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ELECTROCARDIOGRAPHY AND ECHOCARDIOGRAPHY IN ATHLETIC HEART IMAGINING

D.Biały[1,2], A.Derkacz[1], H.Nowosad[1], R.Skalik[3], E.Marszałek[1], R.Poręba[4], M.Protasiewicz[1], Z.Zagrobelny[2]

[1]Cardiosurgery Dept., Medical University of Wroclaw, Poland; [2]Physiotherapy Dept., Academy of Physical Education, Wroclaw, Poland; [3]Dept. of Physiology, Medical University of Wroclaw, Poland; [4]Dept. of Internal Medicine, Occupational Diseases and Hypertension, Medical University of Wroclaw, Poland

Abstract. The aim of the study was evaluation of electrocardiographic and echocardiographic parameters in athletes. „Athletic heart" characteristics were compared with fit persons' heart. 96 athletes participated in the study. Sportsmen were divided into: static (S), dynamic (D) and composite (SD) exercise groups and Polish (I), European (II), World (III) champions. 30 students from Sport Academy formed the control group (K). Electrocardiographic and echocardiographic examination were performed in everyone. As regards the type of exercise, the end-systolic left ventricular (LV) dimension was smaller in S in comparison with D and SD (28.9 vs 32.2 and 32.68 mm; P<0.05). LV mass was bigger in D in comparison with K (273.2 vs 218.6 g; P<0.05). Medium Pulmonary Artery Pressure (MPAP) in S and SD was lower in respect to D and K (11.75; 11.08 vs 15.52; 17.43 mm Hg; P<0.05). We observed lower heart rate in D, SD in comparison with K (58.64; 60.54 vs 68.8; P<0.05), bigger R wave amplitude in V5 (RV5) (21.65; 23.5 vs 15.03 mm; P<0.05) and V6 (RV6) (23.5 vs 15.3 mm; P<0.05) in group S in respect to K. LV mass was bigger in III than in K (261.3 vs 218.6 g; P<0.05). MPAP was lower in I and II in comparison with K (11.42; 13.13 vs 17.43 mmHg; P<0.05). HR was lower in categories I, II than in K (61.32; 60.13 vs 68.8; P<0.05), RV5 was bigger in I in comparison with K (19.5 vs 15.03 mm; P<0.05). The electrocardiography and echocardiography proves to find some significant differences between athletic and fit persons' heart especially as concerns MPAP, RV5, RV6 values.

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Reprint request to: Dr Arkadiusz Derkacz, Klinika Chirurgii Serca, ul. M. Skłodowskiej-Curie 66, 50-369 Wrocław, Poland
Tel./Fax: 0-71-7840938, Tel.: 0-601-872980, E-mail: aderkacz@chirs.am.wroc.pl

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Introduction

For many years the importance of the physical effort in cardiovascular efficiency and general fitness has been underlined. It refers to both people suffering from heart diseases (coronary heart disease, myocardial infarction, heart failure) and healthy individuals. At the same time a physical training of professional athletes has a different sense. It is repeated constantly for many years and its weight exceeds limits normally recognized as physiological. In practice the training load of different athlete disciplines is difficult to measure and to compare. Each discipline is characterized by different training cycle adapted to competitor's abilities and aspirations. In connection with that the concept of "athletic heart" has appeared. It refers to professional athlete's cardiovascular system adaptive distinctions [1,9]. Some authors suggest high physical efforts produces unfavorable changes in humans organism and gradually passes to the stage of pathology [11,3]. Others underline only a limited influence of the training on the cardiovascular system [8]. Nowadays disposing of many diagnostic possibilities in cardiology we can try to verify these different opinions.

The goal of the study was the evaluation of the influence of physical effort on heart structures with electrocardiographic and transthoracic echocardiographic (TTE) examination. We attempted to take in the consideration the difference between sport disciplines and relate possible changes to a different athletes rank, assessed with their sport achievements. Moreover we tried to assess the correlation between parameters describing competitors, their training type and results of TTE and ECG examination.

Material and Methods

In the group of 96 athletes included into the study we examined 19 women and 77 men in the age of 25.6+/-8.9 years.

Considering achieved results athletes were divided in three categories of Results group.

(I) The condition of the inclusion was at least the third place in Polish Championships,

(II) At least the third place in European Championships

(III) At least the third place in World Championships or Olympic Games.

