CARDIORESPIRATORY FITNESS AND ITS ROLE IN MANAGING ATRIAL FIBRILLATION: A LITERATURE REVIEW

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Abstract

Background. Atrial Fibrillation is a prevalent cardiac arrhythmia associated with irregular heartbeats, posing significant health risks. The purpose of the study is literature review seeks to explore the intricate relationship between cardiorespiratory endurance and Atrial Fibrillation, shedding light on how cardiorespiratory parameters can serve as essential markers for assessing physical activity levels.

Materials and methods. The search was conducted using electronic databases, particularly PubMed, Google Scholar, and Scopus. Titles and abstracts of identified studies were screened for relevance, and full-text articles were reviewed for eligibility. The following keywords were used in the search: atrial fibrillation, cardiorespiratory fitness, maximal oxygen consumption, cardiovascular mortality. The search depth is 25 years.

Results. Physical activity adherence lowers overall and cardiovascular mortality in Atrial Fibrillation patients. Tailored exercise regimens alleviate Atrial Fibrillation symptoms, improve heart rate control, and enhance well-being. Standardizing cardiorespiratory testing protocols is crucial for consistent comparisons. Various testing methods, including treadmill protocols and cycle ergometers, offer insights into Cardiorespiratory fitness. Differences between treadmill and cycle ergometer out-comes warrant careful interpretation. Normative values vary across populations, influenced by physical activity, geography, genetics, and testing modalities.

Conclusions. Integrating cardiorespiratory testing into AF management enhances diagnosis and personalized interventions, contributing to a nuanced approach in addressing this prevalent cardiac condition.

Introduction

Atrial Fibrillation (AF) is a prevalent cardiac arrhythmia characterized by rapid, irregular heartbeats originating in the atria – the upper chambers of the heart.[1] In a normal heart rhythm, the atria contract in a coordinated and rhythmic manner, allowing efficient blood flow into the ventricles resulting in an effective pump mechanism. However, in the case of AF, the electrical signals controlling the atrial contractions become chaotic, leading to disorganized and irregular heartbeats.[1,2] Atrial Fibrillation is strongly linked to various health conditions such as heart valve disease, diabetes mellitus,[2] hypertension, and obesity.[3] Additionally, it shares associations with sleep apnea and inflammation.[4]

Both genetic predispositions and modifiable lifestyle factors—such as alcohol consumption and physical inactivity—contribute to its development. Due to its impact on cardiac function and blood flow, AF significantly elevates the risk of ischemic stroke (IS) and contributes to high morbidity, mortality, and economic burden worldwide.[5] According to the Global Burden of Disease (GBD) Study 2019, incident AF cases rose sharply to over 4.7 million in 2019, with a higher prevalence in males (60.82 per 100,000) compared to females (53.50 per 100,000).[6,7]

Age is the most significant risk factor for AF, with prevalence increasing sharply after the age of 50. Many individuals remain undiagnosed and at risk for serious health outcomes. The global burden of AF, measured in Disability-Adjusted Life Years (DALYs) or mortality, is highest in countries with high Socio-Demographic Index (SDI)[8] influenced by factors such as unfavorable metabolic profiles, heightened psychosocial stressors, neighborhood deprivation and socioeconomic disparities.

Cardiorespiratory endurance plays a crucial role in cardiovascular health. Cardiorespiratory testing, specifically with physical stress, has become a widely used and objective method for evaluating fitness levels.[9] Low cardiorespiratory fitness – measured by parameters such as VO_2 max and ventilatory threshold (VT)–is a known predictor of cardiovascular and respiratory mortality.[10]

This literature review aims to explore the relationship between cardiorespiratory endurance and AF, shedding light on how cardiorespiratory parameters can serve as essential markers for assessing physical activity levels. Through this exploration, we endeavor to highlights the importance of physical fitness assessment in the management and prevention of AF, offering insights into improving outcomes for this prevalent cardiac condition.

