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Cardiac hypotrophy in young women with low blood pressure

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Abstract
Evaluating the structure and function of the heart in young women with low systolic blood pressure (LSBP). Echocardiographic parameters of two groups of young women aged 18-35 years were compared: 69 women with systolic blood pressure (SBP) 61-99 mmHg and 35 women with SBP 120-129 mmHg. Signs of cardiac remodeling were revealed in young women with low systolic blood pressure (LSBP), as well as increased sizes of aorta and reduced sizes of left atrium (LA), right ventricle (RV), and end-diastolic dimension (EDD) of left ventricle (LV). We revealed an increase in thickness of the interventricular septum (TIVS), and thickness of the left ventricular posterior wall (TLVPW) in systole and diastole. LSPB is characterized by a higher values of the following parameters compared to that of the control group: fractional shortening (FS), ejection fraction (EF), left ventricular myocardial mass (LVMM), maximum blood flow velocity (V_{max}) on the mitral valve (MV), left ventricle diastolic function – maximum early peak velocity (peak E) (LVDF – V_e) and maximum early peak velocity (peak E)/maximum later peak velocity (peak A) (V_e/V_a) index, left ventricle end-systolic volume (LVESV), left ventricle end-diastolic volume (LVEDV), left ventricle stroke volume (LVSV), cardiac output (Q), stroke volume index (SVI), left ventricle end-diastolic volume/left ventricular myocardial mass (LVEDV/LVMM), stroke index (SI), left ventricle diastolic function – maximum later peak velocity (peak A) (LVDF – V_a), maximum blood flow velocity – aortic valve (V_{max} – AoV), gradient (difference) of blood pressure–mitral valve (Pg_{max} – MV), gradient (difference) of blood pressure – aortic valve (Pg_{max} – AoV), and gradient (difference) of blood pressure – pulmonary valve (Pg_{max} – PuV). LSBP in young women is associated with cardiac hypotrophy–reducing in the sizes of the heart chambers, left ventricular remodeling, isolated diastolic dysfunction and decreased intracardiac hemodynamics.

Keywords: Low blood pressure; cardiac hypotrophy; young women.

Introduction

Nowadays low systolic blood pressure (LSBP) is considered to be a risk factor for cardiovascular complications and impairs quality of life. However LSBP still remains a largely unexplored problem [1]. In young women LSBP occurs in 7.2% of cases [2]. Up to 70% of women with LSBP complain of any health disorder, while 43% of women complain of pain in the heart, and 30% have low physical activity tolerance [3,4]. However, the results of echocardiographic studies of the heart in patients with LSBP are contradictory and don't give a true picture about an organic or functional nature of cardiovascular complaints in women with LSBP. They also hinder an effective patient care.

The purpose of the research is to evaluate the cardiac structure and function in young women with LSBP.

Abbreviations: Ao: Aorta; AoV: Aortic Valve; DF: Diastolic Function; EDV: End-diastolic Volume; EDD: End-diastolic Dimension; ESV: End-systolic Volume; ESD: End-systolic Dimension; LV: Left Ventricle; LA: Left Atrium; MV: Mitral Valve; LVMM: Left Ventricular Myocardial Mass; Q: Cardiac Output; MRI: Magnetic Resonance Imaging Device; LSBP: Low Systolic Blood Pressure; RV: Right Ventricle; PuV: Pulmonary Valve; SBP: Systolic Blood Pressure; SVI: Stroke Volume Index; TLVPW: Thickness of the Left Ventricular Posterior Wall; TIVS: Thickness of the Interventricular Septum; TrV: Tricuspid Valve; SI: Stroke Index; SV: Stroke Volume; EF: Ejection Fraction; FS: Fractional Shortening; ECHO-CG: Echocardiography; Pg_{max}: Gradient (difference) of Blood Pressure; V_{max}: Maximum Blood Flow Velocity; V_a: Maximum Later Peak Velocity (peak A); V_c: Maximum Early Peak Velocity (peak E).

Table 1: Characteristics of the test and control groups.

Parameters	Median (25-75%)		p
	Test group (N = 69)	Control group (N = 35)	
Age (years)	19 (18-20)	19 (18-20)	0.46
Height (cm)	162 (158-165)	164 (158-168)	0.24
Weight (kg)	53 (49-57)	56 (53-61)	0.01
Heart rate (beats per minute)	74 (70-81)	76 (72-83)	0.27

Note: p is the significance level.

