Original Article

Evaluation of Strain Parameters by Three Dimensional Speckle Tracking Echocardiography in Competitive Athletes

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Summary

Introduction: Echocardiography is fundamental in the distinction between physiological adaptations promoted by physical activity and pathological abnormalities. Three-dimensional speckle tracking echocardiography (3D-STE) could prove accurate in detecting subclinical abnormalities in cardiac function.

Objectives: To determine the effect of exercise on the parameters of myocardial strain in athletes through 3D STE.

Method: Elite boxers underwent conventional three-dimensional echocardiography (3D-echo) and 3D-STE to analyze left ventricular (LV) volumes, left ventricular mass indexed to body surface area (LVMIBSA), ejection fraction (EF), longitudinal global strain (LGS), circumferential global strain (CGS), radial global strain (RGS), twist, torsion and tracking area. These data were compared with measurements performed on untrained control individuals.

Results: The analyses included 16 athletes and 14 controls with similar age (23 ± 4 vs. 21 ± 4 years; p = NS) and gender (14 vs. 12 males). LVEF was normal and similar in the 2 groups. LVMIBSA was higher in the athletes (83 ± 21 vs. 65 ± 15 g/m², $p < 0.05$), as well as RGS (24.7 ± 5.2 vs. 16.3 ± 7.2; $p = 0.007$). There was no significant difference for the other parameters, such as CGS (-26 ± 2 vs. -28 ± 6), LGS (-16 ± 2 vs. -17 ± 3), twist (3.1 ± 1.3 vs. 3.7 ± 1.9), torsion (2.0 ± 0.8 vs. 1.4 ± 0.4) and tracking area (37 ± 4 vs. 41 ± 6).

Conclusion: Athletes and untrained individuals have comparable myocardial strain parameters on 3D-STE. However, an increase in RGS was observed only in the athletes. 3D-STE could help in the early detection of subclinical cardiac issues in athletes. (Arq Bras Cardiol: Imagem cardiovasc. 2017;30(3):92-97)

Keywords: Echocardiography, Three-Dimensional/methods; Heart/diagnostic imaging; Speckle Tracking; Athletes; Parameters/analysis.

Introduction

The regular practice of physical activity can promote morphological and functional abnormalities of the heart, which depend on the type of training practiced. Exercise with isometric predominance (predominance of muscle, static and anaerobic force) may determine concentric remodeling (normal left ventricular mass index and increased relative wall thickness), while exercises with isotonic predominance (movement, muscular and aerobic tension), eccentric remodeling (increased left ventricular mass index and normal relative wall thickness), as well as abnormalities of the cardiac automatism such as bradycardia.[1]

The development and dissemination of Doppler echocardiography determined important breakthroughs in the knowledge and understanding of these physiological modifications that are called "athlete's heart," with a fundamental role in the distinction between physiological and pathological adaptations.[2]

The current approach to the analysis of left ventricular function is based on non-invasive methods that investigate the contractile function of the myocardium and its anatomical structure. Strain and strain rate measurements derived from tissue Doppler have been used to evaluate myocardial function and the recently devised speckle tracking technique, which identifies speckles and accompanies them throughout the cardiac cycle, allows quantification of myocardial strain without depending on the angle between the ultrasound beam and the myocardial movement.[3] Speckle tracking measurements, which can be performed through two or three-dimensional Doppler echocardiography, have improved the understanding and characterization of the abnormalities that occur in the heart's adaptation to exercise. Because three-dimensional technology is not limited to an image plane, it has the advantage of integrating the information obtained from this multiplane analysis.[4]

These new diagnostic modalities allow for a detailed study of cardiac function and possibly the detection of subclinical abnormalities of myocardial contractility. Of these parameters,

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the study of longitudinal strain has been more used and validated to study global and segmental myocardial contractility in athletes and untrained patients;[2] other parameters such as radial and circumferential strain should, however, be considered in the study of left ventricular function.[5]

Objective

This study considered evaluating the effect of physical exercise on the different parameters of myocardial strain in elite athletes using three-dimensional Doppler echocardiography (3D-echo) and speckle tracking Doppler echocardiography (3D-STE).

Method

Patients

Competitive high-level athletes (boxers) of both genders and aged > 18 were referred for echocardiographic evaluation by the sports cardiology clinic. The training routine of the athletes consisted of 6 weekly sessions lasting 3 hours each, including aerobic exercises and bodybuilding. A control group of healthy and untrained patients, with similar age and same gender, without risk factors for cardiovascular diseases, was put together for comparison.

