

Pengaruh Latihan Fisik terhadap Residif Fibrilasi Atrium: Studi Meta-Analysis

The Effect of Physical Exercise on the Recurrence of Atrial Fibrillation: A Meta-Analysis

Prastika Dica Izwara^(1*), Muthia Tsabita Rahmi⁽²⁾, Kesowo Soejoko⁽³⁾,
M. Dzikrul Haq Karimullah⁽⁴⁾ & Wirawan Prabowo⁽⁵⁾

¹Faculty of Medicine, Jenderal Soedirman University, Purwokerto, Indonesia

²Faculty of Medicine, Islamic University of Indonesia, Indonesia

³General Practitioner, Kariadi General Hospital, Indonesia

^{4&5}Department of Cardiology and Vascular Medicine, Kediri District General Hospital, Indonesia

Disubmit: 05 Maret 2026; Direview: 06 Mei 2026; Diaccept: 04 Juni 2026; Dipublish: 08 Juni 2026

*Corresponding author: prastikadicha@gmail.com

Abstrak

Bukti mengenai manfaat olahraga terhadap kekambuhan FA setelah terapi masih terbatas. Meta-analisis ini mengevaluasi pengaruh program olahraga terhadap kekambuhan FA. Penelitian-penelitian yang disertakan mengikuti pedoman PRISMA 2020 dan terdaftar di PROSPERO. Pencarian literatur dilakukan di PubMed, Scopus, dan Cochrane Library (2020–2025). Uji klinis acak terkontrol (RCT) pada pasien dewasa dengan AF pasca-pengobatan dan intervensi olahraga ≥ 6 minggu dimasukkan. Hasil utama adalah kekambuhan AF, dengan hasil sekunder berupa VO_2 max dan kualitas hidup. Analisis dilakukan menggunakan RevMan 5.4.1 dengan model efek acak. Sembilan RCT dengan total 760 peserta dianalisis. Durasi intervensi berkisar antara 12 minggu hingga 12 bulan. Meta-analisis terhadap tiga studi (287 peserta) menunjukkan penurunan risiko kekambuhan AF yang signifikan dengan rasio risiko 0,77 [95% CI 0,66–0,89; $p=0,0006$; $I^2=0\%$]. VO_2 max meningkat sebesar 2,77 mL/kg/menit [95% CI 0,59–4,94; $p=0,01$; $I^2=36\%$]. Kualitas hidup membaik dengan selisih rata-rata 4,47 [95% CI 1,41–7,53; $p=0,004$; $I^2=82\%$]. Program olahraga terbukti efektif mengurangi risiko kambuhnya AF sebesar 23%, meningkatkan kapasitas kardiopulmoner, dan meningkatkan kualitas hidup pasien. Olahraga sebaiknya dimasukkan sebagai komponen standar dalam penanganan AF yang komprehensif, bersamaan dengan pengendalian faktor risiko.

Kata Kunci: Fibrilasi Atrium; Residif; Olahraga.

Abstract

Evidence on the benefits of physical exercise on AF recurrence after therapy is still limited. This meta-analysis evaluated the effect of physical exercise programmes on AF recurrence. Studies followed the PRISMA 2020 guidelines and were registered in PROSPERO. Literature searches were conducted in PubMed, Scopus, and the Cochrane Library (2020–2025). RCTs in adult patients with post-treatment AF and exercise interventions ≥ 6 weeks were included. The primary outcome was AF recurrence, with secondary outcomes being VO_2 max and quality of life. Analyses were performed using RevMan 5.4.1 with a random-effects model. Nine RCTs with a total of 760 participants were analysed. The duration of the intervention ranged from 12 weeks to 12 months. A meta-analysis of three studies (287 participants) showed a significant reduction in the risk of AF recurrence with a risk ratio of 0.77 [95% CI 0.66–0.89; $p=0.0006$; $I^2=0\%$]. VO_2 max increased by 2.77 mL/kg/minute [95% CI 0.59–4.94; $p=0.01$; $I^2=36\%$]. Quality of life improved with a mean difference of 4.47 [95% CI 1.41–7.53; $p=0.004$; $I^2=82\%$]. Physical exercise programmes effectively reduce AF recurrence by 23%, improve cardiorespiratory capacity, and enhance patients' quality of life. Physical exercise should be integrated as a standard component in comprehensive AF management alongside risk factor control.

Keywords: Atrial Fibrillation; Recurrence; Physical Exercise.

DOI: <https://doi.org/10.51849/j-p3k.v7i2.982>

Rekomendasi mensitasi :

Izwara, P. D., Rahmi, M. T., Soejoko, K., Karimullah, M. D. H. & Prabowo, W. (2026), *The Effect of Physical Exercise on the Recurrence of Atrial Fibrillation: A Meta-Analysis*. Jurnal Penelitian Pendidikan, Psikologi dan Kesehatan (J-P3K), 7 (2): 64-75.

INTRODUCTION

Atrial fibrillation is the most common cardiac arrhythmia with a continuously increasing global burden. The global prevalence of AF reached 59 million in 2019, a dramatic increase from 33.5 million in 2010, and is projected to reach 17.9 million in Europe by 2060 and 15.9 million in the United States by 2050 (Kornej et al., 2021; Cheng et al., 2024; Schnabel et al., 2022). *The lifetime risk* of developing AF after the age of 45 reaches 1 in 3-5 individuals, increasing to more than 1 in 3 when there is at least one increased risk factor (Kornej et al., 2021; Schnabel et al., 2022; Abed et al., 2024).

Modifiable risk factors such as obesity, hypertension, and physical inactivity play a significant role in the pathogenesis of AF. Weight loss of $\geq 10\%$ in obese patients with AF shows a six-fold reduction in the risk of arrhythmia recurrence and significant improvement in AF (Middeldorp et al., 2018; Pathak et al., 2015; Abed et al., 2019; Chung et al., 2020). Management of risk factors, including weight control, blood pressure control, and glycaemic control, has been shown to reduce the progression of AF from paroxysmal to persistent and improve the success of catheter ablation (Middeldorp et al., 2018; Pathak et al., 2014; Chung et al., 2020; Mohanty et al., 2022).

