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Sports-Related Sudden Cardiac Arrest: Age and Sex Risk Factors

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1. Abstract

Sports-related sudden cardiac arrest (SRSCA) is defined as a natural out-of-hospital collapse of presumed cardiac origin occurring during or within one hour of moderate-to-vigorous physical exercise. Despite the well-documented cardiovascular benefits of physical activity, vigorous exertion can transiently trigger life-threatening arrhythmias in vulnerable individuals, a phenomenon known as the "paradox of exercise". This scientific review aims to evaluate the combined influence of age and sex on the risk and clinical presentation of SRSCA by synthesizing high-quality evidence from contemporary literature, including 37 original research articles drawn from international registries such as the NCAA, FIFA, and ESCAPE-NET. The analysis reveals a striking and consistent male predominance, with men accounting for 90% to 98% of cases across various registries, while women exhibit a 10- to 13-fold lower incidence rate. Furthermore, the underlying pathological substrates shift significantly with age; inherited or congenital structural diseases like hypertrophic cardiomyopathy and coronary artery anomalies predominate in athletes under 35, whereas atherosclerotic coronary artery disease is the primary cause in those over 35. Survival rates following SRSCA are notably favorable compared to non-sports cardiac arrests, ranging from 45% to over 90% in organized settings, largely due to the witnessed nature of these events and the rapid utilization of automated external defibrillators (AEDs), which is associated with survival as high as 86%. Consequently, reducing the burden of sudden death requires a two-tier strategy: primary prevention through preparticipation screening initiated around age 12 to detect phenotypic manifestations of disease, and secondary prevention via robust emergency preparedness, including mandatory AED access and rehearsed emergency action plans at all sporting venues.

Keywords: Sudden cardiac death, athlete, epidemiology, age risk factors, biological sex, prevention.

2. Introduction

2.1. Definition and Epidemiology of Sports-Related Sudden Cardiac Arrest (SRSCA)

Sudden cardiac arrest (SCA) refers to an unexpected, naturally occurring out-of-hospital collapse presumed to be of cardiac etiology that necessitates the initiation of basic life support measures, including chest compressions and/or the use of an automated external defibrillator (AED) [10,22]. When resuscitation attempts fail, the event is categorized as sudden cardiac death (SCD), which is generally defined as death occurring within one hour of symptom onset in witnessed cases or within 24 hours after the individual was last observed alive and in a stable condition when the event is unwitnessed [2,7,8,12,14]. Within the sporting context, sports-related sudden cardiac arrest (SRSCA) is commonly described as an arrest occurring either during physical activity or within one hour following the completion of moderate- to high-intensity exercise [12,16,19,22,29].

The reported incidence of SRSCA and SCD differs between populations and sporting disciplines; nevertheless, these events remain rare despite their severe consequences [1,16,19,22,29]. Among young competitive athletes, annual incidence estimates range from approximately 1 in 40,000 to 1 in 80,000 individuals, whereas selected high-risk groups, particularly male basketball players, may exhibit rates between 1 in 3,000 and 1 in 8,000 [2,11,24,28]. In the broader population participating in endurance competitions such as marathons, incidence estimates vary from 0.5 to 2.2 cases per 100,000 participants [10,29]. Although infrequent in absolute terms, SRSCA constitutes an important public health concern because it frequently affects seemingly healthy individuals and remains the leading medical cause of mortality among young athletes [1,2,7,11,18,19,26,31]. Moreover, these incidents impose substantial personal and societal burdens, often intensified by extensive media coverage when elite or well-known athletes are involved [2,8,31,37].

2.2. Pathophysiology of Exercise-Induced Cardiac Arrest

Sports-related sudden cardiac arrest exemplifies the so-called “exercise paradox.” Although habitual physical activity is strongly associated with improved cardiovascular health and reduced long-term mortality, intense exertion may acutely precipitate potentially fatal arrhythmias in susceptible individuals [8,11,16,19,22]. This transient increase in risk arises from the interaction between an underlying, frequently unrecognized cardiac abnormality and the marked physiological demands of exercise, including substantial catecholamine surges, hemodynamic alterations, and electrolyte disturbances [5,8,18,31,33]. These conditions may promote arrhythmogenic processes, particularly re-entrant ventricular arrhythmias and ventricular fibrillation triggered by extreme physical stress [8,29].

