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Sports and Arrhythmias

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List of abbreviations

AF – atrial fibrillation

BSA – body surface area

CAD – coronary artery disease

DVT – deep venous thrombosis

DOAC – direct oral anticoagulation therapy

ECG – electrocardiographic

INR - International Normalized Ratio

LA – left atrium

LV – left ventricle

LVH – left ventricular hypertrophy

OAT – oral anticoagulation therapy

RA – right atrium

RV – right ventricle

SCD – sudden cardiac death

TEE – transoesophageal echocardiography

VKA – vitamin K antagonist

VTE – venous thromboembolism

NCAA - National Collegiate Athletic Association

Sports and Arrhythmias

Anticoagulation for athletes with atrial fibrillation

1. Summary

Atrial fibrillation is the most common sustained cardiac arrhythmia, characterized by disorganized electrical activity in the atria leading to an irregular ventricular response. Atrial fibrillation is associated with significant morbidity, including an increased risk of stroke, heart failure, and cardiovascular mortality. While regular physical activity is considered a protective factor against cardiovascular diseases, long-term endurance training has paradoxically been linked to an increased incidence of atrial fibrillation in elite athletes.

Managing atrial fibrillation in athletes presents a unique challenge, especially regarding anticoagulation therapy. While anticoagulants effectively reduce stroke risk, they simultaneously increase the risk of bleeding, particularly in contact sports where traumatic injuries are common. However, anticoagulation treatment is the only proven therapy that has been shown to improve the outcome among patients with atrial fibrillation. (1) Current treatment guidelines do not specifically address anticoagulation in athletes with atrial fibrillation, necessitating individualized risk-benefit assessments.

This thesis aims to examine the causes, prevalence, and effects of atrial fibrillation in athletes. The principal emphasis lies in analysing the prevailing evidence regarding the utilization of anticoagulation therapy in athletes diagnosed with atrial fibrillation and exploring the challenges related to treatment in the context of sports participation. The main goals were to review the existing guidelines, evaluate the effectiveness and safety of various anticoagulation treatments and assess how these approaches are tailored to the specific needs of athletic populations.

The research method used was a structured literature review. A systematic approach was used to identify, evaluate, and summarize relevant studies published in academic publications. The review focused on articles addressing anticoagulation therapy, atrial fibrillation, and athletes.

The review results revealed a lack of uniform treatment strategies for athletes with atrial fibrillation needing anticoagulation therapy. Most studies and recommendations rely on general population

data, with few athlete-specific studies. Direct oral anticoagulants have become the preferred treatment choice due to their ease of use and favorable safety profile.

In conclusion, athletes with atrial fibrillation who need anticoagulation treatment require a tailored approach that balances the risk of thromboembolic complications with the bleeding risk that sports might increase. Direct oral anticoagulants offer advantages, but more research is needed to improve treatment and create guidelines for athletes. Engaging in shared decision-making between the athlete and medical team is crucial for safe and effective treatment.

1.1 Keywords

Cardiac arrhythmias, atrial fibrillation, anticoagulation, thromboembolic prevention, athletes,

2. Introduction

2.1. Background of cardiovascular health in athletes

Athletes have been assumed to be superior to the general population in cardiovascular health. The cardiovascular profiles achieved by athletes are due to regular physical activity and healthy lifestyle habits. These benefits include increased cardiac output, lower resting heart rate, and improved blood pressure regulation. These features are hallmarks of "the athlete's heart," a benign spectrum of cardiac remodeling and functional adaptations resulting from sustained training. (2) These benign cardiac remodelings may lead to morphophysiological changes along with complications, the most serious consequence being atrial fibrillation (AF). (3) However, the athlete's heart is a whole heart adaptation rather than exclusive to the heart's function or one chamber.
Sports like endurance training have led to the enlargement of the left and right cardiac cavity sizes and the thickening of the left ventricular (LV) wall. This allows the heart to pump blood more efficiently. Aerobic exercise enhances metabolic flexibility and promotes oxygen delivery to working muscles. Resistance training contributes to improved vascular tone and reduces systemic inflammatory markers. These changes have lowered the risk of coronary artery disease and other cardiovascular events. Furthermore, regular exercise is strongly associated with improved lipid profiles and insulin sensitivity. (4)

The benefits of high-level athletic training come with subtleties. According to data from long-term observational studies, it has been shown that not all cardiovascular changes in elite athletes are benign. An increased risk for specific arrhythmias – most often atrial fibrillation - has been observed, particularly among older male endurance athletes or athletes with long-standing training histories. (5)

2.2. The paradox of atrial fibrillation in athletes

Atrial fibrillation is the most common sustained cardiac arrhythmia. It is characterized by disorganized electrical activity, leading to irregular and rapid heart rhythms. Atrial fibrillation is associated with aging, hypertension, heart disease, and obesity. Paradoxically, it has also been seen in increased rates in elite athletes, particularly those engaged in endurance sports such as cross-country skiing, cycling, and long-distance running.

Clinically, this creates a paradox: exercise is seen as a protective factor against cardiovascular disease, yet extreme levels of endurance training appear to increase the risk of developing atrial fibrillation in older age. (6)

The mechanism behind this paradox is multifactorial and speculative. Still, it may include atrial dilatation, changes in the vagal tone, chronic inflammation, pulmonary foci, and interstitial fibrosis because of excessive strain through augmented cardiac output and atrial stretch. The risk appears to be a U-shaped curve. Moderate exercise reduces the risk of AF, but excessive training may elevate it. This phenomenon challenges the belief that "more is better" regarding physical activity.

Atrial fibrillation can impair exercise performance, causing palpitations and dizziness, but most importantly, increasing the risk of stroke. However, in athletes, atrial fibrillation, in general, is well tolerated due to high baseline fitness levels. As a result, managing, identifying, and alleviating atrial fibrillation in athletes has become a growing interest in sports cardiology. (6)

2.3. Balancing anticoagulation and bleeding risk in athletes

The central consideration in the clinical management of atrial fibrillation is stroke prevention through anticoagulation therapy. AF increases the risk of thromboembolic events. The risk is carefully evaluated and supported often by stroke risk prediction scores such as CHA2DS2-VASc and bleeding-risk tools such as HAS-BLED.

However, anticoagulation comes with its risks – most relevantly, bleeding. In athletes, this poses a unique challenge. Contact sports and extreme endurance events increase the risk of trauma and, thus, bleeding. This complicates the decisions about using anticoagulation therapy with an elite athlete. (8)

It is a continuous balance between preventing a stroke and avoiding major bleeding, and the decision of the treatment must be individualized. Before starting treatment, factors that must be considered include the type of sport, history of bleeding or injury, the intensity and frequency of training and competitions, and personal preferences regarding lifestyle impact. Some clinicians and athletes may prefer rhythm control strategies to minimize the burden of AF and potentially avoid long-term anticoagulation. At the same time, some teams may rely on intermittent anticoagulation guided by event monitoring. (9)

In this case, shared decision-making becomes crucial. Specialists must collaborate with athletes to weigh the risks and benefits of various treatment options, ensuring that the athlete's health is protected without unnecessarily compromising performance or quality of life.

3. Methods

This thesis explores the current understanding and challenges regarding the anticoagulation treatment of atrial fibrillation among athletes. Only limited scientific resources were published in the last 10 years, so a structured literature review was conducted using multiple sources.

The initial literature search was conducted on PubMed with the keywords “atrial fibrillation,” “athletes,” and “anticoagulation.” Additionally, a search was performed using “thromboembolic prevention” instead of anticoagulation to broaden the search scope. The filters set were for full-text availability and publication within the last 10 years. The initial search yielded only a limited number of articles relevant to the topic. Therefore, the search was expanded to include reputable clinical databases and guidelines. UpToDate and the European Society of Cardiology were used as additional sources.

Google Scholar was utilized to refine the findings further.

Using a systematic, multi-source method, a thorough overview of the existing evidence and expert insights regarding anticoagulation therapy for athletes with AF was compiled. The results were then integrated to underpin the thesis, particularly highlighting the gaps in the literature and the distinct challenges encountered by athlete populations.

4. Electrocardiographic abnormalities in athletes

Athletes, like the general population, frequently exhibit electrocardiographic (ECG) abnormalities. However, in many cases, these findings are benign and represent physiological adaptations to regular athletic training. Such adaptations include sinus bradycardia, increased QRS voltages, and early repolarization patterns commonly observed in well-trained individuals.
Despite this, ECG findings in athletes may also indicate underlying pathological conditions. Distinguishing between regular physiological changes and abnormal, non-physiological alterations is crucial for early detection and management of potentially life-threatening cardiovascular diseases. Evaluating ECG abnormalities often requires a comprehensive diagnostic approach, including serial ECG monitoring, Holter studies, echocardiography, and advanced imaging techniques. Due to the frequent asymptomatic nature of many cardiac conditions, identifying an underlying pathology can be challenging and necessitates a systematic approach to cardiovascular screening in athletes.
Athletes exhibit a wide range of electrocardiographic abnormalities, with the nature of their sport significantly influencing the type and frequency of these findings. Endurance athletes are more likely to display ECG alterations compared to non-endurance athletes. The distinction between physiological and pathological changes is critical, as it directly impacts further clinical assessment and the ability to continue training and competing safely.

