CorSalud 2014 Apr-Jun;6(2):167-173

Cuban Society of Cardiology

Original Article

Morphofunctional adjustments assessed by echocardiogram in male elite triathlon athletes

Comlan Géoffroy Agbélélé, MD; Juan A. Prohías Martínez, MD; Ángela M. Castro Arca, MD; Oyantay Mérida Álvarez, MD; and Ricardo A. García Hernández✉, MD

Cardiology Service. Hermanos Ameijeiras Hospital. Havana, Cuba.

Este artículo también está disponible en español

ARTICLE INFORMATION

Received: November 20, 2013
Accepted: January 14, 2014

Competing interests
The authors declare no competing interests

Acronyms
IVS: interventricular septum
LA: left atrium
LV: left ventricle
LVEDV: LV end-diastolic volume
PW: posterior wall

On-Line Versions:
Spanish - English

✉ *RA García Hernández*
San Lázaro 701,
e/ Belascoaín y Marqués González.
Centro Habana 10300.
La Habana, Cuba.
E-mail address:
ramador@infomed.sld.cu

ABSTRACT

Introduction: Cardiovascular adjustments of elite athletes allow predicting the adequacy of the physical training they undergo. The atrial changes, which have not been studied much, are established earlier than the ventricular ones.

Objectives: To evaluate the left ventricular and atrial morphofunctional changes in elite triathlon athletes at different stages of training.

Method: A prospective, longitudinal and descriptive study was conducted by performing two-dimensional and M-mode echocardiography, with pulse tissue Doppler *and* color tissue Doppler, to obtain the specific variables involved in the study of all members of the men's national triathlon team. The universe consisted of six athletes. The study was performed bimonthly for a period of one year, to cover different training stages.

Results: Athletes were 20 to 24 years of age and had a mean body surface area of 1.89 m^2. The septal and posterior wall thickness, and left ventricular end-diastolic volume increased significantly ($p < 0.01$) as the training advanced, and likewise happened with the left atrium diameter and the variables proposed to measure myocardial contractility (Strain and Strain Rate).

Conclusions: Physical exercise produces changes in end diastolic diameter and volumes of left ventricle, in its ejection fraction, and in the thickness of the interventricular septum and posterior wall. The new variables proposed for measuring myocardial contractility demonstrated the training efficiency in the heart of athletes. The diameter, volume and left atrial pressure increased in proportion to the intensity of exercise. This atrial pressure had a tendency to return to baseline values by decreasing the training load.

Key words: Triathlon, Ejection fraction, End diastolic diameter of left ventricle, Septal thickness, Posterior wall, Left atrium

Adaptaciones morfofuncionales evaluadas por ecocardiograma en deportistas masculinos de élite en triatlón

RESUMEN

Introducción: Las adaptaciones cardiovasculares de los deportistas de alto rendimiento permiten pronosticar lo adecuado del entrenamiento físico al que son sometidos. Los cambios auriculares, no tan estudiados, se instauran más precozmente que los ventriculares.

Objetivo: Evaluar los cambios morfofuncionales ventriculares y auriculares izquierdos en atletas de élite de triatlón en las distintas fases de entrenamiento.

Método: Se realizó un estudio prospectivo, longitudinal, descriptivo, mediante la realización de ecocardiograma bidimensional y modo M, con Doppler color, pulsado y tisular, para la obtención de las variables específicas involucradas en el estudio de todos los integrantes del equipo nacional masculino de triatlón. El universo estuvo constituido por 6 atletas. El estudio se realizó bimensualmente durante un período de un año, para abarcar distintas fases de entrenamiento.

Resultados: Los atletas tenían entre 20 y 24 años de edad y una superficie corporal promedio de 1,89 m^2. El grosor septal y de la pared posterior, y el volumen telediastólico del ventrículo izquierdo aumentaron significativamente ($p<0.01$) a medida que avanzó el entrenamiento; de igual forma ocurrió con el diámetro de la aurícula izquierda y las nuevas variables propuestas para medir la contractilidad miocárdica (*Strain y Strain Rate*).

