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FULL RESEARCH PAPER

The use of cardiac imaging in the evaluation of athletes in the clinical practice: A survey by the Sports Cardiology and Exercise Section of the European Association of Preventive Cardiology and University of Siena, in collaboration with the European Association of Cardiovascular Imaging, the European Heart Rhythm Association and the ESC Working Group on Myocardial and Pericardial Diseases

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Aims Pre-participation evaluation (PPE) is recommended to prevent sudden cardiac death in athletes. Although imaging is not advocated as a first-line screening tool, there is a growing interest in the use of echocardiography in PPE of athletes. This survey aimed to map the use of imaging in the setting of PPE and explore physician beliefs and potential barriers that may influence individual practices.

Methods An international survey of healthcare professionals was performed across ESC Member Countries. Percentages were reported based on the number of respondents per question.

Results In total, 603 individuals from 97 countries participated in the survey. Two-thirds (65%) of respondents use echocardiography always or often as part of PPE of competitive athletes and this practice is not influenced by the

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professional or amateur status of the athlete. The majority (81%) of respondents who use echocardiography as a first-line screening tool perform the first echocardiogram during adolescence or at the first clinical evaluation, and 72% repeat it at least once in the athletes' career, at 1–5 yearly intervals. In contrast, cardiac magnetic resonance is reserved as a second-line investigation of symptomatic athletes. The majority of the respondents did not report any barriers to echocardiography, while several barriers were identified for cardiac magnetic resonance.

Conclusions Echocardiography is frequently used as a first-line screening tool of athletes. In the absence of scientific evidence, before such practice is recommended, large studies using echocardiography in the PPE setting are necessary.

Keywords Pre-participation screening • athlete's heart • sudden cardiac death • echocardiography • cardiac magnetic resonance

Introduction

Pre-participation cardiovascular evaluation (PPE) of competitive athletes aims to identify individuals with cardiac conditions at potential risk of exercise induced malignant arrhythmias and sudden cardiac death (SCD).[1] Although PPE is recommended by a number of scientific and sporting organizations, there is considerable debate regarding the individual components of the screening protocol, which has prevented the adoption of a uniform strategy. This relates to controversies regarding the sensitivity and specificity of individual tests as well as the availability of expertise and cost-effectiveness.[2–8]

Efforts over the past decade have predominantly focused on optimizing the 12-lead electrocardiogram (ECG) as a screening tool. The recent international criteria for the interpretation of the athlete's ECG[9] have demonstrated a substantial increase in specificity and a marginal decrease in sensitivity for the differential diagnosis between cardiomyopathies and athlete's heart.[10,11] Recognition of the limitations of the ECG in identifying several structural heart conditions such as a proportion of cardiomyopathies, congenital heart disease including coronary artery anomalies, aortopathies and valvular lesions has fuelled research in the inclusion of echocardiography in the PPE of competitive athletes. Several echocardiographic protocols have been trialled and have consistently demonstrated that the incremental value of echocardiography relates predominantly to identifying congenital and valvular heart disease, at a considerable cost. As such, although the echocardiogram's value as a second line investigative tool for the diagnosis of malignant cardiac conditions and differentiation from physiological adaptation to exercise is well established,[12–15] echocardiography is not recommended as a first-line screening tool in athletes.[16,17]

Despite current recommendations, however, echocardiography is increasingly being used during PPE in various populations, including professional and amateur athletes. The Sports Cardiology and Exercise section of the European Association of Preventive Cardiology in collaboration with the University of Siena, the European Association of Cardiovascular Imaging (EACVI), the European Heart Rhythm Association (EHRA) and the ESC Working Group on Myocardial and Pericardial Diseases conducted a survey aimed to map the use of imaging in the setting of PPE and explore physician beliefs and potential barriers that may influence individual practices.

Methods

An international survey targeting healthcare professionals with an interest in sports cardiology and PPE of athletes was performed across ESC Member Countries. The survey was launched on 18 March 2019 and the call was open until 3 May 2019. The survey was disseminated to ESC members via e-campaigns, individual and group emails, publications on social media, and on the ESC website. An external platform (Survey Monkey) was used and respondents received a link to fill an electronic survey. The full questionnaire is presented as Supplementary Material online. Data collected related to individual and national practices relating to PPE, the use of echocardiography and cardiac magnetic resonance imaging (CMR) for the evaluation of athletes and the presence of barriers to imaging as a screening tool. For the purposes of this survey, competitive athletes were defined as professional or non-professional individuals practising at least 5 h of training per week, being regularly involved in competitions. No identifiable information was included. To comply with GDPR regulations, details about the collection of personal information were included in the introduction to the survey.

