Shimane J. Med. Sci. Vol. 2, pp. 63—69, 1978

Normal Values of Echocardiography in Pediatrics
I. Left Ventricular Muscle Volume (LVMV)
The Shimane Heart Study

(echocardiography/left ventricular muscle volume)

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(Received July 31, 1978)

In mass screening examination of heart diseases, 395 apparently healthy children of school age were given echocardiographic examination. Out of the data obtained, left ventricular muscle volume (LVMV) was calculated in 301 cases (169 males and 132 females). LVMV was in good correlation with body surface area, and sexual and racial differences were apparent to some extent. These data provide knowledge of normal range of LVMV in Japanese children of school age.

Echocardiographic examination of the heart is now widely performed clinically, but quantitative evaluation is still not so universal, particularly in pediatric practice. Such can be partly attributed to the lack of data from healthy pediatric age groups. We used echocardiography in mass screening examinations of schoolchildren for heart diseases, and analyzed the results quantitatively. We report herein our findings on left ventricular muscle volume.

MATERIALS AND METHODS

As listed on Table I, those examined were Japanese school children, in the lst and the 4th grades of primary school and in the lst to the 3rd grade of junior high school. Ages ranged from 6 to 7, 9 to 10 and 12 to 15 years, respectively. History taking, physical examinations and ECG were performed. Body weight, height, chest circumference, skinfold thickness were measured and body surface area was estimated from body weight and height, using nomograms (1).

The apparatuses used to obtain echocardiogram were as follows. Ultrasound transducers : Aloka UST-2161 B (3.5 MHz, 7.5 mm in diameter) for younger children and Aloka UST-2155 (2.25 MHz, 14 mm in diameter) for older children. Ultrasonoscope : Fukuda Denshi SSD-110S. Echocardiogram recorder : Fukuda Denshi ECO-125S.

Abbreviations. LVMV ; Left Ventricular Muscle Volume. LVIDd ; Left Ventricular Internal Dimension in diastole. IVSTd ; Interventricular Septal Thickness in diastole. LVPWTd ; Left Ventricular Posterior Wall Thickness in diastole. BSA ; Body Surface Area.

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Echocardiographic examinations were performed mainly on the left side of the heart, but in each case, efforts were made to determine abnormalities in any structure within the heart.

The left ventricular echocardiogram was recorded when the ultrasound passed through the left ventricle where anterior and posterior mitral leaflets, tendinous cords or papillary muscles, endocardial surfaces of both interventricular septum and left ventricular free wall and epicardium posterior to the left ventricular wall were well visualized and the left ventricular dimension was maximal. Thickness of the interventricular septum and left ventricular posterior wall and maximal left ventricular internal dimension were obtained. The landmarks for measurement were so selected that dense echoes of the endocardium were included in IVST and LVPWT and that LVID was from the posterior border of interventricular septal endocardium to the anterior border of left ventricular posterior wall (the "Standard Convention (2) (3)"). These measurements were made at the phase of end-diastole, practically at the peak of R wave of electrocardiogram simultaneously recorded (Fig. 1). Thus, these values were abbreviated IVSTd, LVPWTd and LVIDd, respectively.