A study involving 1,005 athletes, including ECG and echocardiographic assessments, found that 14% of participants had abnormal ECG findings, while 5% exhibited structural abnormalities on echocardiography. Notably, abnormal ECG findings were frequently associated with increased left ventricular end-diastolic dimension and wall thickness. These findings were predominantly observed in male athletes, younger individuals, and endurance athletes. These findings suggest that exercise training plays a role in LV remodeling, reinforcing the importance of distinguishing adaptive cardiac changes from pathological conditions. (10), (11), (9)

Atrial fibrillation may be present intermittently or persistently. It is the most common arrhythmia in clinical practice (10). ECG is essential in the diagnosis of atrial fibrillation. Typically, atrial fibrillation shows a narrow complex pattern on the ECG, described as "irregularly irregular," with no visible P-waves. Occasionally, fibrillatory waves may appear, but they can also be absent. The isoelectric line between QRS complexes, known as the baseline, features either fibrillatory waves or minimal oscillations. These fibrillatory waves are small, exhibit varied morphology, and have a high frequency, with fluctuating amplitudes. Occasionally, fibrillatory waves may be confused with flutter waves, which occur in atrial flutter. The key distinction between atrial fibrillation and atrial flutter on an ECG is that atrial fibrillation exhibits variability in the morphology of fibrillatory waves and has a higher frequency on the ECG. In contrast, flutter waves have a more uniform appearance. In atrial fibrillation, the ventricular rate typically ranges from 80 to 180 beats per minute. (12), (13). An example of atrial fibrillation in an ECG can be seen in Figure 1.

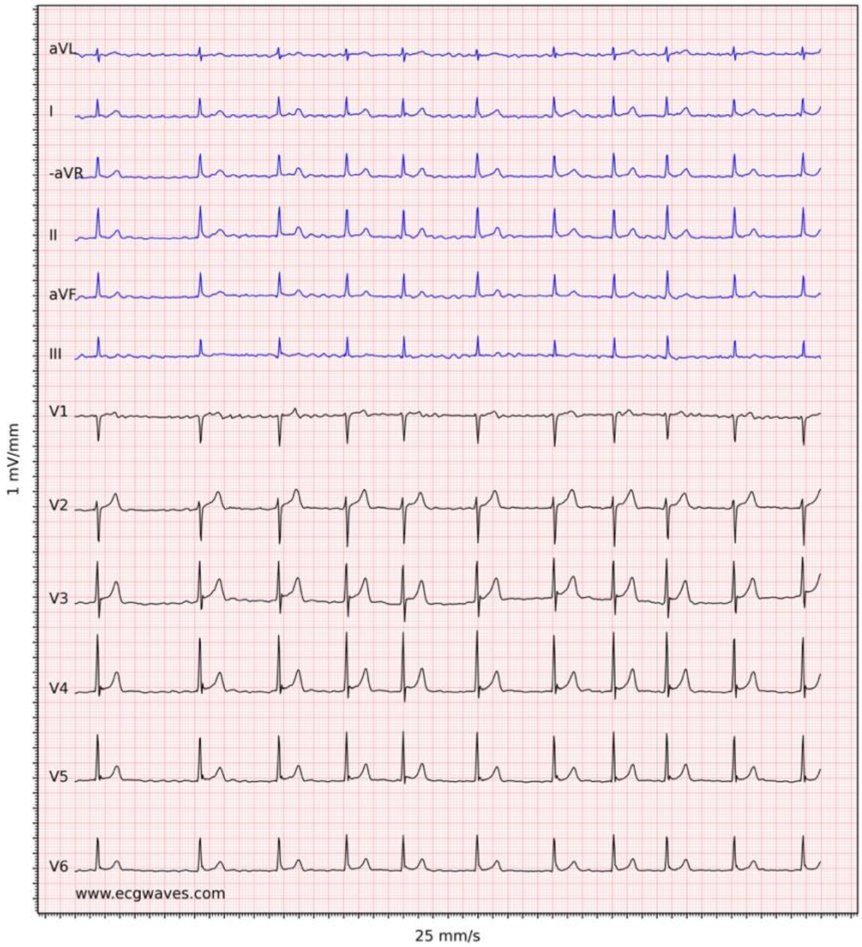

Figure 1. Atrial fibrillation on ECG.(14)

5. Atrial fibrillation in athletes

5.1. Definition and classification of atrial fibrillation

Atrial fibrillation is the most prevalent sustained cardiac arrhythmia, distinguished by an unpredictable atrial electrical activity that results in an irregular heartbeat. This arrhythmia poses a substantial risk of serious complications, including stroke, heart failure, and increased cardiovascular mortality. Atrial fibrillation in critically ill patients might lead to hemodynamic instability. The loss of atrial contraction and rapid ventricular response reduces the heart's minute volume by 20-30%. Consequently, blood flow becomes turbulent, increasing the risk of cardiac thrombi formation and thus increasing the risk for thromboembolic events such as stroke. (1) Athletes, especially those in endurance sports, face unique challenges related to AF, which can significantly affect their performance and health.

Atrial fibrillation can be classified based on its duration and clinical presentation. Paroxysmal atrial fibrillation is classified as episodes that begin suddenly and terminate spontaneously within 7 days. Persistent AF is characterized by episodes lasting longer than 7 days but less than a year. Long-standing persistent AF is in the case of continuous episodes that last longer than a year. This is irrespective of whether the episode was terminated by cardioversion or if it self-terminated. Permanent AF is a designation applied when the patient and clinician mutually cease attempting to restore sinus rhythm, focusing instead on heart rate control. Understanding the classification of AF is essential for managing the condition effectively. (1)

5.2. Etiology and risk factors

The etiology of AF is multifactorial, with risk factors including coronary artery disease, valvular heart disease, hypertension, diabetes mellitus, and obesity. Lifestyle and environmental factors might sometimes serve as the" final hit" in a dual- or multi-hit model of AF in athletes. Alcohol, stimulants, and performance-enhancing drugs (such as anabolic steroids and amphetamines)(15), are all pro-arrhythmic. At the same time, viral illnesses and psychosocial stressors may be critical triggers for AF in athletes. (6)

In the general population, regular physical activity is considered a protective factor against cardiovascular disease, including AF. However, paradoxically, long-term endurance training has been linked to an increased incidence of AF in elite athletes, suggesting a complex interplay between exercise and atrial remodelling.

As previously mentioned, athletes present with a broad spectrum of ECG abnormalities, with atrial fibrillation being the most common sustained arrhythmia. Its prevalence increases with age, making it more frequent in older athletes, whereas it remains relatively rare among younger athletic populations. The sustained endurance exercise is also associated with a 3 to 10-fold higher risk of AF among young or middle-aged athletes without cardiac structural abnormalities. This is not observed in non-athletes. (3)

Multiple factors influence an athlete's cardiac remodelling. In a guideline published in 2025 by the British Society of Cardiology about the recommendations for the use of echocardiography in evaluating young athletes, the importance of the multifactorial nature of the athlete's heart has been well described, highlighting the etiological factors affecting the remodelling of athletes' hearts. The findings are illustrated in Figure 2.

