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# Cardiac Function and Morphological Adaptations in Endurance and Resistance Athletes: Evaluation using a new Method

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***Abstract*****—**Background: Tissue Doppler Echocardiography (TDE) assesses diastolic function more accurately than routine pulse Doppler echo. Assessment of the effects of dynamic and static exercises on the heart by using TDE can provides new information about the athlete's heart syndrome. Methods: This study was conducted on 20 elite wrestlers, 14 endurance runners at national level and 21 non-athletes as the control group. Participants underwent two-dimensional echocardiography, standard Doppler and TDE. Results: Wrestlers had the highest left ventricular mass index, end-diastolic inter-ventricular septum thickness and left ventricular Posterior wall thickness. Runners had the highest Left ventricular end-diastolic volume, LV ejection fraction, stroke volume and cardiac output. In TDE, the early diastolic velocity of mitral annulus to the late diastolic velocity ratio in athletic groups was greater than the controls with no significant difference. Conclusion: In spite of cardiac morphological changes in athletes, TDE shows that cardiac diastolic function won't be adversely affected.

***Keywords*****—**Tissue Doppler Echocardiography, Diastolic function, Athlete's heart syndrome, Static exercise, Dynamic exercise

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## I. Introduction

LONG-TERM exercise training can lead to morphological and functional changes in the heart, which is commonly known as the athlete's heart syndrome [1]. These adaptive changes help athletes to have better function in their specific sports [2]. Among variables such as age, sex, race, body surface area, weight and height, which are related to cardiac morphological and functional changes, the type of exercise is of great importance and has positive relation to left ventricular cavity dimensions. Although adaptive cardiac structural changes of each specific sport are not determined yet, exercises are generally divided into two broad categories: static (isometric) and dynamic (isotonic) [2]. Each of them has its own structural and functional changes on the heart.

In dynamic exercises, the heart is confronted with volume overload; on the other hand, pressure overload affects the heart in static sports [3]. Running for long distances is a typical example of dynamic exercise and power-lifting, body building and wrestling are examples of static ones. However, it should be noted that exercise training has rarely pure dynamic or static characteristics and in this regard most of sports overlap with each other. For example, cycling and rowing have both dynamic and static parts [3].

It has been shown that some changes can lead to cardiac dysfunction in the general population. Increased end-diastolic left ventricular dimensions, left ventricular hypertrophy or increased left ventricular muscle mass following systemic hypertension, coronary artery disease or other primary myocardial disorders can cause sudden cardiac death or diastolic dysfunction [4, 5].

These cardiac changes occur in athletes too, but the question is whether there is any diastolic dysfunction in this population group. Diastolic function can be assessed by echocardiography, but routine echocardiographic procedures have some limitations in the assessment of cardiac diastolic function because flow velocity through mitral valve, which is the most important variable in this evaluation, is dependent on the left ventricular relaxation rate and left atrial pressure [6]. Tissue Doppler Echocardiography (TDE) is known as a non-invasive procedure for assessment of diastolic function and it is a useful method for assessment of left ventricular diastolic dysfunction [7]. This technique is similar to the Doppler ultrasound in the assessment of blood flow, but focuses on slow movements of the myocardium. Nowadays, this method is used for evaluating the left ventricular response to exercise and differentiating between physiological and pathological hypertrophies with emphasis on the contraction and relaxation velocities of myocardium as functional ventricular indices [8]. Because TDE has not the limitations of the conventional Doppler echocardiography, its results are more precise and reliable than other methods. In addition, it can detect diastolic dysfunction even before conventional Doppler echocardiography.

Previous studies used the conventional echocardiography for evaluation of diastolic function in athletes [9, 10]. According to the fact that TDE is more precise than the conventional echocardiographic procedures and it can detect changes in cardiac functions even before conventional methods [11], we used TDE for the assessment of the effects of running (5000 and 10000 m) as a dynamic exercise and wrestling as a static one on cardiac structure and function. Conventional echocardiography and exercise test also were done to prove the related changes of the heart in our athletes.

## II. Materials And Methods

This cross-sectional study was performed on two groups of national level wrestlers and runners and a group of non-athletes as control group in Tehran, Iran.

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### *A. Sample Selection*

National level wrestlers and runners were selected as athletes with high static and dynamic components sports, respectively. To become sure that the participants were elite athletes, conventional echocardiography was performed. Professional Iranian national level athletes (20 wrestlers and 14 endurance runners) with past record of at least 3 years exercise training were selected. Just before study, all of them were in a training camp for two months with 3 hours training sessions 4 days a week. Control group comprised 21 non-athletes which were age matched with athlete groups and randomly selected from healthy students who had not any regular physical activity at least during the last 6 months. All participants were male subjects.