A weighted average for each answer choice was calculated for each answer choice and is reported in the results section. The weighted average was calculated on the basis of a rating scale question, commonly known as a Likert scale, that is a variation of the Matrix question (i.e. a closed-ended question that asks respondents to evaluate one or more row items using the same set of column choices) where the weights to each answer choice can be assigned. Ranking questions calculated the average ranking for each answer choice in order to determine which answer choice was most preferred overall. The answer choice with the largest average ranking was the most preferred choice. The average ranking was calculated as follows, where w = weight of ranked position *and* x = response count for answer choice

$$\frac{x_1w_1 + x_2w_2 + x_3w_3 \ldots x_nw_n}{\text{Total response count}}$$

The percentages were calculated for each question on the basis of the number of respondents per question. For the most relevant questions, answers were divided also according to membership of ESC Associations that the respondents belong to and countries where they live. Comparison between groups was performed using Student's *t*-tests for continuous variables with adjustment for unequal variance if needed and chi-square tests or Fisher Exact Tests for categorical variables. Statistical analysis was performed using the Medcalc software (version 17.4, Ostend, Belgium).

Results

Participant background

A total of 603 respondents from 97 countries participated in the survey (Supplementary *Tables 1* and *2*). Among the respondents, 5%

were <30 years of age, 34% between 31 and 40 years, 24% between 41 and 50 years, 22% between 51 and 60 years and 15% were more than 60 years of age. In total, 42% of the respondents were members of EACVI, 25% of EAPC, 10% of EHRA, 7% of ESC Working Group on Myocardial and Pericardial Diseases, while 35% were not members of the participating associations or working group. Respondents reported as their primary fields of interest imaging (68%), general cardiology (60%), sports cardiology (40%), arrhythmias (25%), cardiac rehabilitation (22%), inherited cardiac disease (14%), sports medicine (13%) and paediatric cardiology (8%) and 11% were interested in other fields, including heart failure, interventional cardiology and emergency cardiology. A minority (13%) of the respondents were involved in writing recommendations/guidelines on the topic of sports cardiology. The majority (72%) of respondents were involved with evaluation of competitive athletes rarely (42%) or monthly (30%), with a smaller proportion involved on a weekly (20%) or daily (8%) basis.

The role of imaging in the evaluation of competitive athletes

In the presence of symptoms, the use of echocardiography was almost universal, with 87% of respondents using it often or always (*Figure 1*(a)). In asymptomatic athletes, the great majority (83%) of respondents use echocardiography on a fairly regular (≥10%) basis as part of their PPE protocol, with 65% using echocardiography often or always (*Figure 1*(b)). There was no significant association between 1) being a member of an association or not, 2) being a member of a specific association, 3) field of interest or 4) age of the respondents and the use of echocardiography in asymptomatic individuals. There was a significant association between the top four countries of origin and the use of echocardiography, with 86% of respondents from Greece (7% of total cohort) using echocardiography often or always in asymptomatic individuals, compared with 68% of respondents from Spain, 62% from the UK and 58% from Italy ($p < 0.05$).

The preferred timing of the first echocardiography study was either the athlete's first evaluation (46%) or adolescence (35%), with only 4% and 6% of the respondents suggesting childhood or adulthood, respectively (*Figure 2*). The majority (65%) of respondents use echocardiography more than once in an athlete's career span, even if the athlete is asymptomatic, with most advocating repeat echocardiographic evaluation independently from abnormal findings (72%): at least once every year (27%), every 2 years (27%) or every 5 years (18%). Conversely, a minority (28%) suggest repeating echocardiography only in the case of abnormal findings (*Figure 3*).