Conclusiones: El ejercicio físico produce modificaciones en los diámetros y volúmenes diastólicos del ventrículo izquierdo, en su fracción de eyección, y en el grosor del tabique interventricular y la pared posterior. Las nuevas variables propuestas para medir la contractilidad miocárdica demostraron la eficiencia del entrenamiento en el corazón de los atletas. El diámetro, el volumen y la presión de la aurícula izquierda aumentaron proporcionalmente a la intensidad del ejercicio. Esta presión auricular tuvo una tendencia a regresar a sus valores basales al disminuir la carga de entrenamiento.

Palabras clave: Triatlón, Fracción de eyección, Diámetro telediastólico del ventrículo izquierdo, Grosor septal, Pared posterior, Aurícula izquierda

INTRODUCTION

Physical activity and particularly sports activities have always been considered part of a healthy lifestyle[1]. The continued training or physical exercise induces a series of physiological and morphofunctional adjustments on the cardiovascular system that can vary according to the influence of various factors[2].

With the advent of radiography and the electrocardiogram, progress was made in the knowledge of cardiac adjustments to training; but it was with the advent of echocardiography in the '70s, that a major boost in this area of research took place. Two-dimensional and M-mode echocardiography and Doppler has been used by many authors to study such changes as well as the Tei index[3-6]. Although at present the evaluation of myocardial deformation with novel techniques (Strain and Strain rate) have displaced these modalities and offer high reliability.

There are few authors who have published studies on the morphofunctional changes in the heart of high-performance athletes in such a complex discipline like triathlon, featuring three high endurance sports (swimming 3.9 km, biking 180 km and running, 42 km), where changes related to the left chambers are essentially described. We were therefore motivated to perform such a study, predominantly focused on adjustments of the left atrium (LA), which so far has not been very well elucidated.

The objective of this research was to evaluate the left ventricular and atrial morphofunctional changes in elite triathlon athletes at different stages of training.

METHOD

A prospective, longitudinal and descriptive study was conducted by performing two-dimensional and M-mode echocardiography, with pulse tissue Doppler and color tissue Doppler, in six athletes of the men's national triathlon team from October 2009 to October 2010.

Training Stages

According to the training program a schedule of one year, divided into two macrocycles of 6 months each was established. The first was divided into three phases: a) general preliminary phase or phase 1, which in turn was divided into two mesocycles (integral basic and special basic), and included the application of techniques that allowed a mental-physical preparation of athletes for the next period , b) special preliminary phase or phase 2, consisting of two mesocycles (preliminary and advanced) in which the different training loads that were to increase the length of the sections and the distance traveled were gradually applied, and c) the competitive phase or phase 3, further subdivided into three mesocycles where the athlete took part in different competitions and the results of the preparation was assessed.

The macrocycle II consisted of three mesocycles (accumulation or phase 4 transformation or phase 5 and relative vacations or phase 6), each lasting two months. Accumulation and transformation mesocycles were characterized by five microcycles each and were distinguished among themselves by rising loads of exercises, and the last mesocycle was aimed at the realization of individual exercises without much pressure or demands.

Echocardiographic technique

After each mesocycle an echocardiography using a Phillips iE33 equipped with a multifrequency transducer S 1-5 MHz was performed. The patient was placed in left lateral decubitus position with previous location of electrodes to record ECG signal; standard echocardiographic views were taken (long and short parasternal axis and apical views of two-and four-chambers) to assess the anatomy of the chambers, heart valves and global and segmental left ventricular function.

M mode was used to determine the measurements (in mm) of the end-diastolic and end-systolic diameters of the left ventricle (LV) as well as that of the interventricular septum (IVS) and posterior wall (PW). The ejection fraction of the ventricle itself was calculated by the method of Teichholz, and the dimension of the LA was measured by the two-dimensional method in apical four chamber view, the transverse diameter in millimeters was determined and its volume was calculated by the Simpson biplane method. Each parameter was evaluated by an average of three measurements.

