjim.1398372
Review

Keywords: *Arrhythmia, physical activity, atrial fibrillation, cardiovascular diseases, physical activity, metabolic equivalent of task*

Received: *November 30, 2023;* ***Accepted:*** *May 29, 2024;* ***Published Online:*** *July 29, 2024*

How to cite this article: *Anamika F, Mendpara V, Sachdeva S, Parikh K, Kanagala SC, Garg S, Garg N, Jain R. Physical therapy and the arrhythmias: The potential benefits and challenges of their kinship. Turk J Int Med 2024;6(3):114-120. DOI: 10.46310/tjim.1398372*

Address for Correspondence:
FNU Anamika, University College of Medical Sciences, New Delhi-110095, India

INTRODUCTION

Cardiovascular disease (CVD) is the primary cause of mortality in the United States, resulting in the death of one person every 34 seconds. In 2020, it claimed the lives of almost 697,000 people, accounting for 1 in 5 fatalities.[1] An abnormality with the rate or rhythm of the heartbeat is known as arrhythmia, and common symptoms include chest pain, palpitations, dizziness, weakness, and shortness of breath. Atrial fibrillation (AF), the most common arrhythmia, affects three to six million people in the United States, and it is the primary diagnosis in more than 454,000 hospital admissions annually.[2,3] By 2030, it is projected that AF will impact around 12.1 million individuals in the United States.[3] This necessitates more effective and innovative techniques to diagnose, treat, and prevent cardiovascular disorders. Exercise therapy is crucial in preventing and treating CVD. Exercise therapy is a structured form of physical activity that is carried out to achieve certain physical benefits. These benefits may include maintaining range of motion, strengthening muscles, increasing joint flexibility, or improving cardiovascular and pulmonary function.[4] According to the Physical Activity Guidelines for Americans (PAG), physical activity can be categorised as mild, moderate, or high intensity based on specific levels of energy expenditure (Table 1). The expression of energy expenditure is done using multiples of the metabolic equivalent of task (MET), with 1 MET being the rate of energy expenditure while in a sedentary position. Non-sedentary walking behaviour that requires less than 3.0 MET is considered light-intensity activity. 3.0 to fewer than 6.0 METs are required for moderate-intensity exercise, and vigorous activity needs 6.0 or more METs. The PAG suggest engaging in a minimum of 150 minutes (2 hours and 30 minutes) to 300 minutes (5 hours) of moderate-intensity aerobic exercise per week. Alternatively, one can opt for 75 minutes (1 hour and 15 minutes) to 150 minutes (2 hours and 30 minutes) of vigorous-intensity aerobic exercise per week. Another option is to combine both moderate- and vigorous-intensity aerobic activities equivalently.5 The EXPERT (Exercise Prescription in Everyday Practice and Rehabilitative Training) tool is an interactive, computerised system designed to provide healthcare practitioners with the ability to prescribe exercise training programs that are both clinically beneficial and medically safe for individuals with CVD.[6]

Physical exercise and cardiac health have a well-established association. Cardiovascular diseases can be prevented and treated through vigorous participation in physical activities, exercise, and achieving optimal cardiorespiratory fitness (CRF). CRF is the ability of the circulatory and respiratory systems to deliver oxygen to the mitochondria in skeletal muscles, which is necessary for energy production during physical activity.[7,8] Promoting regular moderate-to-vigorous physical activity in healthy individuals and most patients with cardiovascular illnesses is advisable. This is because such activity has positive benefits in reducing the burden of risk factors (such as obesity, hypertension, and hyperlipidemia), enhancing overall well-being, and decreasing mortality rates.[9]