According to respondents' opinion, the use of echocardiography clarified the diagnosis in the evaluation of athletes, regardless of ECG

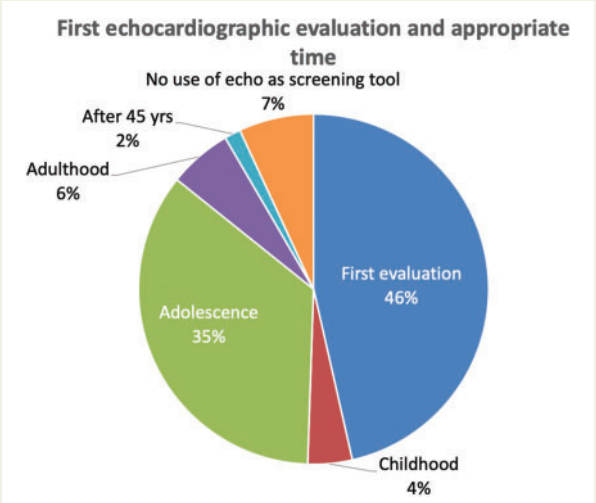

Figure 2 Optimal timing for the first echocardiographic evaluation in the athletes undergoing pre-participation evaluation (Question 14).

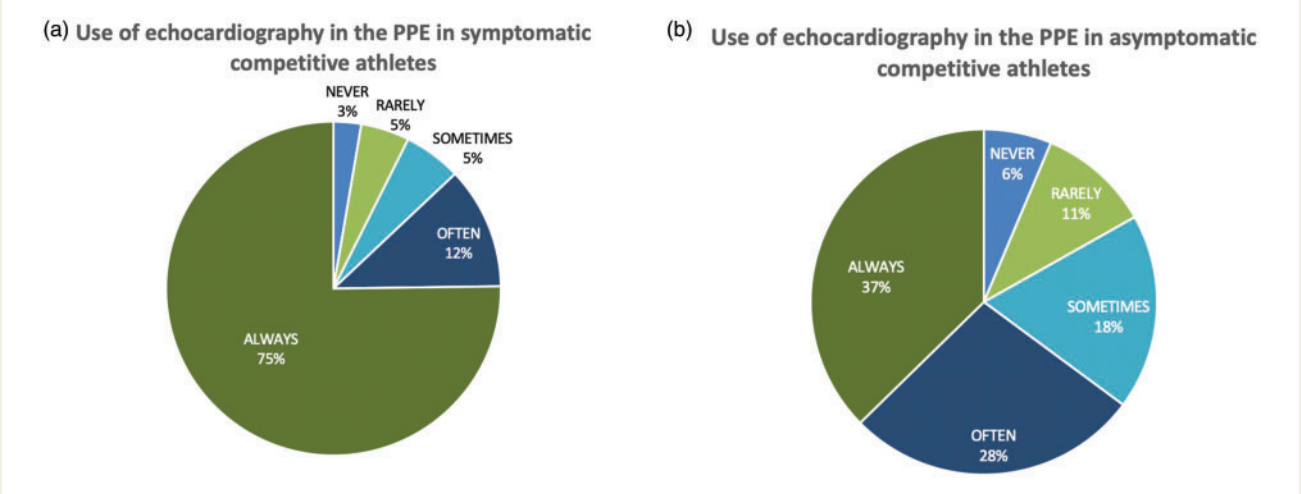

Figure 1 The use of echocardiography as a first-line screening tool in the context of pre-participation evaluation in symptomatic (a) and asymptomatic (b) competitive athletes (Questions 7 and 8). Never = 0%; rarely <10%; sometimes 10–30%; often 31–90%; always >90%. PPE: pre-participation evaluation

