

## Left Ventricular Structure and Function by Echocardiography in Childhood Swimmers

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### SUMMARY

The purpose of this study was to determine the differences in the left ventricular dimensions, mass index and function in school-aged swimmers by echocardiography. The study group consisted of 82 swimmers who participated in a systematic swimming training for at least six months, and the control group consisted of 41 sedentary children of similar age, sex and weight. In the study group, left ventricular dimensions and wall thicknesses, aortic root and left atrium diameters, and left ventricle mass index were significantly greater than the normal children ( $p < 0.05$ ). However, there was no difference in the left ventricular systolic function (ejection fraction, shortening fraction) or in the left ventricular filling characteristics ( $p > 0.05$ ).

In conclusion, in childhood swimmers there was a significant increase in left ventricular dimensions, wall thicknesses and mass index, but no differences in the systolic function and filling characteristics of the left ventricle. Thus, information on endurance training participation is necessary to interpret quantitative echocardiographic data. (*Jpn Heart J* **35**: 295–300, 1994)

### Key words:

Left ventricular dimension    Diastolic function    Training    Swimming  
Children

RECENT studies of the physiologic effects of exercise training indicate important differences between endurance athletes and untrained normal subjects. One of the more noticeable differences in endurance athletes is an increase in heart size.<sup>1-4)</sup> However children, particularly of elementary school age, are rarely classified as athletes.<sup>2)</sup>

Although there are many reports on echocardiographic changes in adult athletes,<sup>1,3-7)</sup> the number of studies on school-aged athletes is relatively few. The

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purpose of the present study was to determine the differences in left ventricular size and mass index, left ventricular systolic function and filling characteristics in school-aged swimmers by echocardiography.

### MATERIALS AND METHODS

The study group consisted of 82 children who participated in a systematic swimming training for at least six months. The control subjects were age, sex, and weight-matched normal, sedentary children without a history or echocardiographic evidence of heart disease. Each subject completed a questionnaire which requested the following information; chest pain, syncope, palpitation, chronic illness-asthma or other lung disease, heart disease or diabetes; medications, number of months swimming on the team, number of hours training in a week.

All children were examined by a pediatric cardiologist to exclude the possibility of unsuspected heart disease. Electrocardiograms and telecardiograms were also available to the pediatric cardiologist. Echocardiograms were performed with a Toshiba SSH 60-A Echocardiograph and 2.5–5 mHz transducers.

**M-mode echocardiographic studies:** The images of the heart were obtained in parasternal long-axis views. Left ventricle chamber and wall dimensions were measured according to standard methods of the American Society of Echocardiography<sup>8</sup> over three cardiac cycles. The ratio of wall thickness to cavity dimensions at end-diastole was calculated as septal thickness plus posterior wall thickness divided by the left ventricular end-diastolic dimension.<sup>9</sup> Left ventricular myocardial mass was calculated using the corrected formula described by Devereux et al<sup>10</sup>: LV mass (g)=0.80 {1.04 [IVS+EDD+PW]<sup>3</sup>-(EDD)<sup>3</sup>}+0.6, where IVS=diastolic interventricular septal thickness (cm), EDD=end-diastolic left ventricular dimension (cm) and PW=diastolic posterior wall thickness (cm). To adjust for differences in body size, left ventricular mass was divided by body surface area, and the left ventricular mass index was calculated.

**Doppler studies:** All recordings were obtained from apical four chamber views, parallel to flow, with optimal definition of the spectral envelope. The peak early diastolic velocity (E wave) and peak velocity of atrial (A wave) contraction were measured; and the ratio of early-to-late diastolic flow velocities (E/A ratio) were calculated. Isovolumic relaxation period (IRP) was measured by the time interval from the aortic closing component of the second heart sound by phonocardiogram to the onset of the diastolic flow velocity waveform by Doppler. The slope of the velocity decline from peak E filling velocity was measured by the rate of decline in the velocity from peak E velocity to baseline. Deceleration time of mitral flow velocity in early diastole was measured from the time of

peak rapid filling velocity to the time of the end of early diastolic flow velocity curve.

**Statistical analysis:** Student's *t* test was used in all comparisons between the sedentary and swimmer groups, with the level of significance set at a probability of less than 0.05. The results are reported as the group mean  $\pm$ SD.

