

Cardiovascular Screening in Physically Active Individuals: Findings from an Ambulatory Cross-Sectional Study

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Abstract Physically active individuals, including both recreational and professional athletes, are often presumed to be inherently healthy. This assumption can result in minimal or absent cardiovascular evaluation, despite evidence that sudden cardiac events may occur in previously asymptomatic populations. International experience shows a range of screening strategies: Italy implements systematic ECG-based pre-participation screening, with observed reductions in sudden cardiac death among athletes, whereas questionnaire-based approaches in countries including the United States, Canada, and the Czech Republic have shown limited detection of latent cardiac conditions. These observations highlight the need for objective early detection methods that complement traditional evaluations. An ambulatory cardiovascular screening program was conducted among 96 physically active participants without prior complaints or referrals. Each participant completed a questionnaire on demographics, training type, and chronic conditions. Cardiac assessment was performed using an AI-driven digital auscultation device that automatically detected and analyzed heart murmurs. Participants with detected murmurs were referred to cardiologists for further evaluation; not all had completed full diagnostic testing at the time of reporting. Cardiac murmurs were detected in 20 of 96 participants (20.8%; 95% CI: 12.7%–28.9%), including both professional and amateur athletes across various training types. The prevalence did not differ significantly between women and men (24.6% vs 15.4%; $p=0.28$). None of the affected individuals had a prior diagnosis of structural or valvular heart disease, underscoring the limitations of relying solely on history- and questionnaire-based screening. Even asymptomatic, physically active individuals may harbor latent cardiovascular abnormalities, which are often missed by routine screening approaches. Minimal objective evaluation can improve early detection and preventive care in sports medicine.

Keywords: cardiovascular screening, heart murmurs, sudden cardiac death, athletes, early detection, sports medicine, AI-assisted auscultation

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1. Introduction

In sports medicine, a pervasive yet misleading assumption remains: young and well-trained equates to being healthy. In practice, this results in insufficient screening, as in many countries evaluations are restricted to questionnaires on symptoms and family history, occasionally supplemented by a brief physical examination. This applies not only to professional athletes prior to competition but also to the majority of physically active individuals, from fitness center participants to recreational tennis players and regular runners, who generally do not undergo targeted cardiovascular screening. However, neither questionnaires nor routine examinations provide sufficient diagnostic accuracy, and a considerable proportion of latent structural cardiomyopathies and conduction system abnormalities

remain undetected [1,2].

Previous studies have shown that history- and symptom-based screening approaches in physically active individuals may fail to identify a substantial proportion of clinically relevant cardiovascular abnormalities, particularly in asymptomatic populations [3,4].

This paradox is evident. At the population level, regular physical activity reduces the long-term risk of cardiovascular disease [5]. Nevertheless, among individuals who train intensively, sudden cardiac death (SCD) events still occur, as underlying cardiac pathology frequently remains undiagnosed until the moment of maximal exertion.

The most vulnerable group consists of young individuals who train systematically and progressively increase both the volume and intensity of their exercise. In those with asymptomatic cardiomyopathies, valvular malformations, or conduction system abnormalities, the additional training load becomes a factor that elevates the

risk of life-threatening arrhythmias and SCD [2,6].

International experience demonstrates wide variation in screening strategies. In Italy, mandatory electrocardiogram (ECG)-based pre-participation programs have significantly reduced the incidence of SCD among athletes [7]. In contrast, countries such as the United States and Canada rely primarily on history and symptom-based questionnaires, which have shown limited diagnostic yield in identifying latent cardiac conditions [8,9]. Recent prospective data also suggest that symptom- and history-based screening protocols have limited sensitivity compared with ECG-based strategies in physically active adult populations [10]. These differences underscore the ongoing challenge of developing efficient, scalable, and evidence-based screening approaches for the physically active population.

The aim of this study was to evaluate the prevalence of latent cardiovascular abnormalities among physically active individuals using ambulatory screening, and to assess the limitations of standard history- and questionnaire-based pre-participation evaluations.

2. Materials & Methods

2.1. Participants and Study Design

Ninety-six physically active participants, including both recreational and professional athletes, were enrolled in an ambulatory cardiovascular screening program. All participants completed a questionnaire capturing age, sex, physical activity status, type of training, and self-reported chronic conditions. Participants underwent automated auscultation using the Stethophone, a digital device cleared by the U.S. Food and Drug Administration (FDA) for heart sound analysis and murmur detection [11]. The study aimed to evaluate the prevalence of latent cardiovascular abnormalities and to assess the limitations of standard history- and questionnaire-based pre-participation evaluations. The prevalence and characteristics of detected murmurs were analyzed descriptively.