The pathological substrate responsible for SRSCA varies considerably according to age and athletic profile. In younger competitive athletes, inherited and congenital cardiovascular abnormalities are the predominant causes, most notably hypertrophic cardiomyopathy (HCM), arrhythmogenic right ventricular cardiomyopathy (ARVC), and congenital anomalies of the coronary arteries [4,11,12,26,29,31]. In contrast, coronary artery disease (CAD) represents the principal underlying pathology in older and recreational athletes and accounts for the majority of cases in these populations [8,14,16,19,23,29]. Notably, a considerable proportion of SRSCA events approaching 50% in certain endurance-sport registries remain unexplained despite comprehensive clinical investigations and postmortem examinations. This observation suggests that currently available diagnostic approaches may fail to identify all individuals at risk [7,11,29].

2.3. Importance of Demographic Risk Factors

Age and biological sex constitute two of the most important demographic predictors of SRSCA. The likelihood of experiencing cardiac arrest during sports participation rises markedly with increasing age [6,10,16,19]. Although public and media attention often focuses on young athletes, epidemiological data indicate that most SRSCA events occur in middle-aged and older individuals, with reported median ages typically ranging from 58 to 61 years [16,19]. This age-related increase is primarily attributable to the growing prevalence of ischemic heart disease in older populations [10,14,16].

Sex-related differences represent one of the most pronounced epidemiological features of SRSCA. Across the majority of studies, males account for approximately 90–98% of all reported cases [10,12,16,17,19,22,29]. Accordingly, the incidence among women is consistently estimated to be 10- to 13-fold lower than among men, irrespective of sport type or age category [6,22,29]. Several mechanisms have been proposed to explain this disparity, including the vasculoprotective effects of endogenous estrogens, sex-dependent differences in autonomic regulation, and distinct patterns of exercise-induced cardiac remodeling [6,22,29].

In addition, women who experience SRSCA are more likely to do so during low- or moderate-intensity activity, whereas men demonstrate a substantially greater tendency for cardiac arrest during vigorous exertion [22]. Recognition of these vulnerable demographic groups, particularly older men and participants in high-intensity sports, is crucial for the development of targeted preparticipation screening programs and the implementation of effective emergency response strategies [10,14,19,22].

2.4. Aim of the Study

The present study aims to assess the combined effects of age and sex on both the risk profile and clinical characteristics of sports-related sudden cardiac arrest. Through the evaluation of data derived from contemporary registries and published literature, the study seeks to determine incidence patterns across distinct demographic groups and to examine the epidemiological and clinical features that differentiate SRSCA among various athletic populations [1,19,22,29]. Ultimately, the findings are intended to provide evidence supporting the development of more effective age-specific and sex-specific screening strategies, as well as preventive interventions designed to reduce the incidence of sudden cardiac death in both competitive and recreational sports environments [19,22,29].

3. Materials and Methods

3.1. Study Design

This review provides a comprehensive overview of current evidence regarding sports-related sudden cardiac arrest (SRSCA), based on a systematic evaluation of literature published during the previous three years. The selection process initially identified 55 potentially relevant publications. Following eligibility assessment, 37 original research studies were included in the final analysis, whereas 18 publications were excluded according to predefined criteria. Excluded articles consisted predominantly of narrative or systematic reviews without original datasets, experimental animal studies, and correspondence articles such as letters to the editor. The final body of evidence comprised studies employing various methodological approaches, including large prospective and retrospective cohort investigations, registry-based population analyses, and forensic autopsy or toxicological studies. The inclusion of these complementary study designs enabled a broad evaluation of the epidemiology, underlying mechanisms, and clinical outcomes of SRSCA across different athletic cohorts and geographical settings.

3.2. Population and Inclusion Criteria

The reviewed literature included individuals participating in a broad range of sporting activities, encompassing both elite and competitive athletes as well as recreational exercisers from middle-aged and older populations. Eligible studies were required to report confirmed cases of SRSCA or sudden cardiac death (SCD). Across the selected publications, sport participation was generally characterized as physical activity performed for recreational purposes, maintenance of physical fitness, or competitive achievement. To facilitate consistency between studies, SRSCA was defined as a cardiac arrest occurring either during exercise or within one hour after completion of moderate- to vigorous-intensity physical activity. Age-based stratification was commonly applied to reflect differences in the underlying cardiovascular substrates associated with cardiac arrest. In most studies, younger athletes were categorized as individuals younger than 35 or 40 years, whereas master or veteran athletes were typically defined using thresholds of 35, 50, or 65 years of age.