For evaluation of myocardial deformation a software available in the laboratory of quantification (Q-LAB) of the echocardiograph Phillips iE33 was used, specifically the SQ complement (Strain quantification or myocardial deformation), which allowed the analysis of the strain rate and the average strain at M mode of longitudinally interventricular septum. Color Doppler imaging was taken after adjusting the equipment parameters with high image quality (200 frames/ sec.) and good edge definition was achieved, and the smallest possible angle between the wall and the ultrasound beam. Then, an "M" virtual line was drawn on the septum, which was readjusted in width not to include the endocardial and epicardial borders. The software automatically performed the analysis of tissue velocities, strain rate and average strain and made a representation in color maps and graphics with the corresponding systolic wave (S) and diastolic (E and A). Normal values were considered according to the ranges established by the American and European Societies of Ecocardiography[7,8].

Statistical processing

Data were processed with the statistical package SPSS-W 13.0 and summary measures of descriptive statistics were determined. The average was used as a measure of central tendency and standard deviation as a measure of dispersion. Nonparametric Friedman test for repeated measures was performed, and it was considered that there was significant difference when the probability of the test was less than 0.05. The results are presented in tables and graphs.

RESULTS

Table 1 shows the age range of the study population (20 to 24 years), and an average body surface area of 1.89 m^2.

Table 1. Characterization of athletes according to age and body surface area.

Variables	Minimum	Maximum	Average
Age (years)	20	24	22,7
Body surface área (m^2)	1,77	2,03	1,89

Table 2 shows the progressive increase in septal thickness and PW, which slightly exceeded values considered normal and reached statistical significance ($p< 0.01$).

Table 3 demonstrates the significant and gradual increase in LV end-diastolic volume (LVEDV) as well as

Table 2. IVS and PW average behavior at different periods.

Variables	Minimum	Maximum	Average
IVS (1)	12,0	13,2	12,76
IVS (2)	12,2	13,2	12,86
IVS (3)	12,3	13,3	12,93
IVS (4)	12,3	13,4	13,01
IVS (5)	**12,4**	**13,4**	**13,06**
IVS (6)	**12,4**	**13,4**	**13,06**
χ^2 (Friedman test) = 27,5 p=0.000			
PW (1)	11,0	13,0	11,78
PW (2)	11,2	13,0	11,95
PW (3)	11,2	13,1	12,00
PW (4)	11,3	13,1	12,05
PW (5)	**11,4**	**13,2**	**12,16**
PW (6)	**11,4**	**13,2**	**12,16**
χ^2 (Friedman test) = 28,8 p=0.000			

Table 3. Behavior of LVEDV and LA diameter in the different periods.

Variables	Minimum	Maximum	Average	TD
LVEDV (1)	120,5	155,0	136,08	14,40
LVEDV (2)	122,0	155,4	136,81	14,01
LVEDV (3)	122,0	155,4	137,15	14,11
LVEDV (4)	122,0	155,9	137,46	14,30
LVEDV (5)	**122,5**	**156,0**	**137,86**	**14,13**
LVEDV (6)	**122,5**	**156,0**	**137,96**	**14,11**
χ^2 (Friedman test) = 28,6 p=0.000				
Diam LA (1)	41,8	45,0	43,03	1,14
Diam LA (2)	41,9	45,4	43,11	1,28
Diam LA (3)	41,9	45,4	43,18	1,24
Diam LA (4)	42,0	45,6	43,28	1,29
Diam LA (5)	**42,3**	**45,6**	**43,38**	**1,20**
Diam LA (6)	**42,3**	**45,6**	**43,40**	**1,21**
χ^2 (Friedman test) = 27,7 p=0.000				

Caption. TD: typical deviation; Diam: diameter

that of the LA diameter, as training progressed.

Table 4 refers to the improvement of the contractile force of the myofibrils detected by the Strain/Strain rate technique.