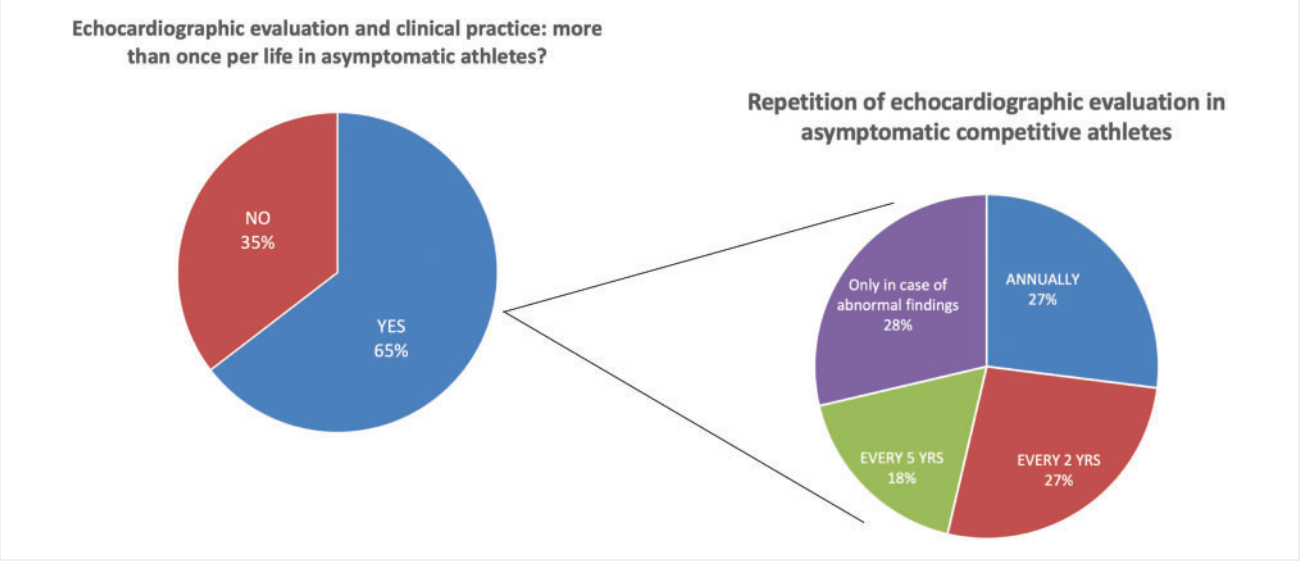

Figure 3 Proportion of respondents suggesting repeat echocardiographic evaluation in asymptomatic competitive athletes. The right-hand panel reports the precise timeline suggested (Question 15).

findings, in most of the cases in 46%, sometimes in 25%, always in 15%, in specific settings in 9%, rarely in 4% and never in less than 1%. When asked about the additional value of echocardiography in identifying heart disease, in the presence of a normal ECG, respondents ranked cardiomyopathies (average score 2.79) at the top followed by aortic aneurysm/dilatation (average score: 2.6) bicuspid aortic valve (average score: 2.53) and other valvular heart disease (average score: 2.08) (*Table 1*). The respondents identified additional conditions with a normal ECG that echocardiography can detect, including coronary artery anomalies, myocarditis, and ischaemic and congenital heart disease.

CMR is used by the great majority of respondents after echocardiography (*Figure 4*), more often in symptomatic rather than asymptomatic athletes (weighted average 3.27 *vs.* 2.6) (*Figure 5*(a) and (b)).

For the majority of respondents (74%), the status of the athlete (professional versus amateur) does not influence their decision relating to the use of the imaging studies during cardiac evaluation.

Main barriers to imaging

The majority of the respondents (69%) believe that in their respective countries there are no barriers to echocardiography. Of the 31% who reported barriers to accessing echocardiography, the barriers most commonly chosen were coverage of screening costs by social/health insurance (average score: 3.26), access to equipment (average score: 2.61), limitations of time per visit with patients (average score: 2.09) and personnel training (average score: 2.04). Additional barriers reported by the respondents were: low referral by other physicians, low expertise with athletes, lack of reimbursement and support by the public health system, long waiting lists, lack of clear indications and lack of a standardized protocols, social disparities, absence of a common network and a common database, reluctance and misinformation of athletes about health screening, lack of licence for sports medicine physicians to perform echocardiography in some countries.

Table 1 List of conditions of which echocardiography may make the diagnosis in the context of a normal electrocardiogram according to respondents' opinions.

Classification of conditions pre-identified by the survey
1. Cardiomyopathies
2. Aortic aneurysm/dilatation
3. Bicuspid aortic valve
4. Other valvular heart disease
Conditions identified by the respondents
Coronary artery abnormalities
Myocarditis
Asymptomatic/silent ischaemic heart disease
Congenital heart disease (including mitral valve prolapse, patent foramen ovale, small patent ductus arteriosus, interatrial and interventricular defects, and subaortic membrane)
Hypertensive cardiomyopathy
Arrhythmias
Pulmonary embolism
Heart failure with preserved left ventricular ejection fraction
Marfan syndrome
Pericardial disease (pericardial effusion and pericarditis)
Atrial myxoma
Endocarditis

Contrary to echocardiography, most respondents (67%) reported barriers to CMR in their respective countries. Among the barriers, access to equipment (average score: 3.09), coverage of screening costs by social/health insurance (average score: 2.97), personnel

training (average score: 2.2) and limitations of time per visit with patients (average score: 1.75) were chosen as the most common limitations to perform CMR in athletes. The respondents identified further barriers, including: long waiting lists, few experts and few expert centres available, costs, conflicts with radiologists, lack of reimbursement by the national health system or presence of reimbursement only for few specific diseases, lack of referral by other physicians and a negative attitude of professional and non-professional athletes towards health screenings.

