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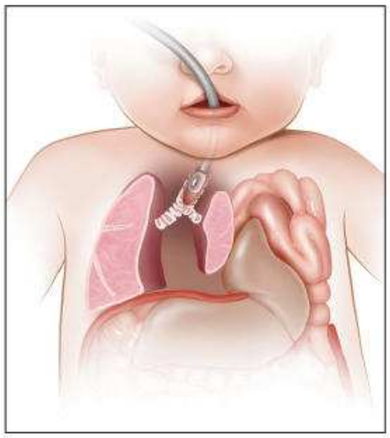

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Focused Physician-Performed Echocardiography in Sports Medicine

A Potential Screening Tool for Detecting Aortic Root Dilatation in Athletes

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Objectives—The purpose of this study was to investigate whether sports medicine physicians can obtain accurate measurements of the aortic root in young athletes.

Methods—Twenty male collegiate athletes, aged 18 to 21 years, were prospectively enrolled. Focused echocardiography was performed by a board-certified sports medicine physician and a medical student, followed by comprehensive echocardiography within 2 weeks by a cardiac sonographer. A left parasternal long-axis view was acquired to measure the aortic root diameter at the sinuses of Valsalva. Intraclass correlation coefficients (ICCs) were used to assess inter-rater reliability compared to a reference standard and intra-rater reliability of repeated measurements obtained by the sports medicine physician and medical student.

Results—The ICCs between the sports medicine physician and cardiac sonographer and between the medical student and cardiac sonographer were strong: 0.80 and 0.76, respectively. Across all 3 readers, the ICC was 0.89, indicating strong inter-rater reliability and concordance. The ICC for the 2 measurements taken by the sports medicine physician for each athlete was 0.75, indicating strong intra-rater reliability. The medical student had moderate intra-rater reliability, with an ICC of 0.59.

Conclusions—Sports medicine physicians are able to obtain measurements of the aortic root by focused echocardiography that are consistent with those obtained by a cardiac sonographer. Focused physician-performed echocardiography may serve as a promising technique for detecting aortic root dilatation and may contribute in this manner to preparticipation cardiovascular screening for athletes.

Key Words—aortic root dilatation; athletes; echocardiography; preparticipation screening; sonography; sports medicine

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Abbreviations
ICC, intraclass correlation coefficient

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Two athletes in the US National Basketball Association were removed from play in the 2012 season due to the threat of a condition called aortic root dilatation. These high-profile cases have attracted attention to the dangers of aortic root dilatation and have challenged the sports medicine community to consider how to better detect this condition in athletes. If not detected in a timely fashion, this condition can lead to aortic insufficiency, aortic aneurysm, aortic dissection, aortic rupture, and ultimately death.[1–3] The gravity of these complications necessitates the appropriate identification and management of athletes with aortic root dilatation.

Although aortic root dilatation is often a manifestation of an underlying connective tissue disease, such as Marfan syndrome, it can also exist as an isolated disease entity.[4,5] Medical management of aortic root dilatation uses beta blockers, with more recent use of angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, and statins.[6–10] In athletes, risk factor modification is also a critical mode of nonsurgical management, by limiting participation in competitive sports, especially those involving high-intensity activity and frequent collisions (such as boxing, bodybuilding, and gymnastics).[11] Indications for surgery are based on comorbidities, the degree of dilatation, and the rate of progression, with lower thresholds for surgery in higher-risk athletes, such as those in high-intensity sports or with underlying conditions such as Marfan syndrome.[12,13]

Aortic root dilatation may have a relatively high prevalence compared to other congenital abnormalities. According to a recent estimation in elite athletes, the prevalence of aortic root dilatation may be as high as 1.3% in male athletes and 0.9% in female athletes, with a higher prevalence in tall athletes.[14] Other reports have cited lower prevalence rates, however, so the precise prevalence and threat of this condition in athletes are still unclear.[15]

According to diagnostic guidelines, the threshold for diagnosis of aortic root dilatation in the general population is an aortic root diameter of 39.1 mm in men and 37.2 mm in women, although the upper limits of normal are thought to relate normatively to anthropomorphic variables (such as height, body size, age, and sex).[16–19] Although comprehensive echocardiography by a sonographer is traditionally used to diagnose aortic root dilatation using these criteria, a focused physician-performed echocardiographic protocol could be developed for use in screening for aortic root dilatation in athletes. Such a protocol is feasible given the development of portable and handheld ultrasound devices that have proven reliable and accurate in measuring other cardiac parameters.[20] In fact, we have recently demonstrated that focused physician-performed echocardiography can accurately assess measurements relevant to the diagnosis of hypertrophic cardiomyopathy.[21] An analogous point-of-care focused protocol has been evaluated in the field of emergency medicine to evaluate thoracic aortic dimensions, dilatation, and aneurysmal disease.[22] Our study begins to explore whether a similar technique can be applied to the detection of aortic root dilatation in athletes.