All sportsmen were examined when preparing for competitions or during competition time. The control group (K) consisted of 30 Academy of Physical Education students who were not professional athletes. The characteristic of the basic parameters and achieved results of examined people are shown in Table 1.

Table 1
Characterization of different groups with respect to achieved results

Group	Number	Age (years)	Height (cm)	Weight (kg)	Training experience (years)
I	70	24.85 +/-9.54	174.64 +/-10.60	78.18 +/-20.99	10.34 +/-6.54
II	15	26.93 +/-7.81	178.53 +/-6.28	82.06 +/-13.80	12.26 +/-7.07
III	11	28.09 +/-5.59	178.09 +/-7.21	87.63 +/-26.69	13.00 +/-6.09
K	30	23.36 +/-4.87	176.40 +/-8.1	73.46 +/-8.75	---

I - at least the third place in Polish Championships; II - at least the third place in European Championships; III - at least the third place in World Championships or Olympic Games; K - control

Competitors of judo, box, athletics, karate, weight lifting and wrestling participated in the study. Considering the sport discipline and kind of discipline sportsmen were divided into tree categories of Dyscipline group.
(S) - mainly static effort: weight lifting
(SD) - static and dynamic effort: judo, box, karate, wrestling
(D) - mainly dynamic effort: athletics.

The characteristic of each Discipline group categories is shown in Table 2.

Table 2
Characteristic of tree groups in respect to the sport discipline

Group	Number	Age (years)	Height (cm)	Weight (kg)	Training experience (years)
S	20	25.00 +/-8.43	170.25* +/-7.29	76.95 +/-15.29	10.60 +/-6.65
SD	57	25.21 +/-9.93	174.35 +/-9.26	80.91 +/-24.06	10.77 +/-6.80
D	19	27.15 +/-6.01	185.21* +/-6.94	79.84 +/-14.97	11.84 +/-6.09

*Statistical difference (P<0.05)
S - mainly static effort-weight lifting; SD - state and dynamic effort-judo, box, karate, wrestling; D - mainly dynamic effort-athletics; K - control

We evaluated both the history of every examined man and results of ECG, TTE, pressure measurement to eliminate the group of people with heart disease. ECG, TTE examination and blood pressure measurement were performed for everyone.

The TTE examination was carried out using typical projections with 2.5MHz Sonos 2000 system (Hewlett-Packard, USA). One and two dimensional echocardiograms were recorded in accordance to American Society of Echocardiography. We evaluated:
Left ventricular end-diastolic dimension (LVDD)
Left ventricular end-systolic dimension (LVSD)
Interventricular septum thickness in diastole (IVS)
Posterior wall thickness in diastole (PW)
Right ventricle end-diastolic dimension (RV)
Left atrium dimension (LA)
Aorta diameter (Ao)
Mean pulmonary artery pressure (MPAP)
Shortening fraction (FS)
Ejection fraction (EF)
Left ventricle mass (LVM)
Left ventricle contractility according to American Society of Echocardiography criteria.

ECG examination: The Examination was performed in lying position using standard 12 leads with Cardiostar 31 system (Siemens, Germany). Heart rate (HR), QRS complex time, QT interval and Sokolow-Lyon (SV1+RV5(V6)) index were analyzed.

Blood pressure measurement: Moreover, in everyone we measured the blood pressure in sitting position. To eliminate a stress influence the examination was carried out after the history taking.

Statistical analysis: The Statistica 5.0 (StatSoft, Poland) software was used to analyze obtained results. As statistical important the value off P<0.05 was accepted.

Results

In the Results group statistically important differences were observed in the case of left ventricle mass (Fig. 1) for categories III and K (261.3+/-5.4 g vs 218+/-6.7 g) and in the case of mean pulmonary artery pressure (Fig. 2) for categories I, II, III, K (11.42+/-4.67 mmHg vs 13.13+/-5.48 mmHg vs 15.0+/-5.0 mmHg vs 17.43+/-4.38 mmHg, respectively). We did not observe any statistically important differences in the rest of TTE assessed parameters.

