The Relationship between Blood Pressure and Left Ventricular Muscle Volume in Normal Children and Adolescents
— The Shimane Heart Study —

TOSHIKAZU NISHIO, M.D., CHUZO MORI, M.D., MASAKAZU SAITO, M.D.
YOSHIHISA KAJINO, M.D., KATSUTOSHI ABE, M.D., NORIYUKI HANEDA, M.D.
AND KOJI WATANABE, M.D.

Blood pressure (BP) and left ventricular muscle volume (LVMV) were measured in 408 children and adolescents aged 9–15 years. LVMV was determined by M-mode echocardiography. Lean body weight was approximately calculated using body weight, upper arm circumference and triceps skin fold thickness. Lean-BSA was obtained by substituting lean body weight for body weight in the formula for BSA. Subjects were divided into the high and the low BP percentile groups according to their BP percentile values. LVMVI (= LVMV/BSA) and lean-LVMVI (= LVMV/L-BSA) were compared between the two groups. LVMVI and L-LVMVI were larger in the high BP percentile group than in the low one. Regression lines of LVMV to BSA were also compared between the two groups. Regression lines of the high BP percentile group were located in a higher position than those of the low percentile group.

These results suggest that LVMV are larger in the high BP percentile group than in the low percentile group even if their BSAs are equal. We concluded that left ventricular hypertrophy has been already initiated in the pre-hypertensive stage of human beings as observed in spontaneously hypertensive rats.

The experimental studies on spontaneously hypertensive rats have indicated that the left ventricular hypertrophy already begins before or immediately after the development of hypertension! We have previously reported analogous observations in hypertensive children and adolescents1,2.

This paper will report on the relationship between blood pressure and left ventricular muscle volume in normal children, and the presence of cardiac hypertrophy in a high blood pressure percentile group.

MATERIALS AND METHODS

Subjects population
A total of 408 healthy children aged 9, 12 and 15 years were randomly sampled from several schools in Izumo, a country city of moderate size and population in Japan (Table I). Children with heart disease, hypertension and renal diseases were excluded by thorough examinations described later.

Examinations
The following examinations were performed:

Key Words:
Blood pressure
Left ventricular muscle volume
Left ventricular hypertrophy
Early hypertension
Lean body weight

Department of Pediatrics, Shimane Medical University, Izumo, Japan
Mailing address: Toshikazu Nishio, M.D., Department of Pediatrics, Shimane Medical University, Izumo 693, Japan

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TABLE I NUMBER OF SUBJECTS

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<th>Age (yrs)</th>
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TABLE II PERCENTILE VALUES OF SYSTOLIC BLOOD PRESSURE IN CHILDREN OF THE PRESENT STUDY

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TABLE III NUMBER OF SUBJECTS BY PERCENTILE GROUPS

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BSA = BWt^{0.425} \times (Height)^{0.725} \times 71.84 \\
L-BSA = (L-BWt)^{0.425} \times (Height)^{0.725} \times 71.84

**Quantitative evaluation of echocardiogram**

Echocardiograms were recorded and evaluated as reported previously\(^2\). Interventricular septum thickness (IVSTd), left ventricular posterior wall thickness (LVPWTd) and left ventricular internal dimension (LVIDd) were measured at the end-diastolic phase using the "standard convention"\(^6\).

The left ventricular muscle volume (LVMV) was estimated by the method of Troy et al. with some modification? The formula used was as follows;

\[
LVMV = 1.05 \times (LVIDd + IVSTd + LVPWTd)^2 \\
\times (LVIDd + IVSTd + LVPWTd)^2 \\
- 1.05 \times (LVIDd)^3
\]

LVMV index (LVMVI) = \frac{LVMV}{BSA}

Lean LVMVI (L-LVMVI) = \frac{LVMV}{L-BSA}

**RESULTS**

**Left ventricular muscle volume index**

In children, the left ventricular muscle volume is correlated with BSA or L-BSA which is closely related to body size and age. In order to exclude the influence of body size and body fatness, LVMV was corrected by BSA and lean BSA (LVMVI and L-LVMVI), respectively.

LVMVI were compared between the high and the low blood pressure percentile groups as shown in Fig. 1. In girls, LVMVI were signifi-

![Figure 1](image)

**Fig. 1.** Comparison of LVMVI between the high and the low blood pressure percentile groups in girls. LVMVI = left ventricular muscle volume index

![Figure 2](image)

**Fig. 2.** Comparison of Lean-LVMVI between the high and the low blood pressure percentile groups in girls.

![Figure 3](image)

**Fig. 3.** Comparison of regression lines of LVMV to body surface area (BSA) between the high and the low blood pressure percentile groups in girls. (---) = High percentile group; (---) = Low percentile group

significantly larger in the high percentile group than in the low group. The same results were obtained when L-LVMVI were compared between the two groups as shown in Fig. 2.

These results suggest that LVMV of the high blood pressure percentile group is larger independent of body size, age and body fatness.

**Regression lines of LVMV to BSA**

The regression lines of LVMV to BSA were compared between two above-mentioned groups. There were statistically significant differences between the two regression lines in girls (Fig. 3). The regression lines of the high blood pressure group were always located in a higher position than those of the low percentile group.
There results mean that LVMV of the high blood pressure percentile group is larger than that of the low percentile group even if their BSAs are equal.

In boys, no significant differences were obtained in LVMVI, L-LVMVI, and regression lines, between the high and the low percentile groups.

DISCUSSION

We have previously reported that the left ventricular hypertrophy does exist in borderline-hypertensive children and adolescents. Similar observations have been reported by Laird, Culpepper, and Zahka. The results of the present study indicate that the LVMV of girls is larger in the high blood pressure percentile group than in the low percentile group. These changes were independent of BSA and body fatness. Similar results were reported by Schieken in normal children. They observed that the left ventricular wall mass was significantly greater in children with blood pressure of the upper quintile than those of lower quintile. They did not mention the sex difference of the findings which were observed in our study.

The results of the present study and Schieken's indicate that left ventricular hypertrophy has already occurred even in children with a borderline-elevation of blood pressure. In spontaneously hypertensive rats, cardiac hypertrophy begins in the early stage of hypertension. These analogous findings in both animals and human beings suggest that the early detection of left ventricular hypertrophy can be a useful indicator for the subclinical stage of essential hypertension.

REFERENCES