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ARTICLE

Ventricular Remodeling Parameters in Mixed-Sport University Athletes Compared with Non-Athletes

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ABSTRACT

Background: The term "athlete's heart" (AH) refers to the morphologic and functional cardiac adaptations. When compared to non-athletic people, these symptoms may include an increase in the sizes of the left and right cardiac chambers, an increase in the thickness of the left ventricular (LV) wall, and an increase in the indices of resting and exercise systolic and diastolic function.
Objective: This research sought to compare the echocardiographic parameters of the left ventricle of a group of university students who participate in sports to another group that does not.
Methods: The study was conducted as a comparative-analytic study in Mosul City/Iraq, from November 2024 to May 2025. Involved a total of 160 participants within the age range of 18 to 25 years old. The participants were divided into two categories: (80 athletic and 80 non-athletic groups), each group contains (50 males and 30 females). Echocardiographic examination was done to measure the dimensions, systolic and diastolic functions of the left ventricle.
Results: The athletic group showed significantly enhanced diastolic function compared with the non-athletic group. This advantage was reflected by higher E/A ratio (1.75 ± 0.44 vs. 1.53 ± 0.21, p = 0.000), increased septal e′ velocity (16.74 ± 2.77 cm/s vs. 15.26 ± 2.65 cm/s, p = 0.001), and higher lateral e′ velocity (18.79 ± 2.96 cm/s vs. 16.10 ± 2.03 cm/s, p = 0.000). Additionally, athletes exhibited a significantly lower E/e′ ratio (4.24 ± 1.42 vs. 5.40 ± 0.94, p = 0.000), indicating more efficient ventricular filling. A structural difference was also observed in interventricular septal thickness (IVS), which was higher among athletes (0.94 ± 0.16 cm) compared with non-athletes (0.86 ± 0.14 cm; p = 0.003).
Conversely, no significant differences were detected in left ventricular size or systolic performance. The left ventricular end-diastolic diameter (LVED) showed comparable measurements between athletes and controls (4.91 ± 0.64 cm vs. 4.82 ± 0.62 cm, p = 0.365), and the left ventricular end-systolic diameter (LVES) demonstrated similar values (2.97 ± 0.50 cm vs. 2.96 ± 0.48 cm, p = 0.972). Likewise, left ventricular ejection fraction (LVEF%) did not differ significantly between groups (0.68 ± 0.06 vs. 0.70 ± 0.06, p = 0.159).
Conclusion: Athletic training had no significant effect on LV dimensions or systolic performance, despite the existence of increased IVS thickness in athletes. In contrast, diastolic function indicators were significantly higher in the athletic group, indicating greater cardiac relaxation. These findings support the hypothesis that young athletes have physiological rather than pathological cardiac remodeling.

Introduction

Numerous studies have attempted to measure the extent of left ventricle (LV) remodeling and adaptation in athletes and investigate the relationship between these alterations and the particular kind of exercise stimulus. The creation of the Morangroth hypothesis over 45 years ago was one of the first and most important contributions to this field which suggested

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that although resistance-trained athletes mostly show concentric LV hypertrophy, endurance-trained athletes mostly generate eccentric LV hypertrophy [1].

Eccentric hypertrophy is distinguished by increased LV mass and left ventricle end-diastolic volume (LVEDV) and normal left ventricular wall thickness (LVWT), whereas concentric left ventricle hypertrophy is defined by increased LVWT and mass but normal LVEDV [2].

Reviews of LV geometry in these athletes yield varying results: some studies describe normal geometry, others concentric hypertrophy, and a fraction eccentric hypertrophy. This variation may be due to variances in resistance training methods, such as powerlifting vs bodybuilding [3].

Functional adaptations also occur, with endurance athletes showing drops in resting Ejection Fraction as low as 12%, which is slightly below normal. The lower ejection fraction is most likely owing to the higher LVEDV, which reduces the contractile effort required to maintain an adequate resting systolic volume. [3] [4].

Notably, Caselli et al. found that Left ventricular ejection fraction (LVEF) remained within the normal range among 1,145 Olympic athletes, with the lowest observed value of 53%. Furthermore, 5.5% of the athletes had Left Ventricular End-Diastolic Diameter (LVEDd) larger than 60 mm, whereas just 2.6% had myocardial thickness of 13 mm or more. [5] Diastolic function of the LV is normal, with a prominent increase in early filling velocity at rest (E/A > 2) [6].

According to studies, at least three hours of exercise each week for at least three months may be sufficient to generate some initial morpho-functional modifications in the heart [7].

Our understanding of the cardiac adaptation has significantly improved as a result of the introduction and quick adoption of two-dimensional echocardiography, which has been the subject of several echocardiographic studies involving thousands of athletes [8].

