A Quantitative Echocardiographic Study of Champion Childhood Swimmers

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SUMMARY  An echocardiographic evaluation of 77 members of a championship childhood swim team showed dimensional variations from normal in most athletes. Cardiac walls were thicker than the 95th percentile of normal: right ventricular anterior wall exceeded the 95th percentile in 100%, interventricular septum in 83% and left ventricular posterior wall in 91%. The left ventricular and left atrial cavities in diastole had mean values at the 50th percentile of normal but showed considerable scatter. The left ventricular cavity in systole had a mean value less than the 5th percentile of normal and also showed wide scatter. The aortic root and the aortic intercusp dimension exceeded the 95th percentile of normal in most subjects, 74% and 77%, respectively. No correlation existed between the coach's estimate of championship ability and echocardiographic wall or chamber sizes. Children who participate extensively in athletic training programs such as swimming may have echocardiograms which are quantitatively different from those of nonathletic youngsters.

ECHOCARDIOGRAPHY HAS PROVEN UTILITY as a qualitative tool for the assessment of gross spatial distortions due to congenital heart disease and has recently been used in a quantitative manner to evaluate dimensional changes in subtler forms of heart disease.1,2 The previously reported normal data for normal children beyond infancy have provided a yardstick for quantitative echocardiographic studies.3 We have observed some apparently normal children whose echocardiographic measurements deviated from normal; by careful questioning we found that many of them were childhood athletes. Echocardiographic data of these youngsters suggested that they formed a separate population with respect to quantitative echocardiographic measurement. This was not surprising, for trained athletes often have electrocardiograms which are classified as "abnormal.4" Recent investigations of Morganroth et al.3 and Roeseke et al.6 have shown that highly trained adult athletes also have echocardiographic measurements which are quantitatively different from controls.

Children, particularly of elementary school age, are rarely classified as athletes. However, current trends in physical education and team competition require reconsideration of this classification. Part of the normal echocardiographic data of Epstein et al.1 were obtained in Tucson, but the children studied lived in areas of relatively low athletic participation. While the randomly selected normal group may have contained some athletes, it was not biased toward athletic participation.

Methods

Approximately 35 children's swim teams are active in the Tucson area, each consisting of 50-100 members. Some teams swim only in the summer but others train throughout the year. Subjects for this study were selected from the city championship swim team of the highest capability division. This team trained throughout the year and the training was strenuous. Each child usually swam 2-6 miles each day, 6 days a week, under competitive and training circumstances. Training sessions lasted 2-4 hours. Some youngsters also participated in other competitive athletics including other swim teams. Review of the practices of other local swim teams indicated that such training was common. Training was similar for all individuals (whether sprint or distance swimmers). Older children trained more strenuously than the younger team members.

The parents of each subject completed a questionnaire which requested the following information: chronic illness—asthma or other lung disease, heart disease, diabetes or other (specified); medications—antiasthmatic, antiepileptic, sedatives or diabietic medication; number of months swimming on the team; participation in other competitive athletic teams—baseball, football, track, basketball, tennis or gymnastics; and if the individual had temporarily ceased participation on the swim team, the date and length of time of this occurrence was asked. Finally, the coach's estimate of championship ability and training level was rated from 0 (poor) to 9 (excellent).

After informed consent was obtained from parents and subjects, echocardiograms were performed in a poolside room at the beginning of swim practice. The study was not controlled for basal condition. All children were examined by a physician to exclude the possibility of unsuspected heart disease.

Echocardiograms were performed with a Smith Kline 20A Echocardiograph. In order to attain the best resolution, the highest frequency transducer which would permit structure visualization was used. Transducer frequencies ranged from 1.6 to 5.0 MHz. Transducers were coupled to the chest wall with an airless contact gel and held at perpendicular to the left parasternal chest wall as possible in order to reduce angulation errors while structures were recorded. Echocardiograms were obtained with the subjects in the supine position. Echocardiograms were recorded on a Honeywell 1856 ultraviolet recorder and an ECG trace was used for timing purposes. Measurements were made with calipers and a variable scale ruler after the method of Epstein et al.7 Each echocardiogram was independently interpreted by at least two and usually three investigators. The mean value for each measurement was used if the differences between the mean and outlying measurement was less than 10%. Differences greater than 10% required re-evaluation of the measurements.