Electrocardiography

All echocardiographic studies were performed by the same experienced professional on an Artida 4D (Toshiba Medical Systems Corporation, Otawara-shi, Japan) and digitally stored for further analysis.

The patients were evaluated using conventional Doppler echocardiography, 3D-echo and 3D-STE, with analysis of conventional parameters (cardiac chamber diameters, myocardial thickness, biventricular systolic function, left ventricular diastolic function, cardiac valves and pericardium), including left ventricular volumes (Simpson's two-dimensional method and 3D-echo) with resultant, left ventricular (LV) ejection fraction (EF) and body mass indexed to body surface.[6]

Diastolic function was analyzed using conventional pulsed Doppler, with determination of the usual parameters of LV diastolic performance, such as isovolumetric relaxation time, mitral transvalvular flow (peak E and A wave velocity, *E* wave deceleration time, *E/A* peaks ratio) and tissue Doppler (analysis of the *e', a', S'* waves of the septal and lateral walls and *E/e'* wave ratio).

Three-dimensional strain

Images were acquired from the apical window with a 2.5 MHz matrix transducer (PST-25SX) after synchronization with the electrocardiogram. During the expiratory pause, sectoral depth and width were adjusted to optimize the image and take a full-volume left ventricular acquisition. Three to four subvolumes were acquired in about 4 consecutive cardiac cycles and were automatically integrated into a pyramidal data volume with as many frames as possible (20-30 Hz). The data were digitally stored for further analysis. The best image was chosen for analysis from among three acquisitions. The measurements were performed after semiautomatic marking of points at the endocardial borders, using specific software (Artida, Toshiba). Small adjustments could be made, if necessary, by editing the dashed borders. The determination of the global longitudinal strain (GLS), global circumferential strain (GCS) and global radial strain (GRS) parameters, as well as the twist (rotation difference between the apex and the LV base), torsion (twist corrected by the LV length in the longitudinal axis) and tracking area (allowing the integration of LV subendocardial area strain information in the longitudinal and radial planes) resulted from the measurements performed automatically. Figure 1 shows a three-dimensional radial strain of an athlete.

Statistical analysis

Data were expressed as mean ± standard deviation or percentage, as required. The different quantitative variables between the groups were compared using the unpaired two-tailed Student's t-test, and the non-parametric variables were compared using the chi-square test. The values were considered statistically significant when $p < 0.05$.

The study was approved by the ethics and research committee of Hospital Israelita Albert Einstein, São Paulo - SP – Brazil, under number 2615-16, year 2015.

Results

The population involved in the study consisted of 16 athletes and 14 untrained healthy controls. Age (23 ± 4 years vs. 21 ± 4 years; p = NS) and gender were similar between the two groups (14 vs. 12 men, p = NS).

The conventional echocardiographic parameters of controls and athletes are listed in Table 1.

As for cardiac structure, as expected, a higher LV mass index (LVMIBSA), obtained by 3D-echo, was observed in the athletes compared to the control group (83 ± 21 vs. 65 ± 15 g/m^2, $p < 0.05$). On the other hand, analyses of LV systolic function (EF) and diastolic function were normal and similar among athletes and untrained individuals. Diastolic function was normal for both groups.

Three-dimensional strain measurements

No patient was excluded due to image quality. Therefore, myocardial strain measurements and related measurements were taken of all individuals. Table 2 shows the variables for both groups, with similar LGS and CGS values. However, RGS was significantly higher in the group of athletes (16.3 ± 7.2 x 24.7 ± 5.2, $p < 0.05$). As for the other parameters derived from 3D-STE, including twist, torsion and tracking area, no significant difference was observed for the two groups (p = NS).

Discussion

The analysis of myocardial strain parameters is a sensitive way for early evaluation of left ventricular function abnormalities. It is able to detect early cardiac mechanics disorders, as it is not influenced by the ventricular geometry and presents less dependence on cardiac preload.[1] Magnetic resonance imaging,

