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Comparison of the Cardiac Structure and Function of Elite Weightlifters and Swimmers

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Abstract

Introduction: Heart is the second major component in the cardiovascular system that is affected by training. The aim of this study was to compare the cardiac structure and function of three groups of swimmers, weightlifters and non-athletes.

Methods: The study was a causal comparative research. The statistical sample consisted of three groups of 10 including swimmers, weightlifters and non-athletes. Athletes were the elite swimming and weightlifting volunteers who participated voluntarily in this study. Inclusion criteria for athletes included a history of at least 5 years of regular exercise. After selecting the statistical samples, all participants took part in the echo-heart test in which they were given Color Doppler M-Mode echocardiography with coordination of an echocardiologist. For data analysis one way ANOVA and bonferroni test post hoc tests were used. The p-value was defined as $p \leq 0.05$.

Results: The results showed that LVIDs in the swimmers had a significant decrease ($p = 0.01$) compared to both weightlifters ($p = 0.03$) and non-athletes ($p = 0.02$). However, there was no significant difference between weightlifters and non-athletes ($p = 0.88$).The results also revealed a significant increase in interventricular septal end diastole (IVSd) in the weightlifters compared to the swimmers ($p = 0.02$) and non-athletes ($p = 0.02$). There was no significant difference between left ventricular internal diameter in diastole (LVIDd) ($p= 0.23$), left ventricular mass index (LVMI) (p = (0.70), left atrium dimensions (LAD) ($p = 0.06$), aortic root dimension (ARD) ($p= 0.96$), left ventricular posterior wall dimensions (LVPWD) ($p = 0.17$), heart rate (HR) ($p = 0.80$) and ejection fraction (EF) ($p = 0.66$) in the swimmers and weightlifters.

Conclusion: Different changes in the cardiac structure and function of the swimmers and weightlifters are considered as physiological adjustments, and not cardiomyopathy. On the other hand, despite the different effects of strength and endurance exercises on the structure of the heart muscle, it seems that the cardiac performance of the athletes in the two disciplines are the same.

Keywords: Heart, Swimmers, Weightlifters

Introduction

Nowadays, due to sedentary behavior and lack of physical activity, the percentage of cardiac diseases is increasing in today's societies (1) and the age of heart disease has decreased (2). One of these cardiac diseases is abnormal enlargement of the heart size that can be due to various cardiac problems. Of course, hypertrophy and increasing the thickness of the heart muscle can occur by exercise (1, 3). Henschen reported the initial finding of cardiac enlargement in athletes. He used the physical examination skills of auscultation and percussion to demonstrate increased cardiac dimensions in elite Nordic skiers (4, 5). Previous echocardiography studies have reported the finding of cardiac chambers enlargement in athletes (3, 6, 7). This enlargement of cardiac chambers, involving not only the ventricles but also the atrials (7).

Weiner *et al*. reported similar observations in a systematic review (5). Also, early chest radiography and 12-lead electrocardiographic work approved the physical examination results of Henschen (8). The application of 2-dimensional echocardiography leads to identify some aspects of exercise-induced cardiac remodeling (EICR), such as ventricular chamber enlargement, myocardial hypertrophy, and atrial dilation (7, 8). The hemodynamic changes are the primary stimulus for EICR. Hemodynamic conditions, especially changes in cardiac output and peripheral vascular resistance, vary widely across sporting disciplines (9). Heart remodeling is differently affected by types of exercise (10). Isotonic exercise includes activities such as long distance running, cycling, rowing, and swimming causes increase in cardiac output (11, 12). While isometric exercise such as weightlifting is characterized by increased peripheral vascular resistance and normal or only slightly elevated cardiac output (5, 11). Increase in peripheral vascular resistance causes systolic hypertension and left ventricle (LV) pressure challenge (5). Changes in cardiac structure and function are accompanied by various consequences. For example, ventricular hypertrophy can be physiologically or pathologically. Physiological changes lead to enhanced heart function, lack of fibrosis, increased angiogenesis and improved myocardial antioxidant capacity. On the other hand, pathological changes are associated with declines in cardiac output, increased apoptosis and fibrosis (13). Physiological changes of the heart are particularly important for healthy lifestyle. One of the main physiological changes of the heart is ejection fraction (EF). It is a traditional indicator of heart function that measures the amount of blood pumped out of the left ventricle (LV) (14). Reduced EF is associated with prior myocardial infarction (15). Also low EF can be regarded as an index for impaired hearts (14). The initial stretching of the cardiac myocytes prior to contraction can be defined as preload. It is related to muscle sarcomer length. Left ventricular internal diameter in diastole (LVIDd) is a indices of preload. Reduced filling and preload leads to a fall in cardiac output (16). Therefore, not only EF and LVIDd but also other functional and structural parameters of the heart such as left ventricular mass index(LVMI), left ventricular internal diameter in systole (LVIDs), interventricular septal end diastole (IVSd), left atrial dimensions (LAD), aortic root dimension (ARD), left ventricular posterior wall dimensions (LVPWD) and heart rate (HR) must be checked. Based on Morganroth theory, this study aimed to investigate the differences between cardiac function and structure of elite swimmers and weightlifters.