Contraindications of exercise test such as any heart pathologies in echocardiography were considered as exclusion criteria. An informed consent was obtained from all participants.

The study was approved by the ethical committee of Tehran University of Medical Sciences.

### *B. Data Collection*

Age, sports experience before study, body mass index (BMI) and body surface area (BSA) were recorded for all participants. After obtaining an ECG, conventional echocardiography and Tissue Doppler Echo (TDE) were performed for all participants by one cardiologist who did not know the participant's group. Cardiac morphological variables including end-diastolic interventricular septum thickness (IVSTd), end-diastolic posterior wall thickness (PWTd), end-diastolic left ventricular internal diameter (LVIDd) and left ventricular end-diastolic volume (LVEDV) and cardiac systolic functional variables such as ejection fraction (EF) by the Simpson method, stroke volume and cardiac output were measured by conventional echocardiography. Relative wall thickness was calculated by sum of end-diastolic interventricular septum thickness and end-diastolic posterior wall thickness divided by end-diastolic left ventricular internal diameter (IVSTd + PWTd)/LVIDd and cardiac output was computed by multiplying heart rate by stroke volume. The indices of morphological variables were characterized by dividing them by the square root of BSA [12]. The left ventricular mass was calculated according to Devereaux formula $(0.8\{1.04[([LVIDd + IVSTd + PWTd]^3 - LVIDd^3)]\} + 0.6$ where LV dimensions represent in centimeters), and dividing it by 2.7 specified its index [13].

Diastolic function was evaluated by pulse Doppler of mitral valve and TDE on mitral annulus. The E (Peak early filling velocity), A (Peak late filling velocity), Ea (Early diastolic velocity of mitral annulus) and Aa (Late diastolic velocity of mitral annulus) waves were measured. The E/A and Ea/Aa ratios of less than 1 were considered as left ventricular diastolic dysfunction and the Ea wave values less than 10 cm/s was considered as grade one diastolic dysfunction.

A maximal exercise tolerance test according to Bruce protocol was performed in order to estimate the VO2max. The resting heart rate and blood pressure were recorded before the test.

The end-point of the exercise test was to reaching to exhaustion or feeling any serious symptoms such as severe fatigue, dyspnea or other symptoms which mandate to stop the test. At the end of the test maximal heart rate and blood pressure were measured and the distance covered by participants was recorded.

### *C. Statistical Analysis*

SPSS for windows (version 13) was used for data analysis. Mean and standard deviation were used for description of variables. In order to make a comparison among groups, independent sample T test, one-way ANOVA and Tukey HSD post hoc tests were applied. P value less than 0.05 was considered as significant level.

## III. RESULTS

### *A. Anthropometric data*

Table I shows anthropometric data of the study groups. The mean (SD) age of participants was 21 ± 4 year and there was no significant difference among groups. The mean (SD) BMI was 22.8 ± 3.3 $Kg/m^2$ which was greater in wrestlers than runners (P=0.014).

The mean (SD) BSA was 1.84 ± 0.15 $m^2$ and there was no significant difference among groups. Wrestlers and runners had no significant difference in terms of sports experience prior to the study (20 ± 8 and 14 ± 5 years, respectively, P = 0.087, independent sample T test).

### *B. Echocardiographic variables*

The mean and SD of echocardiographic variables in the study groups and the comparison among them are illustrated in table II.

TABLE I
ANTHROPOMETRIC DATA IN STUDY GROUPS

| Group | Wrestlers | Runners | Control | P value* |
|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) | |
| Age (yr) | 22 (5) | 21 (3) | 21 (3) | 0.830 |
| Height (m) | 1.72 (0.07)§ | 1.79 (0.06)§ | 1.76 (0.04) | 0.001 |
| Weight (Kg) | 71 (11) | 67 (7) | 71 (13) | 0.463 |
| BMI | 24 (3) § | 21 (2)§ | 23 (4) | 0.014 |
| BSA ($m^2$) | 1.83 (0.17) | 1.84 (0.12) | 1.86 (0.15) | 0.783 |

* One-way ANOVA test and Tukey HSD post hoc test; § Difference between wrestlers and runners groups; BMI = Body mass index, BSA = Body surface area.

### *C. Cardiac morphologic variables*

IVSTd and PWTd of wrestlers were higher than runners, but only differences between wrestlers and control group were significant (P=0.015 and P=0.041, respectively). LVIDd and relative wall thickness had no significant difference among groups. However, the mean IVSTd index and PWTd index were significantly greater in wrestlers than the control group (P=0.012 and P=0.041, respectively).