Table 4. Averaged Strain/Strain Rate behavior at different periods.

Variables	Mínimo	Máximo	Media	DT
Strain (1)	-21,2	-24,0	-22,73	1,05
Strain (2)	-21,4	-24,5	-22,95	1,07
Strain (3)	-21,4	-24,5	-22,95	1,09
Strain (4)	-21,5	-24,6	-23,13	1,08
Strain (5)	-21,6	-24,8	-23,23	1,12
Strain (6)	**-21,6**	**-24,9**	**-23,28**	**1,17**
χ^2 (Friedman test) = 27,6 p=0.000				
Strain Rate (1)	-1,5	-2,0	-1,73	0,186
Strain Rate (2)	-1,5	-2,1	-1,78	0,204
Strain Rate (3)	-1,6	-2,2	-1,81	0,213
Strain Rate (4)	-1,6	-2,2	-1,86	0,206
Strain Rate (5)	-1,7	-2,3	-1,96	0,206
Strain Rate (6)	**-1,8**	**-2,3**	**-2,00**	**0,200**
χ^2 (Friedman test) = 27,4 p=0.000				

Caption. TD: typical deviation

Figure 1 shows that in the first months of the study no increase in systolic functionoccurred, which was indeed demonstrated as the training load was kept rising.

As seen in **figure 2**, the Tei index had a decreasing trend during the study period, indicating a favorable positive change of heart function.

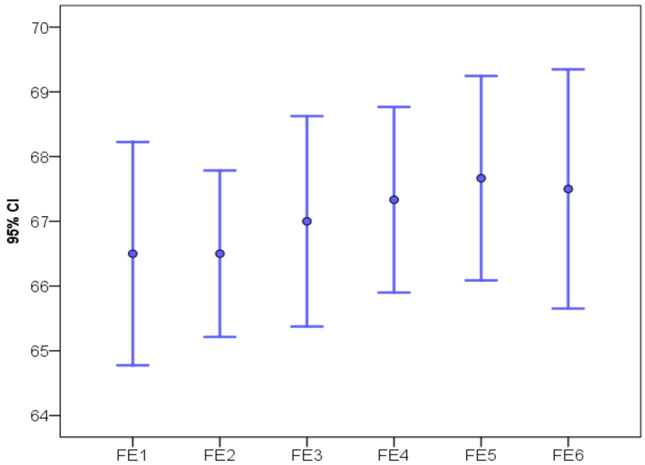
In **figures 3A and 3B** the progressive increase in volume and pressure of the LA is observed, a significant decrease in these variables at the end of phase 6 is noteworthy.

DISCUSSION

During the year of the study time there was a statistically significant increase in the thickness of the IVS in response to the intense and continuous exercise, which helped to improve LV systolic function. Different studies have shown similar findings in athletes of endurance sports[6-11].

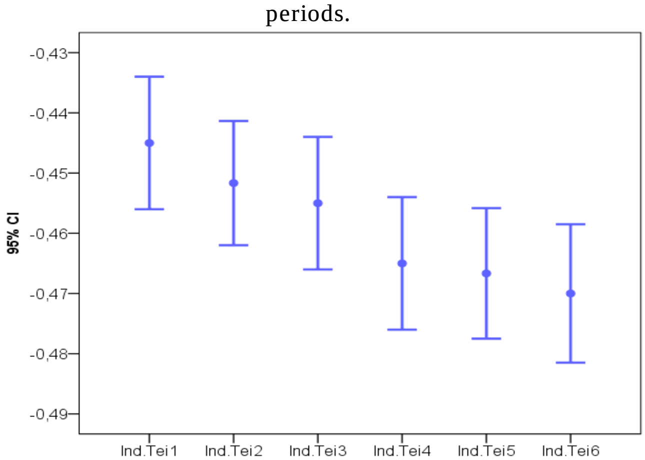
Besides, there has been an increase of over 14 mm in IVS dimensions in athletes that practice static exercises, as has been published in several papers and it

Figure 1. Average behavior of ejection fraction at different periods.