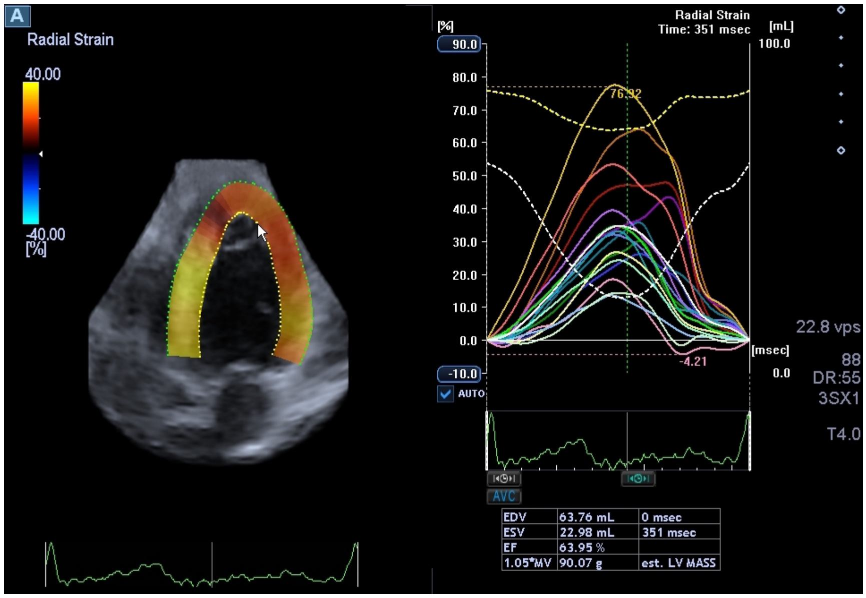

Figure 1 – *Three-dimensional echocardiography showing global radial strain measurement in a competitive athlete.*

Table 1 – Conventional echocardiographic parameters - Controls x Athletes

	Aor (mm)	LA (mm)	LVDD (mm)	LVSD (mm)	ΔD (%)	EF (%)	LVMIBSA (g/m²)
Controls (n = 14)	30 ± 4.76	32 ± 5.17	44 ± 4.67	29 ± 3.42	34 ± 2.77	63 ± 0.03	65 ± 15
Athletes (n = 16)	29 ± 2.9	34 ± 4.28	49 ± 2.96	31 ± 3.03	36 ± 4.45	65 ± 0.05	83 ± 21
p	NS	NS	NS	NS	NS	NS	< 0.05

Aor: aortic root; LA: left atrium; LVDD: left ventricular diastolic diameter; LVSD: left ventricular systolic diameter; ΔD%: left ventricular shortening fraction; EF: left ventricular ejection fraction; LVMIBSA: left ventricular mass indexed to the body surface.

Table 2 – Myocardial strain parameters - Controls x athletes

	Age (years)	RGS (%)	CGS (%)	LGS (%)	Twist	Torsion	Tracking area
Controls (n = 14)	21 ± 4	16.3 ± 7.2	-28 ± 6	-17 ± 3	3.7 ± 1.9	1.4 ± 0.4	41 ± 6
Athletes (n = 16)	23 ± 4	24.7 ± 5.2	-26 ± 2	-16 ± 2	3.1 ± 1.3	2.0 ± 0.8	37 ± 4
p	NS	< 0.007	NS	NS	NS	NS	NS

RGS: global radial strain; GCS: global circumferential strain; GLS: global longitudinal strain.

among other diagnostic methods, has proven effective for this purpose, but presents limitations in terms of image acquisition speed, portability and cost. Doppler echocardiography is a sensitive, reproducible and cost-effective method for this analysis. Several studies have demonstrated the importance of global longitudinal strain measurement, in addition to the classical Doppler echocardiogram parameters, to evaluate structural and functional changes in both athletes and untrained individuals, and it is possible to detect subclinical abnormalities of myocardial contractility. In this study, three-dimensional Doppler echocardiography was chosen because this method correlates better with the data obtained by magnetic resonance imaging. A large advantage over the two-dimensional study is the possibility of acquiring a single block for analysis, as the two-dimensional one demands a number of acquisitions on several planes (apical 4, 3 and 2-chamber sections and transverse apical, middle and basal sections). These acquisitions are taken on different cycles, and different volumes can be taken.