Materials and Methods

Study Population

Twenty male athletes participating in National Collegiate Athletic Association Division I sports, aged 18 to 21 years, were prospectively enrolled. All participants were healthy and had no known history of cardiovascular disease. Participants were recruited by convenience sampling at the athletic training facility of Northeastern University. The study was approved by the Institutional Review Board at Northeastern University as well as New England Baptist Hospital. Written informed consent was obtained from all participating athletes.

Echocardiographic Protocol

Focused echocardiography was performed initially at university facilities by a sports medicine physician and a medical student. Within 2 weeks, participants followed up at a local hospital for comprehensive echocardiography by a cardiac sonographer. The sports medicine physician was board certified in sports medicine and had greater than 5 years of clinical experience in sonography, although most of this experience was in musculoskeletal sonography. The physician received training in sonography through residency training and also completed a weekend course in advanced echocardiography before the onset of the study. The medical student was a fourth-year medical student who had no notable experience in sonography before the study. Both individuals received targeted training by a sonographer before the study. Training sessions comprised 2 hour-long sessions focused on obtaining the measurement relevant to the study.

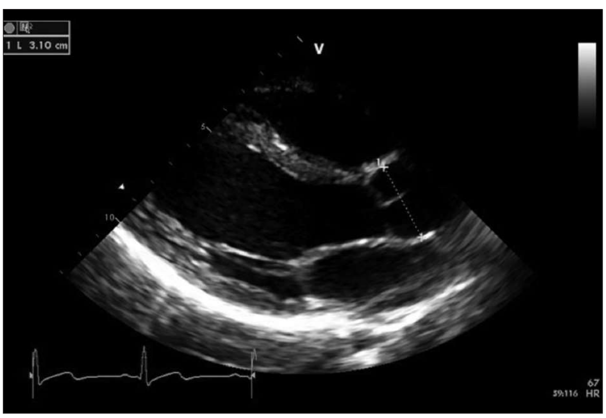
Echocardiographic examinations were performed with participants at rest in the left lateral decubitus position. The readers obtained their measurements independently and were blinded to the results of other readers. The sports medicine physician and medical student obtained 2 separate images and measurements on each athlete, spaced apart in time, to assess intra-rater reliability in obtaining repeated measurements. Focused echocardiography was performed with a commercially available battery-powered portable platform (MicroMaxx; SonoSite, Inc, Bothell, WA) equipped with a 5–2-MHz phased array transducer and a 10.4-in (26.4-cm) diagonal liquid crystal display screen. Comprehensive echocardiography was performed with a Vivid 7 ultrasound system (GE Healthcare, Wauwatosa, WI) equipped with an M4S phased array transducer using second-harmonic (1.7/3.4-MHz) imaging. Images were viewed on a 21-in liquid crystal display. Measurements were acquired from a frozen-frame image captured during end diastole. An electrocardiographic signal was used to identify end diastole during the comprehensive echocardiography; however, this signal was not available for focused echocardiography. With focused echocardiography, end diastole was identified by selecting the frame with the largest left ventricular areas, with associated closure of aortic and mitral valves.

A left parasternal long-axis view was acquired to measure the aortic root diameter at the sinuses of Valsalva (Figure 1). The inner edge-to-inner edge measurement of the aortic root diameter was used on the basis of evidence for increased reproducibility and improved intraobserver and interobserver variability when compared across imaging modalities.[23,24] This measurement of the aortic root was chosen because it has been associated with a higher left ventricular mass, lower systolic function, and a higher cardiovascular risk in individuals with aortic root dilatation.[25]

Statistical Analysis

Continuous data are presented as mean ± standard deviation. The measurements obtained by the sports medicine physician and the medical student were compared to the measurements obtained by the sonographer by pair-wise evaluations of concordance using intraclass correlation coefficients (ICCs) to assess inter-rater reliability. Since 2 measurements were taken by the sports medicine physician and medical student for each athlete, these measurements were averaged to obtain single values for comparison against the single values obtained by the sonographer. Intra-rater reliability of the measurements obtained by the sports medicine physician and the medical student were also measured with ICCs between the 2 measurements taken on each participant by each of the readers. To evaluate agreement/concordance among all 3 readers, ICC calculations were computed across all 3 readers. $P < .05$ was considered statistically significant. All analyzes were performed with an online open-source statistical program.[26]

Figure 1. A parasternal, long-axis view of the heart was obtained from each athlete. The aortic root diameter was measured at the sinuses of Valsalva (dotted line).