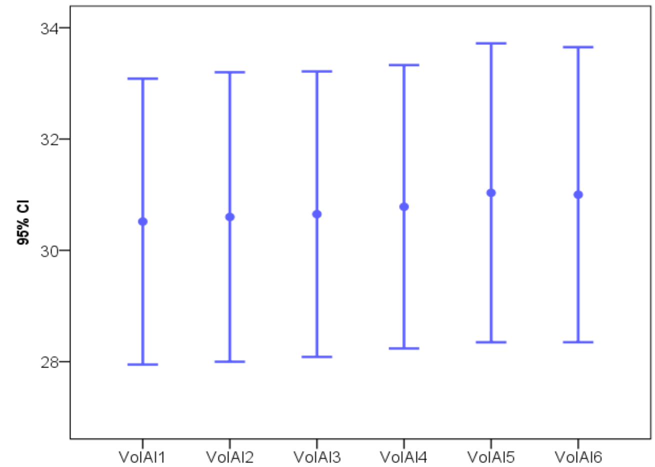
χ² (Friedman test) = 20,3 p=0.001

Figure 2. Average behavior of Tei index in different periods.



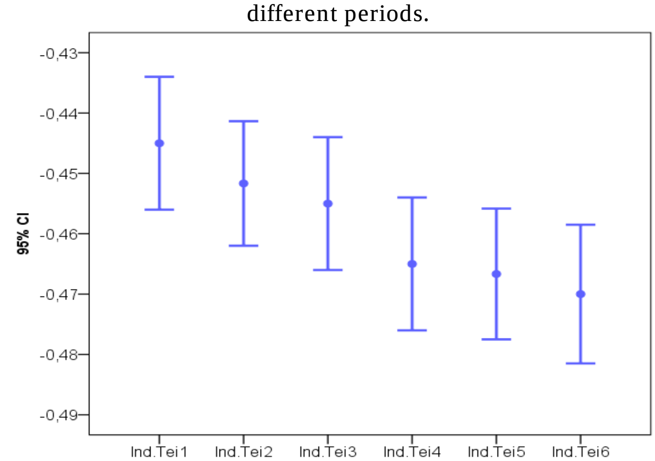
χ² (Friedman test) = 27,5 p=0.000

Figure 3A. Average behavior of LA volume in different periods.



χ² (Friedman test) = 27,9 p=0.000

Figure 3B. Average behavior of pressure in the LA in different periods.



χ² (Friedman test) = 21,5 p=0.001

justifies the high ventricular pressure that characterizes the heart of athletes that practice strength sports on the one hand[9,12,13]; but on the other, a difference in the growth of IVS among runners has been observed, depending on the length of the race[14]. Like this septum, the PW of the LV suffered a gradual rise of its dimensions, which is consistent with several publications on endurance athletes[9,15-18], and this is justified just as what happened with the IVS.

LVEDV had an upward linear increase as training progressed. Hassan et al.[19] measured it in athletes before and after a marathon race, and found that it was increased in almost everyone. Poh et al.[20] found similar results. The fact that the index of contractility or systolic function are normal in athletes and similar in sedentary people suggests that the increased stroke volume of the trained heart at rest (120-130 ml with 70-80 ml) is due to an increase in the LVEDV[21,22].

As shown in **Table 4**, the myocardial fibers of the triathletes studied had a vigorous contraction that improved the performance of the heart to meet the metabolic needs of the organism. Other authors reached the same conclusion when comparing the septal region of the athlete's heart with that same area of non-sports subjects[23].

In the early months of the study a significant increase in systolic function was not found, but as the exercise load was increased a gradually increasing ejection fraction began to appear. These results were consistent with those reported by Hassan et al.[19] and

Zócalo et al.[24] This result could be explained by the complexity of triathlon that involves the synergism of three endurance sports.

The decreasing values of the Tei index as a variable of myocardial performance stressed the positive changes occurred that favor the functioning of the heart of triathletes. This result is similar to that found by de la Rosa et al.[25] in their research.