3.3. Data Collection

Data analyzed in the reviewed studies were predominantly derived from established national and international databases, including the NCAA and FIFA sudden death registries as well as the European ESCAPE-NET population-based registry network. In several investigations, registry information was supplemented through systematic media surveillance and internet-based searches designed to identify publicly reported cases of sudden death among athletes. These cases were subsequently validated through communication with sports governing bodies, coroners, or medical personnel. Extracted variables included demographic and clinical characteristics such as age, sex, ethnicity, and pre-existing medical conditions. Additional event-related information comprised the sporting discipline involved, exercise intensity, and the occurrence of prodromal symptoms. Studies incorporating autopsy or toxicological examinations also collected detailed postmortem findings to establish the structural or electrophysiological cardiac abnormalities responsible for the event.

3.4. Variables and Outcomes

The principal outcome evaluated across the included studies was the occurrence and incidence of SRSCA or SCD, commonly expressed as cases per 100,000 athlete-years or per million participants. Secondary outcomes included clinically relevant measures such as survival to hospital admission, survival to hospital discharge, and neurological recovery at discharge. Neurological outcomes were most frequently assessed using the Cerebral Performance Category (CPC) scale. Furthermore, many studies investigated elements of the "chain of survival," with particular emphasis on the provision of bystander cardiopulmonary resuscitation (CPR) and the accessibility and prompt deployment of automated external defibrillators (AEDs).

3.5. Statistical Analysis

The studies included in this review primarily relied on descriptive statistical methods to summarize population characteristics, reporting variables as means, standard deviations, and frequency distributions. Comparative analyses were frequently conducted to evaluate differences between demographic subgroups, including comparisons according to sex and age, through the calculation of relative risks and incidence rate ratios (IRRs). To identify independent determinants of survival and quantify the effects of specific risk factors, numerous studies employed multivariable logistic regression or Poisson regression models. These analyses generated adjusted odds ratios (aORs) while accounting for potential confounding variables, including age, sex, and established cardiovascular risk factors. Across the reviewed literature, statistical significance was generally defined by a p-value below 0.05.

4. Results

4.1. Characteristics of the Study Population

Across studies investigating sports-related sudden cardiac arrest (SRSCA), a marked predominance of male victims was consistently observed regardless of geographical location or sporting discipline. Data from population-based registries indicate that men account for approximately 91–93% of all sports-related cardiac arrest events [16,19,22]. This imbalance becomes even more pronounced in competitive athletic populations and video-documented cases, where males represent up to 96–98% of affected individuals [12,17]. The age profile of victims differs considerably depending on the study setting. Collegiate athletes experiencing SRSCA are typically around 20 years of age, whereas participants identified through community registries and endurance-event cohorts are substantially older, with median ages generally ranging between 53 and 61 years [2,10,16,18]. Regarding sport-specific distribution, football (soccer) emerges as the discipline most frequently associated with sudden cardiac death (SCD) in European and competitive-athlete cohorts [14,17,23]. In contrast, among recreational and older athletes, endurance-based activities such as running, cycling, and tennis are more commonly implicated [10,14,19]. Notably, individuals affected by SRSCA tend to exhibit fewer cardiovascular risk factors and a lower burden of chronic disease than patients experiencing non-sport-related cardiac arrest [16,19]. Although conditions such as hypertension and obesity may be present, particularly among older athletes, the overall population is characterized by a generally healthier lifestyle and superior physical fitness [13,19].

4.2. Age-Related Risk Factors

Age represents a major determinant of both the incidence and etiology of SRSCA. In children younger than 12 years, cardiac arrest associated with physical activity is exceedingly uncommon; however, incidence rates increase markedly after the age of 12–15 years [7]. Among younger athletes, typically defined as individuals below 35 years of age, inherited and congenital cardiovascular abnormalities constitute the leading causes of SRSCA. These include hypertrophic cardiomyopathy (HCM), arrhythmogenic right ventricular cardiomyopathy (ARVC), and congenital coronary artery anomalies [11,14,29,31]. Additionally, autopsy-negative sudden unexplained death (AN-SUD) is frequently reported in this age group, highlighting the potential contribution of primary electrical cardiac disorders [2]. In contrast, advancing age is associated with a substantial increase in SRSCA risk, largely attributable to the growing prevalence of coronary artery disease (CAD) [10,16,21]. In both marathon participants and general population registries, CAD is responsible for nearly 50% of cases and commonly presents as an acute ischemic event precipitated by the physiological demands of strenuous exercise [10,12,19,23].