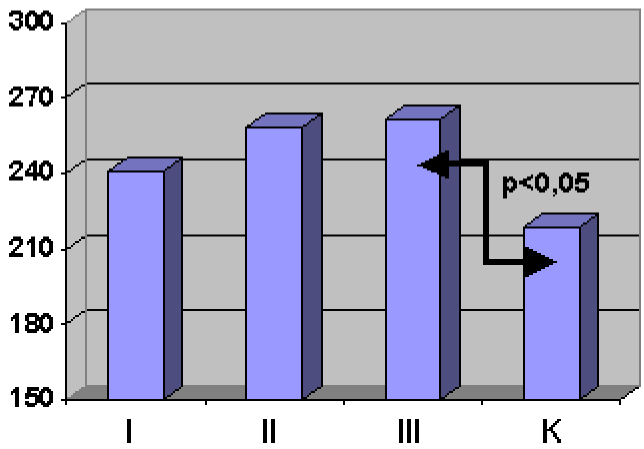

Fig. 1
Left ventricle mass (g) in categories of Results group; Statistical difference was observed between category I and K (P<0.05)

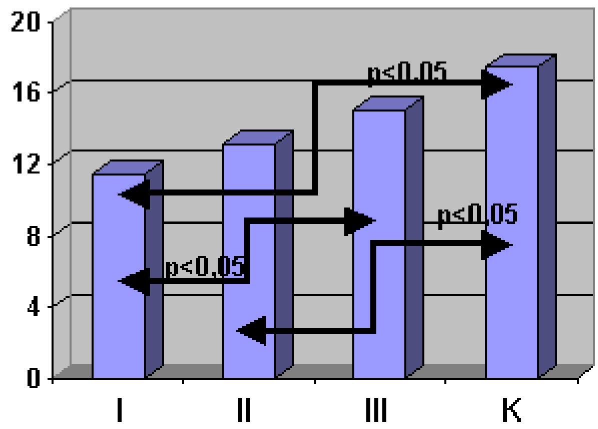

Fig. 2
Mean pulmonary artery pressure (mmHg) in particular categories; Differences noted between categories I, II and K with P<0.05

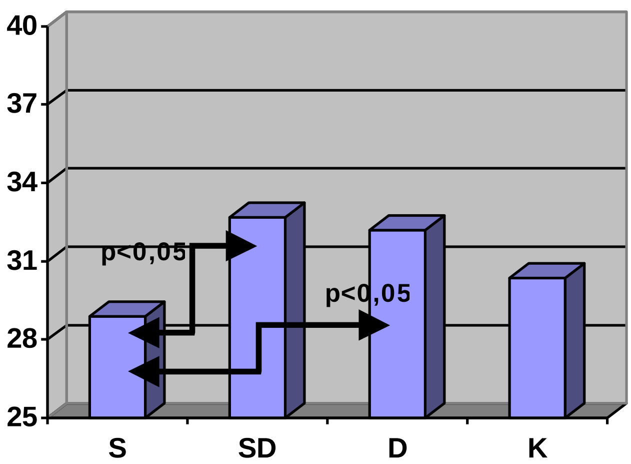

Fig. 3
Left ventricle systolic dimension (mm) in Disciplines categories; Differences noted between categories S-SD and S-D with P<0.05

Statistical differences in Discipline group were noticed in left ventricle systolic dimension (Fig. 3) for categories S, SD, D (28.9+/-3.12 mm vs 32.68+/-5.92 mm vs 32.20+/-5.15 mm vs 30.36+/-4.05 mm, respectively), in left ventricle mass (Fig. 4) for categories D and K(273.2+/-4.6 g vs 218.6+/-6.7 g) and in mean pulmonary artery pressure (Fig. 5) for categories S, SD, D and K (11.75+/-4.06

mmHg vs 11.08+/-4.77 mmHg vs 15.52+/-4.97 mmHg vs 17.43+/-4.38 mmHg, respectively). TTE examination of the Discipline group did not show another statistically important differences.

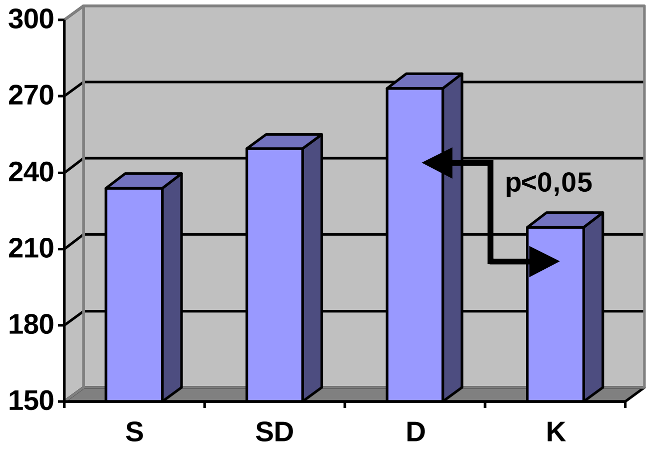

Fig. 4
Left ventricle mass (g); Differences with P<0.05 noted in categories D and K