The relative contribution of contractile, reserve and contribution functions to LV filling is 25, 40 and 35 %, respectively. With the increased stiffness and lack of distensibility of the ventricle, the pressure in the LA increases to maintain a proper filling. This generates a stretch of the atrial myocardium and dilation of the cavity[26], which corresponds to the results found in this research, by measuring the transverse diameter of the LA. That diameter growth tended to expansion in the same period of study, but after vacation time the atrial diameter decreased, although without equaling their initial values. This shows the increase in internal capacity of the LA before intense and maintained exercise, to facilitate ventricular filling which is dependent, in part, on the atrial volume[23,27]; however, other authors suggest that age is a negative factor in atrial level changes that occur in elite athletes[28].

CONCLUSIONS

Physical exercise produces changes in LV diastolic diameters and volumes, in its ejection fraction, and in the thickness of the IVS and PW. The new variables proposed for measuring myocardial contractility (systolic Strain and Strain rate) demonstrated the efficiency of training in the heart of athletes. The diameter, volume and pressure of the LA increased proportionally to the intensity of exercise. This atrial pressure had a tendency to return to baseline values when the training load decreased.

REFERENCES

1. Hoffmann A, Isler R. Appréciation de l´aptitude à la pratique sportive sous l´angle cardiaque. Forum Med Suisse. 2007;7:889-94.
2. Serratosa Fernández L. Adaptaciones Cardiovasculares del Deportista. 2do Congreso Virtual de Cardiología 2001. [Internet]. [citado 2013 Oct 31]. Disponible en: http://pcvc.fac.org.ar/scvc/llave/PDF/serratoe.PDF
3. Kasikcioglu HA, Kasikcioglu E, Oflaz H, Unal S, Topcu B, Tartan Z, *et al*. Discrimination between physiologic and pathologic left ventricular dilatation. Int J Cardiol. 2006;109(2):288-90.
4. Maron BJ. Enfermedad cardiovascular en atletas. En: Zipes DP, Libby P, Bonow RO, Braunwald E, eds. Tratado de Cardiología. 7ma. ed. Madrid: Elsevier, 2006; p. 1985-91.
5. Teske AJ, De Boeck BW, Melman PG, Sieswerda GT, Doevendans PA, Cramer MJM. Echocardiography quantification of myocardial function using tissue deformation imaging, a guide to image acquisition and analysis using tissue Doppler and speckle tracking. Cardiovasc Ultrasound [Internet]. 2007 [citado 2013 Oct 31];5:27. Disponible en: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2000459/
6. Peidro RM. El corazón del deportista. Hallazgos clínicos, electrocardiográficos y ecocardiográficos. Rev Argent Cardiol. 2003;71(2):126-37.
7. Maron BJ, Thompson PD, Ackerman MJ, Balady G, Berger S, Cohen D, *et al*. Recommendations and considerations related to preparticipation screening for cardiovascular abnormalities in competitive athletes: 2007 update. A scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism: Endorsed by the American College of Cardiology Foundation. Circulation. 2007;115(12):1643-55.
8. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA. Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005;18(12):1440-63.
9. Pavlik G, Olexó Z, Osváth P, Sidó Z, Frenki R. Echocardiographic characteristics of male athletes of different age. Br J Sports Med. 2001;35(2):95-9.
10. Escudero EM, Tufare A, Lobrutto C, Pellegrini L, Asenjo A, Pinilla OA. Remodelamiento ventricular izquierdo en el atleta: influencia de diferentes actividades deportivas. Rev Fed Arg Cardiol. 2006;35(3): 150-6.
11. Barbier J, Ville N, Kervio G, Walther G, Carré F. Sports-specific features of athlete´s heart and their relation to echocardiographic parameters. Herz. 2006;31(6):531-43.
12. Laskowski R, Wysocki K, Multan A, Haga S. Changes