Cardiorespiratory fitness and physical activity show a complex relationship with AF. Moderate-intensity exercise reduces the incidence and recurrence of AF through improvement of cardiovascular risk factors, reduction of inflammation, and atrial remodelling (Elliott et al., 2023; Pathak et al., 2015; Garnvik et al., 2020). Improved CRF is

associated with a reduced risk of post-ablation arrhythmia recurrence and decreased mortality in AF patients, with each 1 MET (*Metabolic Equivalent of Task*) increase in CRF reducing the risk of mortality by up to 12% (Pathak et al., 2015; Donnellan et al., 2020; Garnvik et al., 2020; Kunutsor et al., 2024). However, high-intensity endurance training in athletes may increase the risk of AF through mechanisms of atrial dilation, fibrosis, and increased vagal tone (Benito et al., 2011; Elliott et al., 2018; D'Ambrosio et al., 2024; Mohanty et al., 2020).

Although evidence suggests the benefits of physical exercise for AF symptoms, data on the effects of exercise interventions on AF recurrence after therapy remain limited and heterogeneous (Elliott et al., 2023; Buckley et al., 2025; Tzeis et al., 2024). Therefore, this meta-analysis aims to evaluate the effect of physical exercise programmes on AF recurrence in patients with atrial fibrillation.

RESEARCH METHOD

This meta-analysis has been registered in *the International Prospective Register of Systematic Reviews* (PROSPERO). The registration number is CRD420251232165.

This review was conducted according to the PRISMA 2020 guidelines. We conducted a literature search from 1 January 2020 to 30 September 2025 in various major databases such as PubMed, Scopus, and Cochrane Library. The search criteria used keywords such as ("Atrial Fibrillation" OR "atrial fibrillation" OR AFib OR AF) AND ("Exercise" OR "physical activity" OR "exercise training" OR

"aerobic exercise" OR "cardiac rehabilitation" OR "physical training" OR "endurance training") AND ("Recurrence" OR recurrence OR recurrent OR relapse OR outcome OR endpoints). Search results were managed using Rayyan.ai, and the reference lists of eligible studies were also examined. Three researchers, Prastika, Muthia, and Kesowo, independently evaluated the studies, and any disagreements were resolved by the other researchers, Dzikrul and Wirawan, to ensure that all relevant studies were included.

All studies were reviewed according to the criteria listed in **Table 1**. The PICO criteria used are described as follows:

The minimum age of participants was 18 years old with AF who had undergone treatment (e.g., catheter ablation or pharmacological therapy for *rate/rhythm control*). Studies were limited to human research, and ages that did not meet the criteria were excluded.

The intervention consists of a structured physical exercise programme (e.g., aerobic exercise, resistance training, or exercise-based cardiac rehabilitation programmes). The minimum duration of the intervention is 6 weeks.

The comparator is standard care. Standard care consists of medication alone, or standard care with catheter ablation. Standard care may be combined with education on diet or physical exercise.

The primary outcome measure of the study is the recurrence rate of AF. Secondary outcomes extracted include VO_2 Max and quality of life assessed using the SF-36 questionnaire.

Only *randomised controlled trials* (RCTs) in English and Indonesian were

included. Observational studies, literature reviews, and studies that only included abstracts without *full text* and inadequate data were excluded.

Table 1. Inclusion and exclusion criteria

P	Adult patients (≥ 18 years) with AF who have undergone treatment (e.g., catheter ablation or pharmacological therapy for <i>rate/rhythm control</i>).
I	Structured and Programmed Physical Exercise (e.g., aerobic exercise, resistance training, or exercise-based cardiac rehabilitation programmes).
C	Standard Care
O	Primary Outcome: Atrial Fibrillation Recurrence Rate Secondary Outcome: Change in VO_2 max (mL/kg/min) Quality of Life
S	RCT

Table 2 Operational Definitions

Data	Operational Definition
Atrial Fibrillation Recurrence	The incidence rate of the return of irregular and rapid heart rhythm after normalisation in patients who have undergone treatments such as catheter ablation or pharmacological management
Change in VO_2 Max	An increase or decrease in the maximum oxygen consumption by an individual during strenuous physical activity, calculated as the difference between post-intervention and pre-intervention values. Measurements can be taken directly in the laboratory or in the field using <i>the Bleep Test</i> , with units of measurement in mL/kg/min
Quality of Life (QoL)	Related to physical health, psychological health, and social relationships using the WHOQOL-BREF standardised instrument
<i>Standard Care</i>	Regular care without additional interventions such as programmed physical exercise. Standard care can be combined with education related to diet

Two researchers, Prastika and Muthia, collected the data, and the results were double-checked by another researcher, Kesowo. The data collected included all basic study characteristics, such as author names, year of publication, study design, gender, age, total sample size and each intervention or comparison, details of physical exercise such as type of exercise, intensity, frequency, and duration, as well as details of the control group. We also recorded statistical values such as mean \pm standard deviation, mean difference (MD), and 95% confidence interval (95% CI) both before and after the intervention. If the data required for meta-analysis was incomplete, we excluded the study.

The methodological quality and risk of bias of all included Randomised Controlled Trials (RCTs) will be assessed independently by Prastika and Muthia using the Cochrane Risk of Bias Tool (RoB 2.0), with the assistance of RevMan (Review Manager) software version 5.4.1. This tool evaluates the risk of bias in seven domains (including bias from randomisation, intervention, missing outcome data, outcome measurement, and selective reporting), where each domain will be assessed with one of three determinations: Low Risk of Bias, High Risk of Bias, or Some Concerns/Unclear Risk of Bias. Any disagreements in the

assessment will be resolved through discussion or by involving a third reviewer, Kesowo.