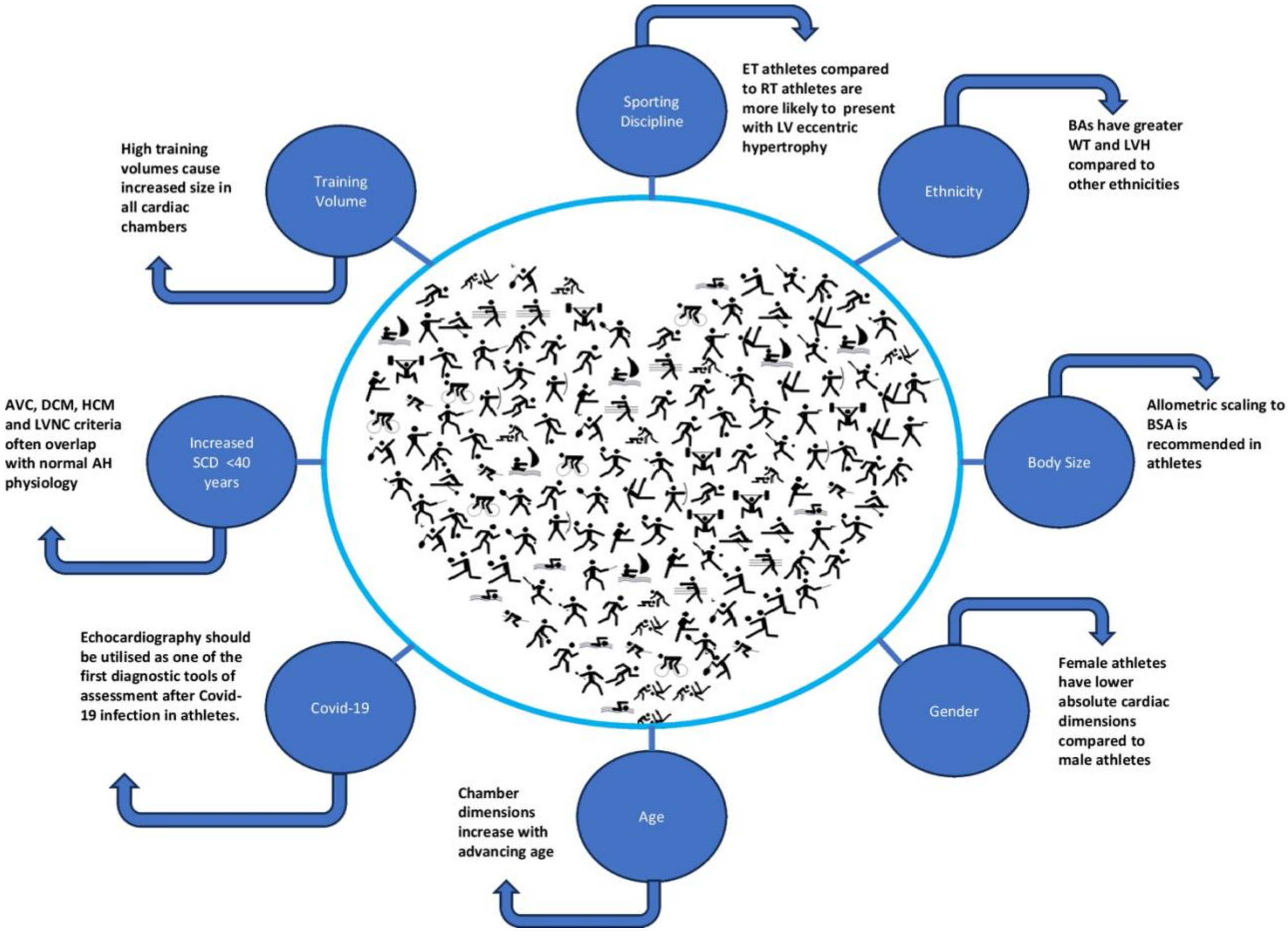

Figure 2. The multi-factorial nature of the athlete´s heart- an overview(4)

Figure 2 illustrates the athlete's heart at its centre, surrounded by multiple influencing factors such as training volume, sport type, ethnicity, body size, gender, age, COVID-19 history, and risks for sudden cardiac death (SCD). It indicates that higher training volumes correlate with increased cardiac chamber sizes. These adaptations are typically physiological. In some cases, their extent can overlap with patterns seen in cardiomyopathies, highlighting the need for detailed clinical evaluation.

The sport played also significantly affects heart remodelling; for instance, endurance-trained athletes often exhibit more left ventricular hypertrophy and bi-atrial dilatation, typically without impaired systolic or diastolic function compared to their resistance-trained counterparts. Although endurance- and resistance-trained athletes might present with larger aortic root dimensions than non-athletes, these findings are not often clinically significant unless they exceed set threshold values.

Studies have shown that ethnicity is another crucial factor in cardiac remodelling. Athletes with black skin colour are more likely to exhibit increased LV wall thickness and cavity size compared to other ethnic groups. Right ventricular (RV) structural changes appear consistent across ethnicities. Caution is advised in case findings are interpreted with elevated relative wall thickness or ECG abnormalities.

Accurate evaluation of cardiac dimensions to body surface area (BSA) using allometric scaling is recommended, especially for athletes with extreme anthropometry.
Gender differences show that female athletes generally have smaller heart dimensions. Female athletes rarely exhibit concentric left ventricular hypertrophy (LVH).
Age is another contributor to chamber size variations. Cardiac dimensions often tend to increase with age, especially during adolescence.

The implications of COVID-19 underscore the need for prompt assessment after infection. Athletes under 40 years of age are at heightened risk for sudden cardiac death, particularly when structural cardiac findings mimic inherited cardiomyopathies such as hypertrophic cardiomyopathy. These highlight the importance of differentiating physiological adaptations from pathological conditions. Ultimately, Figure 2 emphasizes the intricate nature of cardiovascular assessments in athletes, summarizing the various factors that affect heart development and reinforcing the necessity for individualized, context-sensitive interpretations.

Although AF is typically not life-threatening, it can significantly impact athletic performance and quality of life. Due to rapid ventricular rates, athletes with AF most commonly experience symptoms such as palpitations, dyspnea, chest discomfort, dizziness, or syncope. The clinical presentation and severity of symptoms vary widely, necessitating individualized evaluation and management.

In younger athletes, AF may be associated with structural heart abnormalities or underlying causes of heart failure. In contrast, older athletes often develop AF due to hypertension, coronary artery disease, and other cardiovascular risk factors. Additionally, AF can occasionally be linked to conditions associated with sudden cardiac death, such as Wolff-Parkinson-White syndrome, Brugada syndrome, myocarditis, congenital heart disease, and various forms of cardiomyopathy. When AF is diagnosed in an athlete, a thorough clinical assessment, risk factor evaluation, and echocardiographic examination are essential to rule out structural heart disease. The CHA_2DS_2-VASc scoring system often guides the decision to initiate anticoagulation therapy. (4)

5.3. Pathophysiology of atrial fibrillation

The pathophysiology of AF is multifactorial. It involves complex interactions between structural and electrical remodelling of the atrial myocardium. Structural changes include fibrosis and atrial dilatation. Electrical alterations involve changes in ion channel function and conduction properties. These modifications create a substrate conducive to the initiation and maintenance of AF. Additionally, autonomic nervous system imbalances, such as increased vagal tone, can further predispose individuals to AF episodes.

The pathophysiological mechanisms behind atrial fibrillation in elite athletes remain poorly understood, but several factors are believed to contribute. Key among these is left atrial enlargement and hemodynamic stress resulting from chronic volume overload due to prolonged endurance training. This intense training can lead to structural remodelling of atrial tissue, primarily through processes such as myocardial fibrosis and inflammation. Moreover, alterations in autonomic nervous system balance, particularly increased vagal tone, are thought to promote AF episodes.

Genetic predisposition also plays a role in susceptibility to AF. Research indicates a U-shaped relationship between physical activity levels and AF prevalence, suggesting that while moderate exercise is protective, excessive endurance training may elevate the risk of developing AF. Specifically, long-term endurance training can result in structural changes to the heart, including all chambers dilatation, but mainly left atrial dilation, stretching of the pulmonary veins, and microtrauma to the atrial walls. These changes can provoke inflammation and fibrosis, ultimately diminishing the electrical conductivity of the atria and increasing the likelihood of atrial fibrillation. (9)

Research has established a connection between increased exercise and left atrial (LA) size, particularly in prolonged high-intensity endurance training activities such as running, cycling, and skiing. These studies suggest that engaging in these activities may elevate the risk of developing atrial fibrillation. The repetitive and sustained nature of endurance sports can lead to atrial enlargement and increased vagal tone. While increased vagal activity can be beneficial by lowering resting heart rates and improving cardiac efficiency, it also has a downside, though; It may shorten atrial refractory periods. The formation of re-entrant circuits is facilitated by shortening, which may trigger atrial fibrillation. Both left atrial enlargement and increased vagal tone have been implicated in the pathophysiology of AF. For instance, data indicate that marathon runners, who typically log over 4,500 hours of training, have a remarkably high prevalence of atrial fibrillation at 83%.

In contrast, athletes with fewer than 1,500 training hours exhibit a significantly lower probability of developing AF, around 24%. Additionally, endurance training is associated with atrial and ventricular dilatation, particularly increasing the left atrium volume, a well-known risk factor for atrial fibrillation. This phenomenon has been observed in approximately 20% of young competitive athletes. (16), (17)

The role of fibrosis in atrial fibrillation is still being studied. Chronic exposure to high-intensity exercise may induce structural remodelling of the heart, such as atrial dilatation and fibrosis. These changes affect the normal electrical conduction pathways of the heart, creating a baseline that might predispose athletes to AF. The possible remodelling is proportional to the duration and intensity of athletic training. Regular, intense training can lead to electrolyte imbalances, such as hypokalemia and hypomagnesemia, which are known to precipitate arrhythmias. Additionally, prolonged and strenuous exercise may provoke systemic inflammation. If the systemic inflammation is prolonged, it may contribute to atrial structural changes and thus increase AF susceptibility.

Exercise-induced cardiac remodelling, especially in high-level endurance athletes, may cause fibrotic changes in the atria. This most likely leads to underlying myocardial fibrosis and inflammation. Of course, like in any other individual, genetic predisposition also affects the chance

of developing atrial fibrillation, especially when combined with prolonged and intense physical training.
Understanding these mechanisms is crucial for tailoring preventive strategies and treatment approaches, particularly for athletes engaging in high-intensity training. (17),(16)

5.4. Endurance training versus strength training

As seen, a high-performance athlete´s heart adapts to the prolonged endurance and strength training in a similar way to a healthy individual's heart responds to pressure and volume overload, respectively. The internal dimensions of the left ventricle expand due to endurance training with minimal changes in LV wall thickness. Studies have shown that strength training does not affect the size of the LV but rather the thickness of the LV wall. As seen in Figure 3.