Recent studies have explored the correlation between physical activity and AF, indicating that the most physically active individuals exhibit a reduced incidence of AF. For instance, participants with the highest physical activity levels in the Cardiovascular Health Study experienced a 46% lower incidence of AF than their sedentary counterparts.10 The analysis conducted by Ortega-Moral *et al.*[11] reported a significant improvement in resting heart rate, maximum exercise capacity, and vO_2 peak (maximum oxygen uptake) in patients with AF. A separate investigation by Malmo *et al.*[12] determined that a twelve-week aerobic interval training regimen diminishes AF duration in individuals with non-permanent AF. Furthermore, this training is linked to a notable enhancement in AF symptoms, O2 peak (peak oxygen consumption), left atrial and ventricular function, cholesterol levels, and overall quality of life.[13] Medical interventions concern disease causation and disease processes, whereas rehabilitation, which includes most aspects of physical activity, concerns disease consequences. Its goals are to improve symptoms, function, and quality of life.[13] While moderate exercise benefits cardiovascular health, long-term endurance sports practice is associated with a higher risk of symptomatic lone AF.[14] Due to their dread of exercise-induced episodes of AF, people with AF

Table 1. Light, moderate and vigorous intensity physical activities based on the MET[5]

Intensity	MET	Examples
Light	less than 3	walking at a slow pace, cooking
Moderate	3 to less than 6	walking briskly, raking the yard
Vigorous	6 or more	running, jogging

MET: Multiples of the metabolic equivalent of task.

are more likely to lead sedentary lifestyles; however, to maintain a healthy lifestyle, AF patients should engage in physical activity.[15] Physical activity can help to create a bridge between sedentary lifestyles and strenuous exercise that will enhance physical activity without raising the risk of arrhythmia.

Pathophysiology

One of the most effective ways to improve one's health is to engage in physical activity, which can take various forms, ranging from endurance to resistance training. According to the training specificity principle, multiple forms of exercise bring about a unique set of physiological adaptations in the body. In general, endurance exercises improve aerobic energy metabolism and fatigue resistance, whereas resistance training improves muscle hypertrophy and the body's capacity to generate force.[16,17]

On the other hand, interval training consists of shorter bouts of exercise interspersed with periods of rest. Interval training without body weight increases mitochondrial content and peak aerobic capacity (vO_2 max)[18], while interval training using bodyweight resistance exercise increases vO_2 max and muscular strength.[19] Long-term effects of any exercise typically result in brainstem cardiovascular activation, which modulates hemodynamic status during exercise by integrating signals originating from the brain and inducing an increase in blood volume, stroke volume, cardiac output, and vO_2 max along with a reduction in resting heart rate and blood pressure.[20]

Disruptions in the sympathetic and/or parasympathetic nervous systems of the autonomic nervous system (ANS) can cause cardiac arrhythmias. AF is thought to be caused by the simultaneous activation of both the sympathetic and parasympathetic systems. In contrast, ventricular fibrillation or ventricular tachycardia is believed to be caused by increased sympathetic stimulation. Stimulation of the sympathetic system is linked to the occurrence of ventricular tachycardia, which can cause irregular heart rhythms and, in severe instances, cardiac death in hereditary arrhythmia syndromes, including long QT and catecholaminergic polymorphic ventricular tachycardia. There is increasing evidence that altering the ANS can be a safe and effective treatment method for managing cardiac arrhythmias.[21] A delicate balance in these two limbs of the ANS is required to maintain arrhythmia. Several ANS-modulating interventions have been developed over the years to prevent and manage arrhythmias, in addition to traditional drug therapies such as beta-blockers.[22] It is well established that both endurance and resistance exercises can alter autonomic nervous system activity, increasing cardiac parasympathetic tone and decreasing sympathetic activity.[23] This has a positive effect on the prognosis of individuals who suffer from a variety of morbidities. When compared to other forms of exercise, resistance training has a more profound impact on both sympathetic and parasympathetic activities, especially among middle-aged women.[24] Researchers found that in a study using dogs as a model for sudden death, endurance exercise training enhanced the regulation of the parasympathetic nervous system in the heart, normalised the balance of beta-adrenoceptors (specifically, reducing sensitivity and expression of beta(2)-adrenoceptors), and provided protection against ventricular fibrillation resulting from acute myocardial ischemia. Exercise training may enhance cardiac electrical stability in individuals identified as having a heightened risk of sudden cardiac death.[22]