All analyses in this review were performed using RevMan 5.4.1. To compare differences between groups undergoing physical exercise and control, we used the mean and standard deviation of changes between before and after. Because study results varied, we chose a random effects model for all outcomes. We used MD as *the effect size* (ES) if the study outcome units were the same, but used Standardised Mean Difference (SMD) along with (95% CI) if the units were different. Study heterogeneity was measured using I^2 (heterogeneity was considered reasonable if I^2 was between 0% and 50%).

RESULTS AND DISCUSSION

The included studies can be seen in **Figure 1**. Our initial search strategy found a total of 529 studies from electronic databases and 5 from other sources. After removing duplicates, 434 studies were evaluated based on their titles and abstracts, leaving 108 studies that were then screened through full text. Of these, 99 studies were excluded because they did not meet the inclusion criteria. After going through a careful screening process, we obtained 9 studies that were considered eligible and included in this final analysis.

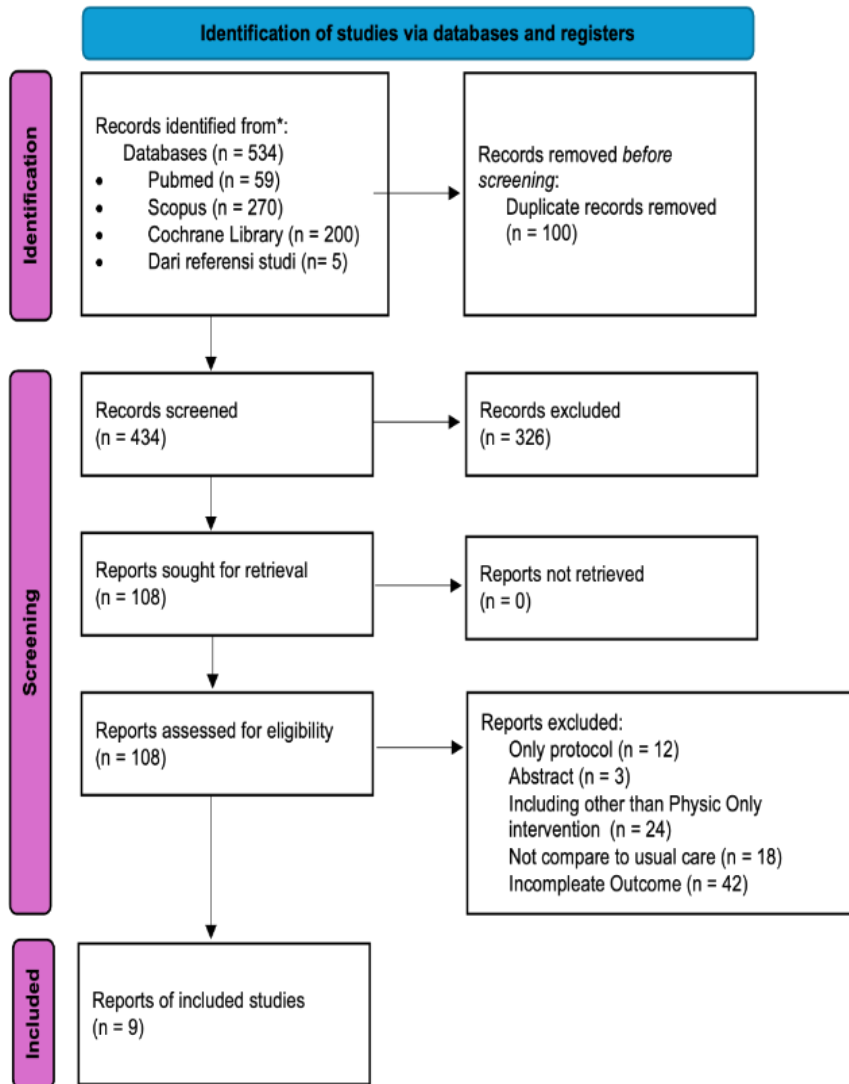


Figure 1. PRISMA Diagram

A total of nine RCT studies were included in this study, focusing on the efficacy of physical exercise in AF patients. These studies involved 760 participants. The population studied was adults, with the reported average age range of participants varying from 56 ± 9 years to 66 ± 9 years. The primary intervention applied was aerobic exercise, sometimes combined with resistance training, with three studies specifically using High-Intensity or Moderate-High-Intensity Interval Training (HIIT), often targeting 85-95% of Heart Rate Reserve (Elliot et al., 2023; Kim et al., 2023; Verdicchio et al., 2023). The duration of the exercise programmes varied,

ranging from a minimum of 12 weeks (Alves et al., 2022; Wahlstrom et al., 2020) to 12 months (Bittman et al., 2022; Bubnova et al., 2022; Elliot et al., 2023; Kim et al., 2023; Verdicchio et al., 2023). In comparison, most control groups received Usual Care, often accompanied by lifestyle education (Alves et al., 2022; Bittman et al., 2022; Bubnova et al., 2022; Elliot et al., 2023; Kim et al., 2023; Risom et al., 2020; Verdicchio et al., 2023; Wahlstrom et al., 2020; Wu et al., 2022).

Primary and secondary outcomes were measured and reported variably across studies. The primary outcome measured, the recurrence rate of AF, was

reported by only three of the nine studies (Bubnova et al., 2022; Elliot et al., 2023; Verdicchio et al., 2023). Meanwhile, $v_{O_2}max$ (mL/kg/min) and QoL were the most frequently reported secondary outcomes, with six studies providing mean and standard deviation data for these variables (Alves et al., 2022; Elliot et al., 2023; Kim et al., 2023; Risom et al., 2020; Wahlstrom et al., 2020; Wu et al., 2022). The study by

Bittman et al. (2022) also reported data but only for the control group. On the other hand, the secondary outcome of Quality of Life (QoL) was hardly explicitly reported in the outcome tables presented, with only the study by Bittman et al. (2022) listing the mean and standard deviation of QoL for both groups. (see Table 2)