2.2. Ethics and Data Governance

The study complied with the ethical principles outlined in the Declaration of Helsinki. All participants provided signed informed consent forms confirming their voluntary participation and permission for anonymized data publication. Identifying information was not collected, and all records were de-identified prior to analysis. The raw acoustic and algorithmic data generated by the mobile application contain sensitive physiological information and cannot be publicly shared for privacy and regulatory reasons.

2.3. Statistical Analysis

Descriptive statistics were used to summarize participant characteristics. The prevalence of cardiac murmurs was expressed as a percentage with 95%

confidence intervals (CI). The association between sex and murmur detection was evaluated using the chi-square (χ^2) test with one degree of freedom; Fisher's exact test was also calculated for confirmation. Statistical significance was defined as $p < 0.05$. All calculations were performed using standard formulas in Microsoft Excel. The study followed the STROBE guidelines for transparent reporting of cross-sectional observational.

3. Results

3.1. Participants and Study Design

A total of 96 physically active individuals were included in the analysis. Demographic and training characteristics of the cohort are summarized in Table 1. The sample comprised 57 women (59.4%) and 39 men (40.6%), with ages ranging from 18 to 74 years (mean 34.2). Most participants (68.8%) were recreational athletes, while 31.2% were professionals.

Primary training types included strength/power (39.6%), endurance/cyclic (20.8%), aerobic/cardio (15.6%), team sports (5.2%), and unspecified (18.8%).

Chronic conditions were self-reported by 31 participants (32.3%).

Table 1. Sample characteristics of the study population*

Number of Participants		96 (100%)	
Age range		18–74 years	
Mean age		34.2 years	
Sex	women	57	59.4%
	men	39	40.6%
Physical-activity level	amateurs	66	68.8%
	professionals	30	31.2%
Primary training type (self-reported)	strength/power	38	39.6%
	endurance/cyclic	20	20.8%
	aerobic/cardio	15	15.6%
	team sports	5	5.2%
	not specified	18	18.8%
Chronic conditions (self-reported)	yes	31	32.3%
	no	65	67.7%

*Values are presented as counts (n) and percentages (%). Percentages are calculated from the total sample (N=96)

3.2. Detected cardiac Abnormalities

Cardiac murmurs were detected in 20 of 96 participants (20.8%; 95% CI: 12.7%–28.9%), including both professional and amateur athletes across various training types. The prevalence did not differ significantly between women and men (24.6% vs 15.4%; $\chi^2(1)=1.18$, $p=0.28$; Fisher's exact $p=0.32$). None of the affected individuals had a prior diagnosis of structural or valvular heart disease, underscoring the limitations of relying solely on history- and questionnaire-based screening. Characteristics of participants with detected murmurs are presented in Table 2.

Table 2. Profile of participants with detected murmurs*

Sex	women	14	70%
	men	6	30%
Age range		18–64 years	
Mean age		30.2 years	
Activity level	professionals	9 (30% of all professionals in the sample)	
	amateurs	11 (16.7% of all amateurs in the sample)	
Training type	strength/power	10	50%
	endurance/cyclic	6	30%
	aerobic/cardio	1	-
	team sports	2	-
	not specified	1	-
Chronic conditions	yes	5	25%
	no	15	75%

*Percentages are based on the subgroup of participants with detected murmurs (n=20). Training-type and activity-level distributions are self-reported

3.3. Clinical Findings and Follow-up

All participants with newly detected murmurs were referred to cardiologists for further evaluation. At the time of reporting, not all follow-up assessments had been completed. Preliminary specialist feedback indicated that several murmurs were functionally benign, whereas others required echocardiographic confirmation to exclude structural abnormalities.

Representative clinical cases are summarized below:

- Male, 35 years: amateur athlete engaged in endurance/cyclic training. Echocardiography revealed a grade I mitral valve leaflet prolapse.
- Male, 19 years: professional athlete specializing in strength training. Cardiology assessment identified sinus bradycardia, respiratory arrhythmia, mitral valve prolapse and trivial tricuspid regurgitation.
- Female, 36 years: amateur athlete engaged in endurance/cyclic training. Cardiology assessment confirmed aortic stenosis and mitral regurgitation.