The complex interaction between the sympathetic and parasympathetic (vagal) limbs of the ANS regulates Ca2+ ion release and reuptake by the sarcoplasmic reticulum, leading to rhythmic contraction and heart relaxation.[25] Sympathetic stimulation causes depolarisation of the surface membrane and transverse tubule, which opens the L-type Ca channels located in them. A little amount of Ca2+ is thus introduced, and this causes a significant rise in [Ca2+] in the dyadic space (the region bounded by the t-tubule and sarcoplasmic reticulum [SR]), which makes the SR Ca2+ release channel (ryanodine receptors [RyR]) open up, causing the influx of a more significant amount of calcium from the SR in a process called calcium-induced calcium release. This calcium now binds to the troponin, which causes the sliding of thick and thin filaments, causing the cell to shorten, which causes the heart to contract. Activation of the parasympathetic nervous system causes Ca2+ to withdraw from the cytoplasm. To achieve this, RyRs close and Ca2+ is pushed back into the SR by the SR Ca-ATPase and pushed out of the cell, mostly via sodium-calcium exchange (NCX). Abnormalities in this intracellular Ca2+ handling are another mechanism that can lead to contractile dysfunction and/or trigger tachyarrhythmias. Several diseases, including heart failure and myocardial infarction, are known to cause dysregulated SR Ca2+ release, which can lead to malignant arrhythmias.[26,27]

Regular physical exercise normalises repolarisation and calcium-handling abnormalities that contribute to the onset of cardiac arrhythmias through changes in the expression of calcium-handling genes.[28] This results in a lower incidence of arrhythmia among exercise-perform-

ing individuals.

Aside from the positive effects, some studies have discovered that exercise has a negative impact on the heart, predisposing healthy individuals to arrhythmia. Exercise training causes significant changes in cardiac physiology and structure, which are referred to collectively as the "athlete's heart."[29] Exercise has been shown to increase parasympathetic tone, and parasympathetic tone shortens the atrial refractory period, allowing for easier re-entry formation and AF formation, contributing to exercise-induced arrhythmia.[30] Long-term exercise and physical activity cause a variety of structural changes. Atrial structural remodelling includes atrial dilatation as well as modifications in tissue properties and ultrastructure. Atrial enlargement is a recognised consequence of endurance exercise training that predisposes to AF. Despite evidence linking endurance exercise to AF, current guidelines do not recommend routine AF screening in athletes.[31] Therefore, patients with exercise-induced arrhythmias must be evaluated and handled appropriately before starting any physical activity.

DISCUSSION

Regular physical activity and high CRF contribute to lower AF incidence. There are some small but significant monitors for the benefits of exercise. Although the risk of cardiovascular disease has reduced and life expectancy has improved with the recommended guidelines[32], the risk of sudden cardiac death may be transiently increased during and just after exercise[33], specifically in patients with unidentified cardiovascular risk factors or so-called "silent" coronary artery disease. Progressive right ventricular remodelling may be another cause of exercise-induced ventricular arrhythmia in a small subset of athletes.[34-36] According to Guasch *et al.*[37], regular endurance exercise over a long period seems to elevate the risk of atrial arrhythmias despite indications of lower mortality in the same cohort. Despite a reduction in cardiovascular disease incidence overall, exercise-induced changes in autonomic tone, as well as the development of an arrhythmogenic atrial substrate, appear to contribute to an excess of AF among athletes.[37]