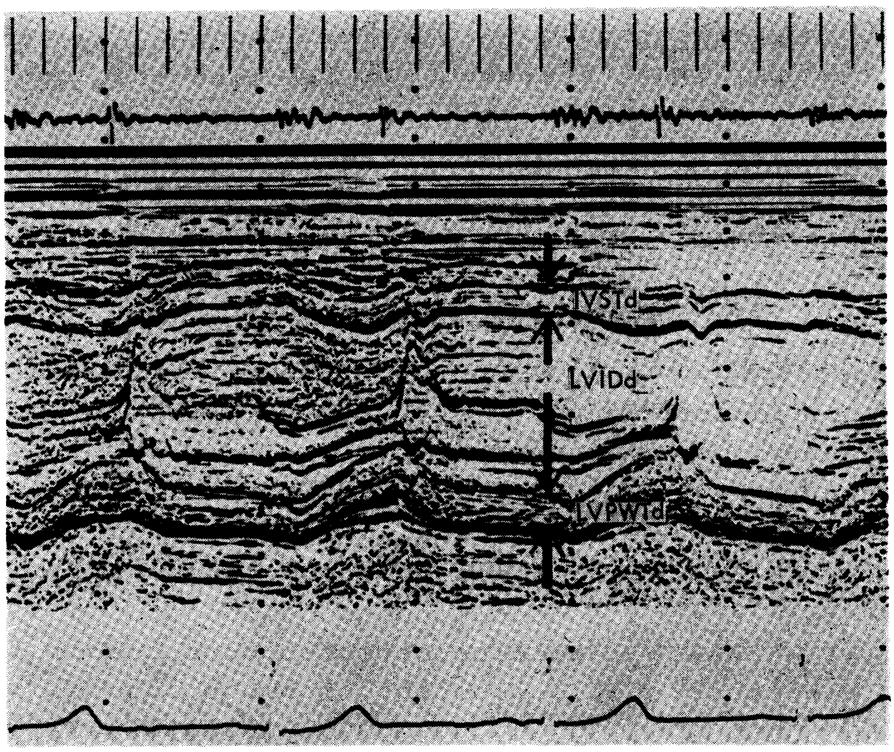

Fig. 1. M-mode echocardiogram recorded. Landmarks for measurement are displayed.

The LVMV was then estimated by the method of Troy *et al.* (4) with some modification. The formula used was :

$$LVMV = 1.05\ (LVIDd + IVSTd + LVPWTd)^2\ (LVIDd + 1/2\ \{IVSTd + PWTd)\} - 1.05\ (LVIDd)^3$$

Original formula was :

$$LVMV = 4/3\cdot\pi\cdot(LVIDd/2 + LVPWTd)^2 (2LVIDd/2 + LVPWTd) - 1/3\cdot\pi\cdot(LVIDd)^3$$

LVPWTd be replaced by 1/2 (LVPWTd + IVSTd), $1/3\cdot\pi$ be approximated 1.05, so that the formula was converted to that described above.

RESULTS

History taking and examinations including echocardiography itself revealed 3 individuals with suspected heart disease and 2 individuals who had had prior heart surgery and these data were excluded. In addition, because of the technical difficulty involved in displaying all these structures i. e. endocardial echoes of IVS and LVPW and posterior epicardial echo simultaneously, echocardiograms did not give definite values of IVST, LVID, LVPWT in a considerable number of subjects, therefore the LVMV could not be estimated. These echocardiograms were also excluded. In all, data analyses were made on estimated LVMV's obtained from 301 cases (Table I).

TABLE I. *Number of Children Examined Echocardiographically and of LVMV's Obtained*

Age(yrs)	Number of school children examined		Number of LVMV's obtained	
	Male	Female	Male	Female
6– 7	99	58	77	43
9–10	70	70	50	42
12–15	48	50	42	47
total	217	178	169	132

Echocardiographically estimated LVMV's of groups differing in age and sex were plotted and their means and standard deviations are noted in Fig. 2. Differences of LVMV's in different age and sex groups were quite evident and actually significant ($p < 0.01$) except between males and females of 9–10 yrs. This was attributed to differences in constitution and corresponded with the difference in BSA described later. The difference in sex was also taken into consideration.

Estimated LVMV's were plotted against BSA in males (Fig. 3) and in females (Fig. 4). In either plotting, there existed good correlations between estimated LVMV and BSA. Correlation coefficients, equations of linear regression and standard errors of estimate were calculated. The gradient of regression equation in males was steeper than in females, making the estimate greater in males, especially at the range of larger BSA. These findings suggest that an appreciable difference in the sexes does exist. This difference, though statistically not fully significant at the range of BSA shown on Figs. 3 and 4 (only $p < 0.10$), could probably be more clearly demonstrated with data from a larger number and at a wider BSA range. Despite the insufficiency, however, linearity of the variation of estimated LVMV was well preserved throughout the range of BSA demonstrated in Figs. 3 and 4 ($p < 0.05$).