Questionnaire data were compared to echocardiographic

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data to see if any correlation existed between any of the responses and the individual’s echocardiogram.

**Results**

The group consisted of 77 subjects (45 male, 32 female) ranging in age from 5 to 17 (mean 10.8) years and in body surface areas from 0.8 to 2.0 m² (mean 1.2). Seven swimmers had a surface area in excess of 1.7 m², which was the largest surface area studied by Epstein. Mean length of team participation was 27 months. Three children had asthma, three had lung disease, one had diabetes and none had heart disease. Four used antihistamines and one required insulin. Participation in other competitive sports included baseball (10), football (9), track (1), basketball (5), tennis (2) and other sports (volleyball, gymnastics [24]).

**Cardiac Walls (fig. 1)**

Right ventricular anterior wall could be measured in 73 subjects and all exceeded the 95th percentile of the previous study of normals. The maximum RV wall thickness was 0.45 cm and the minimum measurement was 0.28 cm.

The interventricular septum was measured in 76 children and exceeded the 95th percentile of normal thickness in 63 of the swimmers (83%). The maximum measurement was 1.0 cm and minimum was 0.50 cm.

The left ventricular posterior wall could be measured in 77 swimmers and exceeded the 95th percentile in 62 (81%). The maximum measurement was 1.0 cm and minimum was 0.55 cm.

**Cavities (fig. 2)**

The right ventricular cavity was measured in 74 subjects and exceeded the 95th percentile in 70 (91%). Maximum dimension was 2.7 cm and minimum was 1.1 cm.

Other cardiac chamber dimensions were variable. Diastolic and systolic left ventricular internal dimensions (LVID) could be measured in 76 subjects. Mean left ventricular diastolic dimension was at the 50th percentile of the normal group, but showed a wider range of variability (minimum 2.8 cm, maximum 5.5 cm). The mean systolic LVID was less than the 5th percentile although considerable scatter existed so that some individuals had values which exceeded the 95th percentile (1.9 cm minimum to 4.1 maximum). The left atrial internal dimension (LAID) could be measured in 77 children and ranged from 1.5 to 3.4 cm. Mean LAID for swimmers was similar to the 50th percentile of normal in the Epstein study.

**Aorta and Aortic Valve (fig. 3)**

The aortic root dimension was measured in 77 children and exceeded the 95th percentile in 57 (74%). Maximum dimension was 3.4 cm and minimum was 1.6 cm.

Aortic intercusp separation was recorded and measurable in 77 children and exceeded the 95th percentile in 59 (77%). Range was 1.0 to 2.5 cm.

**Other Observations**

No significant differences existed in any measurement when swimmers who participated in other sports were compared to those who participated only in swimming.

No correlation existed between the coach’s estimate of championship ability or training level and any of the echocardiographic values.

**Discussion**

The significant finding of this study is that trained childhood swimmers often have quantitative echocardiographic measurements which are significantly different from those of nonathletic children. These data generally agree with those of Morganroth et al. and Rooske et al. who evaluated adult athletes. Our study represents a large number of pediatric subjects and more cardiac structures were evaluated than in the prior studies.

None of our subjects had heart disease, yet many had echocardiographic values which far exceeded previously reported normals. These values probably reflect the effects...
of conditioning and this information is of specific importance to health personnel who interpret echocardiograms of children. A history of athletic participation is necessary in order to avoid misinterpretation of their quantitative echocardiographic values.

Mean echocardiographic left ventricular posterior wall and septal thicknesses of our swimmers were considerably less than the mean of the professional athletes studied by Roeske. With a single exception, no child had chamber, vessel or wall measurements which equaled the mean of the professional or college athletes. This may be a function of body size, since no swimmer was as large as the professional or college athlete. Additionally, few swimmers equalled or exceeded the mean body size of Roeske's controls who were not athletes.