Exercise-based cardiac rehabilitation aims to improve the health of people who have arrhythmia or have been treated for it by getting them to exercise regularly.[38] Patients with exercise-induced arrhythmias should be evaluated and treated as needed.[31] It is generally advisable to gradually and progressively increase exercise intensity while avoiding intense sessions that could immediately activate the sympathetic system and suppress vagal activity. This helps reduce the risk of ventricular fibrillation. On the contrary, habitual vigorous exercise leads to the dominance of the parasympathetic system, which enhances cardiac electrical stability and consequent protection against life-threatening ventricular arrhythmias and modifies the cardiovascular risk by positively affecting lipid levels or reducing the hemodynamic stress on underlying ischemic heart disease.[29] Exercise intolerance and poor quality of life are two hallmarks of AF, particularly when comorbid with conditions like heart failure, diabetes, or valvular heart disease. To this purpose, and considering that regular exercise improves functioning capacity and reduces fatigue, it is generally beneficial to inculcate exercise training in treating AF patients whose HR is appropriately controlled. First, we note that limited prospective randomised controlled trials explain the effects of exercise rehabilitation on individuals with AF. AF is a readily diagnosable condition with well-established treatment guidelines. Even though AF is common among patients involved in rehabilitation programs, few controlled trials employ conventional laboratory procedures and endpoints to assess the usability and efficacy of exercise testing and training in these patients.[39] To evaluate the effectiveness of exercise-based therapies, additional randomised clinical studies with minimal risks of bias and chance must be done in a larger patient group with AF.[38]

CONCLUSIONS

Physical activity and exercise have been widely recognised as beneficial for cardiac health. Despite individuals with AF being potentially more capable of engaging in vigorous physical activity, their arrhythmias frequently disrupt such activities, leading to reduced physical exertion. Paradoxically, this diminished physical activity also contributes to their cardiovascular health benefits. Physical activity and exercise can help maintain a delicate balance in the autonomic nervous system, reducing the risk of cardiac arrhythmias and improving cardiovascular health. Through its effect on the ANS, exercise training can help patients with cardiac arrhythmia, and it may improve the electrical stability of the heart by normalis-

ing the repolarisation and Ca-handling abnormalities that can lead to arrhythmia. More research is needed to fully understand the effect of physical activity on cardiac arrhythmia and help patients with this condition.

Future Perspectives

- With advances in technology and data analysis, exercise regimens can be customised to each individual's specific needs and health conditions. This will help decrease the risk of exercise-induced arrhythmias and optimise the preventive effects of physical activity.
- Further research will explore the effect of different exercise modes (high-intensity interval training and resistance training) and the optimal exercise dose, leading to more effective preventive exercise regimens for arrhythmia.
- In the future, exercise may be incorporated as a critical component of an integrated approach to arrhythmia management, along with medical treatments and modifications to risk factors such as diet and stress management. This comprehensive approach will help control arrhythmias more effectively and reduce the burden on individuals and healthcare systems.

Authors' Contribution

Study Conception: FA, VM, SS, KP, SGK, SG, NG, RJ; Study Design: FA, VM, SS, KP, SGK, SG, NG, RJ; Literature Review: FA, VM, SS, KP, SGK, SG, NG, RJ; Supervision: NG, RJ; Critical Review: SGK, SG, NG, RJ; Manuscript preparing: FA, VM, SS, KP.