4.3. Sex-Related Differences

Sex-related disparities remain among the most prominent epidemiological features of SRSCA. Compared with men, women demonstrate a markedly lower incidence, estimated to be approximately 10–13 times lower across multiple studies and registries [6,22]. This difference is observed consistently across all age categories and sporting environments, with fewer than 100 cases occurring annually among women throughout the European Union [6,10,22].

Beyond incidence, sex-related differences are also evident in the circumstances and physiological characteristics of the event. Female athletes are more likely to experience cardiac arrest during low- or moderate-intensity physical activity, whereas male athletes predominantly suffer events during vigorous exertion [22]. Differences are also apparent in the initial cardiac rhythm recorded by emergency medical services (EMS). Women more frequently present with non-shockable rhythms, including asystole and pulseless electrical activity, compared with men (40.7% versus 19.1%, respectively) [6,22]. Nevertheless, despite these distinctions in presentation, several registries have demonstrated similar survival-to-discharge rates between men and women when prompt bystander intervention is provided [22].

4.4. Interaction Between Age and Sex

Multivariable analyses indicate that age and sex interact significantly in shaping the risk profile of sports-related sudden cardiac arrest. Among men, incidence rates increase progressively with age and reach their highest levels during the fifth and sixth decades of life [6,10]. In contrast, this age-related pattern is far less evident in women, whose incidence remains consistently low across age groups, showing only a modest increase after menopause [6,10]. The literature identifies several particularly vulnerable subpopulations. These include older male recreational athletes engaged in high-intensity endurance activities and young Black male basketball players, both of whom exhibit substantially elevated incidence rates relative to other athletic groups [2,10,28]. These findings suggest that the accumulation of ischemic cardiovascular disease with age contributes significantly to the increasing risk observed in men, whereas women may benefit from persistent physiological or hormonal mechanisms that reduce susceptibility to exercise-induced arrhythmogenic events [6,16,22,29].

4.5. Survival and Prognostic Factors

Outcomes following SRSCA are considerably more favorable than those reported for non-sport-related out-of-hospital cardiac arrest. Survival rates reach approximately 45–48% among older adults and may exceed 90% during organized endurance competitions [10,16,29]. This survival advantage is largely explained by the public nature of many sporting events, where cardiac arrests are frequently witnessed and rapid activation of the "chain of survival" is possible [16,19,22]. Among all prognostic determinants, immediate defibrillation using an automated external defibrillator (AED) appears to be the most influential, with reported survival rates of up to 85–86% when an AED is promptly deployed [7,17]. Conversely, delayed initiation of cardiopulmonary resuscitation (CPR) and the absence of readily available AEDs are strongly associated with poorer outcomes [17]. The location of the event also affects prognosis. Cardiac arrests occurring within organized sports venues generally result in higher survival rates than those taking place in outdoor environments or private locations, reflecting superior emergency preparedness and easier access to resuscitation equipment [16,17,19]. Finally, the presence of an initial shockable rhythm, particularly ventricular fibrillation or ventricular tachycardia, remains an independent predictor of successful resuscitation and favorable neurological outcomes [16,19].

5. Discussion

5.1. Main Findings

The findings synthesized from recent literature highlight the well-recognized "exercise paradox," whereby regular physical activity confers substantial long-term cardiovascular protection while simultaneously producing a transient increase in the risk of sudden cardiac arrest (SCA) during periods of intense exertion [11,16]. One of the most consistent observations across contemporary studies is the pronounced sex-related disparity in risk, with men exhibiting a 10- to 13-fold greater incidence of sports-related sudden cardiac arrest (SRSCA) than women [6,22,29]. Although the overall incidence of SRSCA remains low, the burden is disproportionately concentrated among older male recreational athletes, particularly those participating in endurance-based activities such as running and cycling [10,16,19,21]. In younger athletic populations, inherited structural and electrical cardiac abnormalities continue to represent the predominant causes of SRSCA, whereas autopsy-negative sudden unexplained death (AN-SUD) has emerged as an increasingly common postmortem diagnosis [2,11,14]. By contrast, coronary artery disease (CAD) remains the principal pathological substrate in athletes older than 35 years, frequently becoming clinically manifest under the physiological demands of competitive exercise [10,14,16,29]. Moreover, outcomes following SRSCA are substantially more favorable than those observed after non-sport-related cardiac arrest, a difference largely attributable to the higher likelihood of witnessed events and the widespread availability of automated external defibrillators (AEDs) in organized sporting environments [17,19,22].