in cardiac structure and function among elite judoists resulting from long-term judo practice. J Sports Med Phys Fitness. 2008;48(3):366-70.
13. Venckunas T, Mazutaitiene B. The role of echocardiography in the differential diagnosis between training induced myocardial hypertrophy versus cardiomyopathy. J Sports Sci Med. 2007;6(2):166-71.
14. Calderón FJ, Díaz V, Peinado AB, Benito PJ, Maffulli N. Cardiac dimensions over 5 years in highly trained long-distance runners and sprinters. Phys Sportsmed. 2010;38(4):112-8.
15. MacFarlane N, Northridge DB, Wright AR, Grant S, Dargie HJ. A comparative study of left ventricular structure and function in elite athletes. Br J Sports Med. 1991;25(1):45-8.
16. George K, Shave R, Oxborough D, Cable T, Dawson E, Artis N, *et al*. Left ventricular wall segment motion after ultra-endurance exercise in humans assessed by myocardial speckle tracking. Eur J Echocardiogr. 2009;10(2):238-43.
17. Chan-Dewar F, Oxborough D, Shave R, Gregson W, Whyte G, George K. Left ventricular miocardial strain and strain rates in sub-endocardial and subepicardial layers before and after a marathon. Eur J Appl Physiol. 2010;109(6):1191-6.
18. Papadakis M, Carre F, Kervio G, Rawlins J, Panoulas VF, Chandra N, *et al*. The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin. Eur Heart J. 2011;32(18):2304-13.
19. Hassan MY, Noakes TD, Berlyn P, Shave R, George K. Preload maintenance protects against a depression in left ventricular systolic, but not diastolic, function immediately after ultraendurance exercise. Br J Sports Med. 2006;40(6):536-40.
20. Poh KK, Ton-Nu TT, Neilan TG, Tournoux FB, Picard MH, Wood MJ. Myocardial adaptation and efficiency in response to intensive physical training in elite speedskaters. Int J Cardiol. 2008;126(3):346-51.
21. Zeppilli P, Corsetti R. Adattamenti cardiocircolatori nelle diverse discipline sportive. En: Zeppilli P, ed. Cardiologia dello sport. 2da. ed. Roma: CESI; 1996. p. 37-78.
22. Maron BJ. Structural features of the athlete heart as defined by echocardiography. J Am Coll Cardiol. 1986;7(1):190-203.
23. Nottin S, Doucende G, Schuster-Beck I, Dauzat M, Obert P. Alteration in left ventricular normal and shear strains evaluated by 2D-strain echocardiography in the athlete's heart. J Physiol. 2008;586(Pt 19):4721-33.
24. Zócalo Y, Guevara E, Bia D, Giacche E, Pessana F, Peidro R, *et al*. La reducción en el nivel y la velocidad de la torsión ventricular puede asociarse a incremento en la eficiencia ventricular izquierda: evaluación mediante ecografía speckle-tracking. Rev Esp Cardiol. 2008;61(7):705-13.
25. de la Rosa Hernández A, Boraita Pérez A, Heras Gómez MA, de la Torre Combarros AI, Radabán Ruiz M, Canda Moreno A, *et al*. Análisis de índice de remodelado ventricular izquierdo en deportistas de alto nivel. Rev Esp Cardiol. 2007;60(Supl 2):20. [Resumen].
26. Claessens PJ, Claessens CW, Claessens MM, Claessens MC, Claessens JE. Supernormal left ventricular diastolic function in triathletes. Tex Heart Inst J. 2001;28(2):102-10.
27. Simsek Z, Gundogdu F, Alpaydin S, Gerek Z, Ercis S, Sen I, *et al*. Analysis of athletes' heart by tissue Doppler and strain/strain rate imaging. Int J Cardiovas Imaging. 2011;27(1):105-11.
28. D'Andrea A, Caso P, Vriz O, Citro R, Gravino R, Cocchia R, *et al*. Left atrial enlargement in 515 either endurance or strength competitive athletes. Circulation. 2009;120(18 Suppl):S383. [Resumen].