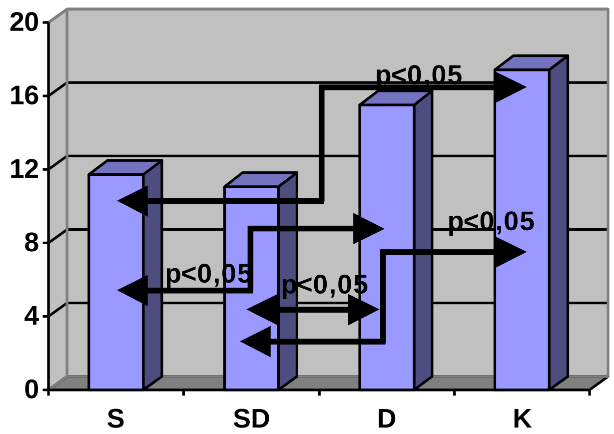

Fig. 5
Mean pulmonary artery pressure (mmHg); Statistical difference with P<0.05 noted in categories S, SD and control group as well as between groups S, SD and D

In ECG examination of the Results group we observed statistical differences in HR results (Fig. 6) in the case of categories I, II, K (61.32+/-10.23 $1 \cdot min^{-1}$ vs

60.13+/-9.53 1·min^{-1} vs 68.80+/-5.33 1·min^{-1}, respectively) and in R wave amplitude in lead V5 (Fig. 7) for categories I, II, K (19.05+/-7.08 mm vs 15.26+/-4.38 mm vs 15.03+/-4.85 mm, respectively). No other significant differences were observed in ECG examination of the Results group.

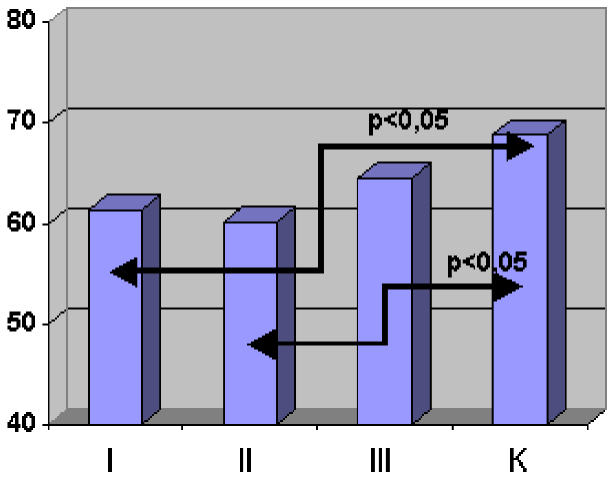

Fig. 6
Heart rate (1·s^{-1}) differences with P<0.05 noted in K and I, II categories of Results group

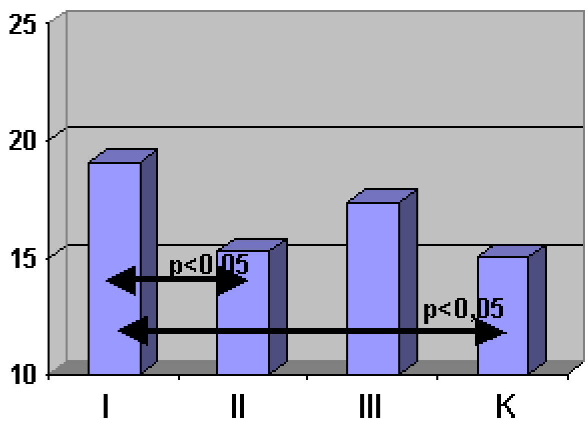

Fig. 7
R wave amplitude (mm) in lead V5;
The differences noted (P<0.05) between K and I categories and categories I-II