REFERENCES

1. Heart disease facts. Centers for Disease Control and Prevention. Available at: https://www.cdc.gov/heartdisease/facts.htm. Published October 14, 2022. Accessed February 8, 2023.
2. Kornej J, Börschel CS, Benjamin EJ, Schnabel RB. Epidemiology of atrial fibrillation in the 21st Century: Novel methods and new insights. Circ Res. 2020 Jun 19;127(1):4-20. doi: 10.1161/CIRCRESAHA.120.316340.
3. Atrial fibrillation (2022). Centers for Disease Control and Prevention. Centers for Disease Control and Prevention. Available at: https://www.cdc.gov/heartdisease/atrial_fibrillation.htm. Accessed February 8, 2023.
4. Larun L, Brurberg KG, Odgaard-Jensen J, Price JR. Exercise therapy for chronic fatigue syndrome. Cochrane Database Syst Rev. 2017 Apr 25;4(4):CD003200. doi: 10.1002/14651858.CD003200.pub7.
5. 2018 Physical Activity Guidelines Advisory Committee. 2018 Physical Activity Guidelines Advisory Committee Scientific Report. February 2018. Washington, DC: U.S. Department of Health and Human Services, 2018. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://health.gov/sites/default/files/2019-09/PAG_Advisory_Committee_Report.pdf. Accessed February 8, 2023.
6. Hansen D, Dendale P, Coninx K, Vanhees L, Piepoli MF, Niebauer J, Cornelissen V, Pedretti R, Geurts E, Ruiz GR, Corrà U, Schmid JP, Greco E, Davos CH, Edelmann F, Abreu A, Rauch B, Ambrosetti M, Braga SS, Barna O, Beckers P, Bussotti M, Fagard R, Faggiano P, Garcia-Porrero E, Kouidi E, Lamotte M, Neunhäuserer D, Reibis R, Spruit MA, Stettler C, Takken T, Tonoli C, Vigorito C, Völler H, Doherty P. The European Association of Preventive Cardiology Exercise Prescription in Everyday Practice and Rehabilitative Training (EXPERT) tool: A digital training and decision support system for optimized exercise prescription in cardiovascular disease. Concept, definitions and construction methodology. Eur J Prev Cardiol. 2017 Jul;24(10):1017-31. doi: 10.1177/2047487317702042.
7. Lavie CJ, Arena R, Swift DL, Johannsen NM, Sui X, Lee DC, Earnest CP, Church TS, O'Keefe JH, Milani RV, Blair SN. Exercise and the cardiovascular system: clinical science and cardiovascular outcomes. Circ Res. 2015 Jul 3;117(2):207-19. doi: 10.1161/CIRCRESAHA.117.305205.
8. Raghuveer G, Hartz J, Lubans DR, Takken T, Wiltz JL, Mietus-Snyder M, Perak AM, Baker-Smith C, Pietris N, Edwards NM; American Heart Association Young Hearts Athero, Hypertension and Obesity in the Young Committee of the Council on Lifelong Congenital Heart Disease and Heart Health in the Young. Cardiorespiratory Fitness in Youth: An Important Marker of Health: A Scientific Statement From the American Heart Association. Circulation. 2020 Aug 18;142(7):e101-18. doi: 10.1161/CIR.0000000000000866.
9. Guasch E, Mont L. Diagnosis, pathophysiology,