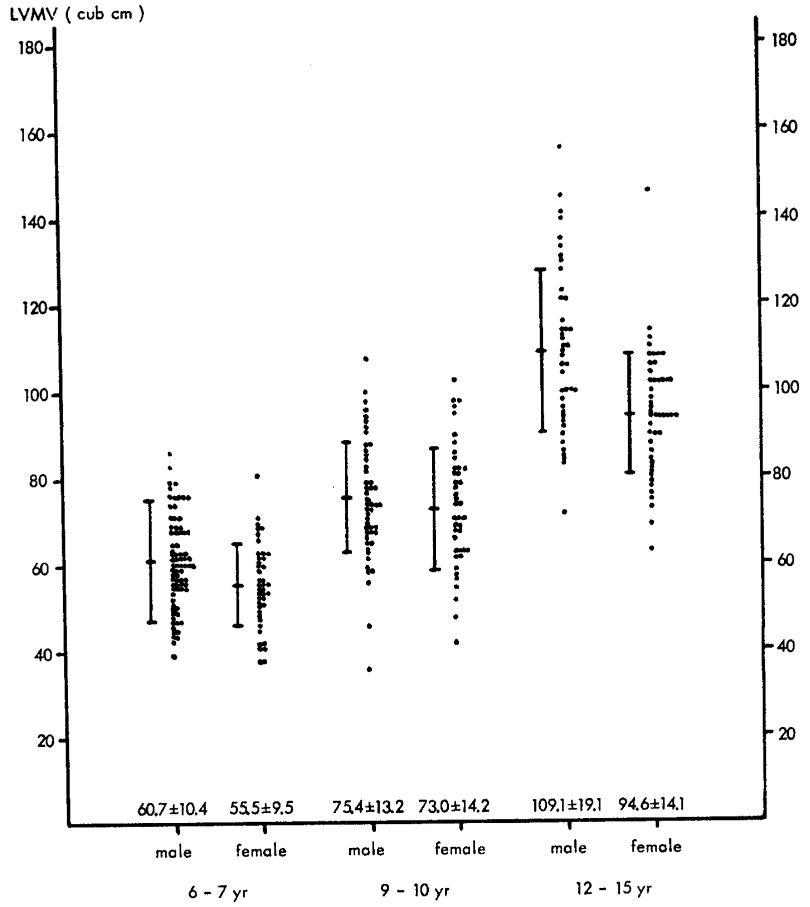

Fig. 2. Distribution of LVMV's in each age and sex group. Means and standard deviations are displayed beside the plottings and noted at the bottom.

DISCUSSION

Because of the cost and technical problems, echocardiography has limited value in mass screening. We do not necessarily consider the examination beneficial for routine use in mass screening. But since intensive cardiac study on relatively restricted groups provides us with information on the normal heart, we utilized echocardiography in mass screening of school children.

The accuracy of echocardiographic measurement has been well discussed (5) (6) (7). Though there are still controversies, most investigators realize the merits of "quantitative echocardiography" because of its noninvasiveness and simplicity. It is reported that echocardiographically estimated left ventricular muscle volumes are significantly correlated with those estimated from electrocardiogram (8) (9), vectorcardiogram (10), angiocardiography (11) and that directly measured from autopsy specimens (3). The LVMV's measured or estimated correlate with BSA as a matter of course, and the regression equation that is proved most reasonable is linear function (12). It was also shown that LVMV is superior to LVIDd or LVPWTd alone as an indicator of left ventricular hypertrophy (9). Today, however, a complicated problem remains in the estimation of LVMV. It is the lack of unity of methods ; first to