One study showed that endurance athletes exhibited larger left atrial and LV dimensions than non-athletes. There was no corresponding increase in LV wall thickness. The reservoir function of the right atrium (RA) is reduced in medium-distance runners and even more so in long-distance runners, reflecting the pattern seen in right ventricular dysfunction. These results strengthen the existence of a dose-response relationship between exercise intensity and the gradual decline in right-sided cardiac performance. (3)

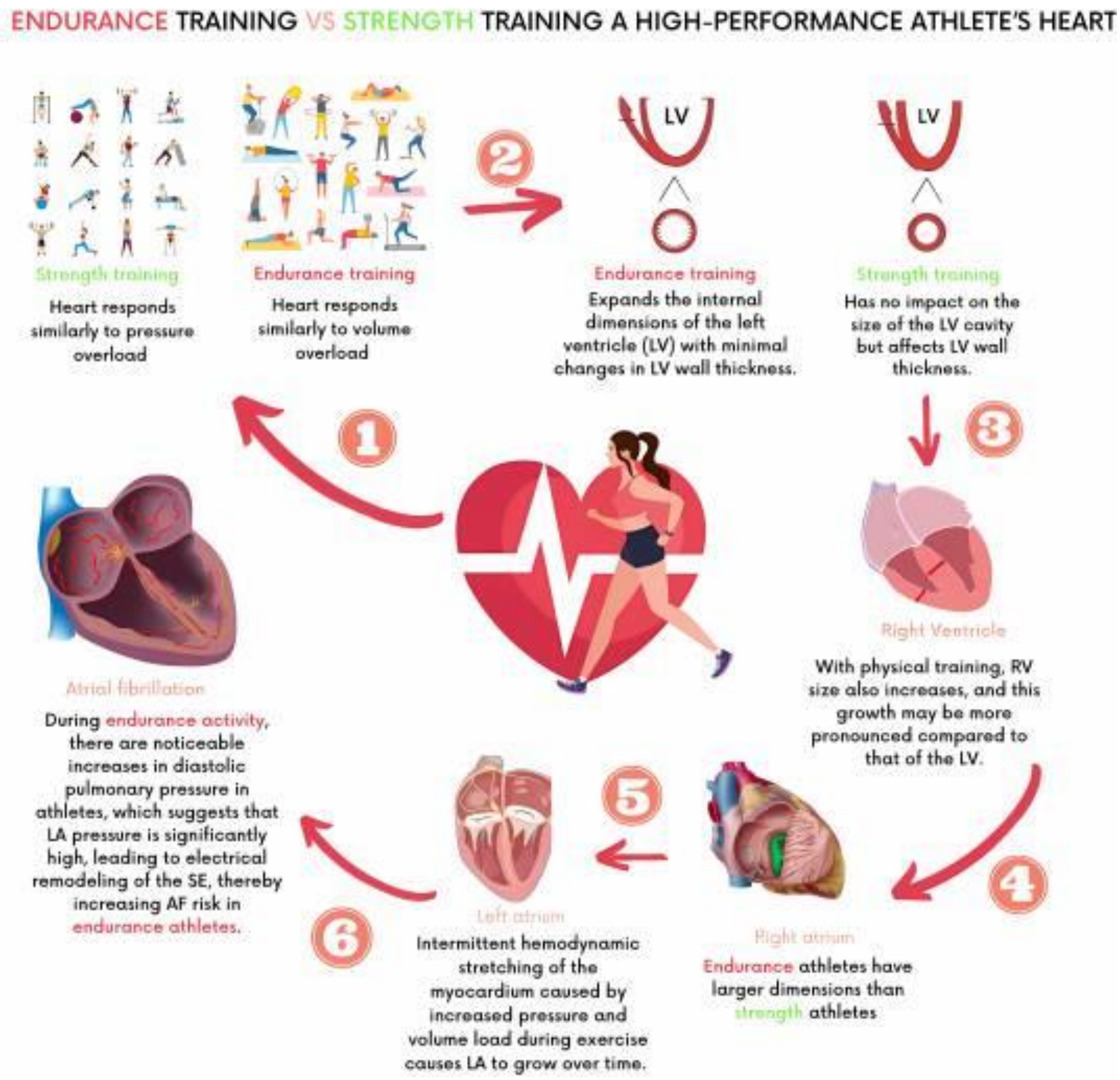

Figure 3. Endurance training vs strength training: A high-performance athlete´s heart. (3)

5.5. Prevalence of atrial fibrillation in athletes

Atrial fibrillation is the most common cardiac arrhythmia, affecting 2-4% of people in the general population. With the aging population, the prevalence of AF is expected to increase significantly in the coming decades. This trend is particularly relevant as more individuals engage in competitive and recreational sports beyond middle age. (9). The incidence of AF increases with age, making it relatively rare in younger athletes and becoming more prevalent in older athletes, particularly those over 65.

AF prevalence in athletes ranges from 0.3% to 12.8%, with key determinants including age, sex, and the specific type of sport practiced. However, the main factor is age. Among younger athletes, AF remains relatively uncommon. Atrial fibrillation may present intermittently or persistently. Among young athletes, atrial fibrillation may present in the absence of any structural heart disease or other provoking condition. In these cases, atrial fibrillation is termed “lone atrial fibrillation”. Even in these cases, many patients have some underlying risk factors for atrial fibrillation. (18) However, in athletes over 65, its prevalence mirrors that of the general population, likely due to structural heart changes rather than direct exercise-induced mechanisms. In one study, the prevalence in athletes was five times greater than in non-athletes. Studies have demonstrated a U-shaped relationship between the prevalence of exercise volume and atrial fibrillation. While moderate physical activity is linked to a lower risk of developing AF, excessive endurance training increases this risk. This indicates that the intensity and duration of exercise play a crucial role in the pathogenesis of AF. (18)

6. Contact sports and bleeding risk

Contact sports are defined as those in which physical body-to-body impact is an inherent aspect of competition, significantly elevating the risk of trauma. Examples include high-risk sports such as football and basketball, which involve regular and frequent physical collisions. Contact sports like ice hockey, boxing, mixed martial arts, and rugby are considered extreme-risk sports, while moderate-risk sports, including cycling, skiing, and baseball, present occasional contact exposure. Low-risk sports like swimming, golf, and running pose minimal trauma risks. (19)

Various studies have assessed trauma risks. Figure 4 below displays concussion rates in National Collegiate Athletic Association (NCAA) sports. This information is crucial for evaluating bleeding risks in certain areas. Figure 4 depicts collegiate concussion rates in numerous NCAA sports, calculated per 10,000 athletic exposures. Notably, the highest concussion rates are found in men's ice hockey, followed by women's soccer and men's American football, each exceeding 6 concussions per 10,000 exposures. Following these are women's ice hockey, women's gymnastics, and men's wrestling, all presenting a heightened risk of concussion. In contrast, sports like women's cross country running, women's track and field, and men's cross country report incidences close to zero. This data highlights the differing levels of concussion risk across sports, emphasizing the need for sport-specific injury prevention strategies.

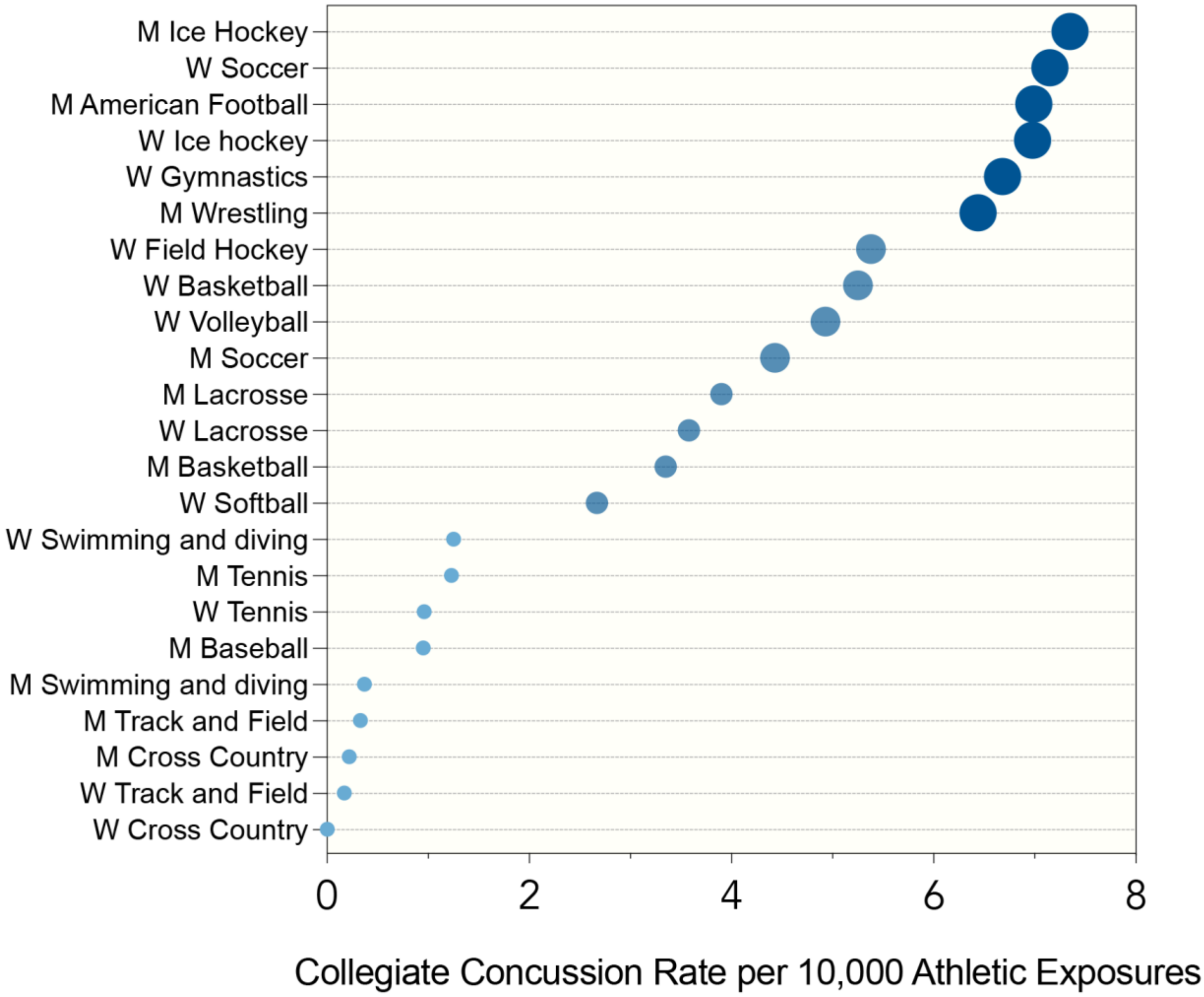

Figure 4. Collegiate Concussion Rate per 10,000 Athletic Exposures (8)