Table 3. Study Outcomes

Study (Author, Year)		Number of Rekurensi AF (a/N)	VO2max (Mean±SD)			Qol (Mean±SD)		
			Mean	SD	Sum	Mean	SD	Sum
Alves et al., 2022	Intervention	NR	19	2.2	13	NR	NR	NR
	Control	NR	13.3	1.5	1.3	NR	NR	NR
Bitman et al., 2022	Intervention	NR	NR	NR	NR	47,4	10.5	38
	Control	NR	NR	NR	NR	41.2	17	34
Bubnova et al., 2022	Intervention	6/24	NR	NR	NR	NR	NR	NR
	Control	9/23	NR	NR	NR	NR	NR	NR
Elliot Et al., 2023	Intervention	36/60	20.6	5.3	36	NR	NR	NR
	Control	48/60	19.9	6.5	32	NR	NR	NR
Kim et al., 2023	Intervention	NR	28.1	5.3	30	NR	NR	NR
	Control	NR	21.5	4.8	31	NR	NR	NR
Risom et al., 2020	Intervention	NR	NR	NR	NR	53.7	8	84
	Control	NR	NR	NR	NR	53.1	8.9	86
Verdicchio et al., 2023	Intervention	41/60	NR	NR	NR	NR	NR	NR
	Control	52/60	NR	NR	NR	NR	NR	NR
Wahlstrom et al., 2020	Intervention	NR	NR	NR	NR	46.0	9	38
	Control	NR	NR	NR	NR	43	9	14
Wu et al., 2022	Intervention	NR	NR	NR	NR	52.6	4.6	30
	Control	NR	NR	NR	NR	48.8	4.1	33

The results of the study quality assessment were described and summarised using RevMan 5.4.1 software. The results of the quality assessment in the

form of graphical visualisations and summaries can be seen in full in Figures 2 and 3.

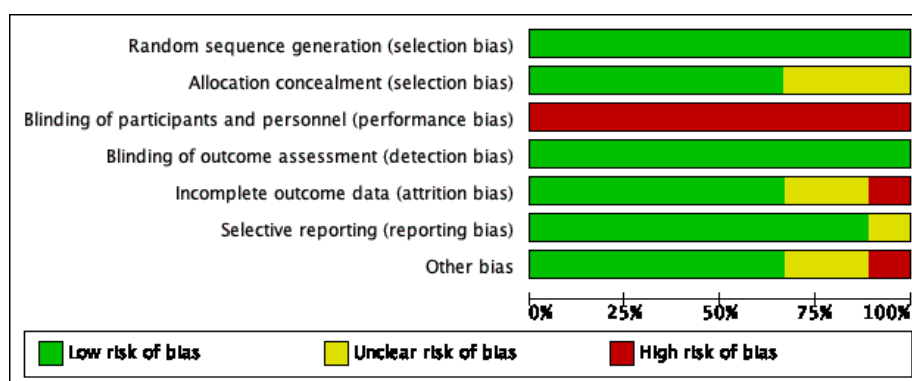


Figure 2. RoB

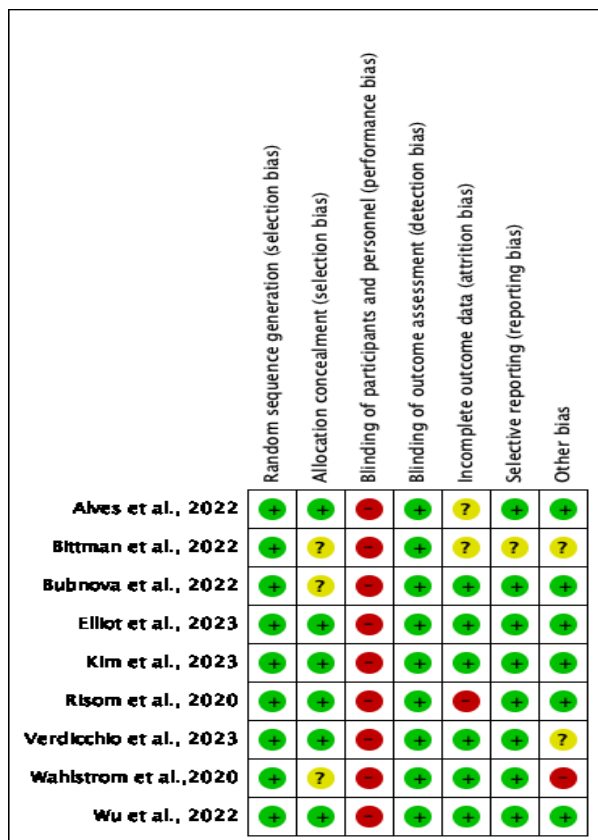


Figure 3. Risk of Bias

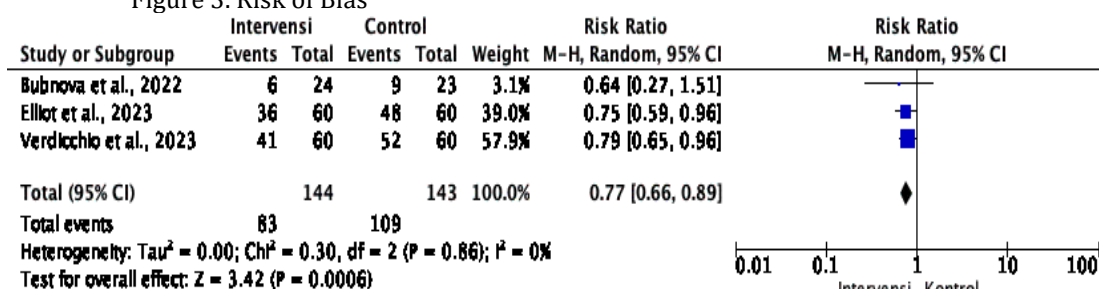


Figure 4. Comparison of Intervention vs Control for AF recurrence Comparison of $v_{O_2}Max$

Four studies with a total of 357 participants were assessed for $v_{O_2}max$ (mL/kg/min) outcomes. The combined results showed a Mean Difference (MD) of 2.77 with a 95% CI [0.59, 4.94]. The overall effect test showed statistical significance (p=0.01). Heterogeneity between studies was categorised as moderate, with a Chi² value of 4.70 (df = 3) and I² of 36% (p heterogeneity = 0.19).