Materials and Methods

The object of the research is young women with LSBP, the subject of the research is structural and functional cardiac parameters, and the type of the study is cross-sectional. LSBP is defined as systolic blood pressure (SBP) equal to 99 mmHg or less [5-7]. Normal SBP was defined as SBP in the range of 120-129 mmHg [1]. The study didn't enroll women with the presence of anemia, dysplasia of connective tissue, cancer, diabetes, hypothyroidism, adrenal insufficiency, collagenoses, congenital heart and blood vessels diseases, cardiac surgery in past, any term of pregnancy, drug abuse, and acute infectious diseases at the moment of the study. Exclusions from the study were carried out on the basis of analysis of medical records and interviews. The study was conducted during an examination of university students before admission to sporting activities. Site of the medical examination is outpatient department with a time of the examination from 15 to 19 hours. We examined 1,264 women aged from 18 to 35 years, divided into 2 groups: a test group with LSBP (N = 69) and control one with normal systolic blood pressure (N = 35 subjects) (Table 1).

The blood pressure was measured after 5 min rest, twice, on the right shoulder in the sitting position, with the forearm on the table and an interval of 3 minutes. A&D UA-777 tonometer was used (AGD Company Ltd., Japan, 2012). Based on the obtained results, the mean value of the two measurements was calculated. Echocardiography was performed at rest using En Vizor CHD device (Philips, 2009). The following parameters were monitored in order to assess cardiac hemodynamics: morphometry of anatomical structures of the heart, Doppler ultrasound to measure the blood flow and functional parameters of the heart.

Ethical issues

The protocol of the study on volunteers conformed to the Helsinki Declaration of 1975 as revised (59th WMA General Assembly, Seoul, Republic of Korea, October 2008). Plan and design of the study were approved by the Ethics Committee of the Academy (protocol number 74). Persons admitted to the survey, gave a written informed consent to participate in this study. Statistical analysis was performed using the software "Statistica 6.1" (serial number AXXR912E53722FA, StatSoft-Russia, 2009). Distribution of variation rows wasn't symmetrical (H. Lilliefors criterion, at $p < 0.05$). Comparing of the two groups was performed using Mann–Whitney U-test [8].

Results

There was an increase in the size of aorta (Ao), and reduction in dimensions of right ventricle (RV) and left ventricle end-diastolic dimension (LVEDD) in the test group. It was also observed an increase in thickness of the interventricular septum (TIVS), thickness of the left ventricular posterior wall (TLVPW) in systole and diastole in the test group (Table 2).

Analysis of the functional echocardiographic parameters revealed some increased parameters in test group than that in the control group: fractional shortening (FS), ejection fraction (EF), left ventricular myocardial mass (LVMM), left ventricle diastolic function – maximum early peak velocity (peak E) (LVDF–V_e), maximum early peak velocity (peak E)/maximum later peak velocity (peak A) (V_e/V_a), maximum blood flow velocity–mitral valve (V_{max}–MV) (Table 3). The following parameters were below the level in the control group: left ventricle end-systolic volume (LVESV), left ventricle end-diastolic volume (LVEDV), stroke volume (SV), cardiac output (Q),

Table 2: Comparative analysis of structural echocardiographic parameters in subjects of the test and control groups.

Parameters	Median (25-75%)		*p*
	Test group (*N* = 69)	Control group (*N* = 35)	
Ao (mm)	26.7 (26.0-26.7)	24.3 (24.3-26.0)	0.000
LA (mm)	29.0 (28.0-30.0)	28.2 (27.0-30.0)	0.094
LVEDD (mm)	44.9 (43.5-45.5)	45.5 (45.0-46.8)	0.012
LVESD (mm)	26.4 (26.0-27.0)	26.9 (25.0-27.9)	0.212
TIVS (diastolic) (mm)	7.6 (7.1-7.6)	7.4 (7.1-10.3)	0.297
TIVS (systolic) (mm)	9.5 (8.7-9.5)	8.7 (8.5-8.7)	0.000
RV (mm)	18.0 (17.0-18.0)	18.8 (17.4-18.8)	0.038
TLVPW (diastolic) (mm)	7.5 (7.2-7.5)	7.2 (7.1-7.2)	0.000
TLVPW (systolic) (mm)	9.7 (9.0-9.7)	8.4 (8.4-8.8)	0.000

Note: p is the significance level.