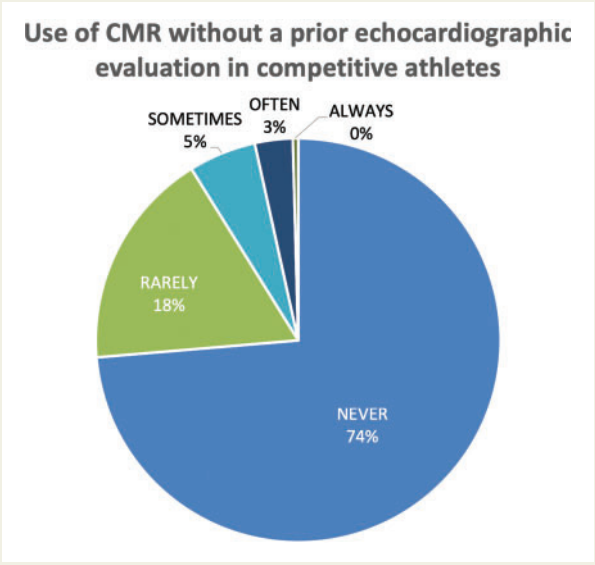

Figure 4 Use of cardiac magnetic resonance without a prior echocardiographic evaluation in competitive athletes (Question 11). Never = 0%; rarely <10%; sometimes 10–30%; often 31–90%; always >90%. CMR: cardiac magnetic resonance.

Comparison of screening practices amongst countries

According to the countries represented by the responders in Question 24, PPE is performed to some extent in 89 of the 97 (92%) countries represented in the survey, with only 8% stating that 'PPE is not performed in my country'. The setting is in specialized centres for 41% of the respondents, primary care in 28% and secondary care in 17%. The majority of respondents (73%) work in countries were echocardiography is not mandated by law in competitive athletes, but 11% of the respondents declared that echocardiography is mandatory in their countries for specific categories of athletes (e.g. professional soccer players).

According to 47% of the respondents, screening of high-risk individuals, such as young individuals with a family history of hereditary and potentially life-threatening cardiovascular condition, is routinely performed in their country and 35% declared that it takes place in specialized centres only.

Discussion

The controversy relating to PPE of young athletes has focused on whether it is indicated, and if implemented what is the best screening modality for detecting cardiac conditions predisposing to SCD. International scientific communities from both sides of the Atlantic support PPE but take opposite stands relating to the value of the 12-lead ECG. Our study suggests that the clinical community has moved beyond this debate. Although in most countries screening may not be universally adopted at national level, in most countries represented in our survey, PPE of athletes is performed to some extent. In addition, 65% of individuals involved in screening use echocardiography as part of their standard protocol on a regular basis, even in the setting of a normal clinical evaluation and 12-lead ECG. This practice is in contrast to contemporary recommendations from EHRA and

