Usefulness of Focused Screening Echocardiography for Collegiate Athletes

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Sudden cardiac death in a young healthy athlete is a rare but catastrophic event. The American Heart Association preparticipation screening guidelines recommend a focused history and physical without routine imaging or electrocardiogram screening. We hypothesized that a focused echocardiogram can identify structural abnormalities that may lead to sudden cardiac death in athletes, which might otherwise go undetected by history and physical. We retrospectively reviewed the charts of all incoming collegiate athletes at a single university from 2005 to 2013, all of whom had undergone a focused, 5-minute echocardiogram along with a guideline-based preparticipation history and physical (PPS H&P). Abnormal findings prompted further testing or referral. We report the prevalence of abnormal findings and the relation between an abnormal PPS H&P and screening echocardiogram. A total of 2,898 athletes were screened and 159 (5%) had findings. Forty athletes underwent further testing and evaluation. Of these athletes, 3 had newly diagnosed abnormalities that warranted restriction of participation: 1 apical-variant hypertrophic cardiomyopathy, 1 large bidirectional atrial septal defect with right ventricular dysfunction, and 1 dilated ascending aorta. Two of these athletes had a normal PPS H&P. Conversely, of the 661 athletes with an abnormal PPS H&P, only 1 (0.15%) had an abnormal screening echocardiogram. In conclusion, although the overall number was low, the 5-minute screening echocardiogram detected athletes at risk for sudden cardiac death not discovered on PPS H&P. **(Am J Cardiol 2019;123:169−174)**

Sudden cardiac death (SCD) in a young, healthy athlete is a rare but catastrophic event. Consensus is lacking, however, in how to identify athletes at risk for SCD. The American Heart Association (AHA) recommends a focused preparticipation screening history and physical (PPS H&P) only, whereas the European Society of Cardiology recommends the addition of a 12-lead electrocardiogram (ECG).[1−3] Both the PPS H&P and ECG screening have limitations, however. In a recent meta-analysis, the sensitivity and specificity of the PPS H&P were 20% and 9%, respectively.[4] The 12-lead ECG is also ineffective at detecting certain structural abnormalities.[5−12] Comprehensive echocardiography could potentially detect a greater range of structural abnormalities but may not be cost effective.[11] A focused echocardiogram with real-time interpretation, however, can significantly reduce the cost and time spent performing the study.[13−16] The University of Wisconsin has developed a focused, 5-minute screening echocardiogram protocol for all incoming athletes.[17] We report the prevalence of abnormal echocardiographic and PPS H&P findings in these athletes. We hypothesized that a focused echocardiogram can identify structural abnormalities associated with SCD, which might otherwise go undetected by the PPS H&P.

Methods

The use of a 5-minute limited, 2-dimensional echocardiogram was initiated as a pilot project with the University of Wisconsin athletes in June 2005. After adjustments in protocol, the screening echocardiogram was initiated for all new varsity athletes beginning in August 2005. The full screening procedure included (1) an orthopedics history and physical examination, (2) a vision screening test, (3) spirometry, (4) blood tests, (5) a history and physical examination by a Sports Medicine physician, and (6) a screening echocardiogram.

The PPS H&P performed included 11 of 12 components of the 2007 AHA guidelines,[1] the exception being obtaining a family history for disability due to heart disease under the age of 50. The entire examination procedure takes place at the University of Wisconsin Hospital. The limited echocardiograms take place in the Adult Echocardiography Laboratory using full-featured, commercially available ultrasound systems. Studies are performed by fully trained adult sonographers. An echocardiography faculty member or senior cardiovascular medicine fellow trained to at least Level 2 standards interprets the examination in real-time. A checklist of findings is present in the electronic medical record system, allowing a report to be completed immediately. During the examination, no measurements are routinely recorded. The examiner has the option, however, to stop the exam and make measurements as needed or add additional views to document any perceived abnormalities in structure or function. If there is any uncertainty in the findings, the athlete is immediately informed, and the findings are discussed with the Sports Medicine physician. The

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default procedure is to bring the athlete back for a comprehensive echocardiogram or other appropriate clinical exam along with follow-up by the sports cardiologist.