Table 3: The results of a comparative analysis of functional echocardiographic parameters of the test and control groups.

Parameters	Median (25-75%)		*p*
	Test group (*N* = 69)	Control group (*N* = 35)	
LVESV (cm^3)	26.8 (26.8-28.3)	29.9 (28.0-31.9)	0.001
LVEDV (cm^3)	94.3 (85.4-100.0)	99.7 (97.3-104.9)	0.002
LVSV (cm^3)	67.6 (62.0-70.0)	70 (69.00-73.00)	0.005
LVSF (%)	40.9 (39.0-41.0)	39.0 (38.0-39.0)	0.001
LVEF (%)	71.5 (70.0-72.0)	70 (69.0-70.0)	0.005
Q (cm^3/min)	5.3 (4.7-5.6)	5.6 (5.1-5.9)	0.014
SVI (l/min/m^2)	3.4 (3.1-3.4)	3.6 (3.6-3.7)	0.006
LVMM (g)	107.1 (103.1-111.1)	104.3 (103.0-107.0)	0.006
LVEDV/LVMM	0.89 (0.89-0.95)	0.94 (0.93-0.97)	0.002
SI (cm^3/m^2)	43.3 (40.0-43.3)	44.0 (41.0-46.0)	0.048
LVDF$-V_e$ (m/s)	0.94 (0.90-0.94)	0.92 (0.90-0.94)	0.114
LVDF$-V_a$ (m/s)	0.49 (0.45-0.50)	0.51 (0.48-0.51)	0.006
V_e/V_a	1.97 (1.80-2.04)	1.82 (1.78-1.86)	0.008
$V_{max}-$MV (m/s)	0.9 (0.86-0.92)	0.89 (0.87-0.89)	0.044
$V_{max}-$AoV (m/s)	1.21 (1.12-1.21)	1.28 (1.24-1.31)	0.001
$V_{max}-$PuV (m/s)	0.89 (0.80-0.98)	0.87 (0.87-0.88)	0.297
$V_{max}-$TrV (m/s)	0.55 (0.52-0.56)	0.56 (0.53-0.56)	0.357
$Pg_{max}-$MV (mmHg)	3.18 (2.90-3.30)	3.41 (3.00-3.41)	0.028
$Pg_{max}-$AoV (mmHg)	5.72 (4.90-5.72)	6.94 (6.20-7.30)	0.000
$Pg_{max}-$PuV (mmHg)	2.61 (2.56-2.80)	3.21 (3.10-3.21)	0.000
$Pg_{max}-$TrV (mmHg)	1.15 (1.00-1.20)	1.2 (1.01-1.34)	0.099

Note: p is the significance level.

stroke volume index (SVI), left ventricle end-diastolic volume/left ventricular myocardial mass (LVEDV/LVMM), stroke index (SI), left ventricle diastolic function – maximum later peak velocity (peak A) (LVDF – V_a), maximum blood flow velocity – aortic valve (V_{max} – AoV), gradient (difference) of blood pressure – mitral valve (Pg_{max} – MV), gradient (difference) of blood pressure – aortic valve (Pg_{max} – AoV), and gradient (difference) of blood pressure – pulmonary valve (Pg_{max} – PuV).

Conclusion

Previously performed studies have shown that LSBP is accompanied by changes in the structure and function of the heart. Poznyakova revealed increased sizes of the aorta base in 10.6% of cases among 81 patients with blood pressure below 100/65 mmHg aged from 16 to 35 years [9]. The study performed by Atayan showed reduced values of left atrium (LA), left ventricle (LV), LVEDV, and LVESV at the level of blood pressure below 105-100/65-60 mmHg. The last study involved 65 men and women of middle age–about 42 years [10]. There was an increase of SVI caused by an increase in the LVEF and the heart rate. Tyurina also shows the reduced size of heart and myocardial mass, the diameter of the aorta and its branches in patients with LSB based on the study of 240 people with primary arterial hypotension with a mean age of 53 years. The author relates an intensity of the structural changes to the minimum level of blood pressure [11]. Belova revealed the presence of diastolic dysfunction, later filling of the left ventricle and increased isovolumic relaxation period revealed in 120 young persons with LSBP [12].