Results

Study Population

Twenty athletes were recruited for the study, and all athletes were able to follow up within 2 weeks of the initial echocardiographic examinations for comprehensive echocardiography. The medical student obtained measurements in 14 of the 20 athletes.

Focused Versus Comprehensive Echocardiography

The aortic root diameter measurements are illustrated in Table 1. The ranges of aortic root diameter values were as follows: 24.6 to 32.1 mm for the sports medicine physician, 24.6 to 34.4 mm for the medical student, and 26.9 to 37.0 mm for the cardiac sonographer. The mean measurements by all 3 readers were 29.0 ± 2 mm for the sports medicine physician, 29.0 ± 2 mm for the medical student, and 30.0 ± 3 mm for the sonographer. The ICC between measurements by the sports medicine physician and the sonographer was 0.80. The ICC between measurements by the medical student and the sonographer was 0.76. The ICC for concordance across all 3 readers was 0.89. The ICCs for intra-rater reliability of repeated measurements were 0.75 for the sports medicine physician and 0.59 for the medical student.

Table 1. Aortic Root Diameter Measurements

	Aortic Root Diameter, mm		
Athlete	Cardiac Sonographer	Sports Medicine Physician	Medical Student
1	29.0	25.9	26.1
2	26.9	25.6	25.9
3	33.0	31.2	32.2
4	28.3	24.6	24.6
5	31.5	29.2	27.0
6	31.9	32.1	30.4
7	30.8	30.4	29.4
8	29.7	28.1	27.4
9	31.8	29.8	27.7
10	33.8	32.1	34.4
11	37.0	31.4	33.9
12	30.4	28.6	28.1
13	29.0	28.8	26.7
14	29.2	27.3	29.3
15	30.0	25.9	
16	28.0	25.6	
17	29.0	31.2	
18	27.0	24.6	
19	30.0	29.2	
20	29.0	32.1	

Discussion

Echocardiographic measurements by a sports medicine physician were found to have strong agreement compared to measurements obtained by a sonographer in a dedicated echocardiography laboratory. This finding was demonstrated by the ICC value of 0.80, which indicates strong agreement between aortic root diameter measurements. This value is comparable to those demonstrated in previous studies comparing portable and comprehensive echocardiography in the hands of sonographers.[12] These data therefore indicate that with adequate training, sports medicine physicians can obtain values for the aortic root diameter that are close to the reference standard.

Furthermore, the echocardiographic measurements obtained by the medical student were also found to have strong agreement with the measurements obtained by the sonographer. This preliminary evidence demonstrates that a dedicated program for teaching focused echocardiography may be adequate to train physicians to obtain accurate measurements relevant to the diagnosis of aortic root dilatation, regardless of prior experience in sonography. Further research and development in educational programming will help confirm this suggestion and to establish standards for competency in focused echocardiography.

A strong ICC calculation (0.89) for measurements across all 3 readers further demonstrates a high level of inter-rater reliability and concordance of aortic root diameter measurements. This level of agreement is comparable to that demonstrated in previous studies comparing linear measurements by portable versus comprehensive echocardiography in the hands of cardiac sonographers.[12] This finding provides further evidence that focused echocardiography can accurately assess the aortic root diameter compared to the reference standard.

In addition to demonstrating the accuracy of measurements, our data also suggest that focused echocardiography can produce reproducible aortic root diameter measurements in the hands of a sports medicine physician. With an ICC of 0.75, this level of intra-rater reliability is comparable to that seen when portable echocardiography has been studied in sonographers.[12] The measurements obtained by the medical student were less reproducible, with a moderate ICC of 0.59. Our preliminary data thus suggest that experience may be more critical for establishing intra-rater reliability than inter-rater reliability of measurements by focused echocardiography.

Prompt identification of aortic root dilatation in athletes is essential for the appropriate management of this condition to reduce the risk of morbidity and mortality. Early identification will help facilitate medical management (with medications such as beta blockers, angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, and statins), which may slow progression of the condition, although the advantages of medication will have to be balanced against potential untoward effects on performance. Early identification of the condition may also affect recommendations for involvement in particular types of sports, with limitation of participation in high-intensity sports involving frequent collisions and encouragement of participation in sports with isokinetic activity involving low static and dynamic components (such as golf and cricket). Identification of aortic root dilatation will also trigger evaluation for underlying connective tissue disease, which will also affect management of athletes with this condition.