In Iraq, there is insufficient data regarding the evaluation of athletes' heart or left ventricular adaptations.

Aim of the study: to evaluate and compare echocardiographic parameters of the left ventricle in university students who regularly engage in sports activities and those who do not.

Methods

A comparative-Analytic study was conducted in Mosul City, Iraq, between November 2024 and May 2025. The study was approved by Ethics Committee of the College of Medicine, University of Mosul. The study was conducted at the scientific laboratory of the Department of Physiology at the College of Medicine, University of Mosul. Before participation, the students were fully informed about the study's objectives and methodologies, and their informed consent was obtained.

A total of 160 students were enrolled in this study, and they were classified into two groups (athletic and non-athletic groups):80 athletic students (50 males, 30 females) who regularly engaging in sports activities and 80 non-athletic students (50 males, 30 females) who were not regularly engaging in sports.

Inclusion criteria comprised students aged 18 to 25 years who were apparently healthy and classified into two groups: athletic students engaged in mixed endurance- and strength-based sports for at least 3 hours per week over a minimum of 1 year, and non-athletic students with a sedentary lifestyle who did not participate in any regular sportive activities. However, exclusion criteria included: Smoking, pregnancy, lactation, congenital heart diseases, recent surgery and chronic disorders (e.g., diabetic, hypertension, chronic asthma, ischemic heart disease).

Data were collected through face-to-face interviews with the students. Anthropometric measurements were also obtained include calculations of body mass index (BMI) defined as weight in kilograms divided by the square height in meters [9].

Echocardiography was performed by a specialist in internal medicine at the scientific laboratory of the Medical Physiology department at the College of Medicine using (VINNO A5 portable device, with phased array cardiac probe the frequency is from 2.8 MHz to 5 MHz). All participants were examined in the left lateral decubitus position, to bring the heart forward to the chest wall and lateral to the sternum, as recommended by the American society of echocardiography with dimmed light room [10].After applying gel to the transducer to offer acoustic coupling between the transducer and the skin. Parasternal long axis view (PLAX) and Apical 4 and 5 chambers view (A4C and A5C) were obtained. Linear internal measurements of the LV were calculated in the PLAX view (using M-mode and 2D echocardiography) which included LVEDd and Left Ventricular End-Systolic Diameter (LVIDs). The interventricular septum (IVS) thickness was also taken. All measurements were taken in systole and diastole. The obtained parameters were used to calculate Ejection Fraction using the following formula: LVEF= ((LVEDV-LVESV)/LVEDV) *100% [11].

Using Pulse wave Doppler, the following parameters were recorded:
The peak E wave velocity (m/sec), the peak A wave velocity (m/sec), the E/A ratio, then by using Tissue Doppler Imaging TDI the early diastolic annular velocity (é) (lateral, septal and average) and was recorded after that, the value of E/é lateral was calculated and this ratio correlates to LV end diastolic pressure.

Statistical Analysis:
All data were analyzed using IBM-SPSS 26. The t-test for independent two means was used to compare the differences among the two studied groups.
The p-value ≤ 0.05 considered as significant.

Results

Comparison between the studied groups according to age and anthropometric characteristics was demonstrated in table 1 which revealed that the mean age among the athletic group (22.13±1.93 years) was older that among the non-athletic group (20.50±1.63 years) with a statistically significant difference (p=0.000).
The height, weight, and BMI showed no significant statistical differences.

Table 1: Demographic of the studied groups

	Studied groups		p-value*	95% CI
	Athletic group	Non-Athletic group		
	Mean± SD	Mean± SD		
Age (years)	22.13±1.93	20.50±1.63	0.000	1.078, 2.196
Height (cm)	168.71±10.14	170.26±8.98	0.308	-4.540, 1.440
Weight (kg)	66.43±11.88	69.31±14.09	0.165	-6.944, 1.194
BMI (kg/cm^2)	23.22±2.62	23.80±3.90	0.266	-1.623, 0.451

***t-test for independent two means**

Table 2 shows comparison between the dimensions and systolic characteristics between the studied groups, significant statistical differences were found regarding the IVS among the athletic group this parameter was higher in compared to non-athletic; it was equal to 0.94±0.16cm. Meanwhile, LVED, LVES, LVEF% showed no significant statistical differences.

