Patterns of Left Ventricular Diastolic Function in Olympic Athletes

Stefano Caselli, MD, PhD, FASE, Fernando M. Di Paolo, MD, Cataldo Pisicchio, MD, Natesa G. Pandian, MD, and Antonio Pelliccia, MD, FESC, *Rome, Italy; and Boston, Massachusetts*

Background: Whether morphologic left ventricular (LV) changes in elite athletes are associated with altered diastolic properties is undefined. The aim of this study was to investigate LV diastolic properties in a large population of Olympic athletes compared to untrained controls.

Methods: A total of 1,145 Olympic athletes (61% men), and 154 controls, free of cardiovascular disease, underwent two-dimensional echocardiography, Doppler echocardiography, and Doppler tissue imaging.

Results: Athletes had similar E velocities (87 ± 15 vs 89 ± 16 cm/sec, $P = .134$) but significantly decreased A velocities (47 ± 10 vs 56 ± 12 cm/sec, $P < .001$) compared with controls, with increased E/A ratios (1.93 ± 0.50 vs 1.63 ± 0.35, $P < .001$) and values ranging up to 4.8. Isovolumic relaxation (83 ± 13 vs 71 ± 16 msec, $P < .001$) and deceleration times (203 ± 40 vs 181 ± 36 msec, $P < .001$) were longer in athletes compared with controls. Doppler tissue imaging e′ (13.8 ± 2.2 vs 16.2 ± 3.7 cm/sec, $P < .001$) and a′ (7.2 ± 1.8 vs 8.5 ± 2.1 cm/sec, $P < .001$) were lower in athletes than in controls, but their ratio was not different between groups; E/e′ ratios (6.37 ± 1.2 vs 5.72 ± 1.33, $P < .001$) were mildly higher in athletes. Subgroup analysis for type of sport showed that endurance athletes had the lowest A and a′ velocities and the largest E/A ratios. Gender analysis revealed that men had significantly lower E and A velocities, as well as e′, e′/a′ ratios, and E/e′ ratios ($P < .01$), compared with women.

Conclusion: This study provides normal values for Doppler echocardiographic and Doppler tissue imaging parameters describing diastolic function in elite athletes, which may be implemented as reference values in the clinical assessment of athlete's heart and prove useful in understanding the physiologic limits of cardiac adaptations in athletes. (J Am Soc Echocardiogr 2015;28:236-44.)

Keywords: Athletes, Diastolic function, LV hypertrophy, Echocardiography, Doppler

Morphologic cardiac adaptations in highly trained athletes have been extensively described, including increased left ventricular (LV) cavity size, wall thickness, and mass, as well as right ventricular changes, which represent the physiologic response to the hemodynamic loading induced by chronic exercise.[1-5]

Most previous studies on athlete's heart, however, have focused on morphologic LV changes that are considered responsible for increased cardiovascular performance during exercise.[2-9] On the other hand, it is not clear whether the morphologic LV changes in athletes are associated with altered LV diastolic properties, to sustain the increased hemodynamic load associated with chronic exercise.

At present, information on the diastolic properties of the left ventricle in trained athletes is still scarce,[10-19] and the normal values and upper limits of LV diastolic functional indexes remain undefined. However, this information has relevant clinical implications, given that abnormal diastolic function may be the first expression of incipient myocardial disease, such as hypertrophic cardiomyopathy, which may precede for a long time the development of LV hypertrophy.[20-24]

The aim of the present study was therefore to investigate the diastolic properties of athlete's heart as assessed by conventional two-dimensional echocardiographic and Doppler parameters in a large population of Olympic athletes involved in different sport disciplines. It was our purpose to understand if, and to what extent, LV diastolic properties were altered in highly trained athletes and to define normal values and upper limits to be implemented in clinical practice.

METHODS

Study Population

The Institute of Sports Medicine and Science is the medical division of the Italian National Olympic Committee and is responsible for the physiologic and medical evaluation of all national elite athletes selected for participation at Olympic Games and world championships. From January 2008 to June 2012, 1,230 consecutive athletes were evaluated in preparation for the 2008 Beijing Olympic Games, the 2009 FINA

From the Institute of Sports Medicine and Science, Rome, Italy (S.C., F.M.D., C.P., A.P.); and the Cardiovascular Imaging and Hemodynamic Laboratory, Tufts University Medical Center, Boston, Massachusetts (N.G.P.).

Reprint requests: Stefano Caselli, MD, PhD, FASE, Institute of Sport Medicine and Science, Largo Piero Gabrielli, 1 - 00197 Rome, Italy (E-mail: *stefanocasellimd@gmail.com*).

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Abbreviations

BSA = Body surface area

DTI = Doppler tissue imaging

IVRT = Isovolumic relaxation time

LA = Left atrial

LV = Left ventricular

PASP = Pulmonary artery systolic pressure

PW = Pulsed-wave

World Championship, and the 2012 London Olympic Games. Of these, 1,145 were included in the present analysis on the basis of age ≥ 18 and ≤ 40 years and absence of cardiovascular disease in our evaluation, routinely including history, physical examination, resting and exercise 12-lead electrocardiography, and Doppler echocardiographic examination.