These findings emphasize the diagnostic potential of structured cardiovascular screening and the need for follow-up in physically active individuals even in the absence of symptoms.

4. Discussion

4.1. Participants and Study Design

The central issue under debate is the balance between effectiveness and feasibility [7]. National programs with mandatory ECG screening, as implemented in Italy, have demonstrated effectiveness in reducing mortality through the detection of conduction abnormalities and certain cardiomyopathies, but they require substantial resources and rigorous organization. By contrast, models that rely primarily on questionnaires and medical history, such as those in the United States and Canada, are simpler and less costly to apply but inevitably fail to identify a proportion of latent pathology. The experience of

individual countries clearly illustrates the diversity of strategies and their respective consequences.

4.1.1. Italy: The Structured National ECG-based Program

The Italian experience remains the most compelling example of the effectiveness of systematic screening in sports cardiology. Since 1982, Italy has maintained a national pre-participation screening (PPS) program that includes mandatory 12-lead ECG and clinical examination. In the landmark Veneto region study (1979-2004), mortality from SCD among athletes decreased by approximately 89-90% after the program's introduction [6]. Contemporary Italian data further confirm the value of serial PPS: in a cohort of 22,324 children aged 7-18 years who collectively underwent 65,397 annual evaluations, 69 individuals (~0.3%) were identified with conditions associated with an increased risk of sudden cardiac death, including congenital heart disease, channelopathies, cardiomyopathies, and non-ischemic left ventricular scar with ventricular arrhythmias (NILVS) [8]. During a mean follow-up of 7.5 ± 3.7 years, one case of resuscitated cardiac arrest was recorded in a child with previously normal screening, corresponding to ~0.6 events per 100,000 athlete-years [8]. Thus, Italy has provided the most compelling evidence that systematic screening with mandatory ECG can substantially reduce the incidence of SCD in the athletic population.

4.1.2. Czech Republic: The Limitations of Questionnaire-Based Screening

In the Czech Republic, as in several other countries, PPS programs rely predominantly on questionnaires and family history. In the study by Jiravska et al. [1], the sensitivity of such questionnaires was shown to be extremely limited. Comparative analyses of different PPS systems revealed low reproducibility and weak diagnostic value: in most adolescents and young athletes with potentially serious cardiac pathology, family history and questionnaires did not provide grounds for suspecting disease [1]. The authors emphasized that even with accurate completion, the detection rate of latent cardiomyopathies or conduction system abnormalities remains minimal. This confirms that in large cohorts, reliance on paper-based tools and self-report is insufficient. In the context of a growing number of young people actively engaging in sports, such an approach effectively reproduces a group of under-screened individuals, in whom sudden death may become the first manifestation of disease.

4.1.3. United States: Reliance on History and Physical Examination

American practice has traditionally been minimalist, based on the 12-element screening protocol that includes medical history and physical examination [9]. In many states, questionnaires are incomplete and clinical examinations are performed only formally; auscultation may be omitted or conducted without adequate quality [12]. The primary focus is on schoolchildren and college students — the largest groups regularly undergoing pre-participation evaluations. For professional and elite athletes, the range of tests is broader (often including ECG and echocardiography), but these practices remain local

and are not universally applied. The cost of this compromise is the failure to detect latent pathology in young and physically active individuals. A recent analysis of NCAA athletes reported an incidence of SCD of approximately 1 case per 63,682 athlete-years [13]. These data pertain to competitive collegiate athletes and do not represent the entire physically active population, but they underscore that even within organized sports leagues, the risk of sudden death remains real.

4.1.4. Canada: A Cautious Approach

The Canadian model largely mirrors that of the United States, with emphasis placed on medical history and physical examination, while instrumental methods are used only when clinically indicated. Reviews have highlighted that the routine use of ECG in screening remains controversial, and even extended protocols cannot guarantee prevention of all cases of sudden death [14]. Epidemiological data confirm the presence of an under-screened population. In a multicenter study conducted between 2016 and 2020 and encompassing adults aged 18 to 85 years, the incidence of sport-related sudden cardiac arrest (SCA) was 1.2 cases per 100,000 person-years [15]. Most episodes occurred in individuals previously considered healthy and physically active. This underscores the limitations of questionnaires and formal examinations as the sole filter, since SCA may represent the first manifestation of latent disease.

4.2. Comparison with Current Findings

Taken together, the debate converges on a central question: what minimal level of evaluation can be considered sufficient to meaningfully reduce the risk of sudden death in physically active individuals?