Materials and methods

The search was conducted using electronic databases, particularly PubMed, Google Scholar, and Scopus. Titles and abstracts of identified studies were screened for relevance, and full-text articles were reviewed for eligibility. (Figure 1)

The inclusion criteria for this review encompassed literature reviews, meta-analyses, and comparative studies that related to atrial fibrillation management,role of cardiorespiratory fitness in the treatment of AF, cardiorespiratory endurance. Additionally, researches reporting on cardiorespiratory fitness testing methods was considered. Both published and unpublished studies were incorporated into the review.

The exclusion criteria eliminated studies that do not provide clear definitions or results for the management of atrial fibrillation and cardiorespiratory fitness, studies not available in English, animal studies, and in vitro studies are excluded.

The following keywords were used in the search: atrial fibrillation, cardiorespiratory fitness, maximal oxygen consumption, cardiovascular mortality, ventilatory anaerobic threshold. The search depth is 25 years. The selection of a 25-year search depth for the study was driven by the need to balance comprehensiveness with relevance. This time frame ensures inclusion of foundational studies that provide critical background information and contextual understanding. Simultaneously, it filters out information that may have become outdated, as statistical data.

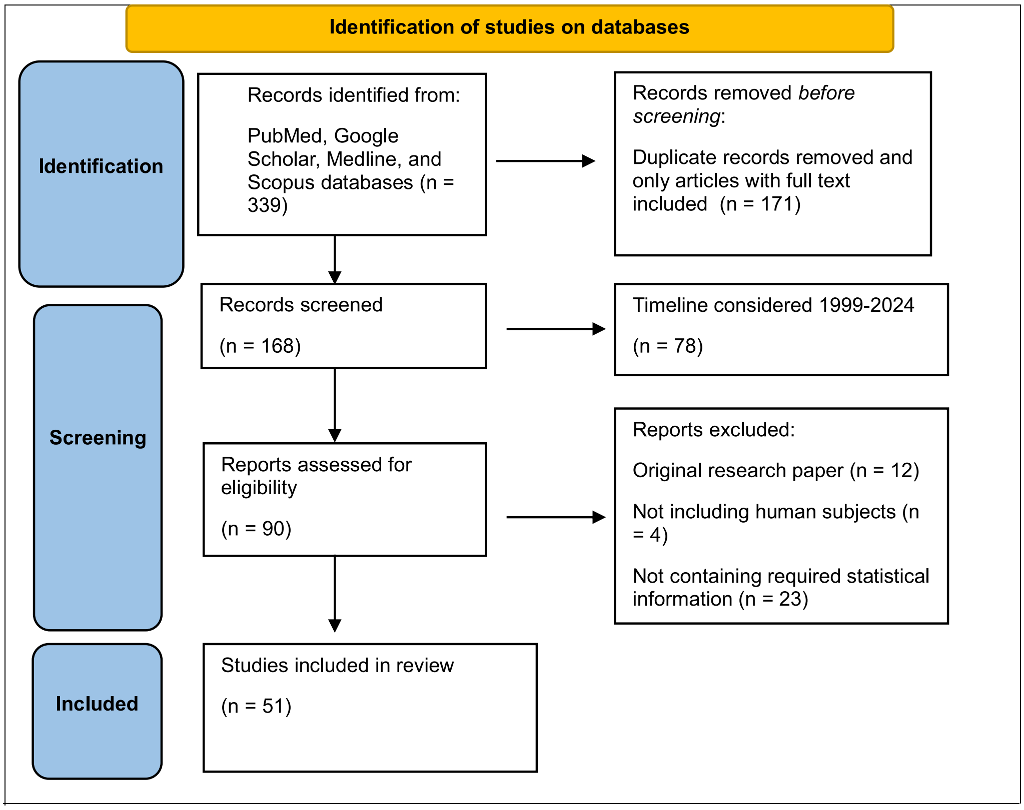

Figure 1.
Flow chart showing selection of studies for literature review

Results

Cardiorespiratory Testing and its Role in Assessing Physical Fitness

Cardiorespiratory testing with physical stress is integral for assessing physical fitness because it provides a dynamic and real-world evaluation of the body's ability to efficiently transport oxygen to working muscles during activity.[11] Unlike resting measurements, which may not fully capture an individual's response to exertion, stress testing simulates the physiological demands of physical activity. This method allows for a comprehensive assessment of the cardiovascular and respiratory systems' performance under stress, mirroring the challenges encountered during various physical activities.[12] The inclusion of physical stress in testing is particularly crucial because it exposes potential limitations and abnormalities that may not manifest during rest. It enables a more accurate evaluation of an individual's capacity to endure exertion, making it an essential tool for tailoring personalized exercise prescriptions and interventions.