The mean age was 26 ± 5 years, and 696 subjects were men (61%). We classified the athletes' sports disciplines into four subgroups according to the predominant characteristics of exercise training: (1) skill (i.e., primarily technical activities; $n = 226$), including golf, table tennis, equestrian, gymnastics, shooting, fencing, karate, taekwondo, and sailing; (2) power activities (i.e., primarily isometric activities; $n = 177$), including weightlifting, wrestling, and short-distance running (100–200 m); (3) mixed disciplines (i.e., disciplines with alternate isometric and isotonic components; $n = 339$), including soccer, basketball, volleyball, handball, water polo, and tennis; and (4) endurance disciplines (e.g., primarily isotonic activities; $n = 403$), including rowing, canoeing, swimming, long-distance running and marathon, cycling, triathlon, and pentathlon.[25-28]

The athletes were compared with a group of 154 healthy sedentary subjects. They were volunteers, selected on the basis of similar age (range, 18–40 years) and gender proportion (86 men [56%]) and were either completely sedentary or engaged in <3 hours of exercise per week, and none was involved in sports competitions. Controls were evaluated at the Institute of Sports Medicine and Science in Rome according to the same medical protocol as the athletes. All were considered free of cardiovascular disease.

Written informed consent was waived for all athletes and controls undergoing a standard clinical evaluation pursuant to Italian law and institute policy. The study design was approved by the review board of the institute and funded by the Italian National Olympic Committee. All clinical data assembled on athletes and controls are maintained in an institutional database.

Echocardiography

Two-dimensional echocardiography was carried out by experienced cardiologists, using commercially available echocardiographic equipment (iE33; Philips Medical Systems, Andover, MA) with an S5 probe (2–4 MHz). Two-dimensional measurements of LV cavity diameters, wall thickness, left atrial transverse diameter, right ventricular outflow tract, and aortic root diameters were performed according to European Association of Cardiovascular Imaging and American Society of Echocardiography criteria.[29]

LV ejection fraction was measured by using the biplane Simpson's rule from the apical four- and two-chamber views, and LV mass was calculated with Devereux's formula.[29]

LV inflow velocities were recorded by using pulsed-wave (PW) Doppler from the apical four-chamber view with a 2-mm sample volume positioned at the tip of the mitral leaflets, with the ultrasound beam aligned parallel to the flow stream; acquisitions were performed at a sweep speed of 50 mm/sec, and measurements of peak early filling (E) and late diastolic filling (A) were performed at end-expiration during breath holding. Isovolumic relaxation time (IVRT) was measured by means of continuous-wave Doppler, by placing the ultrasound beam in the LV outflow tract, to calculate the time from the end of aortic ejection to the onset of mitral inflow.

Myocardial Doppler tissue imaging (DTI) signals were recorded using PW Doppler in the apical four-chamber view, with a 5-mm sample volume positioned in the myocardium at or within 1 cm of the septal insertion of anterior mitral leaflet. Particular attention was paid to aligning the ultrasound beam to the plane of excursion of the septal aspect of the mitral annulus. The velocity scale was set at about 25 cm/sec and sweep speed at 50 mm/sec. Early (e′) and late (a′) diastolic peak velocities were measured at end-expiration during breath holding. Derivate parameters (E/A, e′/a′, and e/e′ ratios) were subsequently calculated.[30]

Pulmonary artery systolic pressure (PASP) was calculated as previously reported, assuming a right atrial pressure of 5 mm Hg.[31]

Statistical Analysis

Continuous data are expressed as mean ± SD and categorical data as frequencies. The fifth and 95th percentiles of diastolic functional parameters are reported as the outer boundaries and reference values of the study population. Statistical significance was set for a two-tailed P value < .05. Differences between proportions were calculated by using χ^2 tests. Differences between the athletes and controls for continuous variables were evaluated with unpaired-samples t tests and Levene tests for the equality of variance.

Stepwise regression analysis was performed in the athletes group to identify the determinants of those diastolic function indexes showing significant difference between athletes and controls. The continuous variables included in the analysis were: age, body surface area (BSA), systolic and diastolic blood pressure, heart rate, septal wall thickness, end-diastolic diameter, LV mass, LV ejection fraction, and left atrial (LA) diameter.

The impact of type of sport was assessed by means of one-way analysis of variance with post hoc Bonferroni correction. Gender-related differences in diastolic function were assessed by means of unpaired-samples t tests.

Subgroup analysis was also performed to compare diastolic functional indexes in athletes with LV hypertrophy (i.e., wall thickness ≥ 13 mm) or marked LV cavity enlargement (i.e., cavity diameter ≥ 60 mm) with the remaining athlete cohort, by means of unpaired-samples t tests.[32]

Statistical analysis was performed with SPSS version 15.0 (SPSS, Inc., Chicago, IL).

RESULTS

Baseline Characteristics of Study Population

Demographic characteristics and cardiac dimensions of athletes and untrained controls are reported in Table 1.

Athletes were slightly younger than controls and showed higher BSAs. Cardiac dimensions were larger in athletes compared with controls, including LV wall thickness, cavity size, and mass. Substantial increases in LV wall thickness (≥13 mm) were found in 29 subjects (2.6%) and no controls; marked LV cavity enlargement (end-diastolic diameter > 60 mm) was found in 60 athletes (5.5%) and no controls. LV mass was significantly higher in athletes; specifically, a large subset of female (38%) and male (40%) athletes showed values above the accepted normal limits (95 g/m^2 in women and 115 g/m^2 in men).[29]

LA transversal diameter was larger in athletes compared with controls, but the difference was not significant when corrected for BSA; specifically, 119 athletes (10%) had values above the normal limit