The inherent risk of trauma in contact sports is particularly concerning for athletes undergoing anticoagulation therapy, as the potential for haemorrhagic complications is considerably heightened. Athletes requiring anticoagulation may face restrictions or disqualification from competition, which can impact their careers, financial stability, and psychological well-being. (9,20)
For professional and high-performance athletes, the decision to initiate anticoagulation therapy necessitates a careful balance between the benefits of stroke prevention, especially in conditions like atrial fibrillation, venous thromboembolism (VTE), or coronary artery disease (CAD), and the risks of bleeding associated with high-impact sports. (19)

There are no universally accepted guidelines for anticoagulation management in athletes, making individualized decision-making critical. The risk for trauma can be classified based on contact exposure: non-contact sports, like golf, swimming, and running, have a low trauma probability. Limited contact sports such as baseball, volleyball, and cycling involve infrequent, unintentional contact. High-risk sports like basketball and soccer have a high probability of trauma. Collision sports, including ice hockey and American football, as mentioned before, are characterized by significant bodily contact, placing athletes in these disciplines at greater risk for trauma-related bleeding. (17)

The management of anticoagulation therapy in athletes presents clinical challenges, particularly for those with AF. While anticoagulation effectively reduces thromboembolic events, it complicates the risk-benefit landscape regarding bleeding during athletic activities. The lack of specific guidelines for athletes with AF further complicates decision-making, necessitating individualized approaches based on thorough risk assessments and sport-specific factors.

Athletes undergoing anticoagulation therapy encounter multiple challenges, particularly regarding participation restrictions and increased risks of bleeding. Management strategies vary: mild to moderate bleeding may be managed through temporary treatment interruption. In contrast, significant bleeding or trauma might necessitate the use of specific reversal agents like idarucizumab for dabigatran or andexanet alfa for factor Xa inhibitors. (20) The different treatment options that we will speak about later.

In summary, the use of anticoagulation therapy in athletes, especially those competing in high-trauma sports, presents a unique dilemma. While it significantly reduces the risk of thromboembolic events, it simultaneously raises the risk of bleeding. This is particularly concerning for younger athletes aspiring to professional levels, as the decision to initiate therapy can have profound implications for their safety and career longevity.

7. Management of atrial fibrillation in athletes

The management of atrial fibrillation is based on stroke prevention, rate and rhythm control, and management of underlying conditions and risk factors. (21) Treatment of athletes with rate or rhythm control medications can be challenging. Overtraining and stress reactions are essential to identify, as reduction or temporary cessation of training might significantly decrease or even prevent atrial fibrillation occurrence. The first line of management should start with a decrease in physical activity. (21)

Logically, it has been thought that if the risk of atrial fibrillation increases with increasing exercise levels, reduced exercise training will reduce the incidence of recurrent AF. The European Society of

Cardiology recommends a total detraining period of up to 2 months for restoration and maintenance of sinus rhythm. This becomes challenging and is not acceptable to the athlete at the elite level. However, the American Heart Association and American College of Cardiology have recommended that athletes with well-tolerated AF may participate in all competitive sports without therapy. (6)

In athletes, rhythm and rate control might be more challenging than in the general population. Often, athletes have a physiologically lower resting heart rate. Due to that, rhythm control medication has to be carefully selected. A frequently used group of rhythm control medications is class IC antiarrhythmic drugs. Most often, flecainide is a ”pill in the pocket” for athletes with vagal-mediated paroxysmal AF in the absence of structural heart disease. (16), (6) Class IC antiarrhythmic agents have been proven to reduce the risk of AF recurrence more than beta-blockers. Class IC drugs also have a better safety profile than class IA drugs in non-athletes.

Electrical cardioversion could be indicated for athletes whose atrial fibrillation has lasted less than 48 hours or, under transoesophageal echocardiography (TEE) guidance, if the duration is unknown. After cardioversion and returning to practice, the athletes have an increased risk of reoccurrence of atrial fibrillation due to increased autonomic hyperactivation.

In some cases, catheter ablation might be an option, especially among individuals whose atrial fibrillation is thought to be caused by the vagus nerve. The studies have shown excellent results with ablation among athletes. The effectiveness of this treatment in athletes is often due to a younger age and a healthier body. (16)

Finally, we will focus primarily on managing stroke prevention, which focuses on antithrombotic medications to prevent the formation of thrombi. We will discuss this in the following chapters.

8. Anticoagulation indications and options in atrial fibrillation in athletes

8.1. Indications of anticoagulation therapy in athletes

Anticoagulation therapy in athletes requires a nuanced approach, considering the unique risk factors and performance needs that sports involve. Historically, atrial fibrillation treatment guidelines have aligned with general population recommendations, using scoring systems such as CHA_2DS_2-VASc and HAS-BLED to guide therapy. However, the distinct circumstances faced by athletes necessitate careful individual assessments.

The CHA_2DS_2-VASc score is the primary tool for assessing stroke risk in patients with AF. It assigns points based on several criteria, as in Figure 5: 1 point for each: congestive heart failure, hypertension, diabetes, vascular disease, age 65-74 and female gender. 2 points each for the following: prior stroke, transient ischemic attack (TIA), thromboembolism, age ≥75.
According to international guidelines, anticoagulation therapy is generally recommended for men with CHA_2DS_2-VASc scores of ≥2 and women with scores of ≥3.
For men with a score of 1 and women with a score of 2, oral anticoagulation therapy (OAT) should be evaluated on a case-by-case basis, considering bleeding risks and individual patient preferences. Notably, for patients with no thromboembolic risk factors (CHA_2DS_2-VASc score of 0 in men and 1 in women), OAT is typically not recommended unless specific circumstances arise, such as peri-procedural anticoagulation for cardioversion or catheter ablation.

CHA_2DS_2-VASc	Score
C ongestive heart failure/LV dysfunction	1
H ypertension	1
A ge ≥ 75 years	2
D iabetes mellitus	1
S troke/TIA/TE	2
V ascular disease [prior MI, PAD, or aortic plaque]	1
A ge 65-74 years	1
S ex category (female)	1

Figure 5. CHA2DS2-VASc table.(22)

On the other hand, as seen in Figure 6, the HAS-BLED score focuses more on assessing an individual's bleeding risks on anticoagulation. It considers variables such as hypertension, abnormal renal and liver function, stroke, bleeding, INR value, age, and the use of drugs or alcohol. It helps professionals evaluate and minimize bleeding risks, unlike the CHA2DS2-VASc score, which identifies who needs anticoagulation therapy.

Letter	Risk factor	Score
H	Hypertension	1
A	Abnormal renal and liver function (1 points each)	1 or 2
S	Stroke	1
B	Bleeding	1
L	Labile INRs	1
E	Elderly (e.g., age >65 years)	1
D	Drugs or alcohol (1 point each)	1 or 2

Figure 6. HAS-BLED.(23)

Athletes often do not follow the regular guidelines. Usually, younger athletes, those with" lone AF," do not require anticoagulation due to minimal stroke risk. However, older athletes, individuals aged 65 years and older, face an increased thromboembolic risk and often need direct oral anticoagulation (DOAC) therapy. The decision to initiate treatment should consider a thorough individualized assessment of risks.

For athletes who have atrial fibrillation and might undergo cardioversion, standard anticoagulation protocols apply. If AF duration is unknown or exceeds 48 hours, oral anticoagulation treatment for at least 3 weeks is required before and after the procedure. Athletes undergoing catheter ablation for AF may benefit from rhythm control strategies rather than lifelong anticoagulation. (24)

Athletes engaged in contact sports or activities with a higher risk of trauma, such as cycling, should receive counselling regarding the risks of minor and catastrophic bleeding associated with anticoagulation. The decision to initiate anticoagulation treatment is complex and requires a thorough individualized assessment. Individualized participation plans should be developed to balance their competitive aspirations with safety considerations. (9)

As shown in Figure 7, several critical considerations should be systematically addressed when evaluating the need and type of anticoagulation for an athlete. Firstly, thoroughly understanding the patient's health status is essential. The kind of sport and the likelihood of impact and trauma should be evaluated and identified. Furthermore, the way the athlete participates in the sport, encompassing the frequency and intensity of play, needs to be considered as the risk accumulates not only from the sport but also from how the athlete plays the sport.