Cardiorespiratory fitness (CRF), as evaluated through parameters like maximal oxygen consumption and ventilatory anaerobic threshold, offers valuable insights into an individual's aerobic capacity and overall fitness. VO2 max represents the maximum amount of oxygen that an individual can utilize during intense exercise, and this value remains constant despite an increase in workload over a given time period.[13] It serves as a gold standard measure of aerobic fitness, reflecting the efficiency of oxygen transport and utilization. A higher VO2 max generally indicates better cardiovascular and respiratory fitness.[13] VT signifies the point during exercise at which the body transitions from aerobic to anaerobic metabolism. It reflects the threshold beyond which the body relies more on anaerobic pathways, indicating the limit of sustainable exercise intensity. Monitoring VT is crucial for optimizing training intensity and preventing premature fatigue during physical activities.[14]

A compelling body of evidence supports the association between low VO2 max and an elevated risk of mortality from cardiovascular diseases.[15] Individuals with lower aerobic capacity often exhibit reduced cardiovascular and pulmonary health, making them more susceptible to conditions such as coronary artery disease, heart failure, and hypertension.[16] The link between low VO2 max and cardiovascular mortality underscores the importance of cardiorespiratory fitness as a prognostic marker. Regular assessment of VO2 max can serve as a powerful tool for identifying individuals at higher risk and implementing targeted interventions to enhance cardiovascular health and reduce mortality rates.[17]

Cardiorespiratory Fitness in the Context of AF

A significant volume of evidence, originating from epidemiological studies, shows the connection between CRF and diverse health outcomes. These outcomes include the risk of mortality from all causes, cardiovascular diseases (CVD),[18] cancer,[19] diabetes,[20] hypertension,[21] and obesity.[20] Cardio respiratory endurance emerges as a cornerstone in shaping both the prognosis and the effective management of AF, playing a pivotal role in various dimensions of the condition.[22]

A recent systematic review and meta-analysis examining the correlation between CRF and CVDs revealed noteworthy findings. In patients with CVD, those with high CRF exhibited a significant 58% reduction in the risk of all-cause mortality and a remarkable 73% lower risk of cardiovascular mortality compared to their less fit counterparts.[18] Additionally, for each 1 metabolic equivalent (1-MET) increase in CRF among CVD patients, there was a substantial 19% decrease in the risk of cardiovascular mortality. Individuals with higher cardiorespiratory endurance often show case better cardiovascular health. Further analysis within the subgroup of coronary artery disease patients highlighted a noteworthy 68% lower risk of all-cause mortality for those with high CRF, with each 1-MET increase correlating with a significant 17% reduction in the risk of all-cause mortality in this specific patient population.[18] Regular physical activity not only aids in weight management and blood pressure control but also cultivates a resilient cardiovascular system capable of coping with the challenges posed by CVDs.

Although the relationship between cardiovascular diseases and CRF seems straightforward, some re-search show that intense and prolonged exercise training is correlated with an increased incidence of atrial fibrillation.[23] This connection is likely attributable to modifications in atrial volume, left ventricular hypertrophy, and adjustments in autonomic nervous system activity. In addition, the Physicians' Health Study provided information on[9,16,21] individuals engaged in athletics, revealing that a higher frequency of intense exercise was linked to an elevated likelihood of developing AF in young men and joggers.[24] However, this risk diminished with age, offset by the recognized positive impacts of vigorous exercise on other factors associated with AF risk.[24] Despite these findings, a wealth of research data substantiates the link between low cardiorespiratory endurance and an elevated risk of developing and progressing AF. Sedentary lifestyles, often associated with poor physical fitness, contribute significantly to the initiation and advancement of AF.