Table 2: Dimensions and systolic characteristics

	Studied groups		p-value*	95% CI
	Athletic Group	Non-Athletic group		
	Mean± SD	Mean± SD		
LVED (cm)	4.91±0.64	4.82±0.62	0.365	-0.106, 0.286
LVES (cm)	2.97±0.50	2.96±0.48	0.972	-0.149, 0.155
IVS (cm)	0.94±0.16	0.86±0.14	0.003	0.025, 0.121
LVEF%	0.68±0.06	0.70 ±0.06	0.159	-0.032, 0.005

***t-test for independent two means**

Comparison between the studied groups according to diastolic function characteristics was demonstrated in table 3, there was statisticaly significant difference between the e/a (1.75±0.44), Septal e (16.74±2.77 cm/s), lateral e (18.79±2.96 cm/s), and e/e'(4.24±1.42) among the athletic group and e/a (1.53±0.21), Septal e (15.26±2.65 cm/s), lateral e (16.10±2.03 cm/s), and e/e'(5.40±0.94) among the non-athletic groups. Concerning the ev, difference between the two studied group was statistically not significant (p=0.951).

Table 3: Diastolic function characteristics.

	Studied groups		p-value*	95% CI
	Athletic Group	Non-Athletic group		
	Mean± SD	Mean± SD		
Ev (cm/s)	84.46±14.22	84.34±10.73	0.951	-3.812, 4.057
e/a	1.75±0.44	1.53±0.21	0.000	0.115, 0.330
Septal e (cm/s)	16.74±2.77	15.26±2.65	0.001	0.636, 2.328
Lateral e (cm/s)	18.79±2.96	16.10±2.03	0.000	1.895, 3.479
e/e'	4.24±1.42	5.40±0.94	0.000	-1.530, -0.776

***t-test for independent two means**

In relation to sex, athletic males (22.14±1.84 years) were older than non- athletic group (20.92±1.66 years) in a statistically significant way (p=0.001). Similar significant difference was found regarding the mean age in females (p=0.000). The height of females among the athletic group was significantly lower than that among the female in non-athletic group (p=0.027), as shown in table 4.

Table 4: Anthropometric characteristics in relation to sex.

	Sex	Studied groups		p-value*	95% CI
		Athletic Group	Non-Athletic group		
		Mean± SD	Mean± SD		
Age (years)	Males	22.14±1.84	20.92±1.66	0.001	0.523, 1.916
	Females	22.13±2.11	19.80±1.32	0.000	1.422, 3.244
Height (cm)	Males	174.98±6.32	175.42±6.07	0.723	-2.900, 2.020
	Females	158.26±5.64	161.66±5.93	0.027	-6.389, -0.410
Weight (kg)	Males	71.52±11.14	74.80±12.63	0.172	-8.005, 1.445
	Females	57.96±7.51	60.16±11.52	0.384	-7.224, 2.824
BMI(kg/cm^2)	Males	23.30±2.91	24.30±3.87	0.146	-2.364, 0.356
	Females	23.08±2.08	22.97±3.87	0.891	-1.494, 1.715

***t-test for independent two means**

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According to echocardiographic characteristics in relation to sex was demonstrated in table 5 which revealed significant higher level of IVS and e/a ratio in both males and females among the athletic group in comparing to non-athletic group. Regarding the septal e, lateral e, only males showed higher mean level and e/e' showed lower level among the athletic group in compared to non-athletic group. Meanwhile, only the female among the athletic group showed significant lower mean level of LVEF% in compared to non-athletic group (p=0.013).

Table 5: Echocardiographic characteristics in relation to sex.

	Sex	Studied groups		p-value*	95% CI
		AthleticGroup	Non-Athletic group		
		Mean± SD	Mean± SD		
LVED (cm)	Males	4.92±0.52	4.83±0.63	0.478	-0.147, 0.312
	Females	4.90±0.81	4.79±0.60	0.577	-0.265, 0.472
LVES (cm)	Males	2.95±0.38	3.00±0.48	0.555	-0.224, 0.121
	Females	2.99±0.65	2.90±0.48	0.529	-0.201, 0.388
IVS (cm)	Males	0.98±0.15	0.92±0.15	0.047	0.001, 0.119
	Females	0.87±0.16	0.77±0.07	0.003	0.033, 0.159
LVEF%	Males	0.69±0.06	0.69±0.06	0.871	-0.022, 0.026
	Females	0.67±0.06	0.71±0.06	0.013	-0.071, -0.008
Ev (Cm/S)	Males	81.22±14.96	83.77±11.22	0.338	-7.790, 2.702
	Females	89.86±11.18	85.30±9.98	0.100	-0.909, 10.043
e/a ratio	Males	1.81±0.51	1.56±0.22	0.002	0.093, 0.405
	Females	1.65±0.25	1.48±0.19	0.003	0.062, 0.295
Septal e (Cm/S)	Males	16.69±3.03	14.89±2.67	0.002	0.663, 2.928
	Females	16.83±2.33	15.87±2.54	0.132	-0.299, 2.219
Lateral e (Cm/S)	Males	19.85±2.64	15.90±1.89	0.000	3.038, 4.861
	Females	17.02±2.63	16.44±2.23	0.358	0.676, 1.842
e/e'	Males	3.60±1.33	5.47±1.02	0.000	-2.344, -1.402
	Females	5.32±0.78	5.28±0.80	0.819	-0.359, 0.453