The 5-minute screening echocardiogram protocol has been previously described in detail.[17] Briefly, the examination includes the parasternal long-axis, parasternal short-axis, apical 4-chamber, and 5-chamber views. The parasternal long-axis evaluation includes left ventricular size and function, evaluation of mitral, aortic and tricuspid valves for motion, morphology, and regurgitation. The left ventricular outflow tract is examined by color Doppler. The ascending aorta is visualized. From the parasternal short-axis view, the coronary artery ostia are located. The pulmonary, tricuspid, and mitral valves are then examined for motion, morphology, and flow. The main pulmonary artery is examined for size and flow, and the region is screened for high ventricular septal defects. The left ventricle at the mid-papillary muscle level is examined for function and wall thickness. The apical 4-chamber view evaluates the morphology and function of the left and right ventricles. The tricuspid and mitral valves are examined as in previous views. The 5-chamber view evaluates flow across the aortic valve and left ventricular outflow tract. The atrial septum is screened by color flow Doppler.

With regard to the chart review, we undertook a retrospective analysis of all screening studies performed from June 2005 to May 2013 after approval was obtained from the Minimal Risk Institutional Review Board and the Provost at the University of Wisconsin. All screening echocardiogram reports were examined and the results placed into a database. Abnormalities were categorized. For all athletes that had any evidence of significant cardiac pathology, the University of Wisconsin medical record was examined for the presence of further diagnostic tests and also for outcomes during the athlete's collegiate career.

A second investigator reviewed the results of the Sports Medicine PPS H&P, which was done the same day as the screening echocardiogram. The University of Wisconsin-Madison Provost approved access and review of student athlete medical records for the purposes of this study. The PPS H&P information had been previously recorded onto a paper chart and stored in either an off-site secure storeroom for previous athletes or the clinic for active athletes. Efforts were made to obtain all of the off-site charts; however, some had since been destroyed after athlete graduation for privacy reasons and some of the available charts had incomplete documentation. A complete chart included a physician-completed H&P which documented the following elements: a history, which included family history of SCD at age <50 and an exam which evaluated for the presence of a murmur, stigmata of Marfan syndrome, abnormal femoral pulses, and a blood pressure. An athlete-completed preparticipation survey was also included, which added the following historical features: exertional chest discomfort or excessive dyspnea on exertion, exertional dizziness or syncope, history of heart murmur, abnormal blood pressure, and family history of congenital heart disease. Gender, age at time of screening, sport, if and what form of additional workup an athlete underwent, and clearance to participate were also recorded. The H&P was performed independent of the echocardiogram, and no results were available to the examining physician.

Results

There were 2,898 athletes who underwent a screening echocardiogram and 1,484 (51%) were women. The