5.2. Comparison With Previous Literature

The present findings are broadly consistent with earlier reports documenting a strong male predominance in SRSCA, while also providing updated insights into changes in incidence patterns and underlying etiologies. Historically, hypertrophic cardiomyopathy (HCM) was regarded as the most common cause of sudden cardiac death (SCD) among young athletes. However, recent registry data, including findings from the 20-year NCAA investigation, indicate a decline in overall SCD incidence alongside an increasing prevalence of AN-SUD and idiopathic left ventricular hypertrophy among documented causes of death [2,8]. This transition may reflect improvements in preparticipation screening (PPS) programs, which are increasingly effective in detecting overt structural cardiac abnormalities such as HCM before athletic participation [8,23]. In addition, incidence rates reported in endurance events, including marathons, remain relatively stable at approximately 0.5–2.2 cases per 100,000 finishers, mirroring observations from previous decades. Nevertheless, more recent evidence from Paris-based registries has identified a notable clustering of events during the final kilometer of races, a phenomenon that has received limited attention in earlier literature [10,29].

5.3. Mechanisms Explaining Age and Sex Differences

The substantial difference in SRSCA incidence between men and women is likely explained by a complex interaction of hormonal, structural, electrophysiological, and behavioral factors. Endogenous estrogens have been proposed as an important protective mechanism in women because of their favorable effects on vascular function, including enhanced vasodilation and modulation of platelet activity, potentially reducing susceptibility to exercise-induced ischemic events [6,22,29]. Structural adaptations to training may also contribute, as male athletes generally demonstrate more pronounced cardiac remodeling, characterized by greater increases in ventricular wall thickness and left ventricular mass, which could facilitate arrhythmogenesis during periods of extreme physiological stress [29,36]. Electrophysiological differences further distinguish the sexes. Female athletes more frequently present with non-shockable rhythms and appear less vulnerable to the autonomic triggers that precipitate ventricular fibrillation during maximal exertion [6,22]. Behavioral patterns may also influence risk. Evidence from endurance competitions indicates that men are approximately twice as likely as women to markedly increase pace in the final stages of a race, potentially exceeding physiological limits and increasing exposure to arrhythmogenic stimuli [29].

5.4. Clinical and Public Health Implications

The epidemiological patterns identified in this review have important consequences for both clinical practice and public health strategies. Given the exceptionally low incidence of SRSCA among women, cardiovascular assessment in female athletes may benefit from a greater emphasis on general cardiovascular health promotion and risk factor management rather than intensive screening for occult cardiac disorders [6,22]. In contrast, ongoing cardiovascular screening remains particularly important for male athletes older than 12 years, as many inherited cardiomyopathies become clinically apparent during adolescence and early adulthood [7]. Furthermore, evidence demonstrating a greater prevalence of cardiovascular abnormalities among para-athletes supports the development of screening strategies specifically adapted to their unique physiological characteristics [30]. In addition to primary prevention, optimizing secondary prevention remains crucial. Rapid activation of the "chain of survival," including immediate bystander cardiopulmonary resuscitation (CPR) and strategic deployment of AEDs in high-risk locations such as sports venues and race finish areas, continues to represent the most effective approach for reducing mortality associated with SRSCA [7,16,17,19,22].

5.5. Study Limitations

Several limitations should be considered when interpreting the available evidence on SRSCA. A substantial proportion of existing registries depend on media reports and internet-based case identification, introducing the potential for ascertainment bias. Consequently, events involving elite athletes or sports with greater public visibility may be disproportionately represented, whereas cases occurring during recreational activities or in private settings may remain underreported [1,14,16,17]. Another important limitation is the absence of accurate denominator data in many studies. Because the precise number of individuals participating in specific sporting activities is often unknown, incidence calculations frequently rely on estimates, potentially affecting the accuracy of reported rates [8,16,19]. Additionally, the majority of available data originate from predominantly White European and North American populations, which may limit the applicability of findings to other ethnic and geographical groups [4,6,22]. Finally, low autopsy utilization rates and inconsistencies in postmortem investigation protocols across different regions hinder accurate etiological classification, contributing to the relatively high proportion of cases categorized as having an unknown cause [1,2,29].

