Relationship between Left Ventricular Muscle Volume and Body Surface Area Corrected by Subcutaneous Fat Weight in Normal Children

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Left ventricular muscle volume (LVMV) was measured echocardiographically in 688 normal children ranging in age from 5 to 15. Lean body surface area (BSA) was obtained from height and lean body weight, which was estimated using triceps skinfold thickness, upper arm circumference and body weight.

Regression lines of LVMV against BSA or lean-BSA were compared between boys and girls. There was statistically significant sex difference in regression lines when LVMV were plotted against BSA (p < 0.005), but this difference disappeared when plotted against lean-BSA.

We conclude that the sex difference of LVMV with a similar BSA originates from the difference of lean body weight between boys and girls.

**LEFT ventricular muscle volume (LVMV)** is well correlated with body surface area (BSA) in both sexes. However, when LVMV is compared to a similar BSA, there are significant differences between the sexes. The purpose of this study is to demonstrate the correlation between LVMV and lean-BSA in both sexes and clarify the reason for sex difference in LVMV.

**MATERIALS AND METHODS**

Subjects Population
The subjects consisted of 688 normal school children ranging in age from 5 to 15 (Table I). All children in each class participated in the present study, except those with heart diseases, hypertension and renal diseases, who were excluded by thorough examinations described later.

**Examinations**
The following examinations were performed: anthropometric measurements (body weight, height, upper arm circumference and triceps skin fold thickness), physical examination, blood pressure, hemoglobin, urinalysis, ECG, VCG and echocardiography. Skin fold thickness was measured using a Harpenden caliper.

**TABLE I NUMBER OF SUBJECTS BY AGE AND SEX**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>75</td>
<td>65</td>
</tr>
<tr>
<td>6</td>
<td>57</td>
<td>84</td>
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<tr>
<td>9</td>
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<td>12</td>
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<td>15</td>
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<td>59</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>355</strong></td>
<td><strong>333</strong></td>
</tr>
</tbody>
</table>

**Key Words:**
Left ventricular muscle volume
Sex difference of LVMV
Lean body weight
Echocardiography

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Echocardiography was done utilizing a transducer with a 3.5 MHz frequency for younger children and that with 2.25 MHz for older children. Ultrasonoscope (Fukuda Denshi, SSD-110S) and echocardiogram recorder (Fukuda Denshi, ECO-125S) were used.

Lean body weight (L-BWt) was calculated by the following formula:

\[ L-BWt = \text{body weight} - \frac{\text{arm fat area}}{\text{arm area}} \times \text{body weight} \]

Arm area = \( \frac{C^2}{4\pi} \)

Arm fat area = \( \frac{T}{2} (C - \frac{1}{2} \pi T) \)

where \( C \): upper arm circumference, \( T \): triceps skin fold thickness.

Arm area means the cross-sectional area of upper arm. Arm fat area is that of subcutaneous fat layer of upper arm. Lean body weight was obtained by subtracting the subcutaneous fat weight from body weight. The fat weight was approximately calculated by multiplying the body weight by the ratio of arm fat area to arm area\(^4\).

BSA was estimated by the following equation\(^5\):

\[ BSA = (\text{body weight})^{0.425} \times (\text{height})^{0.725} \times 71.84 \quad \ldots (a) \]

Lean-BSA was obtained by substituting L-BWt for body weight in the above-mentioned formula.

**Quantitative Evaluation of Echocardiogram**

The left ventricular echocardiogram was recorded when the ultrasound passed through the left ventricle where the left ventricular dimension was maximal and the following structures were well visualized: anterior and posterior mitral leaflets, tendinous cords or papillary muscles, endocardial surfaces of both the interventricular septum (IVST) and the left ventricular posterior wall (LVPWT) and the maximal left ventricular internal dimension (LVID) 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"\(^6,7\)).

These measurements were made at the phase

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of end-diastole, practically at the peak of R wave of electrocardiogram recorded simultaneously. These values were abbreviated IVSTd, LVPWtd and LVIdDd, respectively.

The left ventricular muscle volume was estimated by the method of Troy et al.8 with some modification! The formula used was as follows:

$$LVMV = 1.05 \left( \frac{LVIdDd + IVSTd + LVPWtd}{LVIdDd + 1/2(IVSTd + LVPWtd)} \right)^2 - 1.05 (LVIdDd)^3$$

Statistical Analysis

Correlation coefficients and regression equations were estimated between LVMV and BSA (or lean-BSA) in both sexes. Regression lines of both sexes were analysed by variance analysis method. A p value less than 0.05 was considered significant.

RESULTS

LVMV were plotted against BSA in both sexes (Fig. 1). Correlation coefficients were 0.93 in boys and 0.91 in girls. Figure 2 shows regression lines of both sexes. The difference between both regression lines was statistically significant ($p < 0.005$). When the BSAs were equal, the LVMVs were larger in boys than in girls as shown in Fig. 2.

In Fig. 3, LVMV were plotted against lean-BSA in both sexes. Correlation coefficients were 0.93 in boys and 0.90 in girls and there was no statistically significant difference between them ($p > 0.1$) as shown in Fig. 2.

DISCUSSION

Recent advances in echocardiography have made it possible to evaluate various cardiac indexes noninvasively. In a previous paper, we reported that LVMVs were closely correlated with BSA in normal children ($r = 0.85$ in both sexes)1 Similar observations have been reported in both children and adults.2,9

As shown in Figs. 1 and 2, the statistically significant difference in the relation of LVMV and BSA was observed between both sexes ($p < 0.005$). In other words, when BSAs were similar, LVMVs were larger in boys than in girls. There were few reports which investigated or even speculated about the reason for the sex difference in LVMV2 In order to clarify it, we performed the following statistical procedures:

It is presumed that LVMV is correlated with circulatory blood volume in normal subjects. As adipose tissues are poor in blood, the circulatory blood volume is probably correlated with lean body weight, which is calculated by subtracting the weight of adipose tissues from body weight. Therefore, in the present study, lean body weight was used instead of actual body weight to calculate the BSA and we designated a value thus obtained lean-BSA.

LVMV were closely correlated with lean-BSA ($r = 0.93$ in boys and 0.90 in girls), but there was no statistically significant difference between regression lines of both sexes. This result indicates that sex difference in LVMV disappears by substituting lean body weight for body weight in the equation (a) mentioned above.

Because of abundant subcutaneous fat layers in girls, their body weight and BSA are relatively larger than those of boys. Thus, we conclude that the sex difference in LVMV with a similar BSA can be attributed to the difference of lean body weight between boys and girls.

REFERENCES