A population-based study from Khan and colleagues showed that elevated CRF levels are linked to a decreased occurrence of AF.[25] Research indicates that heightened CRF levels correspond to lower levels of inflammatory markers, such as C-reactive protein.[26] Therefore, the diminished risk of AF at increased CRF levels may be influenced by a reduction in systemic inflammation. In the Norwegian study, re-searchers tracked 1117 AF patients to explore how self-reported physical activity and estimated cardiorespiratory fitness relate to outcomes. They found that AF patients who had followed physical activity guidelines had a lower risk of overall (HR = 0.55, 95%CI 0.41-0.75) and CVD mortality (HR = 0.54, 95%CI 0.34-0.86) compared to those who were inactive.[27] Additionally, for every 1 MET increase in CRF, there was a lower risk of overall (HR = 0.88, 95%CI 0.81-0.95) and CVD mortality (HR = 0.85, 95%CI 0.76-0.95) as well as morbidity (HR = 0.88, 95%CI 0.82-0.95).[27] Recognizing and understanding this association forms the foundation for targeted interventions, underscoring the critical role of promoting physical activity as a preventive measure against AF development and progression.

The transformative impact of improving physical fitness on individuals with AF extends beyond the prevention of onset and progression. Tailored exercise regimens have emerged as a powerful tool in alleviating symptoms and enhancing the overall quality of life for AF patients. Regular exercise contributes to better heart rate control, optimized blood circulation, and enhanced cardiovascular function, all of which are essential components in managing the symptomatic aspects of AF.[28] Furthermore, increased cardiorespiratory endurance is intricately linked to a reduction in fatigue, an improvement in mood, and an overall enhancement in well-being.[29,30] Integrating physical fitness into the comprehensive management of AF not only addresses the immediate symptomatic challenges but also fosters a holistic approach that seeks to improve the overall health and resilience of individuals navigating the complexities of life with AF.

Cardiorespiratory Fitness Testing Methods

There are several methods to access cardiorespiratory endurance. Here the widely used ones will be discussed. The conventional approach for evaluating VO2 max involves utilizing specialized metabolic measuring equipment and follows a widely adopted treadmill-based protocol known as the Bruce protocol. The protocol entails stepping onto a treadmill and progressively elevating both speed and incline at three-minute intervals. The test concludes when you reach 85% of your maximum heart rate, your heart rate surpasses 115 beats per minute for two consecutive stages, or a determination is made that the test should be discontinued.[31]

The Balke Protocol, also treadmill-based, initiates with a constant speed of 3.3 miles per hour (mph), which is equal to 5.3 km per hour (kph) for men and 3.0 mph (4.8 kph) for women.[32] The test commences with a 0 percent incline, and for men, the incline rises by 2 percent after the first minute and then by 1 percent every subsequent minute. For women, the incline increases by 2.5 percent every 3 minutes.[33] Participants are expected to sustain this pattern for as long as possible, consistently pushing the pace and elevating the incline until reaching exhaustion. Notably, documenting the cessation time is crucial, as it is utilized in the calculations for determining VO2 max.

Another treadmill test follows Astrand protocol. The modified Astrand protocol starts with a 5-minute warm-up walk at 3.5 miles per hour [mph], which is equal to 5.6 kilometrres per hour (kph)< with a 2.5 percent grade.[34] Subsequently, participants run to exhaustion, where the running speed is adapted to tire each individual within a duration of 7 to 10 minutes.[34] This specific timeframe is considered adequate for the body to undergo optimal physiological adjustments.