Assessing the thrombotic risk is a crucial aspect, as previously discussed. It involves evaluating the bleeding profile of the selected therapy. The on-off kinetics of DOACs often make them a more favourable choice for athletes, which we will discuss in the next chapter. It's essential to understand the pharmacokinetics of the therapeutic agent, including its absorption, distribution, metabolism, and excretion. Ultimately, all these considerations and decisions should be made collaboratively with the athlete and medical professionals. Risk assessment and potential alternative options regarding anticoagulation must be considered.

Consideration	Description
Patient	Understand the patient's unique health status
Sport	Identifying the type of sport and the associated likelihood of impact and trauma
Athlete-Sport Interaction	Consider how the athlete uniquely plays the sport and the frequency and intensity of participation. Risk accumulates not only from the sport but how the athlete plays the sport.
Thrombotic Risk	Evaluate the thrombotic risk of the disease in question: AF, provoked or unprovoked VTE, CAD, Need for artificial heart valve
Therapy's Bleeding Profile	Considering the bleeding profile of the chosen therapy. DOACs have faster on-off kinetics making them preferable agents for athletes who chose to continue sport.
Pharmacokinetics of Therapy	Assessing the rate of absorption, distribution, metabolism, and excretion of the therapy
Individual Decision	Use shared decision making to determine an acceptable level of risk, possibly exploring opportunities for intermittent anticoagulation or abbreviated DAPT

Figure 7. Management considerations for antithrombotic therapy in athletes.(8)

8.2. Anticoagulation options: warfarin vs. DOACs in athletes

Before the oral anticoagulants came onto the market, warfarin, a vitamin K antagonist (VKA), was primarily used for thromboembolic prevention in cases of atrial fibrillation. However, warfarin requires frequent monitoring of the INR (International Normalized Ratio) value. INR is an international standard for prothrombin time, which indicates how long it takes for an individual's blood to clot. (25)The monitoring is inconvenient for an individual, as it often requires visits to the laboratory and managing the daily dosage. For athletes, this might be draining and not the best option if the sport involves a lot of traveling.

As no surprise, direct oral anticoagulants have primarily replaced warfarin in most cases due to their faster onset of action, predictable effects, fewer drug interactions, and shorter half-life. These characteristics make them particularly suitable for athletes, as they allow for better control over anticoagulation timing and reduce the burden of frequent monitoring. DOACs provide the flexibility to tailor anticoagulation regimens around training and competitions, thereby minimizing bleeding risks while maintaining effective stroke prevention. Long-term oral anticoagulation therapy reduces blood coagulation factors II, VII, IX, and X by inhibiting hepatic vitamin K-dependent protein synthesis. Previously, VKAs, such as warfarin, were the primary anticoagulant agents for AF management. However, newer generation medications, such as direct oral anticoagulants, have replaced mainly VKAs due to their more predictable pharmacokinetics, reduced need for monitoring, fewer drug interactions, and fixed dosing regimen. (26)

As Figure 8 shows, direct oral anticoagulants and vitamin K antagonists differ significantly in their mechanisms, pharmacokinetics, and clinical implications. These differences are particularly relevant in athletic populations with critical bleeding risk and rapid reversibility. The mechanism of action in each drug is slightly different.

Dabigatran is a direct thrombin inhibitor, while apixaban, edoxaban, and rivaroxaban are factor Xa inhibitors. Coumarin derivatives inhibit the synthesis of vitamin K-dependent clotting factors (II, VII, IX, and X), resulting in delayed and less predictable anticoagulation effects.

Reversal is crucial for athletes, particularly in high-risk or contact sports. Therefore, reversibility and bleeding management are essential when considering treatment for athletes. Dabigatran has a specific reversal agent, idarucizumab, while apixaban and rivaroxaban can be reversed with andexanet alfa. Edoxaban currently lacks a widely accepted specific reversal agent. VKAs can be reversed using vitamin K and prothrombin complex concentrates, although the reversal process is slower and more complex.

The onset and half-life are essential when creating a drug schedule for an individual, especially for an athlete. DOACs have a rapid onset of action (1–4 hours), which allows for more flexible dosing around training or competition. Their half-lives range from about 5 to 15 hours. In contrast, VKAs have a slower onset and highly variable half-lives, making precise control around sporting events more difficult.

Dabigatran has low bioavailability (6.5%) and is affected by food intake, which can delay its absorption. In contrast, other DOACs and VKAs have higher bioavailability and more consistent absorption profiles. Renal function significantly influences DOAC clearance. Dabigatran is primarily renally excreted, about 85%, which may limit its use in athletes with fluctuating renal function due to dehydration or intense physical exertion. Apixaban, with 27% renal elimination, may offer a safer profile. VKAs are less dependent on renal clearance, though their safety and efficacy are less predictable.

Drug interactions are a crucial part of making the drug choice. DOACs interact primarily with P-glycoprotein (P-GP) and cytochrome P450 (CYP) pathways. VKAs, however, are highly susceptible to numerous drug and dietary interactions, necessitating regular monitoring and adjustments, which are impractical for most athletes.

One of the main advantages of DOACs is that they do not require routine coagulation monitoring, unlike VKAs, which require consistent INR checks. This makes DOACs more appealing for athletes seeking to minimize disruption to their training and travel schedules.

In summary, as seen in the table above, when anticoagulation is necessary for athletes in cases such as atrial fibrillation and venous thromboembolism, DOACs are generally preferred over VKAs. This is mainly due to DOACs' more predictable profiles, ease of use, rapid onset and offset, and more manageable bleeding risks. However, individual risk assessment and careful planning around athletic events remain crucial. (26) Especially for athletes, DOACs provide additional advantages. They have a much shorter half-life, allowing for adjustments around practices and competitions. DOACs also offer more predictable anticoagulation effects, reducing the need for frequent monitoring. Considering athletes in contact sports, DOACs are more favourable as they present a lower risk of intracranial bleeding than vitamin K antagonists. (26)
Despite these advantages, data on DOAC use in athletes remains limited, as most studies on anticoagulation in athletes have historically focused on warfarin and deep-vein thrombosis.

	Dabigatran	Apixaban	Edoxaban	Rivaroxaban	Coumarin derivatives
Target	Thrombin	fXa	fXa	fXa	Vit K epoxide reductase (VKORC1). Lower levels of vit-K-dependent factors (II, VII, IX, and X)
Prodrug	Yes	No	No	No	No
Reversible inhibition	Yes	Yes	Yes	Yes	No
Bioavailability	3%–7%	50%	62%	66%; 80%–100% with food intake	>95%
Food intake effect	Delayed, no reduction in bioavailability	None	None	Augmented bioavailability	None
Distribution volume (L)	60–70	21	>300	50	10
Protein binding	35%	87%	40%–59%	>90%	99%
Other carriers	Unknown	BCRP/ABCG2	Unknown	BCRP/ABCG2	None
Cmax (H)	1–3	3–4	2	2–4	2–4
Half-life (H)	12–17	12	10–14	5–9	40
Cytochrome metabolism	None	CYP3A4/5, CYP2J2 (minor), and CYP1A2 (minor)	CYP34A	CYP3A4/5 and CYP2J2 (equal)	CYP2C9, CYP3A4, CYP2C19, and CYP1A2
P-GP substrate	No	Yes	Yes	Yes	No
Renal clearance/non renal clearance of the absorbed dose	80%/20%	27%/73%	50%/50%	35/65%	Metabolites eliminated 80%/20%
Hemodialysis clearance	60%–70%	Unlikely	Possible	Unlikely	No
Daily administration frequency	Twice	Twice	Once	Once	Once
Formulation	Capsule (unopened and uncrushed)	Pill (crushable)	Pill (crushable)	Pill (crushable)	Pill (crushable)
AF stroke prevention standard dose	150 or 110 mg/bid	5 mg/bid	60 mg/day	20 mg/day	Variable according to INR
Lower dose	110 mg/day	2.5 mg/bid	30 mg/day	15 mg/day	
Dose-reduction criteria	• ≥80 years old or • concomitant therapy with a strong P-GP inhibitor or • increased bleeding risk	• CrCl 15–29 mL/min or if 2 of: • weight <60 kg • Cr > 1.5 mg/dL • >80 years of age	• weight <60 kg or • CrCl <50 mL/min or • concomitant therapy with a strong P-GP inhibitor	CrCl <50 mL/min	

AF, atrial fibrillation; Cr, creatinine; CrCl, creatinine clearance; P-GP, P-glycoprotein.

Figure 8. Pharmacokinetic and pharmacodynamic properties of DOACs and coumarin derivatives.(27)(26)

8.3. Bleeding risk management

Historically, anticoagulated athletes were often banned from competitive sports. Yet still nowadays, according to some articles, an athlete should be restricted from participating in high-impact sports because of a high bleeding risk. (28) Most studies regarding antithrombotic treatment in athletes have been done regarding the treatment of deep venous thrombosis (DVT). In these cases, the athlete has often been banned from a contact sport if they are on anticoagulation therapy. Standard treatment for a first episode of DVT lasts three months, though if no clear predisposing factor, such as prolonged immobilisation or a long flight, is identified, therapy may be prolonged. A return-to-training protocol generally allows light training at three weeks post-diagnosis, but full-contact sports participation is discouraged until anticoagulation therapy is discontinued. However, the return to contact sports has not been fully evaluated, and minimal resources exist. (19)

Atrial fibrillation most likely requires long-term anticoagulation, but certain cases allow for temporary anticoagulation therapy. Athletes who recognize AF onset early, have low thromboembolic risk, and undergo successful cardioversion within 48 hours may not require long-term anticoagulation. However, for patients who fail to acknowledge AF onset or who seek medical attention beyond 48 hours, a three-week course of anticoagulation therapy is usually required before performing cardioversion to minimize the risk of thromboembolism.