The mean LVIDd index was lower in the control group than others (P=0.006). The LV mass index was greater in wrestlers in comparison to other two groups (P<0.001). The highest LVEDV was seen in the runner group, following by wrestlers and control group respectively. Differences between the athletes and control group were statistically significant (P<0.001).

*D. Systolic function variables*

The highest LV EF belonged to the runners and then were the control group and wrestlers, respectively. There was no significant difference among these groups. Runners had the greatest left ventricular stroke volume and wrestlers placed in the second position. The control group had the lowest LV SV. Differences between the control group and the others were statistically significant (P<0.001). Runners had the highest cardiac output but there was no significant difference among the groups.

TABLE II
ECHOCARDIOGRAPHY VARIABLES IN STUDY GROUPS

| Morphological characteristics | Wrestlers | Runners | Control | P value* |
|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) | |
| IVSTd (mm) | 11.1 (1.5)[¶] | 10.3 (0.8) | 9.9 (1)[¶] | 0.015 |
| IVSTd (index) | 7.6 (0.9)[¶] | 7.4 (0.7) | 6.8 (0.7)[¶] | 0.012 |
| PWTd (mm) | 10.3 (1.5)[¶] | 10.1 (1.1) | 9.3 (0.9)[¶] | 0.041 |
| PWTd (index) | 7.6 (0.9)[¶] | 7.4 (0.7) | 6.8 (0.7)[¶] | 0.012 |
| LVIDd (mm) | 49.9 (4) | 50.1 (2.8) | 47.7 (2.7) | 0.070 |
| LVIDd (index) | 36.9 (2.2)[¶] | 36.9 (1.9)[$] | 35 (1.8)[¶,$] | 0.006 |
| RWT | 0.43 (0.06) | 0.41 (0.04) | 0.4 (0.03) | 0.298 |
| RWT (index) | 0.32 (0.05) | 0.3 (0.03) | 0.3 (0.03) | 0.162 |
| LV mass | 46.6 (9.3)[¶,§] | 38.9 (5.7)[§] | 34.9 (5)[¶] | < 0.001 |
| LVEDV (cc) | 109.4 (26.6)[¶] | 117.1 (17)[$] | 89.5 (12.7)[¶, $] | < 0.001 |
| **Cardiac Systolic Function** | | | | |
| EF (%) | 60.4 (5.5) | 62.3 (5) | 61.6 (4.7) | 0.537 |
| SV (cc) | 65.7 (16.2)[¶] | 73.4 (14)[$] | 54.3 (9.2)[¶,$] | < 0.001 |
| CO (L/min) | 3.9 (1.2) | 4.2 (0.9) | 4.1 (1.1) | 0.707 |
| **Cardiac Diastolic Function** | | | | |
| E (m/s) | 0.8 (0.2)[¶] | 0.78 (0.2) | 0.6 (0.1)[¶] | 0.011 |
| A (m/s) | 0.51 (0.05) | 0.51 (0.07) | 0.51 (0.08) | 0.837 |
| E/A | 1.6 (0.3)[¶] | 1.6 (0.3)[$] | 1.3 (0.4)[¶, $] | 0.011 |
| Ea (cm/s) | 11.9 (2) | 12.9 (1.7) | 12 (2.6) | 0.376 |
| Aa (cm/s) | 6.6 (1.1)[¶] | 7.2 (1.5) | 8.7 (3)[¶] | 0.031 |
| Ea/Aa | 1.9 (0.5) | 1.9 (0.5) | 1.5 (0.6) | 0.116 |

[*] One-way ANOVA test and Tukey HSD post hoc test; [¶] Difference between wrestlers and control groups; [$] Difference between runners and control groups; [§] Difference between wrestlers and runners groups; IVSTd = Interventricular septum thickness (End-diastolic), PWTd = Posterior wall thickness (End-diastolic), LVIDd = Left ventricle internal diameter (End-diastolic), RWT = Relative wall thickness, LVEDV = Left ventricle end-diastolic volume, LV = Left ventricle, EF = Ejection fraction, SV = Stroke volume, CO = Cardiac output, E = Peak early filling velocity wave, A = Peak late filling velocity wave, Ea = Early diastolic velocity of mitral annulus, Aa = Late diastolic velocity of mitral annulus.

*E. Diastolic function variables*

E wave was lowest in the control group and there was a significant difference between this group and wrestles (P=0.011). There was no significant variation among study groups in the A wave case. The E/A ratio was similar in both wrestler and runner groups and was significantly greater than that of the control group (P=0.011). E/A ratio less than 1 (left ventricle diastolic dysfunction) was not found in athletic groups but was observed in 5 participants of the control group.