***t-test for independent two means**

Discussion

Over the past 35 years, a number of cross-sectional echocardiographic (or cardiac magnetic resonance) investigations, often conducted in highly trained people, have characterized cardiac dimensions modifications related with sports training [12]. Regular physical exercise promotes heart health. Exercise is strongly associated with a reduced risk of cardiovascular disease and mortality [13]. In the present study found no significant difference in BMI between students who were athletic and those who were not. Although the athletic group showed a slightly lower mean BMI compared to their non-athletic counterparts, both groups were within the normal BMI range indicating that BMI is not a sufficient indicator of how physical activity affects body conformation. In "Correlation between body mass index and body composition in elite athletes," when evaluating obesity in athletes and young people, % fat may be a better predictor than BMI, although it is still used to evaluate obesity in young adults, despite its potential disadvantages[14]. Regarding the left ventricular adaptation according to Utomi *et al.*, LV enlargement in young adults is commonly subtle and greatly influenced by the type and level of training.[15] Echocardiography often shows minor increases in LV dimensions, such as LVED and LVES volumes, primarily in endurance and mixed-sport athletes. According to study by Baggish et al., these alterations are considered normal physiological remodeling rather than pathogenic abnormalities and may be reversed by detraining.[16] In the current study athletic students also had LVED and LVES values that were within normal physiological ranges and did not differ significantly from those of students who weren't engaged in sports. Also, there is a statistically significant increase in IVS thickness in athletes compared to non-athletic group. These results are in agreement with previous researches showing that regular exercise can cause mild septal hypertrophy that stays within the normal range, supporting the idea of the "athlete's heart"[17] The LVEF% is a crucial indicator of the heart's systolic function. Athletes' LVEF usually stays within normal physiological parameters even when they exhibit structural alterations like concentric or eccentric remodeling. According to Johnson *et al*., male athletes show retained LVEF despite considerable LV remodeling, indicating that systolic performance is maintained as part of physiological cardiac adaptation.

There was no statistically significant difference between the groups in this study, indicating that mixed sports do not negatively impact young adults' systolic function. These data support the interpretation of these changes as physiological rather than pathological, as they are consistent with previous research indicating maintained LVEF in physically active populations.[15][18] Diastolic function is a crucial factor in assessing total cardiac performance and is best assessed non-invasively using Doppler echocardiography, according to recommendations from the American Society of Echocardiography and the European Association of Cardiovascular Imaging[19]. In the current study, there was no significant difference in mitral E velocity between athletes and non-athletes, indicating that early diastolic filling was maintained in both groups. However, the E/A ratio was significantly higher in these athletes, which is in line with improved ventricular relaxation. The athletes' considerably greater septal and lateral early diastolic velocities (e′) further supported the athletic group's enhanced diastolic performance. Athletes also exhibited far lower E/e′ ratios, a recognized measure of LV filling pressure, which suggests lower diastolic pressures and more efficient ventricular filling. These findings align with studies based on guidelines that suggest physiological cardiac remodeling in athletes is often characterized by retained or increased diastolic parameters rather than pathological dysfunction[19][20][21] Both common and sex-specific patterns of echocardiographic adaptations in athletes were observed in the current study. Both male and female athletes showed increased IVS and elevated E/A ratios but male athletes showed better diastolic function and greater filling capacity, as evidenced by their higher septal and lateral e′ velocities and lower E/e′ ratios. Higher absolute cardiac output and training volume, as well as the action of testosterone, which boosts myocardial hypertrophy and chamber enlargement, are probably responsible for these adaptations[22][23] Conversely, LVEF% of female athletes was marginally lower than that of female non-athletes. Their slightly lower ventricular chamber size and sex-specific remodeling processes may be the reason of this. Although estrogen exerts cardioprotective effects through microvascular and metabolic pathways, it does not drive myocardial hypertrophy to the same extent as testosterone, which results in decreased volumetric adaptations in females [23][24].

Conclusions

The research indicates that cardiac modifications in young athletes reflect a physiological remodeling process, characterized by preserved global systolic function LVEF% and normal LV dimensions. Mild increases in IVS remain within normal physiological limits, while the most notable changes are observed in diastolic function, indicating enhanced ventricular relaxation and filling. These adaptations show gender-specific variations, emphasizing the importance of using sex-specific reference ranges in clinical evaluation. Two-dimensional and Doppler echocardiography remains essential non-invasive tools for determining these modifications and differentiating them from early manifestations of pathological conditions.

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Conflict of Interest

Regarding this manuscript's publication, the authors declare that they have no conflicts of interest.

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