In addition to treadmills, contemporary methodologies involving cycle ergometers, acknowledged as recently developed approaches, can be employed for the assessment of CRF. Cycle ergometry presents an attractive testing modality, distinct from treadmill procedures, due to several advantages: 1) it enables the precise selection of work rates, expressible in appropriate units of power [e.g., kgm•min-1]; 2) the non-weight-bearing nature of cycle ergometer exercise renders it well-tolerated by individuals with orthopedic or physical constraints; and 3) the facile collection of heart rate, blood pressure, and electro-cardiographic data during the testing protocol.[35] According to American Heart Association, two categories of stationary bicycles, namely mechanically braked and electronically braked, should be employed for testing purposes.[36] Mechanically braked ergometers necessitate the maintenance of a specified cycling rate to uphold a constant work rate. In contrast, electronically braked ergometers possess the capability to automatically modify internal resistance, ensuring the maintenance of prescribed work rates corresponding to the cycling rate. Irrespective of the specific stationary bicycle type, it is imperative that the ergometer exhibits the capacity to adjust the work rate, either automatically or manually, in incremental measures.[36] In a Finnish study, a maximal incremental exercise test using a cycle ergometer was con-ducted by commencing the test at an initial workload of 60W, with subsequent increments of 20W applied each minute until the point of exhaustion.[37] In a Lithuanian study, the participants had 2 minutes of cycling without resistance, and the workload was increased for 15-30W each minute depending on the expected physical capacity, gender, age, and body mass.[38,39] The maximum duration of exercise was 8-12 minutes to induce maximal stress on the cardiopulmonary system.

Normative Values and Factors Influencing Exercise Tolerance

The evaluation of VO2 max should be adjusted to the corresponding age of individual and exercise modality. Considering the age-related decline in CRF, it is noteworthy that elevated values are typically observed in men[39] and there is a tendency for higher values on the treadmill as opposed to the cycle ergometer.[36] In addition, various investigations have demonstrated that the VO2 max recorded using a cycle ergometer is consistently 3% to 29% lower than the corresponding VO2 max values obtained through treadmill assessment.[40,41] The assessment of VO2 max exhibits notable variations across studies due to the diverse testing modalities employed. The utilization of different protocols, such as the Bruce protocol on treadmills, the Balke protocol, the modified Astrand protocol, and various cycle ergometer protocols, introduces considerable methodological diversity. These differences encompass factors like speed, incline, workload increments, and duration of the tests, making direct comparisons between study results challenging.

The treadmill engages a broader range of muscle groups, typically resulting in a higher VO2 max com-pared to the cycle ergometer.[42,43] Conversely, the cycle ergometer offers improved electrocardiographic (ECG) analysis due to fewer artifacts stemming from upper body motion.[34,44] This disparity in muscle involvement and ECG data quality between the two modalities can lead to inconsistent results in studies and assessments. Researchers should acknowledge and consider these inherent differences when interpreting and comparing VO2 max outcomes derived from treadmill and cycle ergometer testing. It is crucial to recognize that the choice of testing modality and protocol can significantly influence the obtained VO2 max values, as it was proven by previous research.[45,46] Researchers should be careful when comparing results from distinct studies, considering the distinct testing methodologies that contribute to the observed discrepancies in VO2 max outcomes.

In addition to the aforementioned differences, cardiorespiratory fitness within a specific population is intricately influenced by physical activity patterns, geographic location, body composition, genetic factors, and various other elements.[38,47] Consequently, reference values for cardiorespiratory fitness may exhibit significant divergence among different populations. Table 2 below illustrates age and sex-adjusted mean values of VO2 max in various countries, serving as reference benchmarks for the respective populations.