Circumferential and radial strain, twist, torsion and area tracking were studied in this group of athletes. The analysis of systolic function evaluated by longitudinal and circumferential strain did not find significant differences between the groups. However, increase of radial strain was observed in the group of athletes compared to the group of untrained individuals. Previous studies involving the analysis of radial function[7] have shown that it is preserved in endurance athletes at rest, leading us to infer that the increase in cardiac output in this group is due to higher diastolic volume, rather than increased radial function. However, this finding was based on the measurement of function through M-mode (systolic thickening of inferolateral wall). The measurement of three-dimensional strain could possibly be more sensitive for the detection of the abnormalities that precede ventricular remodeling in this population. This information may be potentially relevant in the early detection of subclinical signs of dysfunction and in the differentiation between physiological adaptation and cardiomyopathy. Additionally, these modifications could be related to specific training (resistance) or exercise duration. Similar findings were found by D'Ascenzi et al.,[8] who studied athletes and controls with two and three-dimensional strain, showed that the values of longitudinal and circumferential strain were smaller in athletes, whereas three-dimensional radial strain was increased in this group, compared to two-dimensional strain.[8] The comparison between two and three-dimensional strain techniques shows that their results are not completely interchangeable. Maffessanti et al.,[9] comparing athletes and healthy untrained individuals using the two and three-dimensional techniques, found larger cardiac dimensions in the athletes group, but similar left ventricular ejection fraction in the two groups, as well as LGS, RGS and GCS. However, GRS levels were higher in the three-dimensional study compared to the two-dimensional study. Some literature studies[10] have demonstrated similar longitudinal myocardial strain values between athletes and non-athletes when the evaluation is performed with the two groups under resting conditions. However, when analyzed immediately after strenuous exercise, reduction of systolic function and development of regional contractility abnormalities, such as apical radial strain drop, may be observed. It is speculated that the apical region be more sensitive and dependent on sympathetic stimulation compared to the basal portion of the left ventricle, so a relative increase in the parasympathetic stimulation induced by the exercise would be responsible for the decreased apical strain in athletes.[11] In our sample, the measurements were taken only at rest, and it was not possible to extrapolate the results to a stress situation (exercise).

The other myocardial strain parameters analyzed (twist, torsion and tracking area) did not show significant difference between the athletes and control groups. Their values remained within the normal range.[12] Since these parameters are derived by the rotation movement between the left ventricular base and apex, along with the left ventricular length, significant modifications would not be expected, since both groups had left ventricles of preserved dimensions, thus the length – which significantly impacts the calculation of these measures – was not abnormal.

Regarding abnormal cardiac structures, any stimulus that promotes hemodynamic overload may lead to left ventricular hypertrophy, whether adapted (physiological) or not (pathological). Physiological hypertrophy is that resulting from transient stimuli, as observed in gestation and in regular physical exercising, while pathological hypertrophy, of persistent stimuli, such as in untreated systemic arterial hypertension, stenosis and aortic coarctation.[9] Athletes who practice mainly dynamic or isotonic physical activity such as running are subjected to long periods of left ventricular volume overload. The heart's response to this training is the increase in left ventricular chamber size and myocardial wall thickness, as a result of the "serial" deposition of new sarcomeres (eccentric hypertrophy).[10] Those dedicated to strength and power training (isometric training) such as bodybuilding, present short but considerable periods of increase in systolic and diastolic blood pressure, heart rate, systolic volume and cardiac output. The cardiac response to such effort is characterized by the "parallel" deposition of these new sarcomeres (concentric hypertrophy).[10] This way, we have a modification of the spatial structure of myofibrils, which precedes the changes in muscular ultrastructure. Regarding cardiac structure and dimensions, studies report that the groups of isotonic and isometric trainers have higher left ventricular mass indexed to body surface area than the control group.[9] In our sample, this data was reproduced with a higher value in the athletes group (83 ± 21 vs. 65 ± 15 g/m^2, $p < 0.05$), although still within normal limits. The boxers involved in this study carry out a mixed-pace training regime, alternating isometric and isotonic exercises, and were evaluated during the rest period. This mixture of stimuli may provide this group with both parallel and serial deposition of sarcomeres, depending on the training time and stimulus intensity.

Limitations

This study included echocardiographic evaluation in a limited sample (16 athletes). Moreover, because it is a cross-sectional study, it is not possible to determine if the results would have any influence on the individuals' follow-up. Finally, the abnormalities were found during the rest period, so the data obtained cannot be extrapolated to the situation immediately after exercise, which could influence the appearance of other myocardial strain abnormalities.

Conclusions

Hearts of athletes and untrained individuals are comparable in myocardial strain parameters. However, an increase in radial strain was observed only in the athletes group. The analysis of these myocardial strain parameters through three-dimensional Doppler echocardiography may prove to be a useful tool for the early detection of subclinical cardiac abnormalities in athletes.

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Authors' contributions

Research creation and design: Daminello E; Data acquisition: Cordovil A, Oliveira WA, Lira Filho EB, Piveta RB, Vieira MLC, Fischer CH, Morhy SS; Data analysis and interpretation: Daminello E, Rodrigues ACT; Statistical analysis:

Echenique L; Manuscript drafting: Daminello E; Critical revision of the manuscript as for important intellectual content: Rodrigues ACT.

Potential Conflicts of Interest

There are no relevant conflicts of interest.

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Academic Association

This study is not associated with any graduate programs.

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