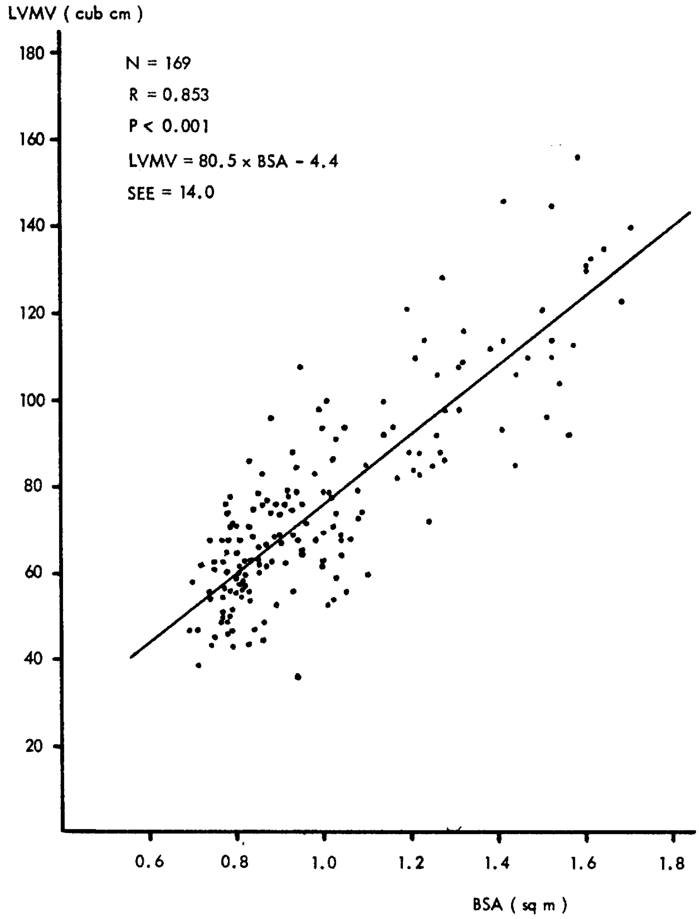

Fig. 3. Plottings of LVMV's against BSA in males. Regression line is displayed in the figure.

measure ventricular inner dimension or wall thickness (3) (12), and the second to calculate LVMV (4) (10) (11). In these circumstances, comparisons of individual values estimated by different methods are almost impossible.

The sample population of this study was not equal in its variation in age, BSA and therefore LVMV. Data from children at the age of 10 to 15 yrs whose BSA's scatter at wide range due to the prepuberal growth spurt are smaller in number and, in addition, data from children and infants less than 5 yrs whose BSA's would be less than 0.7 sq. m. are completely lacking. This is why we do not here present the prediction band or normal range of echocardiographically estimated LVMV based on statistical analysis. Nevertheless, linearity in variations in LVMV's here presented was well preserved, so that a gross normal range of LVMV could be estimated at a given BSA.

Our data suggested the existence of sexual and racial differences. There are few reports which present LVMV's of males and females separately. LVMV appears to be greater in males and such is expected to be confirmed in the future when a larger number of data have accumulated. Knowledge of echocardiographic measurements in the Japanese population is poor (13). In

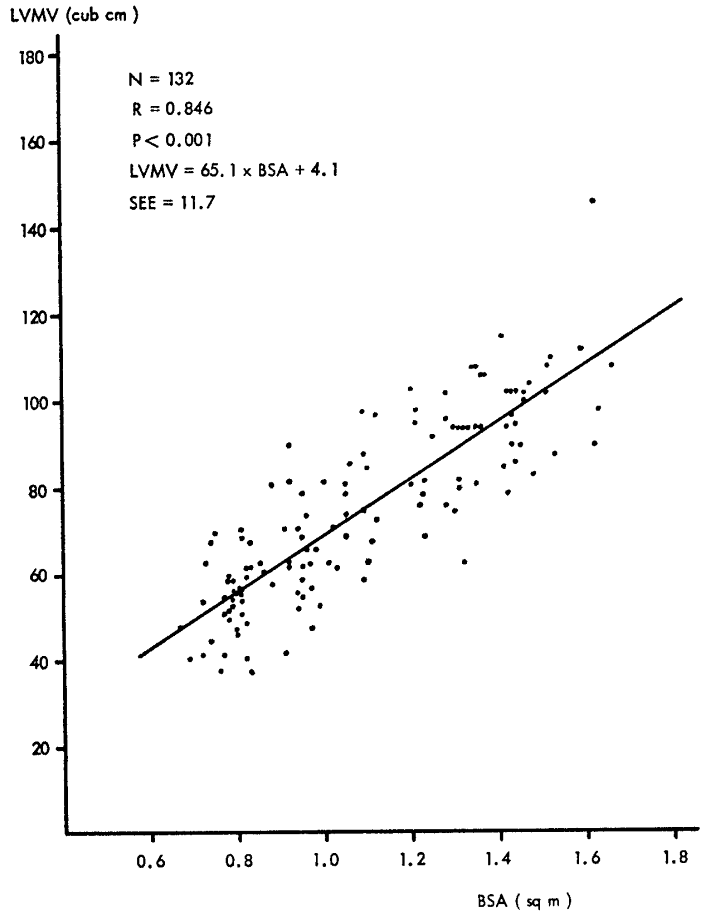

Fig. 4. Plottings of LVMV's against BSA in females. Regression line is displayed in the figure.

comparison with other data of LVMV in Americans by a similar method of estimation (12), the estimated LVMV's in this report are considerably smaller. This may be due to racial differences, but, again, such should be ascertained on data from a larger number of measurements.

The authors are grateful to Dr. T. Hayashidera, Kyoto University, Department of Pediatrics, for pertinent advice and to all the staff of the schools for kind cooperation during examinations.

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