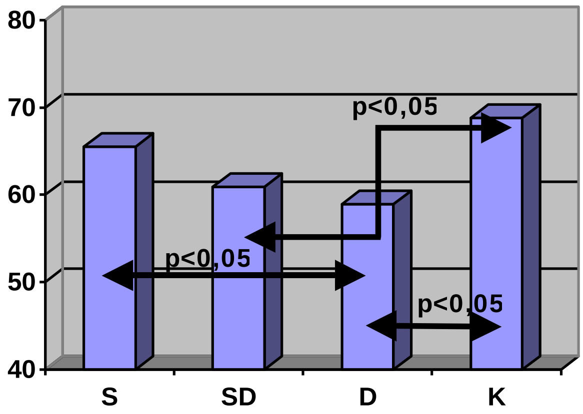

Fig. 8
Heart rate per minute ($1 \cdot s^{-1}$) in particular categories;
Differences (P<0.05) noticed in K and D, SD as well as between D and S

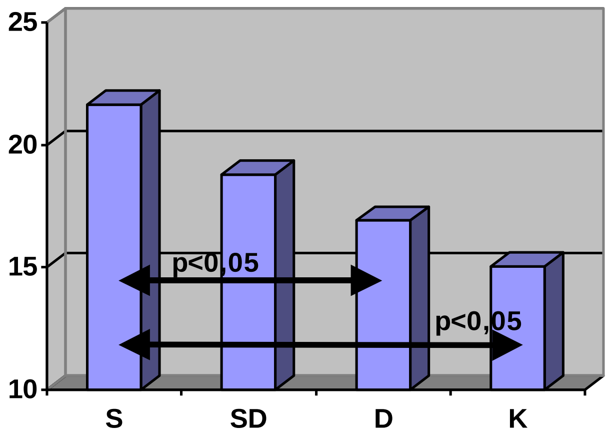

Fig. 9
R wave amplitude (mm) in V5 lead;
Important differences (P<0.05) noted in case of K and S, S and D categories

ECG examination of the Discipline group showed statistically important differences in HR results (Fig. 8) for categories S, SD, D, K (65.55+/-11.58 $1 \cdot min^{-1}$ vs 60.94+/-9.43 $1 \cdot min^{-1}$ vs 58.94+/-8.69 $1 \cdot min^{-1}$ vs 68.80+/-5.33 $1 \cdot min^{-1}$, respectively), in R wave amplitude in lead V5 (Fig. 9) for categories S, D, K (21.65+/-6.64 mm vs 16.91+/-8.08 mm vs 15.03+/-4.85 mm, respectively) and in R wave amplitude in lead V6 (Fig. 10) for categories S, SD, D, K (23.50+/-12.03 mm vs 15.19+/-4.48 mm vs 16.63+/-4.48 mm vs 15.30+/-4.04 mm, respectively). In ECG examination of the Discipline group there were no other significant differences.

We did not observed statistical differences in blood pressure parameters in Results and Discipline groups.

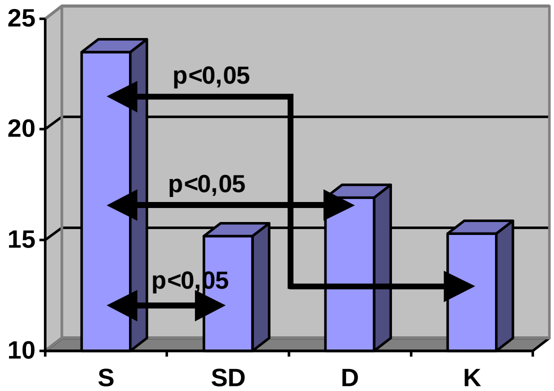

Fig. 10
R wave amplitude (mm) in V6 lead;
Important differences ($P<0.05$) noted in S and D, S and SD, K and S categories

Discussion

Authors of previously described studies noticed changes in heart muscle dimensions of professional sportsmen. Data suggest the symmetric hypertrophy of the heart muscle which regards its left and right part appears as a result of hemodynamic effort and the adaptation to the training [6]. Analyzing all the results one have to consider genetic conditions and a beginning of the training in youth [2,12]

Long term TTE observation in 1000 sportsmen and 800 control group showed the difference in heart muscle wall thickness of only 1.6 mm and in left ventricle dimensions of 5.3 mm. Differences after 52 months-lasting training were even smaller, respectively: 0.3 and 2.1 mm which gives border statistical significance [7].

Other researchers underline cyclic changes in cardiovascular system with the increase of the heart mass during training time and return to the initial values after the sport season [10]. Analyzing results of the performed studies one have to consider two overlapping cyclic changes of the heart muscle.