For asymptomatic athletes with persistent AF**,** permanent anticoagulation therapy is often the only viable treatment option. However, this poses a significant challenge for contact sport athletes, as anticoagulation therapy may disqualify them from competition, placing their careers at risk. This restriction can have severe psychological consequences, impact future career prospects, and result in financial losses. Athlete responses to this dilemma vary—some prioritize their health and accept anticoagulation therapy, while others may choose to forgo treatment in favor of continued competition despite the risks. (1)

Modern approaches emphasize shared decision-making, allowing athletes and physicians to weigh stroke prevention against trauma risk. Treatment decisions should be based on an athlete's specific sport, the severity of their AF, and their overall risk of stroke and bleeding complications.
The "fast-on/fast-off" profile of DOACs has revolutionized how anticoagulation is managed in athletes, offering more personalized treatment options. However, this resource-intensive approach may be more feasible for elite athletes with access to specialized medical care.

The clearance time of DOAC can be measured at an individual level. This helps the athlete and physician determine optimal dosing schedules to minimize bleeding risks during training and competitions. This requires pharmacokinetic (PK) and pharmacodynamic (PD) studies, involving plasma concentration measurements over 24 hours after DOAC administration. This way, the drug's elimination half-time can be determined and the point at which the drug's half-life is reached. Plasma drug concentration reaches a level where the bleeding risk is minimal; this timing can be identified individually. Additional plasma measurements at 36 and 48 hours can be helpful for athletes with prolonged drug half-lives. It should be noted that there may be intra-individual variability in drug levels with DOACs. There is evidence of this, seen especially with dabigatran, but other DOACs have not been thoroughly evaluated in this regard. By utilizing this data, DOAC dosing can be scheduled such that plasma levels have dropped below a threshold, meaning a level at which bleeding risk is low or minimal, when the athletic performance begins. When the risk of trauma or bleeding decreases, for example, after the competition, a single dose of the drug can quickly restore anticoagulation to the therapeutic range. If trauma has occurred, resuming DOAC treatment should be delayed in this case. (19) It should be mentioned that the drug elimination time from blood may vary depending on a single type of DOAC. Their residual activity might not be negligible even 24 hours after the last dose intake. (29)

While DOACs provide advantages in treatment control, the risk of bleeding remains a significant concern for athletes. The strategy for managing bleeding includes multiple factors. In the case of mild to moderate bleeding a temporary treatment interruption for a few days is generally adequte. In the occurence of major bleeding or trauma reversal agents such as idarucizumab for dabigatran or andexanet alfa for factor Xa inhibitors may be necessary.

Antithrombotic therapy is essential in preventing thromboembolism in athletes with DVT, AF, or coronary artery disease. However, the heightened risk of trauma-related bleeding complicates its use, especially in contact sports. (8)

9. Psychological burden of atrial fibrillation and its treatment for an athlete

Athletes frequently view a portion of their identity through the lens of their sport. Their sense of self is shaped by their physical skills and performances. A diagnosis of atrial fibrillation can weigh heavily on this identity, affecting mental well-being. It may disrupt an athlete's self-image, resulting in considerable psychological distress. Research on this topic is limited, but existing studies indicate that athletes with AF face heightened rates of depression and anxiety. Estimates of psychological distress linked to this diagnosis range from 25% to 50%.

Each athlete responds psychologically differently to the diagnosis of AF. The diagnosis often triggers emotional distress, reported with feelings such as anxiety and depression. Accepting the illness might take time, particularly due to the implications it has on their performance and identity as competitors. Acceptance levels differ based on the athletes' understanding of atrial fibrillation and their past possible experiences with it. Psychological factors, such as depression, can amplify the perception of AF symptoms. Additionally, athletes frequently report heightened awareness and anxiety about their health, which can exacerbate symptoms following an AF diagnosis. Social support systems, including teammates, coaches, and healthcare professionals, play a crucial role in the acceptance of an AF diagnosis.

Research has indicated that athletes utilize various coping strategies. Educating athletes about AF enhances their understanding, which can help alleviate symptoms. Numerous athletes have found psychosocial counselling beneficial for managing their emotional responses and developing effective coping strategies. Additionally, athletes may adopt new habits, such as altering their exercise routines or incorporating stress-reduction practices like yoga into their weekly schedules. Yoga has proven to alleviate symptoms and enhance quality of life. Consistent monitoring and adherence to prescribed medications allow athletes to manage AF more effectively while maintaining performance. Connecting with peers facing similar conditions has positively impacted coping with atrial fibrillation.

The relationship between atrial fibrillation and mental health is complex. Living with AF can heighten anxiety due to a fear about experiencing palpitation episodes. In many cases, the psychosocial burden may be more limiting than the symptoms of AF itself.

Although women generally show a lower prevalence of AF, studies suggest they often experience a reduced quality of life and increased anxiety levels. There is a notable connection between AF and depressive symptoms. Reports indicate a threefold increase in depression among these patients. A significant relationship exists between mental health and the management of AF. Research has shown that individuals who address their psychological symptoms tend to experience fewer AF symptoms in the long run. Therefore, regular psychosocial assessments are vital for athletes, as untreated mental health issues can exacerbate symptoms and diminish overall quality of life.

Furthermore, anxiety and depression have been linked to the recurrence of AF following treatments such as cardioversion, underscoring the importance of timely mental health evaluations and interventions. Addressing psychosocial factors has been shown to enhance treatment outcomes for AF while minimizing the impact of the diagnosis on an athlete's career. (30)

The impact of anticoagulation treatment itself in cases of atrial fibrillation has also been shown to come with its own mental health burdens. The athlete might experience a diminished quality of life due to the demands of anticoagulation therapy. Mental health issues can also be exacerbated by the need for regular medication intake and lifestyle changes to treat AF promptly. Additionally, anticoagulation therapy might affect the physical aspect of performance. The requirement for regular anticoagulation therapy often necessitates adaptations in athletes' training routines. Athletes may need to modify their training based on their anticoagulation status, which significantly impacts their overall performance mindset. Also, anticoagulation comes with increased risks for bleeding. Athletes might face concerns about bleeding and injury due to anticoagulation therapy, which may lead to hesitance in performing at the usual intensity level. Again, this highlights the importance of building a supportive environment for athletes, including coaches, healthcare professionals, and trainers. This can help athletes manage the psychological impacts of anticoagulation therapy, fostering a more positive mindset. Athletes might encounter stigma or misconceptions regarding the treatment, influencing their mental health and willingness to engage in competitive sports. (30)

10. Discussion

It can be seen that athletes' cardiovascular health is complex but an essential and central part of sports medicine. Its understanding often requires complex knowledge from multiple fields of medicine and insights from specific sports and age groups. This multidisciplinary approach highlights the team effort to provide security and prompt treatment for athletes without limiting their practice or attendance in sports competitions.

Regular training reflects in the heart of an athlete. Multiple physiological adaptations have been observed in athletes, such as improvements in heart function. However, these changes can lead to abnormalities in the ECG. Most often, these are benign, harmless, and linked to intensive training. Nevertheless, some of these abnormalities could negatively affect the athlete's health.

Athletes in prolonged endurance training might face additional risks associated with conditions like atrial fibrillation. However, strength training has not proven to be a risk factor for AF as prominently as endurance training due to the nature of the form of movement. The relationship between exercise intensity and the risk of AF is typically U-shaped: moderate exercise is a protective factor. In contrast, excessive training can increase the likelihood of complications. This highlights the need for tailored management strategies to address each athlete's needs and training demands. Implementing injury prevention protocols and considering the risks associated with contact sports would also be essential for the athletes. Furthermore, athletes would benefit from psychosocial support to foster overall well-being and enhance performance outcomes.

It is essential to create supportive environments for athletes to enhance the culture of safety and consideration at the individual level. As we advance in sports cardiology, future research will deepen our understanding of athletes' cardiovascular needs. This will ensure the balance between health, safety, and performance.

10.1. Anticoagulation therapy in athletes

The complexities of anticoagulation therapy in athletes highlight the importance of individual evaluation and consideration in every case. It shows how multicomplex field medicine can be. Anticoagulation therapy is increasingly recognized as a vital intervention for athletes at risk of thromboembolic events due to conditions like deep vein thrombosis and atrial fibrillation. Direct oral anticoagulants are most commonly prescribed in these scenarios. However, the significant bleeding risks associated with their use, particularly in athletes who participate in contact sports, should be seriously evaluated. The challenges in the anticoagulation therapy of an athlete lie in managing these risks effectively, as athletes may be more susceptible to trauma-related bleeding. This shows how much a tailored approach is needed for the anticoagulation treatment.

When faced with mild to moderate bleeding, a temporary interruption of anticoagulation therapy for a few days is usually sufficient. In the event of significant bleeding or trauma, immediate action is required. This often involves the administration of specific reversal agents such as idarucizumab for dabigatran or andexanet alfa for factor Xa inhibitors. This highlights the urgent need for personalized treatment plans that consider various factors. These factors should include the type of sport, the athlete's prior history of bleeding or injuries, and their competition and training intensity and frequency.