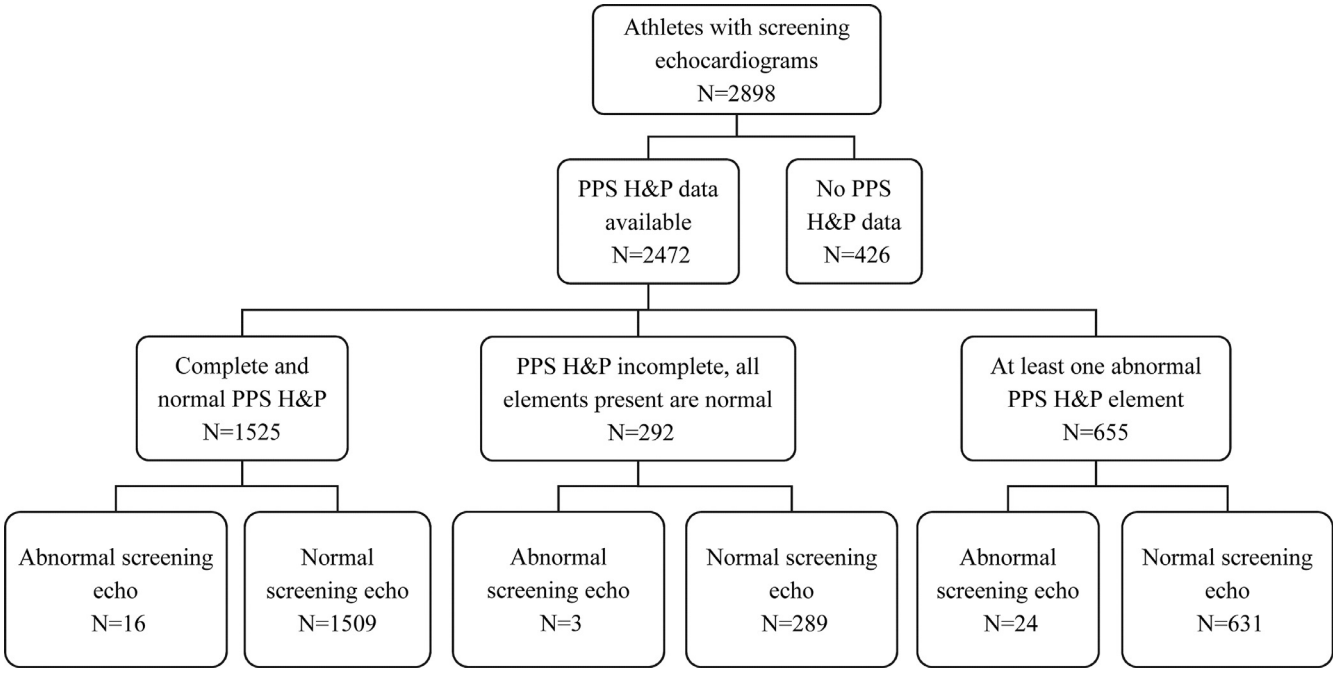

Figure 1. A summary of the participation of 2,898 athletes screened in this program. The completeness of data is shown followed by the relation between the screening history and physical and the echocardiography findings. PPS H&P = preparticipation history and physical.

average age was 18.8 years with a range from 17 to 28 years. Ethnicity was not available. The athletes represented 13 different sports. The proportion of the total amount of screening echocardiograms to the available athlete PPS H&P data is shown in Figure 1.

From the history and physical exam perspective, there were 661 athletes with at least 1 positive PPS H&P response or finding. Of this group, only 24 (4%) had a screening echocardiogram finding and 1 (0.15%) was excluded from participation. Athletes' findings by individual PPS H&P elements are shown in Table 1.

Most (95%) athletes had completely normal screening echocardiograms. As detailed in Table 2, there were 159 athletes with echocardiographic findings (5%). Notably, 49 of 56 athletes who screened positive for an abnormal coronary origin were those in whom 1 or more of the ostia could not be visualized or the athlete was believed to have a nonpathologic anomalous coronary origin. The remaining 7 athlete screens were concerning for a potentially pathologic anomalous coronary origin and further evaluation was recommended. Overall, 49 (1.6%) had findings that were believed to require further testing or referral to cardiology clinic. A total of 40 (1.4%) athletes ultimately underwent the recommended follow-up imaging and/or referral to a cardiologist.

Three of the athletes had new diagnoses discovered on screening echocardiography that ultimately resulted in activity restriction: 1 apical-variant hypertrophic cardiomyopathy (disqualified from football), 1 large bidirectional atrial septal defect with right ventricular dysfunction (referred and underwent surgical closure), and 1 significantly dilated ascending aorta (disqualified from football). Of these 3 findings, the dilated aorta and the apical-variant hypertrophic cardiomyopathy would not have been detected on routine PPS H&P. In addition, 1 athlete was diagnosed with a left atrial myxoma; this athlete was evaluated by an outside physician and ultimately chose not to participate. There was also 1 athlete with previously known hypertrophic cardiomyopathy who was cleared to play golf.