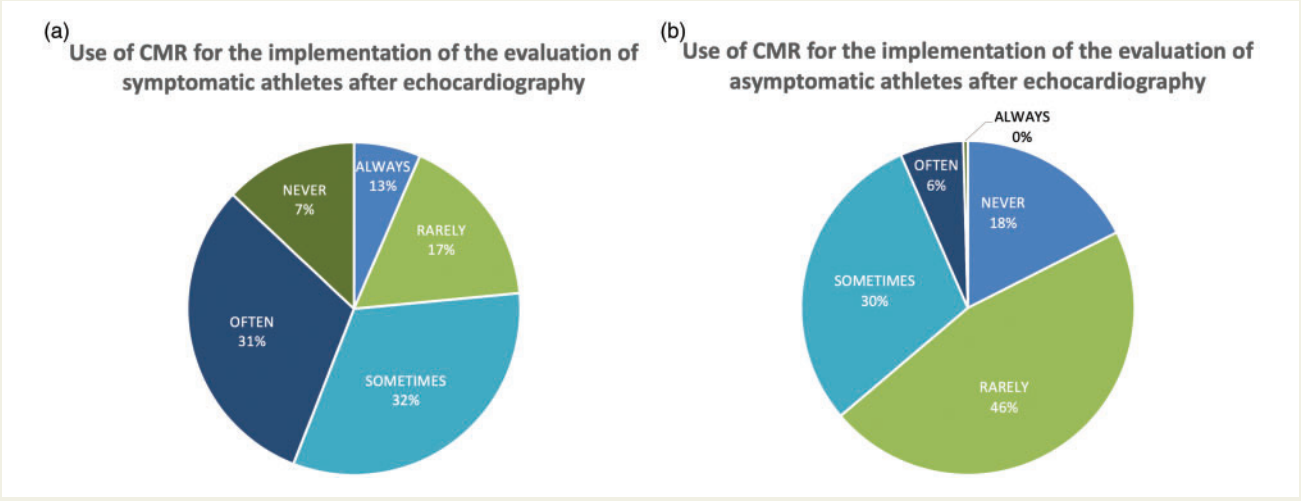

Figure 5 The use of cardiac magnetic resonance after echocardiography for the evaluation of symptomatic (a) and asymptomatic (b) athletes after echocardiography (Questions 9 and 10). Never = 0%; rarely <10%; sometimes 10–30%; often 31–90%; always >90%. CMR: cardiac magnetic resonance.

EAPC and seems to reflect the practice of cardiologists from a fairly diverse background.

The routine use of echocardiography during PPE in our survey seems to stem from the clinicians' perception regarding the value of echocardiography in detecting heart disease. Respondents considered that echocardiography provided additional value to the 12-lead ECG for diagnosing a range of structural heart diseases including cardiomyopathies, aortic aneurysm/dilatation, valvular heart disease, coronary artery anomalies, myocarditis, congenital heart disease and even quiescent ischaemic heart disease. Indeed, the inherent limitation of the 12-lead resting ECG to identify a significant proportion of cardiomyopathies[4] and most aortopathies and congenital structural abnormalities has prompted a number of sporting organizations to advocate echocardiography as part of the screening protocol. Most studies in healthy children and young athletes, however, have demonstrated that the addition of echocardiography to the 12-lead ECG, as a first-line screening tool, will detect congenital shunts or valvular heart disease, but does not increase the diagnostic yield of cardiomyopathies. This finding may reflect the fact that in most cases electrophysiological anomalies precede or co-exist with overt structural abnormalities evident on conventional transthoracic echocardiography (TTE) and as such ECG may suffice to raise suspicion and prompt further evaluation. On the contrary, in a study by Grazioli et al. evaluating 2688 competitive athletes, echocardiography identified two athletes with hypertrophic cardiomyopathy who had a normal medical history, physical examination and 12-lead ECG.[17] This calls for caution when interpreting the results of relatively small studies, when one considers the prevalence of cardiomyopathies, as results may simply represent a chance finding.

Time and cost constrains are commonly implicated as reasons for not widely adopting echocardiography as a screening tool.[18] Investigators have employed a number of screening protocols in an attempt to optimize the diagnostic utility of echocardiography for conditions predisposing to SCD in athletes, while minimizing time and costs.[19–23] Protocols range from 1-min targeted visualization of the parasternal views to a 20-min comprehensive echocardiographic study. Weidenbener et al. focused on the long and short axis parasternal views[22] of the left cardiac chambers in an attempt to identify athletes with hypertrophic cardiomyopathy, Marfan's syndrome, aortic stenosis or mitral valve prolapse. Most TTE studies were completed within 2 min. Wyman et al. employed a more comprehensive 5-min screening protocol in US collegiate athletes, which included colour Doppler and velocities.[21] Of importance, the authors were able to identify the origin of both coronary arteries in 96% of the athletes.[21] Weiner et al. designed an out-of-hospital 17-image protocol including both two dimensional images and Doppler tissue imaging to identify specific conditions associated with SCD in athletes.[20] The authors demonstrated that although community-based echocardiography has a significant learning curve, it is feasible and is associated with a high rate of technically adequate imaging. These results, though encouraging, should be viewed with caution as the challenges posed by cardiac adaptation to exercise require detailed assessment by experienced echocardiographers in a significant minority of athletes in order to distinguish between athlete's heart and life-threatening cardiomyopathies.[24–26]