Quality of life outcomes were analysed from three studies involving a

A meta-analysis of three studies involving a total of 287 participants showed a combined risk ratio (RR) of 0.77 with a 95% confidence interval (CI) [0.66, 0.89]. The overall effect test showed statistical significance (p=0.0006). These results indicate very high homogeneity among the included studies, with a Chi² value of 0.30 (df = 2) and a heterogeneity percentage (I²) of 0% (p heterogeneity = 0.86). Details of the comparison between intervention and control groups for AF recurrence rates are presented in **Figure 4**.

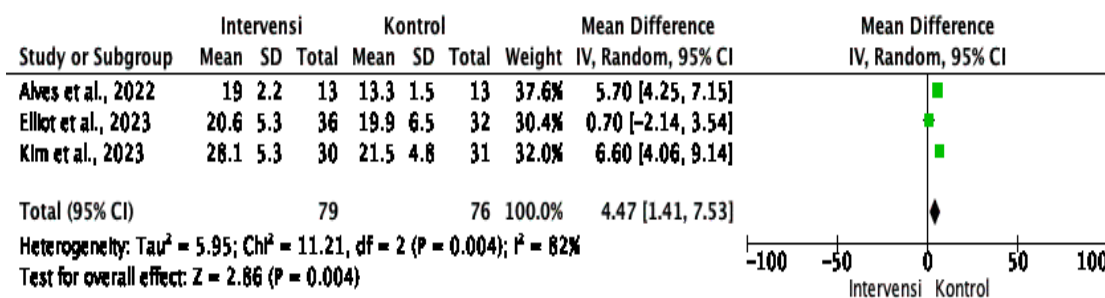


Figure 5. Comparison of Intervention vs Control on Quality of Life

This meta-analysis shows that physical exercise programmes can reduce the risk of AF recurrence in patients who have undergone therapy (Buckley et al., 2025; Elliott et al., 2023; Li et al., 2024; Tzeis et al., 2024). The pooled analysis results from the studies show a consistent association between exercise intervention and a reduction in AF recurrence, improved cardiorespiratory capacity, and improved quality of life (Elliott et al., 2023; Risom et al., 2020; Wahlstrom et al., 2020; Wu et al., 2022). These findings provide a strong empirical basis that physical exercise is not merely a supportive intervention, but an integral component of holistic management of AF patients (Chung et al., 2020; Middeldorp et al., 2018; Pathak et al., 2015; Mohanty et al., 2022).

The mechanisms underlying the protective effects of exercise on AF are multifactorial and interactively linked. Moderate aerobic exercise can modulate arrhythmogenic substrates through systemic inflammation reduction, endothelial function improvement, and reversible atrial remodelling (Schotten et al., 2024; Nattel & Harada, 2014; Burstein & Nattel, 2008). This process involves a decrease in proinflammatory markers such as TNF- α , IL-6, and high-sensitivity C-reactive protein, which correlates with a reduction in atrial fibrosis (Yao et al., 2025; Zhang et al., 2025; Watanabe et al., 2025;

Schotten et al., 2024). Additionally, exercise enhances the activity of endogenous antioxidant pathways that inhibit oxidative stress and reduce extracellular matrix deposition in the atrial myocardium (Yao et al., 2025; Nattel & Harada, 2014; Schotten et al., 2024; Burstein & Nattel, 2008). Autonomic regulation also plays a crucial role, as regular exercise reduces sympathetic hyperactivity while modulating vagal tone, creating a balance that reduces atrial ectopic triggers (Chen & Tan, 2014; Qin et al., 2019; Linz et al., 2019; Kusayama et al., 2021).

Cardiorespiratory capacity emerges as a strong prognostic biomarker in the AF population. Cohort studies demonstrate an association between CRF (*Cardiorespiratory Fitness*) and AF incidence, where each 1 MET increase in exercise capacity is associated with a reduction in AF risk and cardiovascular mortality (Qureshi et al., 2015; Khan et al., 2015; Garnvik et al., 2020; Kunutsor et al., 2024).

In obese patients with AF, the interaction between CRF and body mass index shows a complex pattern, where high fitness may compensate for some of the risks posed by obesity (Pathak et al., 2015; Kokkinos et al., 2020; Donnellan et al., 2020). Post-exercise improvements in CRF are also associated with

improvements in atrial structural parameters, such as reduced left atrial volume and increased atrial *compliance* (Donnellan et al., 2020; Malmo et al., 2016; Mujović et al., 2021; Zhao et al., 2025). These physiological adaptations may include reduced atrial filling pressure, reduced atrial wall strain, and improved atrial pumping mechanisms, all of which contribute to electrophysiological stabilisation (Kokkinos et al., 2020; Khan et al., 2015; Donnellan et al., 2020; Mujović et al., 2021).

The findings of this meta-analysis are consistent with the ACTIVE-AF study, which showed that supervised exercise intervention for 6 months reduced AF recurrence by up to 50% compared to standard care (Elliott et al., 2023; Verdicchio et al., 2023). However, several studies have reported a non-linear relationship between exercise intensity and AF risk (Mohanty et al., 2020; D'Ambrosio et al., 2024; Benito et al., 2011; Wilhelm et al., 2014). In athletes undergoing long-term high-intensity exercise, there is an increased prevalence of lone AF, which is thought to cause progressive atrial dilation, focal atrial fibrosis, and increased vagal tone (Benito et al., 2011; Wilhelm et al., 2014; D'Ambrosio et al., 2024; Mohanty et al., 2020). These differences likely reflect a *dose-response* effect, where moderate exercise provides optimal protection while extreme exercise may trigger maladaptive remodelling (Mohanty et al., 2020; Garnvik et al., 2020; Kunutsor et al., 2024). Studies in this meta-analysis predominantly used moderate to moderate-high intensity exercise protocols, which may explain the consistency of the protective results we

found (Elliott et al., 2023; Kim et al., 2023; Verdicchio et al., 2023; Alves et al., 2022).