Table 1.
VO2 max (mLO2/kg/min) Reference Values across Countries

Sex	Male					
Agegroup (y.o.)	**18/20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**
USA [44]	N/A	43.0±9.9 (n = 963)	38.8±9.6 (n = 1327)	33.8±9.1 (n = 1078)	29.4±7.9 (n = 593)	25.8±7.1 (n = 137)
Norway[48]	N/A	49.1±7.5 (n = 324)	47.2±7.7 (n = 536)	42.6±7.4 (n = 466)	39.2±6.7 (n = 300)	35.3±6.5 (n = 76)
Norway	N/A	46.2±8.5 (n = 73)	42.7±9.3 (n = 91)	36.8±6.6 (n = 88)	32.4±6.4 (n = 81)	30.1±4.8 (n = 23)
Brazil[44]	45.0±7.5 (n = 1201)	43.5±7.9 (n = 4427)	41.6±7.8 (n = 4383)	38.6±7.9 (n = 1728)	33.7±7.1 (n = 362)	28.7±6.7 (n = 48)
Lithuania[49]	40.35±5.77 (n = 21)	36.65±8.16 (n = 24)	32.89±5.75 (n = 30)	29.54±5.48 (n = 16)		
Denmark[50]	43.4±6.6 (n = 343)	40.0±6.5 (n = 797)	38.9±6.4 (n = 1254)	36.4±6.2 (n = 1098)	33.2±5.2 (n = 921)	29.6±3.9 (n = 225)
Korea [51]	42.3±6.3 (n = 209)	42.0±5.0 (n = 170)	41.4±5.6 (n = 238)	38.0±5.7 (n = 274)	32.4±6.2 (n = 134)	27.2±5.6 (n = 83)
Sex	**Female**					
USA [52]	37.6±10.2 (n = 410)	30.9±8.0 (n = 608)	27.9±7.7 (n = 843)	24.2±6.1 (n = 805)	N/A	N/A
$Norway_1$ [53]	43.0±7.7 (n = 215)	40.0±6.8 (n = 359)	38.4±6.9 (n = 493)	34.4±5.7 (n = 428)	N/A	N/A
$Norway_2$ [54]	40.3±7.1 (n = 37)	37.6±7.5 (n = 63)	33.0±6.4 (n = 86)	30.4±5.1 (n = 79)	N/A	N/A
Brazil[44]	36.9±6.6 (n = 732)	36.0±7.0 (n = 2028)	34.7±7.1 (n = 1985)	31.4±6.5 (n = 624)	N/A	47.6±11.3 (n = 513)
Lithuania[49]	34.68±6.75 (n = 21)	27.37±4.11 (n = 18)	25.34±3.66 (n = 20)	24.98±4.52 (n = 18)	N/A	54.4±8.4 (n = 199)
Denmark[50]	35.6±5.5 (n = 592)	33.1±5.7 (n = 1158)	32.1±5.6 (n = 1782)	29.8±5.1 (n = 1543)	N/A	48.9±9.6 (n = 38)
Korea [46,51]	34.3±4.3 (n = 110)	32.2±4.5 (n = 211)	30.8±4.6 (n = 284)	28.3±4.6 (n = 367)	26.0±5.7 (n = 336)	23.9±4.4 (n = 195)

Note: *N/A = Not Applicable; this indicates that the specific data point does not apply to the study's design, methodology, or outcomes.*

Limitations. This literature review has several limitations. First, the included studies varied in design, population characteristics, and methodology, which may affect the consistency and comparability of the results. In particular, differences in cardiorespiratory fitness testing protocols (e.g., treadmill vs. cycle ergometer) and reporting standards may lead to heterogeneity in VO_2 max values. Second, not all studies stratified data by age and sex, which limited our ability to provide comprehensive normative comparisons across subgroups. Third, most data were derived from high-income countries, and therefore may not reflect population-specific differences in lower-income or underrepresented regions, including Central Asia. Finally, as this is a narrative literature review and not a systematic review or meta-analysis, there is a risk of selection bias and incomplete retrieval of all relevant evidence.

What' known? CRF has long been recognized as an important predictor of cardiovascular and all-cause mortality. Low VO_2 max levels are linked to poorer outcomes in patients with cardiovascular disease. Physical activity is known to support heart health, but its connection with AF has not been widely emphasized.

What's new? This review brings together recent findings that highlight the role of CRF in AF. It explores how improving physical fitness can reduce symptom burden, lower mortality risk, and enhance overall management. The review also discusses practical aspects of exercise testing and reference values across populations.

Conclusions

This literature review delves into the intricate connection between cardiorespiratory endurance and AF. Various testing protocols, such as the Bruce protocol, Balke protocol, modified Astrand protocol for treadmills, and cycle ergometer protocols, contribute to assessing CRF. However, differences in methodologies, like muscle group involvement and electrocardiographic data quality, necessitate careful interpretation and comparison of VO2 max outcomes. Promoting physical activity has proven beneficial in preventing and managing AF. Higher CRF levels are linked to a reduced AF risk and improved cardio-vascular health. Tailored exercise regimens enhance the well-being of individuals with AF. This comprehensive understanding contributes to a nuanced approach to addressing this prevalent cardiac condition. As research progresses, standardizing testing protocols and reference values will facilitate more consistent comparisons. Integrating cardiorespiratory testing into the clinical management of AF holds promise for improving outcomes and enhancing overall health.

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