## RESULTS

The study group consisted of 82 subjects (41 males, 41 females) ranging in age from 7–14 years (mean  $11.2 \pm 1.8$ ) and in weight from 20 to 64 kg (mean  $29.8 \pm 8.6$ ). In this group, five had chest pain, two had palpitations and in these subjects the possibility of heart disease was ruled out by physical examination, electrocardiogram, chest roentgenogram, echocardiogram, Holter ambulatory electrocardiogram and exercise test. The control group consisted of 41 healthy subjects (22 males, 19 females) ranging from 7 to 15 years (mean  $10.8 \pm 2.7$ ) and in weight from 21 to 60 kg (mean  $28.3 \pm 9.9$ ). There was no difference statistically between the groups in age, sex and weight.

The heart rate and pulse pressure were similar in both groups. The heart rate was  $78 \pm 14$ /minute in the study group and  $84 \pm 19$ /minute in the control group ( $p > 0.05$ ). The values of systolic pulse pressure in the study and control groups were  $113 \pm 14$  mmHg and  $109 \pm 18$  mmHg, respectively, ( $p > 0.05$ ) and diastolic pulse pressure  $74 \pm 8$  mmHg and  $71 \pm 9$  mmHg, respectively, ( $p > 0.05$ ).

The children who were in the study group all participated in systematic swimming training for at least six months, averaging  $32 \pm 21$  months (range 6 months–8 years). The training was performed 7–20 hours a week (mean  $14 \pm 4$  hours).

Table I gives the mean values and standard deviations of M-mode measurements in both groups. Left ventricular end-diastolic and end-systolic diameters in the study group were larger than the control group ( $p < 0.001$ ). Left ventricle ejection fraction and shortening fraction were similar in both groups ( $p > 0.05$ ). Interventricular septum and left ventricular posterior wall thickness were significantly different ( $p < 0.001$ ). The swimmers also had significantly larger aortic root ( $p < 0.001$ ) and left atrium internal diameters ( $p < 0.01$ ). In addition, the study group had a significantly higher ratio of wall thickness to cavity dimensions ( $p < 0.05$ ). Left ventricular mass index in swimmers was  $105.2 \pm 25.3$  g/m<sup>2</sup> and significantly greater than the control groups ( $p < 0.001$ ).

The study group was divided into two subgroups according to the training time as hours per week, such as 7–12 hours/week (first subgroup) and 13–20 hours/week (second subgroup). The average ages in these subgroups were similar ( $11.2 \pm 1.9$  years vs.  $11.6 \pm 1.6$  years, respectively). The LVID<sub>d</sub> was  $44.3 \pm 4.3$  mm in

**Table I.** M-Mode Echocardiographic Data for Both Groups

|                                  | Swimmers   | Control   | P      |
|----------------------------------|------------|-----------|--------|
| LVID <sub>d</sub> (mm)           | 46.2±4.4   | 40.4±4.3  | <0.001 |
| LVID <sub>s</sub> (mm)           | 29.2±4.1   | 24.4±3.6  | <0.001 |
| EF (%)                           | 69.2±6.5   | 71.6±7.6  | >0.05  |
| SF (%)                           | 39.3±4.9   | 40.5±6.1  | >0.05  |
| IVS (mm)                         | 8.2±1.0    | 7.1±0.9   | <0.001 |
| LVPW (mm)                        | 8.5±0.9    | 7.3±1.0   | <0.001 |
| AO (mm)                          | 27.1±3.6   | 23.1±2.6  | <0.001 |
| LA (mm)                          | 26.9±4.7   | 24.8±3.7  | <0.01  |
| Ratio of WT to LVID <sub>d</sub> | 0.37±0.05  | 0.35±0.05 | <0.05  |
| Mass index (g/m <sup>2</sup> )   | 105.1±16.9 | 85.7±19.8 | <0.001 |

LVID<sub>d</sub>=left ventricular diastolic internal diameter; LVID<sub>s</sub>=left ventricular systolic internal diameter; EF=ejection fraction; SF=shortening fraction; IVS=interventricular septum thickness; LVPW=left ventricular posterior wall thickness; AO=aortic root diameter; LA=left atrium internal diameter; WT=wall thicknesses.