The clinical implications of these findings suggest that structured physical exercise programmes should be integrated as a standard component of AF management (Buckley et al., 2025; Chung et al., 2020; Tzeis et al., 2024; Middeldorp et al., 2018). The ABC approach to AF, which stands for Anticoagulation, Better symptom control, and Cardiovascular risk factor optimisation, can be expanded by adding an additional exercise component tailored to the individual and based on the patient's capacity and comorbidities (Pathak et al., 2014; Abed et al., 2024; Chung et al., 2020).

Limitations of this meta-analysis include heterogeneity of exercise protocols across studies, varying follow-up durations, and a limited number of studies for the primary outcome of AF recurrence (Elliott et al., 2023; Buckley et al., 2025; Tzeis et al., 2024). Variations in AF monitoring methods and endpoint definitions across studies may also influence the interpretation of results (Elliott et al., 2023; Verdicchio et al., 2023; Bubnova et al., 2022; Malmo et al., 2016).

CONCLUSION

A meta-analysis of nine RCTs showed that structured physical exercise programmes significantly reduced the risk of atrial fibrillation (AF) recurrence by 23%, while improving cardiorespiratory capacity (VO₂max) and patients' quality of life compared to standard care. These findings confirm that physical exercise is an effective non-pharmacological intervention and should be integrated as a standard component in comprehensive AF

management, alongside risk factor control and modification. Its protective mechanism is thought to be related to reduced inflammation and improved cardiovascular fitness. Therefore, the implementation of structured and personalised exercise programmes in various clinical settings needs to be optimised to support long-term outcomes. However, further research with large-scale RCTs and longer follow-up periods is still needed to determine the most optimal exercise dose and intensity.

REFERENCES

- Abed, H. S., Wittert, G. A., Leong, D. P., Shirazi, M. G., Bahrami, B., Middeldorp, M. E., Lorimer, M. F., Lau, D. H., Antic, N. A., Brooks, A. G., Abhayaratna, W. P., Kalman, J. M. & Sanders, P., 2019. Meta-analysis of effect of modest ($\geq 10\%$) weight loss in management of overweight and obese patients with atrial fibrillation. *The American Journal of Cardiology*, 124(11), pp.1568-1574. <https://doi.org/10.1016/j.amjcard.2019.08.00z>
- Alves, E. D., Sousa, C. V., Barreto, P. R., Sales, M. M. & Aguiar, S. S., (2022). Effects of different aerobic training intensities on health-related quality of life and exercise capacity in patients with atrial fibrillation: a pilot study. *Motriz: Revista de Educação Física*, 28, p.e10220004922. <https://doi.org/10.1590/S1980-65742022004922>
- Benito, B., Gay-Jordi, G., Serrano-Mollar, A., Guasch, E., Shi, Y., Tardif, J. C., & Mont, L. (2011). Cardiac arrhythmogenic remodeling in a rat model of long-term intensive exercise training. *Circulation*, 123(1), 13-22. <https://doi.org/10.1161/CIRCULATIONAHA.110.938282>
- Bittman, K., Krätschmer-Hahn, E., Münch, J., Born, P., Friedmann-Bette, B., Ehlken, N., Hund, H., Katus, H. A., Thomas, D. and Schweizer, P. A., (2022). Aerobic training increases peak oxygen uptake in patients with atrial fibrillation and heart failure with preserved ejection fraction: a randomized controlled trial. *Clinical Research in Cardiology*, 111(8). 931-943. <https://doi.org/10.1007/s00392-022-01994-2>
- Bubnova, M. G., Aronov, D. M., Ioseliani, D. G., Krasnova, T. N., Novikova, N. K. & Rodzinskaya, E. M., (2022). Cardiac rehabilitation improves exercise tolerance and quality of life in patients with atrial fibrillation. *Kardiologiia*, 62(4), pp.4-13. <https://doi.org/10.18087/cardio.2022.4.n1978>
- Buckley, B. J., Van Hout, L., Fitzhugh, C., Lip, G. Y., Taylor, R. S., & Thijssen, D. H. (2025). Exercise-based cardiac rehabilitation for patients with atrial fibrillation: a narrative review. *European heart journal open*, oead025. <https://doi.org/10.1093/ehjopen/oead025>
- Burstein, B., & Nattel, S. (2008). Atrial fibrosis: mechanisms and clinical relevance in atrial fibrillation. *Journal of the American College of Cardiology*, 51(8), 802-809. <https://doi.org/10.1016/j.jacc.2007.09.064>
- Chen, J. & Tan, A. Y., (2014). Dysfunction of the autonomic nervous system in atrial fibrillation. *Journal of Thoracic Disease*, 7(2), 60-65. <https://doi.org/10.3978/j.issn.2072-1439.2015.01.13>
- Cheng, S., He, J., Han, Y., Han, S., Li, P., Liao, H., & Guo, J. (2024). Global burden of atrial fibrillation/atrial flutter and its attributable risk factors from 1990 to 2021. *Europace*, 26(7), euae195. <https://doi.org/10.1093/europace/euae195>
- Chung, M. K., Eckhardt, L. L., Chen, L. Y., Ahmed, H. M., Gopinathannair, R., Joglar, J. A., & Trulock, K. M. (2020). Lifestyle and risk factor modification for reduction of atrial fibrillation: a scientific statement from the American Heart Association. *Circulation*, 141(16), e750-e772. <https://doi.org/10.1161/CIR.0000000000000748>
- D'Ambrosio, P., Claessen, G., Kistler, P. M., Heidbuchel, H., Kalman, J. M., & La Gerche, A. (2024). Ventricular arrhythmias in association with athletic cardiac remodelling. *Europace*, 26(12), euae279. <https://doi.org/10.1093/europace/euae279>
- Donnellan, E., Wazni, O. M., Harb, S., Kanj, M., Saliba, W. I., & Jaber, W. A. (2020). Higher baseline cardiorespiratory fitness is associated with lower arrhythmia recurrence and death after atrial fibrillation ablation. *Heart Rhythm*, 17(10), 1687-1693. <https://doi.org/10.1016/j.hrthm.2020.05.013>
- Elliott, A. D., Verdicchio, C. V., Mahajan, R., Middeldorp, M. E., Gallagher, C., Mishima, R. S., & Sanders, P. (2023). An exercise and physical activity program in patients with atrial