Table 2
Screening echocardiogram findings

Abnormality	Athletes	Clinical impression	
		Benign	Further evaluation recommended
Coronary origin abnormality*	56 (2%)	47	9
Mitral valve prolapse	24 (0.8%)	24	-
Bicuspid aortic valve	21 (0.7%)	4	17
Dilated right ventricle	22 (0.8%)	16	6
Right ventricular dysfunction	3 (0.1%)	-	3
Dilated left ventricle	6 (0.2%)	2	4
Left ventricular dysfunction	1 (0.03%)	-	1
Hypertrophic cardiomyopathy	2 (0.07%)	-	2
Atrial septal defect	19 (0.7%)	16	5
Ventricular septal defect	2 (0.07%)	1	1
Patent ductus arteriosus	2 (0.07%)	1	1
Dilated aorta	5 (0.2%)	1	4
Left atrial myxoma	1 (0.03%)	-	1
Total number of athletes†	**159 (5%)**	**112 (4%)**	**49 (1.7%)**

* Includes coronary origins not visualized and those believe to have abnormal course.
† Some athletes with more than 1 finding.

Table 1
Prevalence of abnormal preparticipation screening history and physical elements and screening echocardiogram findings

AHA athlete screening guideline elements	Athletes with available records*	Athletes with abnormal element	Echo findings in athletes with abnormal element
Exertional chest pain	2171	77 (4%)	2 (3%)
Dizziness or syncope	2471	210 (9%)	4 (2%)
Excessive dyspnea on exertion	2171	69 (3%)	0
History of precordial murmur	2167	99 (5%)	10 (10%)
History of hypertension	2169	39 (2%)	0
Family history of premature cardiac death	2467	127 (5%)	3 (2%)
Family history of congenital cardiac conditions†	2171	34 (1%)	3 (19%)
Precordial murmur on examination	2441	36 (2%)	7 (19%)
Abnormal femoral pulses on examination	2438	0	-
Stigmata of Marfan syndrome on examination	2441	1 (0.04%)	0
Hypertension	2449	115 (5%)	8 (7%)

AHA = American Heart Association.
* Total number varies due to incomplete documentation in records.
† Hypertrophic or dilated cardiomyopathy, long-QT syndrome or other channelopathies, Marfan syndrome, or clinically important arrhythmias.

Table 3
Valve findings on screening echocardiogram and corresponding history and examination

	Aortic stenosis	Aortic regurgitation	Pulmonic stenosis	Pulmonic regurgitation	Tricuspid regurgitation	Mitral regurgitation
Trivial/mild	2	115	1	1058	977	615
History of precordial murmur	0 (0%)	8 (7%)	1 (100%)	34 (3%)	32 (3%)	14 (2%)
Precordial murmur on examination	0 (0%)	2 (2%)	0 (0%)	7 (0.7%)	6 (0.6%)	6 (1%)
Moderate	-	1	1	17	4	-
History of precordial murmur	-	0 (0%)	1 (100%)	0 (0%)	0 (0%)	-
Precordial murmur on examination	-	0 (0%)	1 (100%)	0 (0%)	0 (0%)	-

Follow-up testing for all screens resulted in 30 comprehensive echocardiograms, 6 coronary computed tomography angiograms, 2 cardiac magnetic resonance imagings, 6 exercise stress echocardiograms, 1 exercise stress test without imaging, and 14 cardiology clinic visits. This is a 1.5% rate of additional testing based on screening echocardiogram results.

The majority of athletes had essentially normal valve function, as noted in Table 3. Of the 23 athletes with moderate regurgitation or stenosis, 1 (4%) had a corresponding history and examination finding. No severe regurgitation or stenosis was present.

Discussion

The extent and method of screening for cardiac dysfunction in competitive athletes currently lacks consensus. A PPS H&P is universally recommended, however, the addition of a screening 12-lead ECG is recommended by the European Society of Cardiology and not the AHA.[1–3,10] This may in part be explained by the disparity in the supporting data in the respective populations. A large study from the Veneto region in Italy demonstrated a significant mortality reduction associated with the initiation of universal ECG screening.[18] This benefit has not been reproduced in the Israeli national ECG screening program, however.[19] Additionally, in a study comparing the Veneto population after the initiation of ECG screening to Minnesota athletes who underwent only a PPS H&P, there was no mortality difference.[9] ECG screening is limited by false positives, which can occur in 5% to 20% of all athlete ECGs.[10] As an alternative adjunct to the PPS H&P, screening echocardiography has been explored and adopted by our institution.