Our data demonstrate that even among physically active individuals without symptoms or a significant medical history, a considerable proportion exhibit previously unrecognized signs of potential cardiac pathology. This observation aligns with international evidence: in Italy, systematic screening incorporating mandatory ECG has been associated with a marked reduction in athlete mortality, whereas in North America and the Czech Republic, protocols relying primarily on questionnaires and routine physical examinations have been shown to miss asymptomatic cardiomyopathies and conduction system abnormalities.

Importantly, the problem is not confined to professional sport. In many countries, athletes are by default considered healthy and therefore undergo only minimal evaluation; in reality, however, all categories of physically active individuals, from schoolchildren and students to adults engaged in regular fitness or recreational sports, remain largely outside of comprehensive medical oversight. For some of them, SCA represents the first clinical manifestation of disease.

4.3. Strengths and Limitations of the Study

The strengths of the present study include its focus on a real-world, non-clinical population and the use of an accessible screening modality that reflects practical

conditions for large-scale implementation. However, certain limitations should be acknowledged. The study sample size was relatively small, and echocardiographic verification was not performed systematically. Consequently, while auscultation-based findings highlight potential pathology, definitive diagnosis requires further instrumental confirmation. In addition, the study was conducted within a limited geographical and demographic context, which may restrict generalizability.

In addition, the sample size of 96 participants, while sufficient to illustrate the practical feasibility of ambulatory screening, limits the precision of prevalence estimates and should be expanded in future studies.

4.4. Implications for Preventive Cardiology

The objective is not to establish a universal, costly screening program but to address diagnostic gaps at the foundational level of pre-participation evaluation and prevention. A minimally mandatory, objective screening step is needed to ensure timely referral of suspicious cases for further evaluation.

The key task of preventive cardiology today is to change the paradigm of risk assessment in physically active individuals. Reliance on youth and training experience as “guarantees of health” has proven misleading. Our observations indicate that even in the absence of symptoms or medical history, conditions requiring cardiological attention can be identified in this group. The foundation of modern preventive strategy should therefore rest not on presumed well-being but on regular, objective verification of cardiovascular status. These findings are consistent with prior evidence demonstrating the limited sensitivity of history- and questionnaire-based screening alone and support the integration of objective screening modalities in the cardiovascular evaluation of physically active individuals [3,4,10].

5. Conclusions

A combined analysis of international experience and our own ambulatory screening data demonstrates that the concept of “health by default” in physically active individuals does not withstand scrutiny. All too often, youth and training status are regarded as “proof of health”, while underlying latent cardiomyopathies, valvular abnormalities, or conduction system disorders remain undetected.

Our findings indicate that a substantial proportion of physically active individuals harbor previously unrecognized cardiac pathology requiring specialist attention. Questionnaires and formal physical examinations, often conducted without cardiac or pulmonary auscultation, are insufficient to address this issue, while costly national screening programs are not universally available. Preventive cardiology should therefore rely on objective evaluation rather than the presumption of health. Even minimal, accessible screening can detect latent pathology before clinical manifestation and substantially improve the safety of sports participation — a step that sports medicine can no longer afford to postpone.

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Statement of Competing Interests

The authors declare that they have no conflicts of interest related to this work.

Availability of Data and Material

An anonymized dataset containing participants' demographic characteristics, training profiles, and screening outcomes is provided as a supplementary Excel file. No personal identifiers are included.

Ethics Approval

The study was reviewed and approved by the Internal Ethics Committee of LLC Ukrainian Sports Clinic (Approval 01-A/2025, dated 10 January 2025). The approved documents included the Study Protocol, Consent Statement, and Data Anonymization Plan.

All procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki (2024 revision).

Consent to participate and consent for publication: All participants provided signed informed consent prior to inclusion in the study and agreed to the use of anonymized data for scientific publication.

Author Contributions

Yana Totska, Juliia Padalko, Tetiana Tereshchenko, and Oleg Kasatka contributed to the conception and design of the study, data acquisition, data analysis, and interpretation. Oleg Kasatka drafted the manuscript. All authors critically revised the text, approved the final version, and agree to be accountable for all aspects of the work.

List of Abbreviations

AI - artificial intelligence

CI - confidence interval

ECG - electrocardiogram

FDA - U.S. Food and Drug Administration

NCAA - National Collegiate Athletic Association

NILVS - non-ischemic left ventricular scar

PPS - pre-participation screening

SCA - sudden cardiac arrest

SCD - sudden cardiac death.

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