- fibrillation: the ACTIVE-AF randomized controlled trial. *Clinical Electrophysiology*, 9(4), 455-465..
<https://doi.org/10.1016/j.jacep.2022.12.002>
- Garnvik, L. E., Malmö, V., Janszky, I., Ellekjær, H., Wisløff, U., Loennechen, J. P., & Nes, B. M. (2020). Physical activity, cardiorespiratory fitness, and cardiovascular outcomes in individuals with atrial fibrillation: the HUNT study. *European heart journal*, 41(15), 1467-1475.
<https://doi.org/10.1093/eurheartj/ehaa032>
- Khan, H., Kunutsor, S., Rauramaa, R., Savonen, K. & Laukkanen, J. A., (2015). Cardiorespiratory fitness and atrial fibrillation: a population-based follow-up study. *Heart Rhythm*, 12(7). 1424-1430.
<https://doi.org/10.1016/j.hrthm.2015.03.052>
- Kim, H. N., Januzzi, J. L., Agarwal, S. K., Pashun, R., Mentz, R. J., DeVore, A. D., Felker, G. M., Ahmad, T. & Grodin, J. L. (2023). Effect of empagliflozin on natriuretic peptide levels and cardiac function in patients with acute decompensated heart failure. *JACC: Heart Failure*, 11(6). 633-644.
<https://doi.org/10.1016/j.jchf.2023.01.008>
- Kokkinos, P., Faselis, C., Samuel, I. B. H., Liff, M., Zhang, P., Faillace, R. T., Kokkinos, J. P. & Myers, J. (2020). Association between cardiorespiratory fitness, obesity, and incidence of atrial fibrillation. *Mayo Clinic Proceedings*, 95(12). 2660-2668.
<https://doi.org/10.1016/j.mayocp.2020.04.049>
- Kornej, J., Benjamin, E. J., & Magnani, J. W. (2021). Atrial fibrillation: global burdens and global opportunities. *Heart*, 107(7), 516-518.
<https://doi.org/10.1136/heartjnl-2020-318480>
- Kunutsor, S. K., Kurl, S., & Laukkanen, J. A. (2024). Cardiorespiratory fitness, atrial fibrillation and stroke: a review of the evidence in 2024. *Expert Review of Cardiovascular Therapy*, 22(9), 493-508.
<https://doi.org/10.1080/14779072.2024.2409440>
- Kusayama, T., Wan, J., Yuan, Y. & Chen, P. S., (2021). Neural mechanisms and therapeutic opportunities for atrial fibrillation. *Methodist DeBakey Cardiovascular Journal*, 17(1). 43-47.
<https://doi.org/10.14797/FVDN2224>
- Linz, D., Sanders, P., Dobrev, D., Hermans, A. N., Reilly, S. & Pluijmers, V. (2019). The autonomic nervous system in atrial fibrillation—pathophysiology and non-invasive assessment. *Frontiers in Cardiovascular Medicine*, 10. 1327387.
<https://doi.org/10.3389/fcvm.2023.1327387>
- Malmö, V., Nes, B. M., Amundsen, B. H., Norges, Wisløff, U., Skogvoll, E., Slørdahl, S. A., Støylen, A. & Loennechen, J. P. (2016). Aerobic interval training reduces the burden of atrial fibrillation in the short term: a randomized trial. *Circulation*, 133(5). 466-473.
<https://doi.org/10.1161/CIRCULATIONAHA.115.018220>
- Middeldorp, M. E., Pathak, R. K., Meredith, M., Mehta, A. B., Elliott, A. D., Mahajan, R., ... & Sanders, P. (2018). PREVENTion and regRESSive Effect of weight-loss and risk factor modification on Atrial Fibrillation: the REVERSE-AF study. *EP Europace*, 20(12), 1929-1935.
<https://doi.org/10.1093/europace/euy117>
- Mohanty, S., Mohanty, P., Tamaki, M., Natale, V., Gianni, C., Trivedi, C., Gokoglan, Y., Gunes, M. F., Bai, R., Al-Ahmad, A., Burkhardt, J.D., Gallinghouse, G. J., Horton, R. P., Sanchez, J. E., Bailey, S., Zagrodzky, J. D., Hongo, R. H. & Natale, A. (2020). Differential association of exercise intensity with risk of atrial fibrillation in men and women: evidence from a meta-analysis. *Journal of Cardiovascular Electrophysiology*, 31(2). 462-469.
<https://doi.org/10.1111/jce.14284>
- Mohanty, S., Trivedi, C., Della Rocca, D. G., Gianni, C., MacDonald, B., Mayedo, A., ... & Natale, A. (2022). Impact of digital monitoring on compliance and outcome of lifestyle-change measures in patients with coexistent atrial fibrillation and obesity. *Cardiovascular Digital Health Journal*, 3(2), 75-79..
<https://doi.org/10.1016/j.cvdhj.2022.01.001>
- Mujović, N. M., Marinković, M. M., Nedeljković, I., Marković, N., Banović, M., Vučićević, V., Kocijančić, A., Stojanov, O., Lip, G. Y. & Potpara, T. S. (2021). Improvement of maximal exercise performance after catheter-ablation of atrial fibrillation and its prognostic significance for long-term rhythm outcome. *Journal of the American Heart Association*, 10(3). e017445.
<https://doi.org/10.1161/JAHA.120.017445>
- Nattel, S., & Harada, M. (2014). Atrial remodeling and atrial fibrillation: recent advances and translational perspectives. *Journal of the American College of Cardiology*, 63(22), 2335-2345.
<https://doi.org/10.1016/j.jacc.2014.02.555>
- Pathak, R. K., Elliott, A., Middeldorp, M. E., Meredith, M., Mehta, A. B., Mahajan, R., ... & Sanders, P. (2015). Impact of CARDIOrespiratory FITness on arrhythmia recurrence in obese