Methods

The present study was a causal comparative that investigated the cardiac structure and function of elite weightlifters, swimmers and non-athletes. The study protocols and procedures had previously been approved by the Research Ethics Committee of Islamic Azad University, Omidiyeh Branch (IAUOB). Written informed consent was obtained from each subject at the beginning of the study. The detailed information about the study was given to the volunteers during the first meeting. The statistical sample consisted of three groups of 10 including swimmers, weightlifters and non-athletes. Athletes were the elite swimming and weightlifting volunteers who participated voluntarily in this study.The selection was based on determined inclusion/exclusion criteria for this research. The inclusion criteria were: (1) participation consent (2) age range 25 to 35 (3) a history of at least 5 years of professional training. Exclusion criteria included (1) ages below 25 or above 35yrs (2) a history of below 5yrs of professional training (3) any cardiomyopathy disease. Training groups were all elite national level athletes Khouzestan province in both swimming and weightlifting. After sampling and consultation with a cardiologist, the groups were called for echocardiography. For this purpose, echocardiography Eco Color Doppler M-Mode with coordination of an echocardiologist was used to measure the dimensions. All exams were performed by the same cardiologist. Statistical analysis of data was carried out through SPSS, version 19. Significance level was defined as $p \leq 0.05$. Data normality was done by Kolmogorov- Smirnov test. Differences between groups were assessed by one-way analysis of variance (ANOVA) and post-hoc multiple comparisons were performed using the Bonferroni test. Pearson correlation was used to describe the linear relationship between continuous variables such as: height, weight, age, body mass index (BMI), left ventricular mass index (LVMI), left ventricular internal diameter in systole (LVIDs), left ventricular internal diameter in diastole (LVIDd), interventricular septal end diastole (IVSd), left atrial dimensions (LAD), aortic root dimension (ARD), left ventricular posterior wall dimensions (LVPWD), heart rate (HR), ejection fraction (EF). LVMI was calculated using the modified Devereux formula (17). All variables were adjusted to the participants' age, weight, height and BMI.

$$LVMI= 0.8[1.04(IVS + PWD + LVDd)^3 - LVDd^3] + 0.6$$

Results

Table 1 and 2 show descriptive data regarding some of the anthropometric and physiological characteristics of the subjects. Also, these tables show one way ANOVA and Bonferroni post-hoc results of independent variables in swimmers, weightlifters and non-athletes groups. Table 3 presents data related to one way ANOVA result of variables in swimmers, weightlifters and non-athletes groups. Bonferroni post-hoc test results in Table 4 showed that swimmers had less LVIDs compared to both weightlifters ($p= 0.03$) and non-athletes ($p= 0.02$), while LVIDd significantly increased in swimmers compared to non-athletes ($p= 0.03$). The results also showed that weightlifters presented higher IVSD compared to both swimmers ($p = 0.02$) and non-athlete ($p= 0.02$) groups. No significant differences were observed bwtween weightlifters and swimmers on LAD, ARD, LVPWD, HR and EF.