and management of exercise-induced arrhythmias. Nat Rev Cardiol. 2017 Feb;14(2):88-101. doi: 10.1038/nrcardio.2016.173.
10. Mozaffarian D, Furberg CD, Psaty BM, Siscovick D. Physical activity and incidence of atrial fibrillation in older adults: the cardiovascular health study. Circulation. 2008 Aug 19;118(8):800-7. doi: 10.1161/CIRCULATIONAHA.108.785626.
11. Ortega-Moral A, Valle-Sahagún B, Barón-Esquivias G. Efficacy of exercise in patients with atrial fibrillation: Systematic review and meta-analysis. Med Clin (Barc). 2022 Oct 28;159(8):372-9. doi: 10.1016/j.medcli.2021.11.013.
12. Malmo V, Nes BM, Amundsen BH, Tjonna AE, Stoylen A, Rossvoll O, Wisloff U, Loennechen JP. Aerobic interval training reduces the burden of atrial fibrillation in the short term: A randomized trial. Circulation. 2016 Feb 2;133(5):466-73. doi: 10.1161/CIRCULATIONAHA.115.018220.
13. Stucki G, Kroeling P. Physical therapy and rehabilitation in the management of rheumatic disorders. Baillieres Best Pract Res Clin Rheumatol. 2000 Dec;14(4):751-71. doi: 10.1053/berh.2000.0111.
14. Molina L, Mont L, Marrugat J, Berruezo A, Brugada J, Bruguera J, Rebato C, Elosua R. Long-term endurance sport practice increases the incidence of lone atrial fibrillation in men: a follow-up study. Europace. 2008 May;10(5):618-23. doi: 10.1093/europace/eun071.
15. Skielboe AK, Bandholm TQ, Hakmann S, Mourier M, Kallemose T, Dixen U. Cardiovascular exercise and burden of arrhythmia in patients with atrial fibrillation - A randomized controlled trial. PLoS One. 2017 Feb 23;12(2):e0170060. doi: 10.1371/journal.pone.0170060.
16. Egan B, Zierath JR. Exercise metabolism and the molecular regulation of skeletal muscle adaptation. Cell Metab. 2013 Feb 5;17(2):162-84. doi: 10.1016/j.cmet.2012.12.012.
17. Hawley JA, Lundby C, Cotter JD, Burke LM. Maximizing cellular adaptation to endurance exercise in skeletal muscle. Cell Metab. 2018 May 1;27(5):962-76. doi: 10.1016/j.cmet.2018.04.014.
18. MacDougall JD, Hicks AL, MacDonald JR, McKelvie RS, Green HJ, Smith KM. Muscle performance and enzymatic adaptations to sprint interval training. J Appl Physiol (1985). 1998 Jun;84(6):2138-42. doi: 10.1152/jappl.1998.84.6.2138.
19. McRae G, Payne A, Zelt JG, Scribbans TD, Jung ME, Little JP, Gurd BJ. Extremely low volume, whole-body aerobic-resistance training improves aerobic fitness and muscular endurance in females. Appl Physiol Nutr Metab. 2012 Dec;37(6):1124-31. doi: 10.1139/h2012-093.
20. Nobrega AC, O'Leary D, Silva BM, Marongiu E, Piepoli MF, Crisafulli A. Neural regulation of cardiovascular response to exercise: role of central command and peripheral afferents. Biomed Res Int. 2014:2014:478965. doi: 10.1155/2014/478965.
21. Franciosi S, Perry FKG, Roston TM, Armstrong KR, Claydon VE, Sanatani S. The role of the autonomic nervous system in arrhythmias and sudden cardiac death. Auton Neurosci. 2017 Jul:205:1-11. doi: 10.1016/j.autneu.2017.03.005.
22. Billman GE. Cardiac autonomic neural remodeling and susceptibility to sudden cardiac death: effect of endurance exercise training. Am J Physiol Heart Circ Physiol. 2009 Oct;297(4):H1171-93. doi: 10.1152/ajpheart.00534.2009.
23. Blomqvist CG, Saltin B. Cardiovascular adaptations to physical training. Annu Rev Physiol. 1983;45:169-89. doi: 10.1146/annurev.ph.45.030183.001125.
24. Lee CK, Lee JH, Ha MS. Comparison of the effects of aerobic versus resistance exercise on the autonomic nervous system in middle-aged women: A Randomized Controlled Study. Int J Environ Res Public Health. 2022 Jul 27;19(15):9156. doi: 10.3390/ijerph19159156.
25. McCorry LK. Physiology of the autonomic nervous system. Am J Pharm Educ. 2007 Aug 15;71(4):78. doi: 10.5688/aj710478.
26. Rubart M, Zipes DP. Mechanisms of sudden cardiac death. J Clin Invest. 2005 Sep;115(9):2305-15. doi: 10.1172/JCI26381.
27. Zipes DP, Rubart M. Neural modulation of cardiac arrhythmias and sudden cardiac death. Heart Rhythm. 2006 Jan;3(1):108-13. doi: 10.1016/j.hrthm.2005.09.021.
28. Qin R, Murakoshi N, Xu D, Tajiri K, Feng D, Stujanna EN, Yonebayashi S, Nakagawa Y, Shimano H, Nogami A, Koike A, Aonuma K, Ieda M. Exercise training reduces ventricular arrhythmias through restoring calcium handling and sympathetic tone in myocardial infarction mice. Physiol Rep. 2019 Feb;7(4):e13972. doi: 10.14814/phy2.13972.
29. Eijsvogels TM, Fernandez AB, Thompson PD. Are there deleterious cardiac effects of acute and