In TDE, Ea wave was greater in runners than other two groups but there was no significant difference between them. Two wrestlers (12.5%) had Ea < 10 cm/s (grade one diastolic dysfunction), but none of the runners had it. The Aa wave was greater in the control group than runners and wrestlers, respectively, and a significant difference was observed only between the control and wrestler groups (P=0.031). Ea/Aa ratio was higher in athletes than the control group but there was no significant difference among groups. None of the athletes had Ea/Aa ratio of less than 1 but it was found in 2 participants (9.5%) of the control group.

*F. Exercise test findings*

Resting and maximum heart rate were significantly higher in the control group than athletes (P<0.001). The mean (standard deviation) of distance travelled on treadmill was significantly different among groups (1952 ± 301m in runners, 1410 ± 194m in wrestlers and 1139 ± 150m in the control group, P<0.001). The VO2max was significantly different among the groups, too (73.6 ± 7.9 ml/kg/min in runners, 61.4 ± 3.9 ml/kg/min in wrestlers and 51.3 ± 5.3 ml/kg/min in the control group, P=0.002). Table 3 shows the results of exercise stress test in each group.

## IV. DISCUSSION

Findings about cardiac morphological variables by the conventional echocardiography in this study showed that running as a dynamic exercise has the highest affect on left ventricular internal diameter (left ventricular end diastolic diameter and volume) and wrestling as a static exercise has the greatest impact on ventricular wall thickness (inter-ventricular septum and left ventricular posterior wall thicknesses) and cardiac muscle mass. According to the volume overload in dynamic exercises and pressure overload in static ones, these results are not surprising and resemble that of previous similar studies [2].

Diastolic function was evaluated by measuring the pulse Doppler of mitral valve and quantifying the E wave, A wave and E/A ratio. For example, in a study on soccer players, mitral valve Doppler flow was measured and in spite of the existence of left ventricular hypertrophy, it was better than the control group [9]. Nowadays, TDE is presented as a new non-invasive method for evaluation of systolic and diastolic functions [14]. This technique can measure motion velocity of cardiac walls in multiple points via Doppler principles and rules [8] and in contrast with Doppler profile of mitral valve flow, it seems that movement of cardiac walls is less sensitive to preload changes. In addition, measurement of cardiac wall motion via TDE can specify left ventricular diastolic dysfunction prior to conventional Doppler echocardiography [11].

In this study, the diastolic function measured by TDE did not show any significant diastolic dysfunction in athletes especially in the wrestlers whom it was possible to have such a dysfunction. In addition, there was no significant difference between diastolic function of wrestlers and runners. Anyhow, both athletic groups had better performance than the control participants. Therefore, in line with the results of conventional echocardiography, diastolic function assessment via TDE did not show any difference between athletes who perform dynamic or static exercises and showed that hypertrophied athletes' heart especially in sports with high static component does not affect diastolic function such as in patients suffering from cardiac hypertrophy. To justify these findings it has been argued that by comparison of natural changes of the athletes' heart and pathologic cardiac alterations, the ratio of left ventricular radius to wall thickness diameter in athletes is normal but is increased in patients and the ratio of inter-ventricular septum thickness to left ventricular end-systolic diameter can to some extent differentiate between athletes and patients with hypertrophic cardiomyopathy [1].

TABLE III
FINDINGS OF EXERCISE TEST IN STUDY GROUPS

| Group | Wrestlers | Runners | Control | P value* |
|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) | |
| Resting HR (Beat/min) | 59 (7)¶ | 57 (8)$ | 75 (11)¶, $ | < 0.001 |
| HR max | 190 (8)¶ | 188 (7)$ | 198 (7)¶,$ | < 0.001 |
| $VO_{2max}$ (ml/kg/min) | 61.4 (3.9)¶, § | 73.6 (7.9)$, § | 51.3 (5.3)¶, $ | 0.002 |
| Distance (m) | 1410 (194)¶,§ | 1952 (301)$,§ | 1139 (150)¶,$ | < 0.001 |

* One-way ANOVA test and Tukey HSD post hoc test; ¶ Difference between wrestlers and control groups; $ Difference between runners and control groups; § Difference between wrestlers and runners groups; HR = Heart rate.

## V. CONCLUSION

In line with the other studies, the findings of our study showed that running as a dynamic exercise has the highest affect on left ventricular internal diameters and wrestling as a static one has the highest impact on ventricular wall thickness and cardiac muscle mass. In spite of these cardiac morphological changes, TDE showed that cardiac diastolic function of these athletes will not be adversely affected.