We discovered 3 athletes with previously unknown pathology that ultimately precluded them from participation. Of this group, the athlete with the dilated ascending aorta had a completely negative PPS H&P. The athlete with the apical-variant hypertrophic cardiomyopathy did not have PPS H&P data available. Based on records from this athlete's subsequent clinic visit, however, his PPS H&P was also likely completely negative. The third athlete had closure of his septal defect at an outside facility and chose not to return to competitive athletics. Although 3 athletes of 2,898 is not a high number, this does support our hypothesis that the 5-minute screen can be an effective adjunctive screening method.

One potential concern regarding the 5-minute screening echocardiogram is its comparability with a comprehensive study. Although there are no prospective data available, our data are comparable to previous studies investigating preparticipation echocardiography. A study investigating 2,688 Spanish athletes with comprehensive echocardiograms found 203 athletes (7.5%) had abnormal echocardiograms, of which 4 were excluded from participation. Twelve (0.4%) bicuspid valves were identified.[20] Another study with 508 athletes using a screening echocardiogram exam similar to ours detected structural abnormalities in 2% of athletes and excluded 0.6% from participation.[21] Similarly, a 2012 Italian study evaluating 3,100 male soccer players with comprehensive echocardiograms detected 56 with abnormalities (1.8%), and 4 were excluded from participation.[22] Twenty-four (0.8%) athletes with bicuspid valves were identified. These data are in line with our results, with 49 (1.7%) screening findings, 21 (0.7%) bicuspid valves identified, and 3 excluded from participation. Taking the results of our study and these other 3 reports together, a total of 9,194 athletes were screened and show a highly consistent picture of the spectrum of abnormalities expected in young athletes.

One advantage to our approach is the low rate of additional testing. Only 1.5% of the screens resulted in additional imaging and only 0.4% required a cardiology clinic visit. Some additional tests were avoided by on-the-spot cardiologist availability that solved simple questions of clinical significance. On-the-spot interpretation has also been described with the use of hand-held cardiac ultrasound. A 2015 study from the United Kingdom utilized this method for screening in a pediatric population and noted it added only £16.5 (approximately $25) per patient.[23] Another pilot study trained sports medicine physicians to perform hand-held echocardiograms and successfully cleared all 6 of the athletes with either an abnormal ECG or PPS H&P.[14]

There are several limitations to our study. The H&P records were incomplete, resulting in the inability to correlate all of the echo data with the PPS H&P. Our PPS H&P

was also missing 1 of the 12 AHA-recommended elements from the 2007 guidelines, the standard of care at the time the data were collected.[1] Additionally, some athletes did not follow up with recommended testing or received testing outside our system, which limits conclusions about the diagnostic accuracy of the focused echocardiogram. As images were not saved, inter-reader reliability of real-time echocardiographic interpretation could not be performed. Also, whereas there were no SCD events, we cannot necessarily point to the PPS H&P or the screening echocardiography as the reason for this. The incidence of SCD in the competitive athlete population has been estimated at about 1:55,703 to 1:83,333 athlete-years.[24–26] At most, our sample represents 11,592 athlete-years (2,898 athletes, assuming 4 years of participation) and likely represented fewer as many do not participate for 4 years. Thus, there is not an adequate sample size to draw firm conclusions about SCD prevention. The data collected also relied on athlete self-reporting on a questionnaire in addition to a physician-obtained PPS H&P. The wording of the survey was such that the athletes may have reported symptoms related to noncardiac issues. As we recorded these responses as abnormal, however, this should have if anything enhanced the sensitivity of the PPS H&P. These findings are consistent with a previous study that used a survey.[27] Even with this allowance, 2 of 3 athletes who were ultimately excluded from participation had a completely normal PPS H&P.

Ultimately, whereas a low overall number, we were able to identify athletes with structural heart disease not discovered in the PPS H&P using our 5-minute screening echocardiogram protocol. Cost analysis was outside the scope of our study and warrants further investigation. We additionally broadly applied our screening echocardiogram protocol. Given the low overall number of athletes ultimately disqualified and the previously reported differences in SCD rates based on sport, gender, and ethnicity,[26] future investigation into selective screening echocardiography for only those at the highest risk of SCD would be of benefit.

Disclosures

The authors have no conflicts of interest to disclose.

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