In our study we revealed that women with LSBP had a lower body weight compared with women of the same age and normal blood pressure. Low body weight by itself is associated with hemodynamic changes and signs of cardiac hypotrophy. Romano *et al.* showed that the weight loss can cause cardiac hypotrophy accompanied by a decrease in hemodynamics parameters. Echocardiographic parameters of 91 women with an average age of 20 years and the body mass index of 15.6 kg/m^2 were compared with such parameters of 62 women with an average age of 22 years and the body mass index of 22.5 kg/m^2 [13]. The following findings were revealed in women with low body weight:

1. Lower left ventricular myocardial mass with systolic dysfunction.
2. Smaller dimensions of the left ventricle.
3. Thinner walls of the left ventricle.
4. Considerable decrease in ejection fraction, heart rate, stroke volume and cardiac output.
5. Increase in peripheral resistance.

The results of our study showed some differences from the previously received echocardiography data in patients with LSBP:

a) Besides the already known structural features (Ao dilatation and reduced dimensions of RV, LVEDD), we showed an increase in TIVS and TLVPW in systole and diastole, as well as an increase in the left ventricular myocardial mass;

b) As well as in the previous studies it was shown that LVEF value was increased, however the values of SVI, SI, Q, and LVSV were reduced while LVSF was increased;

c) Slower rate of a blood flow at the level of the mitral and aortic valves;

d) There was a smaller pressure gradient during the passage of blood through the mitral, aortic, and pulmonic valves;

e) Diastolic dysfunction of the left ventricle in the form of growth of V_e/V_a index is the subject of special attention. In our study this index is significantly higher than that in patients with normal blood pressure, and is close to 2.0.

Luo relates an increase in V_e/V_a index to the most severe manifestations of isolated diastolic dysfunction in the absence of a compensatory increase in total body fluid due to an increased passive stiffness (restrictive or R-type) [14]. This R-type is manifested by three features, two of which were identified in our study:

1) Increase in the velocity of peak E of the diastolic flow;
2) Decrease in the velocity of peak A of the diastolic flow;
3) An increase in E/A ratio greater than 2.

We assume that structural and functional changes of the heart in young women with LSBP are associated with the signs of cardiac hypotrophy. It is possible that cardiac hypotrophy is a primary nosology, while LSBP develops as a complication of cardiac hypotrophy. Cardiac hypotrophy and atrophy were described previously in induced starvation and malnutrition, including young women [15-18]. A group of scientists from Ireland led by Owens performed 24-hour blood pressure monitoring in 254 bank employees and their families and found that the low weight is the most important independent predictor of low blood pressure. This is especially true for women [19]. The relationship between LSBP and reduced weight is also shown in other studies [7,19-21]. Cardiac hypotrophy is described after a long-term (more than 6 weeks) bed rest in a horizontal position, or after a brief space flight, i.e., in the absence of an adequate physical exercises. Perhonen and colleagues used magnetic resonance imaging (MRI) to measure the mass of the left and right ventricular myocardial mass, end diastolic volume of the left ventricle in 3 healthy men before and after 2-, 6-, and 12-weeks of bed rest in a horizontal position, and in 8 astronauts before and after 10-day space flight. During a bed rest LVMM decreased by 8%, an average TLVPW decreased by 4%, and LVEDV decreased by 14%. After the space flight LVMM decreased by 12% [22]. Dorfman revealed cardiac atrophy in women after 60 days of a bed rest [23]. MRI in 24 healthy women aged 32 years revealed a significant decrease in the volume of the LV (from 96 to 77 ml) before and after 60 days of a bed rest and a decrease in the volume of the RV (from 104 to 86 ml).

We hypothesize that the LSBP is associated with cardiac hypotrophy and hypofunction of the heart on the background of low body weight of a young woman. However the main feature of cardiac hypotrophy (myocardial mass reduction) wasn't found. It's likely that myocardial mass reduction didn't occur due to an increase in TLVPW and TIVS. Additional sign indicating left ventricular remodeling is its isolated diastolic dysfunction. We can also explain an absence of reduction in myocardial mass in our study by an involuntary physical and social activity in a young age, indicating an adequacy of the adaptation period allowing cardiovascular system to adapt to the lower weight and lower blood pressure.

Summary

LSBP in young women is associated not only with the lower body weight, but also with cardiac hypotrophy – reduced sized of the heart chambers, left ventricular remodeling, isolated diastolic dysfunction, and decreased intracardiac hemodynamics.

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