## REFERENCES

[1] J.C. Puffer, "Overview of The Athletic Heart Syndrome," in Exercise & Sports Cardiology, 1st ed., P.D. Thompson, New York: McGraw-Hill, 2001, pp. 30-42.
[2] J. Barbier, N. Ville, G. Kervio, G. Walther, F. Carre, "Sports-Specific Features of Athlete's Heart and their relation to Echocardiographic parameters," *Herz.,* vol. 31, no. 6, pp. 531-543, Sep. 2006.
[3] R. Fagard, "Athlete's Heart," *Heart.,* vol. 89, no. 12, pp. 1455-1461, Dec. 2003.
[4] A.E. Atchley, P.S. Douglas, "Left Ventricular Hypertrophy in Athletes: Morphologic Features and Clinical Correlates," *Cardiol Clin.,* vol. 25, no. 3, pp. 371-382, Aug. 2007.
[5] F. Halabchi, T. Seif-Barghi, R. Mazaheri, "Sudden Cardiac Death in Young Athletes; A Literature Review and Special Considerations in Asia," *Asian Journal of Sports Medicine.,* vol. 2, no. 1, pp. 1-15, March. 2011.
[6] S.F. Nagueh, K.J. Middelton, H.A. Kopelen, W.A. Zoghbi, M.A. Quinones, "Doppler Tissue Imaging: A Noninvasive Technique for Evaluation of Left Ventricular Relaxation and Estimation of Filling Pressures," *J Am Coll Cardiol.,* vol. 30, no. 6, pp. 1527-1533, Nov. 1997.
[7] S.F. Nagueh, C.P. Appleton, T.C. Gillebert, P.N. Marino, J.K. Oh, O.A. Smiseth, A.D. Waggoner, F.A. Flachskampf, P.A. Pellikka, A. Evangelista, "Recommendations for the evaluation of left ventricular diastolic function by echocardiography," *J Am Soc Echocardiogr.,* vol. 22, no. 2, pp. 107-133, Feb. 2009.
[8] G. Pela, G. Bruschi, L. Montagna, M. Manara, C. Manca, "Left and Right Ventricular Adaptation Assessed by Doppler Tissue Echocardiography in Athletes," *J Am Soc Echocardiogr.,* vol. 17, no. 3, pp. 205-211, Mar. 2004.
[9] A.B. Sozen, V. Akkaya, S. Demirel, H. Kudat, T. Tukek, M. Unal, M.M. Beyaz, O. Guven, F. Korkut, "Echocardiographic findings in professional league soccer players. Effect of the position of the players on the echocardiographic parameters," *J Sports Med Phys Fitness.,* vol. 40, no. 2, pp. 150-155, Jun. 2000.
[10] M.L. Martinez-Mas, F. Javier Chorro, J. Sanchis, J.F. Asensi, J.A. Losada, R. Ruiz, V. Lopez-Merino, "Doppler assessment of left ventricular diastolic function in marathon runners," *J Sports Med Phys Fitness.,* vol. 34, no. 1, pp. 50-55, Mar. 1994.
[11] A. Schmidt-Trucksass, A. Schmid, C. Haussler, G. Huber, M. Huonker, J. Keul, "Left ventricular wall motion during diastolic filling in endurance-trained athletes," *Med Sci Sports Exerc.,* vol. 33, no. 2, pp. 189-195, Feb. 2001.
[12] P. Obert, S. Nottin, G. Baquet, D. Thevenet, F.X. Gamelin, S. Berthoin, "Two months of endurance training does not alter diastolic function evaluated by TDI in 9-11 year-old boys and girls," *Br J Sports Med.,* vol. 43, no. 2, pp. 132-135, Feb. 2009.
[13] L.A. Gondoni, A.M. Titon, G. Silvestri, F. Nibbio, O. Taronna, P. Ferrari, G. Leonetti, "Short term effects of physical exercise and low calorie diet on left ventricular function in obese subjects: a tissue Doppler study," *Nutr Metab Cardiovasc Dis.,* vol. 17, no. 5, pp. 358-364, Jun. 2007.
[14] N.R. Van de Veire, O. De Winter, J. Philippe, M. De Buyzere, D. Bernard, M. Langlois, T.C. Gillebert, J. De Sutter, "Maximum oxygen uptake at peak exercise in elderly patients with coronary artery disease and preserved left ventricular function: The role of inflammation on top of tissue Doppler-derived systolic and diastolic function," *Am Heart J.,* vol. 152, no. 2, pp. 297.e1-7, Aug. 2006.