The decision-making for athletes on anticoagulation is complex and highlights the importance of comprehensive risk evaluations customized to each athlete and their respective sport. There is still a significant gap in the literature and research regarding athlete-specific anticoagulation guidelines.

This becomes a more and more needed topic as more middle-aged and older athletes engage in competitive sports. Future research is essential to explore vital areas, such as the long-term effects of DOACs on athletic performance, risk stratification for athletes involved in contact sports, and optimizing dosing strategies that promote safety and performance.

Moreover, effective management of anticoagulation therapy cannot occur in isolation. It requires active teamwork between healthcare providers and athletes, often encapsulated in shared decision-making. This collaborative approach ensures that treatment plans align with clinical evidence, the athlete's preferences, and competitive goals. By balancing the risks associated with stroke prevention against the potential for severe bleeding, stakeholders can enhance both safety and performance among athletes on anticoagulants.

In conclusion, while anticoagulation therapy plays a crucial role in mitigating serious cardiovascular risks for athletes, the associated bleeding risks, particularly in contact sports, demand careful and thoughtful management. Creating comprehensive, athlete-specific guidelines and promoting a collaborative approach to treatment will be essential in navigating the complexities of anticoagulation therapy in the athletic population now and in the future. These strategies will enhance safety and support the ongoing performance of athletes who require anticoagulation.

Involving athletes in treatment discussions enables healthcare providers to effectively weigh the risks of bleeding against the necessity of preventing thromboembolic events. Regular cardiovascular screenings, athlete education on symptom recognition, and ongoing monitoring and following of athletic performance are crucial for early detection of athletes' health problems.
Moreover, the implementation of injury prevention protocols and the consideration of the unique risks associated with contact sports are essential for safeguarding the health of athletes.
Furthermore, psychosocial support is equally important, fostering overall well-being and enhancing performance outcomes.

11. Future directions in anticoagulation for athletes

Further research is needed to develop athlete-specific anticoagulation recommendations as more middle-aged and older athletes participate in competitive sports. The studies should focus on the long-term effects of DOACs on athletes, the risk profile of anticoagulated athletes in contact sports, and optimized dosing strategies for safe sports participation.

The increasing awareness of AF among athletes and the evolving field of anticoagulation therapy emphasize the need for individualized, risk-adjusted treatment. Approaches that prioritize both stroke prevention and athletic performance.

Athlete-specific guidelines are needed because of the increased risk of traumatic bleeding in sports. Further research is required to determine optimal anticoagulation regimens for athletes, best practices for anticoagulated athletes participating in contact sports, and the long-term effects of DOACs in high-performance athletes.

Atrial fibrillation is a complex condition in athletes that requires careful risk assessment and individualized treatment strategies. Although anticoagulation therapy remains crucial for stroke prevention, it poses significant challenges to sports participation, particularly in contact sports. The introduction of DOACs has provided new opportunities for flexible anticoagulation management, but further research is needed to develop sport-specific guidelines. Specific, clear guidelines for athletes using anticoagulation because of atrial fibrillation should be established in the future. This field of medicine will benefit from clear guidelines and recommendations.

12. Recommendations

Based on the conclusions of this thesis, some recommendations could be made regarding anticoagulation treatment in athletes with atrial fibrillation. As noted, anticoagulation therapy and the decision surrounding it require individualized assessment. For athletes, this often necessitates balancing the risk of thromboembolism against the risk of bleeding. At the same time, the type of sport practiced, the level of intensity and professionalism, and the athlete's overall health status should be carefully evaluated.

The assessment should include a sports-specific risk stratification. Different sports have unique features that place some athletes at a higher risk of injury. For instance, ice hockey is a high-contact, collision sport that poses a significant risk of trauma and bleeding. Moderate-risk sports like cycling require careful individualized assessment. However, low-contact sports may be compatible with ongoing anticoagulation treatment with appropriate monitoring. Choosing an anticoagulant is a complicated decision that requires careful evaluation. DOACs are often preferred over VKAs because they pose a lower risk of intracranial hemorrhage, offer more predictable pharmacokinetics, and feature fixed dosing regimens. Agents with shorter half-lives, like rivaroxaban and apixaban, allow for better timing around training and competition.

An assessment of the options for temporarily interrupting anticoagulation treatment should also be conducted. A prompt treatment plan should be developed, taking into consideration potential travel and lighter off-season training periods. If possible, a non-pharmacological alternative should also be explored.

Significantly, athletes should be involved in the decision-making process, and if feasible, coaches and support teams should also be consulted. Additionally, engaging with the sports club and insurance company can provide a broader perspective on screening methods and follow-up strategies available, particularly since these may incur financial implications.

This process should be documented with the athlete's preferences, understanding, and informed consent. This involvement can help minimize conflicts and ensure the athlete's safety, as in some sports, athletes may be “owned” by teams during the season. Such conflicts regarding the team players’ health might compromise the care of athletes, as medical professionals and the athletes themselves may feel pressure from team management to prioritize team performance over individual health. To alleviate these issues, it is advisable for every sports organization to ensure that medical professionals serving athletes are independent of team employment. For instance, in the NFL, a recommendation has been made to separate medical roles into two distinct entities: one focused solely on player care, and the other on team evaluations, ensuring that team interests do not sway athletes' health decisions. (31)These insights reiterate the importance of establishing medical oversight to safeguard athletes' health and autonomy.

In addition to the debate over whether to initiate anticoagulation therapy and select the most appropriate treatment, another significant factor emerges: the psychological impact of an atrial fibrillation diagnosis and adapting to potential anticoagulation treatment. Given that the intensity of atrial fibrillation symptoms and depression are often correlated, regular psychological evaluations are essential for athletes. If mental health issues remain unaddressed, they can exacerbate both atrial fibrillation and symptoms of depression and anxiety, ultimately deteriorating an athlete's quality of life. Furthermore, providing accurate and timely information about atrial fibrillation and its treatment options can alleviate symptoms and enhance an athlete's overall performance capacity.

Women have been reported to suffer more from anxiety due to atrial fibrillation, even though the prevalence among women is much lower compared to men. Could this be partly due to a lack of support from fellow athletes, which encompasses feelings of being different and alone in the situation? That we do not know. What seems to be beneficial would be support groups and as discussed earlier, patient education about this topic.

With these points, the field of sports medicine could create specific recommendations and clear guidelines for physicians to follow, ensuring athletes continue their careers without limitations. Support groups, as well as patient education, would be beneficial. To reach the guidelines and sport-specific recommendations, much more research is needed on the topic of atrial fibrillation and anticoagulation treatment in athletes.

13. Conclusion

The well-established preventive and therapeutic benefits of sports are clear. However, as the population ages and life expectancy increases, the average age of active athletes also rises. This brings new insights into existing issues, raises new questions from old treatment guidelines, and forces changes and updates to be developed.

This thesis explores the complex topic of anticoagulation therapy for athletes with atrial fibrillation. This area is particularly challenging due to the often-insufficient evidence available for clinical decisions, which evaluates the specific demands of various sports, and is more complex and more based on the physician and the athlete. Although atrial fibrillation typically does not affect young athletes, the issues related to anticoagulation treatment become increasingly significant as the active athlete population ages. While anticoagulation is vital for stroke prevention in atrial fibrillation patients, its application in athletes raises unique concerns, particularly for those in high-risk sports where trauma and bleeding are significant issues.

Current research indicates that elite endurance athletes, especially older males, have a greater chance of developing atrial fibrillation, likely due to the long-term physiological effects of intense training. There is a significant gap in the management of anticoagulation treatment for these individuals. Especially regarding the timing and duration, as well as the selection of anticoagulation, while ensuring that the risk of sports does not rise too high.

Direct oral anticoagulants have become more popular than vitamin K antagonists owing to their consistent effects and lesser need for monitoring. However, their application among athletes raises significant safety issues, especially among athletes in contact sports. The potential for trauma-related bleeding combined with the lack of definitive protocols based on solid evidence necessitates a tailored and careful management strategy. Athletes who require long-term anticoagulation therapy might still experience huge losses. Yet, direct oral anticoagulants and the research conducted to date cannot provide sufficient information on this topic. This impacts the athlete's career, as they may face disqualification from their sport. Unsurprisingly, this can affect the athlete's mental health, overall lifestyle, financial stability, and career paths.

Comprehensive guidelines designed for athletes with atrial fibrillation are still lacking. Current recommendations primarily arise from research on the general population, often overlooking athletes' unique physiological and professional circumstances. As noted before, this highlights the urgent need for additional research about the anticoagulation treatment of athletes in the case of atrial fibrillation.

Large-scale, sport-specific studies that can illuminate the bleeding risks, performance considerations, and best management practices for athletes on anticoagulants are much needed. There is still data lacking that shows that athletes could safely return to play with clear directions for the treatment and its continuation. This requires that the intermittent dosing and the reversal agents are known. The physician must work as a team with the athletes, considering the specific sports, health status, and personal preferences. The complexities that the anticoagulation therapy requires in atrial fibrillation in athletes, particularly among those athletes who are engaged in high-risk or contact sports, are not yet clearly tailored. In the future, once these regulations have been made with ongoing research, athletes can receive optimal cardiovascular treatment and an opportunity to participate and compete at the elite level safely.

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