Given the high degree of accuracy and reproducibility of measurements obtained by the sports medicine physician in our study, this technique holds the potential to affect clinical practice regarding the diagnosis of aortic root dilatation in athletes. In the United States, current recommendations for preparticipation screening do not address the importance of diagnosing this condition in athletes.[27] Recent efforts in the United States have focused on developing modified electrocardiographic criteria to improve screening for conditions such as hypertrophic cardiomyopathy and sudden death but have not addressed the detectability of conditions such as aortic root dilatation.[28–30] This lack of attention is concerning given the potentially high prevalence of this condition among athletes, its association with connective tissue disease such as Marfan syndrome, and its known association with threatening cardiovascular complications when left unaddressed.

The strongest argument against implementing such a program in the United States is one of cost-effectiveness, given the cost of providing formal echocardiography to all athletes relative to the low prevalence of detectable conditions. Such arguments are often focused on the use of screening to diagnose hypertrophic cardiomyopathy, which is a relatively rare condition with a prevalence of around 0.1% to 0.2%.[31] Given that aortic root dilatation may have nearly a 10-fold higher prevalence over hypertrophic cardiomyopathy, the cost-effectiveness argument may need to be readdressed with aortic root dilatation in mind. Confirmatory studies of the prevalence of aortic root dilatation in athletes will be required to further support this argument. In addition, the implementation of focused physician-performed echocardiography rather than formal echocardiography may further improve the cost-effectiveness profile of a screening program that uses echocardiography for preparticipation evaluation. In line with these thoughts, sports associations worldwide have implemented comprehensive screening programs for athletes that include echocardiography.[32] A comparable screening program has also been instituted by the National Basketball Association for professional basketball athletes in the United States but has not yet become standard practice across all professional sports or across all levels of sports participation nationwide.

Limitations

Although our study demonstrated a strong correlation between values obtained by a sports medicine physician and a sonographer and between a medical student and a sonographer, a stronger correlation was documented in previous studies comparing sonographers.[33] At least part of this discrepancy is attributed to the difference in devices used by the readers in our study. Had the sonographer used the same portable device used by the other readers, these pair-wise comparisons may have demonstrated improved concordance. Regardless, as discussed previously, studies assessing the correlation between echocardiographers using portable and comprehensive echocardiographic machines have shown a similar level of correlation as that seen in our study.

Another major limitation of our study was its sample size. The study was designed as a pilot to assess feasibility for further investigation and was not meant to produce definitive results. The next step will be to gather additional enrollees at the primary site and also to expand the study to a multisite investigation. The small sample size of 20 restricted heterogeneity of the sample and also limited generalizability of the data to larger populations. Further investigations with larger numbers and multisite recruitment will help improve the validity and generalizability of these data.

Another limitation to the implications of our study was that only healthy athletes without a history of cardiovascular disease were recruited. As expected, measurements obtained by all readers were within normal limits for the aortic root diameter. Although this finding provides preliminary evidence that trained operators can obtain accurate and reproducible measurements using focused echocardiography, it does not prove that this technique can be applied to diagnosis and screening for aortic root dilatation. Additional studies including high-risk athletes as well as athletes with aortic root dilatation will be required to validate this method in its application for evaluating athletes for this condition.

Last, although strong inter-rater reliability was demonstrated regardless of the level of prior experience with echocardiography, only the sports medicine physician had strong intra-rater reliability. This finding may have been a result of the smaller effective sample size evaluated by the medical student, but it may also indicate that prior experience is more critical to establishing reliability than accuracy of measurements. Further investigations involving varied levels of prior experience will help confirm whether this indication is true and will also inform the design of training programs for focused physician-performed echocardiography. Should such a technique be considered for broad incorporation into a larger screening program for aortic root dilatation, the effects of prior experience will need to be better delineated to assess the amount and type of specialized training that will be required to establish competency in this technique.

Conclusions

Sports medicine physicians may be able to obtain measurements with focused echocardiography that are relevant to the diagnosis of aortic root dilatation and are both accurate and reproducible when compared to measurements by sonographers in dedicated laboratories. As more sports medicine physicians become proficient in the use of echocardiography, a focused physician-performed protocol could provide the basis for a larger screening strategy for detecting aortic root dilatation in athletes. Such a protocol may improve detection of this threatening condition and will hopefully inform larger policies regarding routine preparticipation evaluation of cardiovascular conditions in athletes. Prompt identification of aortic root dilatation in athletes will inform management of this condition to slow progression of disease and to allow safe participation in sports.

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