- individuals with atrial fibrillation: the CARDIO-FIT study. *Journal of the American College of Cardiology*, 66(9), 985-996. <https://doi.org/10.1016/j.jacc.2015.06.488>
- Qin, M., Zeng, C. & Liu, X. (2019). The cardiac autonomic nervous system: a target for modulation of atrial fibrillation. *Clinical Cardiology*, 42(6), 644-652. <https://doi.org/10.1002/clc.23190>
- Qureshi, W.T., Alirhayim, Z., Blaha, M. J., Juraschek, S. P., Keteyian, S. J., Brawner, C. A. & Al-Mallah, M. H. (2015). Cardiorespiratory fitness and risk of incident atrial fibrillation: results from the Henry Ford Exercise Testing (FIT) Project. *Circulation*, 131(21), 1827-1834. <https://doi.org/10.1161/CIRCULATIONAHA.114.014833>
- Risom, S. S., Zwisler, A. D., Johansen, P. P., Sibilitz, K. L., Lindschou, J., Gluud, C., Taylor, R. S., Svendsen, J. H., Thygesen, L. C., Berg, S. K. & Christensen, M. (2020). Exercise-based cardiac rehabilitation for adults with atrial fibrillation. *Cochrane Database of Systematic Reviews*, (1), CD011197. <https://doi.org/10.1002/14651858.CD011197.pub2>
- Schnabel, R. B., Wallenhorst, C., Engler, D., Blankenberg, S., Pfeiffer, N., Spruenker, N. A., ... & Freedman, B. (2022). Refined atrial fibrillation screening and cost-effectiveness in the German population. *Heart*, 108(6), 451-457. <https://doi.org/10.1136/heartjnl-2020-318882>
- Schotten, U., Goette, A., & Verheule, S. (2025). Translation of pathophysiological mechanisms of atrial fibrosis into new diagnostic and therapeutic approaches. *Nature Reviews Cardiology*, 22(4), 225-240. <https://doi.org/10.1038/s41569-024-01088-w>
- Tzeis, S., Gerstenfeld, E. P., Kalman, J., Saad, E. B., Sepeshri Shamloo, A., Andrade, J. G., ... & Trines, S. A. (2024). 2024 European heart rhythm association/heart rhythm society/Asia Pacific heart rhythm society/Latin American heart rhythm society expert consensus statement on catheter and surgical ablation of atrial fibrillation. *Europace*, 26(4), euae043. <https://doi.org/10.1093/europace/euae043>
- Verdicchio, C. V., Elliott, A. D., Pathak, R. K., Gallagher, C., Middeldorp, M. E., Mahajan, R., Mishima, R. S., Hendriks, J. M., Lau, D. H., Kalman, J. M., Abhayaratna, W. P., Wong, C. X., Sia, C. H. & Sanders, P. (2023). Effect of high-intensity aerobic interval training on exercise capacity, ventricular function, and atrial fibrillation recurrence: the HI-FIT randomized trial. *Heart Rhythm*, 20(9), 1250-1257. <https://doi.org/10.1016/j.hrthm.2023.05.025>
- Wahlstrom, M., Rosenqvist, M., Medin, J., Holzmann, M. J., Fridlund, B. & Jansson, J. H. (2020). Effects of exercise on atrial fibrillation burden: the BEAF trial. *Europace*, 22(5), 705-711. <https://doi.org/10.1093/europace/euz343>
- Watanabe, M., Yokoshiki, H., Mitsuyama, H., Yamamoto, T., Mizukami, K. & Tsutsui, H. (2025). Interactions between atrial fibrosis and inflammation in atrial fibrillation. *Frontiers in Cardiovascular Medicine*, 12, 1578148. <https://doi.org/10.3389/fcvm.2025.1578148>
- Wilhelm, M., Zueger, T., De Marchi, S., Rimoldi, S. F., Brugger, N., Steiner, R., Stettler, C., Nuoffer, J. M., Seiler, C. & Ith, M. (2014). Inflammation and atrial remodeling after a mountain marathon. *Scandinavian Journal of Medicine & Science in Sports*, 24(2), 519-525. <https://doi.org/10.1111/sms.12030>
- Wu, L., Quan, W., Liang, Y., Zhang, M., Li, P., Song, R., Zhang, N., Zhang, L., Zhang, Y., Zhang, Z., Chen, L., Feng, R., Hou, Z., Li, Y. & Xia, Y. (2022). Effects of different exercise intensities on health-related quality of life and exercise capacity in patients with non-permanent atrial fibrillation. *European Journal of Cardiovascular Nursing*, 21(3), 275-283. <https://doi.org/10.1093/eurjcn/zvab048>
- Yao, Y., Bai, F., Chen, J., Liu, Y., Wang, Y., Huang, X., Wang, Y., Li, X., Shi, D. & Zhang, Y. (2025). Inflammation pathways as therapeutic targets in angiotensin II induced atrial fibrillation. *Frontiers in Pharmacology*, 16, 1515864. <https://doi.org/10.3389/fphar.2025.1515864>
- Zhang, J., Li, Y., Wang, Q., Yang, X., Sun, Y., Chen, R. & Wang, X. (2025). Atrial fibrosis in atrial fibrillation: mechanistic insights, diagnostic challenges, and emerging therapeutic targets. *International Journal of Molecular Sciences*, 26(1), 249. <https://doi.org/10.3390/ijms26010249>
- Zhao, G., Sun, J., Che, Q., Xu, W., Song, M., El-Ansary, D., Adams, R., Han, J., Meng, S. & Li, Y. (2025). Development and validation of clinical prediction models for cardiorespiratory fitness in atrial fibrillation patients following radiofrequency catheter ablation. *Frontiers in Cardiovascular Medicine*, 12, 1659905. <https://doi.org/10.3389/fcvm.2025.1659905>