**Table II.** Pulsed Doppler Echocardiographic Data for Both Groups

|                                 | Swimmers   | Control    | p     |
|---------------------------------|------------|------------|-------|
| E wave (m/sn)                   | 0.83±0.06  | 0.85±0.07  | >0.05 |
| A wave (m/sn)                   | 0.45±0.05  | 0.47±0.06  | >0.05 |
| Ratio of E/A                    | 1.94±0.19  | 1.86±0.26  | >0.05 |
| IRP (msn)                       | 44.2±9.2   | 52.6±9.0   | >0.05 |
| Dec. slope (m/sn <sup>2</sup> ) | 6.30±0.7   | 6.52±1.0   | >0.05 |
| Dec. time (msn)                 | 133.8±21.4 | 132.5±20.1 | >0.05 |

E=early diastolic flow velocity; A=late diastolic flow velocity; IRP=isovolumic relaxation period; Dec=deceleration

the first subgroup, 47.9±5.9 mm in the second subgroup ( $p < 0.005$ ), LVID<sub>s</sub>, 26.9±3.5 mm and 30.2±4.9, respectively ( $p < 0.001$ ), left ventricular mass index 91.0±22.9 g/m<sup>2</sup> and 109.5±29 g/m<sup>2</sup>, respectively ( $p < 0.005$ ).

Doppler echocardiographic data in swimmers and in normal control subjects are summarized in Table II. There was no difference between the groups in peak early diastolic and atrial flow velocities, E/A ratio, isovolumic relaxation time, deceleration time and deceleration slope ( $p > 0.05$ ).

## DISCUSSION

Echocardiography, which allows quantitative assessment of cardiac structure and function without risk or discomfort to the subject, is widely used in sports medicine. Therefore, echocardiography has been an indispensable method in evaluating athletes.

This study revealed significant differences between the two groups. Left ventricular dimensions, wall thickness and mass index in the group of swimmers were greater than the control group. In addition, this difference was more signifi-

cant in the subjects who participated in swimming training of more than 13 hours a week. Allen et al<sup>2)</sup> studied 77 swimmers without a control group and found that left ventricular dimensions and wall thicknesses exceeded the 95th percentile of normal persons. Medved et al<sup>11)</sup> also studied 72 swimmer and sedentary children and found similar results. In spite of significant increases in left ventricular dimension and wall thicknesses, there was no difference in left ventricular systolic functions. Douglas et al<sup>3)</sup> also found no differences in systolic functions in 26 adult athletes. The ratio of wall thicknesses to end-diastolic chamber dimension and left ventricular mass index were greater than the normal. Finkelhor et al<sup>5)</sup> reported that these parameters were also greater in adult athletes. Störk et al<sup>7)</sup> showed a significant left ventricular hypertrophy in long distance runners.

Physiologically, the heart maintains its ability to function adequately as a pump by altering heart rate and contractility when a sudden demand is placed on it. When a long-term demand is imposed on the heart, pump function is maintained by means of cardiac adaptive responses. When pressure overload is chronic, the heart responds by increasing septal and free-wall thickness to normalize cardiac wall stress.<sup>12)</sup> When chronic volume overload occurs, left ventricular end-diastolic diameter increases, with a proportional increase in septal and free wall thickness to normalize wall stress. The increase in the diameter and in ventricular wall thickness can be considered appropriate compensation for the chronic volume overload placed on the hearts of athletes.<sup>12)</sup>

No significant differences between the swimmers and the control group were found with respect to left ventricular filling characteristics with normal E/A ratios and other parameters. These findings correspond to previous reports.<sup>3,6,8)</sup> In contrast, in pathologic left ventricular hypertrophy (such as in hypertensive heart disease, aortic stenosis and hypertrophic obstructive cardiomyopathy) a shift of mitral blood flow from early (E wave) to late (A wave) diastole has been observed.<sup>5,13)</sup> From a purely mechanical standpoint, left ventricular chamber distensibility might be expected to decrease with any increase in wall thickness, leading to impairment of diastolic filling.<sup>3)</sup> The cause of this difference between the physiologic and pathologic hypertrophy is not known. Although the structural response to exercise in athletes appears similar to that described in pathologic pressure overload, the functional response may be somewhat different.<sup>3)</sup> Furthermore, it was shown experimentally that physiologic and pathologic hypertrophy were biochemically and ultrastructurally different.<sup>14)</sup>

In conclusion, in childhood swimmers there was a significant increase in left ventricular internal diameters, wall thicknesses and mass index and internal diameters of aortic root and left atrium. However there were no differences in left ventricular systolic and diastolic functions. Thus, information on endurance training participation is necessary to interpret quantitative echocardiographic

data.

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