chronic endurance exercise? Physiol Rev. 2016 Jan;96(1):99-125. doi: 10.1152/physrev.00029.2014.
30. Shen MJ, Choi EK, Tan AY, Lin SF, Fishbein MC, Chen LS, Chen PS. Neural mechanisms of atrial arrhythmias. Nat Rev Cardiol. 2011 Sep 27;9(1):30-9. doi: 10.1038/nrcardio.2011.139.
31. Manolis AS, Manolis AA. Exercise and arrhythmias: A double-edged sword. Pacing Clin Electrophysiol. 2016 Jul;39(7):748-62. doi: 10.1111/pace.12879.
32. Lau DH, Linz D, Schotten U, Mahajan R, Sanders P, Kalman JM. Pathophysiology of paroxysmal and persistent atrial fibrillation: Rotors, foci and fibrosis. Heart Lung Circ. 2017 Sep;26(9):887-93. doi: 10.1016/j.hlc.2017.05.119.
33. Mahajan R, Lau DH, Brooks AG, Shipp NJ, Manavis J, Wood JP, Finnie JW, Samuel CS, Royce SG, Twomey DJ, Thanigaimani S, Kalman JM, Sanders P. Electrophysiological, electroanatomical, and structural remodeling of the atria as consequences of sustained obesity. J Am Coll Cardiol. 2015 Jul 7;66(1):1-11. doi: 10.1016/j.jacc.2015.04.058.
34. Elliott AD, Maatman B, Emery MS, Sanders P. The role of exercise in atrial fibrillation prevention and promotion: Finding optimal ranges for health. Heart Rhythm. 2017 Nov;14(11):1713-20. doi: 10.1016/j.hrthm.2017.07.001.
35. Reeves JT, Groves BM, Cymerman A, Sutton JR, Wagner PD, Turkevich D, Houston CS. Operation Everest II: cardiac filling pressures during cycle exercise at sea level. Respir Physiol. 1990 May-Jun;80(2-3):147-54. doi: 10.1016/0034-5687(90)90078-d.
36. Takahashi Y, Jaïs P, Hocini M, Sanders P, Rotter M, Rostock T, Hsu LF, Sacher F, Clémenty J, Haïssaguerre M. Shortening of fibrillatory cycle length in the pulmonary vein during vagal excitation. J Am Coll Cardiol. 2006 Feb 21;47(4):774-80. doi: 10.1016/j.jacc.2005.10.043.
37. Guasch E, Benito B, Qi X, Cifelli C, Naud P, Shi Y, Mighiu A, Tardif JC, Tadevosyan A, Chen Y, Gillis MA, Iwasaki YK, Dobrev D, Mont L, Heximer S, Nattel S. Atrial fibrillation promotion by endurance exercise: demonstration and mechanistic exploration in an animal model. J Am Coll Cardiol. 2013 Jul 2;62(1):68-77. doi: 10.1016/j.jacc.2013.01.091.
38. Risom SS, Zwisler AD, Johansen PP, Sibilitz KL, Lindschou J, Gluud C, Taylor RS, Svendsen JH, Berg SK. Exercise-based cardiac rehabilitation for adults with atrial fibrillation. Cochrane Database Syst Rev. 2017 Feb 9;2(2):CD011197. doi: 10.1002/14651858.CD011197.pub2.
39. Keteyian SJ, Ehrman JK, Fuller B, Pack QR. Exercise testing and exercise rehabilitation for patients with atrial fibrillation. J Cardiopulm Rehabil Prev. 2019 Mar;39(2):65-72. doi: 10.1097/HCR.0000000000000423.