Our subjects had left ventricular wall and septal thickness greater than normal. These results differ from those of Morganroth et al. In their study, collegiate and world class swimmers and runners had left ventricular wall thicknesses which were not significantly different from normal. The reason for the differences between the two studies is not clear. Morganroth suggested that swimmers should have increased left ventricular end-diastolic volume and normal left ventricular wall thickness. He found that athletes who participated in isometrics or resistance exercises, such as shotputting, constituted the only group with increased left ventricular mass. As mean left ventricular cavity dimensions were normal in our study and increased in Morganroth's, cardiac mass increase in children might be reflected by increased wall thickness with normal LV cavities and in adults by normal wall thickness around a larger cavity.

Echocardiographic right ventricular anterior wall thick-

![Figure 2](https://circ.ahajournals.org/)

**FIGURE 2.** Comparisons of echocardiographic values of athletes to the 5th and 95th percentiles of normal are shown. Most had increase in right ventricular (RV) cavity dimension but values for the left ventricular cavity in systole (LVIDs) and diastole (LVIDd) showed scatter. The same was true for the left atrial internal dimension (LAID).

![Figure 3](https://circ.ahajournals.org/)

**FIGURE 3.** The data for aorta and aortic intercusp dimension (ICD) are displayed. Most athletes had larger aortas and greater intercusp measurements than the 95th percentile of normal.
ness and cavity size have not been studied previously in athletes. In this investigation, RVAW was increased in all participants and RV cavity was increased in most. Whether this increase in RVAW was part of the general hypertrophy which occurs in the heart of if this was related to prolonged elevation of pulmonary artery pressure during in-water training for 2-4 hours per day is not known. Clearly this is not an altitude factor alone since the previous normals were from the same community. We cannot explain why the aortic and aortic cusp separation measurements exceeded the 95th percentile of normal in most swimmers.

In summary, the unique finding of this investigation is that children who participate extensively in training programs (swimming) may have echocardiograms which are quantitatively different from youngsters who do not participate in such strenuous activity. Thus, knowledge of athletic participation, at least in swimming, is necessary to interpret quantitative echocardiographic data.

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REFERENCES


Mid-diastolic Aortic Valve Opening in Severe Acute Aortic Regurgitation

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SUMMARY A case of severe acute aortic regurgitation is reported. Echocardiographic findings included mid-diastolic opening of the aortic valve, premature closure of the mitral valve, diastolic shuddering of the anterior mitral leaflet, probable demonstration of the flail aortic cusp in the left ventricular outflow tract, and increased left atrial and left ventricular dimensions. Correlation with hemodynamic, angiographic and surgical evidence is made.

HEMODYNAMIC AND ECHOCARDIOGRAPHIC FEATURES of acute aortic regurgitation have been described previously. The sudden volume and pressure overload of the left ventricle in acute aortic regurgitation has been shown to cause premature diastolic closure of the mitral valve in some cases. We recently evaluated a young man with acute severe aortic regurgitation who had not only early diastolic mitral valve preclosure but also mid-diastolic aortic valve opening.

Case Report

A 21-year-old male was in good health until early June 1975, when he had a febrile illness. He consulted his physician and was treated with oral antibiotics of unknown type. Fever and chills continued intermittently for several weeks but finally subsided. Approximately July 20, 1975, the patient noted the onset of exertional dyspnea which progressed over a period of two weeks until he could not carry on his usual activities. He saw his physician again and a cardiac murmur was noted for the first time. The patient was then referred to our institution for cardiac evaluation. Physical examination revealed temperature 98.8 degrees, pulse 70, respirations 20, blood pressure 100/54 mm Hg in both arms. No stigmata of bacterial endocarditis were noted and there was no evidence of Marfan’s syndrome. Carotid pulsations had a brisk upstroke with systolic collapse. A heaving cardiac apical impulse was located at the midclavicular line in the sixth intercostal space. There was a palpable apical diastolic thrill. A grade II/VI systolic ejection murmur was loudest at the left sternal border in the second and third intercostal spaces and radiated into both carotid arteries. A grade IV/VI medium frequency early diastolic murmur, heard maximally at the left sternal border, had a crescendo-decrescendo configuration and ended in mid diastole (fig. 1). The liver and spleen were not palpable, and the remainder of the examination was unremarkable. Frequent rectal temperatures taken during his hospitalization were normal. Numerous aerobic, anaerobic, and fungal blood cultures revealed no growth. Standard 12-lead ECG revealed a 42 mm S wave deflection in V2 but

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