Regarding the timing of echocardiography, most respondents suggested to perform an echocardiogram in adolescence or during the first PPE, with a repeat study at 1–5-yearly intervals, even in the context of a normal clinical evaluation and 12-lead ECG. Indeed, the literature suggests that adolescence is an especially vulnerable period for athletes with quiescent cardiac disease[5,27,28] and screening is recommended from the ages of 12–14 years onwards. Although a one-off echocardiogram during adolescence will exclude the presence of congenital heart disease, it may miss the presence of inherited cardiomyopathies and aortopathies which may manifest later in the athlete's career. Malhotra et al. screened 11,168 adolescent football players with a mean age of 16.4 ± 1.2 years using history, physical examination, 12-lead ECG and echocardiography. During a mean follow-up of 10.6 ± 8.3 years, there were eight SCDs, five of which were due to cardiomyopathies that had not been detected on screening. This study raises concerns that both ECG and echocardiography during adolescence may fail to detect a substantial proportion of athletes who have or will develop a cardiomyopathy, either because the disease is not yet manifest or because ECG and echocardiography are not sensitive enough to detect early disease.[5]

The expanding role of CMR in the evaluation of athletes is confirmed in our survey, where up to 74% of respondents may use it in the evaluation of symptomatic athletes. However, significant obstacles relating to the additional cost, lack of expertise and infrastructure remain, and it is therefore predominantly reserved as a second-line imaging modality after echocardiography. Furthermore, the risk of misdiagnosis/overdiagnosis and the need of a standardized approach to the interpretation and clinical significance of some specific CMR findings in athletes should be taken into account.

Limitations

Given the nature of the survey and the vastly different participation rates from different countries, with some countries having as low as 10 participants, our results may not accurately represent practices in individual countries. However, on evaluation of the results in countries with the highest participation rates, Greece was the only country that significantly deviated from the mean of 65% of respondents who used echocardiography as a first-line screening tool. In addition, it is not possible to exclude with certainty biases relating to demographics and field of interest. Although 42% of the respondents declared to be members of EACVI and 52% had an interest in imaging, neither was associated with higher use of echocardiography as a first-line screening tool. Finally, the study did not address perceptions and potential concerns relating to the challenges of interpretation of echocardiographic and CMR images in athletes and the potential for overdiagnosis or misdiagnosis, which may have affected individual responses.

Conclusions

The present survey indicates that in contrast to contemporary recommendations, echocardiography is often used as a first-line screening tool in clinical practice, for professional and amateur competitive athletes, with most respondents advocating repeat routine echocardiography at least every 5 years. In the absence of scientific evidence, before such practice is recommended, large studies using echocardiography in PPE settings are necessary in order to assess its impact in preventing cardiac morbidity and mortality, and potential risk of

misdiagnosis, as well as cost-effectiveness, and identify optimal echocardiographic protocols.

Additional resources

(1) Beaumont Children's Hospital. Grosse Pointe Hospital offers free student heart checks, http://www.beaumontchildrenshospital.com/node/831 (accessed 31 July 2011).
(2) Priority Physicians. Echocardiogram screening, http://www.priorityphysicianspc.com/?p=155 (accessed 31 July 2011).
(3) Championship Hearts Foundation, http://www.thehearttoplay.com/faq.html (accessed 31 July 2011).
(4) The Quinn Driscoll Foundation, http://www.cvus.net/student-athlete.php (accessed 31 July 2011).
(5) Heart Partners of Indiana. North Central High School echo screening athlete sudden death prevention, http://www.sportlinkheart.com (accessed 31 July 2011).
(6) Sportlink, http://www.sportlinkusa.com/physical.asp (accessed 31 July 2011).

Supplementary material

Supplementary material is available at *European Journal of Preventive Cardiology*.

Author contribution

MP and PD contributed equally as senior authors. FD and SM contributed to the conception or design of the work. FD, FA, GF contributed to data analysis or interpretation. FD, FA and MP drafted the manuscript. FD, FA, SM, GF, SC, MSG, CS, PEA, MG, YA, AP, JN, HH, MP, PD critically revised the manuscript. All gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of conflicting interests

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