Table 1. One way ANOVA result of anthropometric and physiological characteristics

variables	Groups	Number	M±SD	Sig
Age (Yr)	Swimmers	10	32±5.92	0.79
	weightlifters	10	30.50±4.19	
	Non-Athletes	10	32.10±7.04	
Height (Cm)	Swimmers	10	179.70±5.51	0.34
	weightlifters	10	178± 6.21	
	Non-Athletes	10	176.10±4.20	
Weight (Kg)	Swimmers	10	79±1.12	0.01 *
	weightlifters	10	90.90±8.72	
	Non-Athletes	10	83.50±5.03	
BMI (Kg/m^2)	Swimmers	10	24.40±2.46	0.01*
	weightlifters	10	28.72±2.85	
	Non-Athletes	10	26.90±0.87	

M±SD: mean±standard deviation, BMI: body mass index, *Significant changes

Table 2. Bonferroni post-hoc result of anthropometric and physiological characteristics

Variables	Bonferroni post-hoc			
	Groups	**Groups**	**Mean differences**	**Sig**
Weight (Kg)	weightlifters	Swimmers	11.900	0.04*
BMI (Kg/m^2)	weightlifters	Swimmers	4.322	0.01*
		Non-Athletes	1.813	0.008*
	Non-Athletes	Swimmers	2.508	0.01*

M±SD: mean±standard deviation, *Significant changes.

Table 3. One way ANOVA result of variables in swimmers, weightlifters and non-athletes groups

Variables	Groups	Number	M±SD	Sig
LVIDs (cm)	weightlifters	10	3.02±0.92	0.01 *
	swimmers	10	2.43±0.33	
	Non-Athletes	10	3.22±0.27	
LVIDd (cm)	weightlifters	10	4.73±0.51	0.03*
	swimmers	10	5.21± 0.16	
	Non-Athletes	10	4.54±0.52	
IVSd (cm)	weightlifters	10	1.22±0.18	0.01 *
	swimmers	10	1.08±0.01	
	Non-Athletes	10	1.09±0.05	
LVMI (g/m^2)	weightlifters	10	178.67±40.38	0.91
	swimmers	10	172.83±20.00	
	Non-Athletes	10	171.82±30.67	
LAD (cm)	weightlifters	10	3.22±0.23	0.01 *
	swimmers	10	3.41±0.24	
	Non-Athletes	10	3.06±0.15	
ARD (cm)	weightlifters	10	2.93±0.30	0.01 *
	swimmers	10	2.96±0.22	
	Non-Athletes	10	2.57±0.21	
LVPWD (cm)	weightlifters	10	0.84±0.92	0.01 *
	swimmers	10	0.70±0.14	
	Non-Athletes	10	1.02±0.07	
HR (bpm)	weightlifters	10	69.30±9.01	0.02 *
	swimmers	10	67.10±1.66	
	Non-Athletes	10	74.00±4.00	
EF (%)	weightlifters	10	57.00±2.58	0.01 *
	swimmers	10	56.50±2.41	
	Non-Athletes	10	53.50±2.41	

M±SD: mean±standard deviation, LVIDs: left ventricular internal diameter in systole, LVIDd: between left ventricular internal diameter in diastole, IVSd: interventricular septal end diastole, LVMI: left ventricular mass index, LAD: left atrial dimensions, ARD: left ventricular posterior wall dimensions, LVPWD: left ventricular posterior wall dimensions, HR: heart rate, EF: ejection fraction, * significant changes.

Table 4. Bonferroni post-hoc result of variables in swimmers, weightlifters and non-athletes groups

Variables	Bonferroni post-hoc			
	Groups	Groups	Mean differences	Sig
LVIDs (cm)	weightlifters	Swimmers	0.933	0.03*
	Non-Athletes	Swimmers	0.860	0.02*
LVIDd (cm)	Non-Athletes	Swimmers	0.656	0.03*
IVSd (cm)	weightlifters	Swimmers	0.204	0.02*
		Non-Athletes	0.158	0.02*
LAD (cm)	Non-Athletes	Swimmers	0.396	0.01*
ARD (cm)	weightlifters	Non-Athletes	0.337	0.01*
	Non-Athletes	Swimmers	0.330	0.01*
LVPWD (cm)	weightlifters	Non-Athletes	0.193	0.01*
	Non-Athletes	Swimmers	0.291	0.01*
HR (bpm)	weightlifters	Non-Athletes	7.11	0.01*
	Non-Athletes	Swimmers	6.26	0.04*
EF (%)	weightlifters	Non-Athletes	6.35	0.01*
	Non-Athletes	Swimmers	3.55	0.008*

M±SD: mean±standard deviation, *Significant changes.