5.6. Future Directions

Future efforts to reduce the burden of SRSCA should prioritize the establishment of independent, prospective, multinational registries capable of providing standardized and comprehensive data collection [1,8,14,18]. The incorporation of advanced postmortem diagnostic techniques, particularly molecular autopsy based on genetic testing, may substantially improve the detection of concealed cardiomyopathies and inherited channelopathies in cases of AN-SUD [2,15,21]. Emerging personalized medicine approaches, including the application of polygenic risk scores and three-dimensional electroanatomical mapping, offer promising opportunities for identifying individuals at elevated risk before the occurrence of a sentinel event [11,29,33]. Furthermore, advances in artificial intelligence and wearable monitoring technologies, such as connected smartwatches, may facilitate real-time assessment of physiological stress during exercise and contribute to early risk detection [1,13,29]. Ultimately, meaningful progress will require coordinated collaboration among sports organizations, healthcare professionals, researchers, and governmental agencies to improve risk stratification strategies and promote a culture of safer participation in sport [1,14,17].

6. Conclusions

Sports-related sudden cardiac arrest (SRSCA) remains an infrequent yet highly consequential event, with age and biological sex representing the strongest demographic factors influencing its occurrence [2,10,16]. Evidence derived from international registries consistently demonstrates a marked male predominance, while women experience a 10- to 13-fold lower incidence of sports-related cardiac arrest events across diverse populations and sporting settings [17,22]. The risk of SRSCA increases progressively with age, particularly among men, reaching its highest levels in middle-aged and older recreational athletes engaged in high-intensity endurance activities [6,10,16,19]. Moreover, the underlying pathological mechanisms vary substantially throughout the lifespan. In younger individuals, inherited cardiomyopathies and primary electrical disorders, including autopsy-negative sudden unexplained death (AN-SUD), predominate, whereas atherosclerotic coronary artery disease (CAD) becomes the principal cause in older athletic populations [2,11,12,14,16,19].

The clinical relevance of these observations reflects the well-established “exercise paradox,” whereby vigorous physical activity, despite its long-term cardiovascular benefits, may acutely trigger malignant arrhythmias in individuals harboring overt or concealed cardiac abnormalities [11,16,18]. Nevertheless, survival following SRSCA is considerably higher than that reported for non-sport-related out-of-hospital cardiac arrest, with outcomes ranging from approximately 40% to 90%, depending on the population and circumstances of the event [17,19,22,29]. This advantage is largely attributable to the public setting in which many events occur, the high likelihood of immediate recognition by bystanders, and the prompt activation of the “chain of survival” [17,19,22,29].

From both clinical and sports medicine perspectives, reducing the burden of sudden cardiac death requires a comprehensive strategy integrating primary and secondary prevention measures [7]. Primary prevention should include preparticipation screening (PPS) based on a targeted medical history, physical examination, and resting 12-lead electrocardiography, with implementation ideally beginning around the age of 12 years, when many inherited cardiomyopathies begin to manifest clinically [4,7]. However, because no screening strategy can identify all individuals at risk particularly those with AN-SUD or acquired conditions such as myocarditis secondary prevention remains equally critical [2,7]. Essential components include universal access to automated external defibrillators (AEDs) at sporting facilities, widespread cardiopulmonary resuscitation (CPR) training, and the establishment of well-rehearsed emergency action plans (EAPs) [7,17,24]. Furthermore, for athletes diagnosed with inherited cardiovascular disorders, the growing adoption of shared decision-making (SDM) frameworks enables individualized eligibility assessments, balancing patient autonomy with evidence-based risk evaluation and personalized therapeutic management [18,34].

AI

In the study, AI was used to improve the language of the manuscript, ensuring consistency and compliance with scientific standards. After using this tool, the authors reviewed and edited the content as necessary, taking full responsibility for the substantive content of the publication.

Author Contribution

Conceptualization: W.S, M.S, D.S, K.O, M.K, A.K

Methodology: W.S, M.S, D.S, K.O, M.K, A.K

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