The first one, one-year lasting, consists of training time, competitions and rest. The second is related to long standing training and growing old of the sportsmen [5].

The present study describes competitors with approximately 10 years training experience. All of them were examined during competition time (high sport form) which is probably related to the biggest heart muscle and cardiovascular changes.

All examined groups were similar considering age, weight and training time. The competitors of the category D were higher than the rest of the examined people but statistical differences were noted only in the height of the sportsmen for categories S and D. It could influence the results of left ventricle mass assessment because in this group we noted the highest value of heart mass.

Effort which must be overcame by a heart during a training can be described as a volumetric one in the case of dynamic disciplines and a pressure one in the event of static disciplines.

Left ventricle systolic and diastolic volume exceeded normal value for respectively 20.08% and 21% but the changes were noted mainly for dynamic disciplines. Not very big differences of left ventricle dimensions gave in the results statistically important differences of left ventricle mass between D and K.

One should pay the particular attention on the decrease of LVSD in the case of static disciplines (not described by other authors) which influenced on the results of the ejection fraction and shortening fraction (without statistical significance but the highest in all categories).

Data suggest that the left ventricle remodeling depends on the kind of the sport effort. 10 years lasting static training changes left ventricle mass, its volume and wall thickness in much smaller manner than the dynamic one. Mixed kind of the training produces intermediate changes. Ejection fraction increases more under the influence of static sport disciplines.

Kinoshita et al. in their study analyzed 2000 competitors (from 15 to 34 years old) and found aorta dilatation in only 0.26% of cases, mainly in very tall sportsmen. In our study 37 mm of aortic diameter was noted in 5 cases. Diameter over 40mm concerned 4 sportsmen (3 judo, 1 marathon runner). Mean training experience time in this group was approximately 20 years. This data suggest that long-time, intensive training may cause aorta dilatation [4].

The analysis of selected electrocardiographic parameters showed not large ECG changes. One should pay its attention on the statistically important increase of the R wave amplitude in sportsmen of static effort group where, in the same time, the insignificant increase of left ventricle mass and interventricular septum thickness were found.

The case of static effort group proves that apart from morphological changes there are some functional changes of heart muscle which are seen as electric activity modification.

We noted the biggest left ventricle diastolic diameter in the group of European Champions (II), and the smallest one in World Champions (III). In the same time we have to remember these results were not significant (NS) different from the results of control group. The same relation was found for the left ventricle systolic diameter. Nevertheless shortening and ejection fraction results were the highest in the group III, though not significantly different in comparsion to the rest of achived parameters. In the same category we noticed an insignificantly bigger interventricular septum and posterior wall thickness which caused the significantly higher left ventricle mass but not importantly bigger aorta diameter.

Left atrium diameter in Discipline and Results was 2 mm bigger (NS) than the diameter in control group. Right ventricle size was comparable. Mean pulmonary artery pressure was insignificantly lower in all sportsmen groups in respect to the control cohort.

Heart rate was lower for all sportsmen categories in comparison to control group with statistical significance for Polish and Europe Champions categories. The highest R wave amplitude in lead V6 was noted in group I. It was significantly bigger than the amplitude in groups of European Champions and control. The rest of electrographic parameters and mean arterial pressure were not significantly different.

The picture of World Champion heart is not unequivocal. We noticed an insignificant tendency of ejection fraction increase, interventricular septum and posterior wall thickening which cause in significantly bigger left ventricle mass.

The analysis of the remaining parameters does not allow to distinguish sportsmen in relation to achieved results.

Comparing TTE and ECG parameters of examined sportsmen with results of control group one should remember that the latter was composed of Academy of Physical Education students. The sport fitness and potential cardiovascular changes in this group are undoubtedly bigger in comparison to general public. In the same time the group is much more homogenous and allows to find the differences between professional sportsmen and healthy people more precisely.

Conclusions

1. Static effort reduces left ventricle systolic diameter, increase shortening and ejection fraction. In the same time it reduces mean pulmonary artery pressure, causes the rise of the R wave amplitude in leads V5 and V6.
2. Dynamic effort increase left ventricle diastolic diameter and diminish its mass.
3. Both kinds of effort provoke heart rate decrease and rise of right ventricle diameter.
4. The mass and ejection fraction of World’s champion’s left ventricle is bigger in comparison with the rest of sportsmen.

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