Discussion

In this study, the cardiac structure and function of three groups, namely, swimmers, weightlifters and non-athletes were investigated by an echocardiologist using Doppler echocardiography. The results showed that there was a significant difference between LVIDs in the three groups, so that the swimmers group had a lower volume than the other two groups. On the other hand, based on the results, it was indicated that the LVIDd in the swimers group showed a significant increase compared to the non-athlete group and a nonsignificant increase compared to the weightlifting group. It seems that this increase in the LVIDd and the decrease in LVIDs is due to the preload in left ventricle (18). Csajagi *et al.* showed remarkable LV morphological adaptation in the swimmers (19). Type of exercise is an important factor that affects the structur or function of the heart (10, 20). Swimming as an aerobic and isotonic exercise causes increase in cardiac output (11, 12). While weightlifting as an isometric exercise is characterized by increased peripheral vascular resistance (5, 11). It seems that preload feature due to swimming exercise compared to afterload feature due to weightlifting exercise, is an important factor in LVIDd size. The results revealed that the IVSd in the weightlifting group is more in diameter than the other two groups. However, there is no significant difference between the LVPWD of the swimmers and the weightlifters. Aerobic exercise, according to Franck Starling's law, causes a volume load on the heart that results in an increase in the heart cavity, in particular the left ventricle, resulting in an increase in the relative dimensions of the walls of the heart (7). Lee *et al* showed that long term aerobic exercise leads to increase in LVIDd, LVIDs and IVSd (21). Also, Szauder *et al.* with comparison of LV mechanics in runners (endurance) versus bodybuilders (power) showed higher different pattern of LV mechanics in runners versus bodybuilders (22). It seems that the type of exercise is the most important factor in these differences. Adaptations related to the size and structure of the heart are also affected by Laplace's law that the wall tension is proportional to the pressure and radius of deviation. Non-athletes, in weight-lifting individuals, whose nature of their training is anaerobic, the ventricular afterload increases. With increasing afterload, the internal ventricular pressure increases, which leads to increased wall tension and thus increased dimensions (18, 23, 24). Therefore, both preload and afterload have the same effect on the LVPWD. However, the lower LVPWD in the swimmers group suggests that ventricular preload cannot lead to structural changes in the LVPWD as much as afterload. The reason for this is that the preload is usually expressed as the LVIDd, not the radius. Thus, an increase of 100 % in the ventricular volume, will increase the wall tension by only 26 %. While a 100 % increase in left interventricular pressure induced by afterload can increase the wall tension by 100 % (25). This increase in internal pressure has increased the IVSd of the weightlifting group compared to the other two groups. The results showed that the LAD in the swimmers group had a greater increase compared to the non-athletic and weightlifting groups. Many previous studies have reported the growth of the left atrium after training (26, 27). Pelliccia *et al*., studying 1777 athletes, showed that left atrium increased in 20% of athletes (28). D'Andrea *et al* also reported enlargement of the left atrium in their study (29). It seems that the preload caused by swimming exercise has more effects on the LAD than the afterload caused by weightlifting exercise. Therefore, it can be stated that the left ventricle and left atrium internal dimensions are affected in the same way by aerobic training. The results showed that there was no significant difference between the LVMI, ARD, HR and EF of the two groups of swimmers and weightlifters. These results are harmonious with findings obtained by Szauder *et al.* (22). However, there was a significant difference between the two groups of exercise and the non-athlete group. Also, cardiac structural and functional changes of experimental groups are in harmony with Weiner *et al.* findings (5).

Conclusion

Cardiac structural and functional changes in swimmers and weightlifters are considered as physiological adaptations and differ from cardiomyopathy changes. Nevertheless, although both aerobic and anaerobic exercises, depending on the type of cardiac contraction, can somewhat lead to different structural and functional changes in the athlete's heart, it appears that at the professional level, there is no significant difference between the EF of aerobic (swimmers) and anaerobic (weightlifters) exercises to show the superiority of cardiac muscle strength in either of these groups.

Ethical issues

The study protocols and procedures had previously been approved by the Research Ethics Committee of Omidiyeh Branch, IAU. All participants signed a written informed consent regarding participation in the research project.

Authors' contributions

All authors contributed equally to the writing and revision of this paper.

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