Effect of Sex and Sporting Discipline on LV Adaptation to Exercise

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ABSTRACT

OBJECTIVES This study sought to investigate the effect of different types of exercise on left ventricular (LV) geometry in a large group of female and male athletes.

BACKGROUND Studies assessing cardiac adaptation in female and male athletes indicate that female athletes reveal smaller increases in LV wall thickness and cavity size compared with male athletes. However, data on sex-specific changes in LV geometry in athletes are scarce.

METHODS A total of 1,083 healthy, elite, white athletes (41% female; mean age 21.8 ± 5.7 years) assessed with electrocardiogram and echocardiogram were considered. LV geometry was classified into 4 groups according to relative wall thickness (RWT) and left ventricular mass (LVM) as per European and American Society of Echocardiography guidelines: normal (normal LVM/normal RWT), concentric hypertrophy (increased LVM/increased RWT), eccentric hypertrophy (increased LVM/normal RWT), and concentric remodeling (normal LVM/increased RWT).

RESULTS Athletes were engaged in 40 different sporting disciplines with similar participation rates with respect to the type of exercise between females and males. Females exhibited lower LVM (83 ± 17 g/m² vs. 101 ± 21 g/m²; p < 0.001) and RWT (0.35 ± 0.05 vs. 0.36 ± 0.05; p < 0.001) compared with male athletes. Females also demonstrated lower absolute LV dimensions (49 ± 4 mm vs. 54 ± 5 mm; p < 0.001) but following correction for body surface area, the indexed LV dimensions were greater in females (28.6 ± 2.7 mm/m² vs. 27.2 ± 2.7 mm/m²; p < 0.001). Most athletes showed normal LV geometry. A greater proportion of females competing in dynamic sport exhibited eccentric hypertrophy compared with males (22% vs. 14%; p < 0.001). In this subgroup only 4% of females compared with 15% of males demonstrated concentric hypertrophy/remodeling (p < 0.001).

CONCLUSIONS Highly trained athletes generally show normal LV geometry; however, female athletes participating in dynamic sport often exhibit eccentric hypertrophy. Although concentric remodeling or hypertrophy in male athletes engaged in dynamic sport is relatively common, it is rare in female athletes and may be a marker of disease in a symptomatic athlete. (J Am Coll Cardiol Img 2016; ■ ■ ■ ■ © 2016 by the American College of Cardiology Foundation.)

Long-term athletic training is associated with a series of alterations in cardiac structure, function, and electrical activity that are collectively termed athlete’s heart (1-3). The ability to accurately diagnose cardiovascular diseases and, specifically, to differentiate physiological cardiac adaptation caused by exercise from cardiac pathology constitutes one of the most fundamental aspects of sports cardiology (4-6). Although numerous studies have evaluated the cardiac response to regular physical training in male athletes, there are limited data on female athletes, who constitute an increasing number of elite athletes worldwide. A former large study of female Italian Olympian athletes revealed that none exhibited an absolute left ventricular (LV) wall thickness exceeding predicted upper limits for the general population and the LV cavity was considered...
enlarged in only 8% (7). These results indicate that the quantitative alterations in absolute cardiac dimensions in females rarely overlap with the primary cardiomyopathies, which are recognized causes of exercise-related sudden cardiac death in young adults. Absolute values for cardiac dimensions are dependent of sex, size, and type of sport. In this regard, the assessment of LV geometry using left ventricular mass (LVM) index and relative wall thickness (RWT) is an increasingly important component in differentiating athlete’s heart from pathological left ventricular hypertrophy (LVH), such as hypertrophic cardiomyopathy (8-10). However there are few reports on sex-specific LV geometry alterations in athletes. This study compared LV geometry in a large cohort of highly trained male and female athletes.

METHODS

STUDY SETTING. The United Kingdom does not support a state-sponsored cardiac screening program in athletes. However, the charitable organization Cardiac Risk in the Young (www.c-r-y.org.uk) has an established cardiac screening program for young individuals and also serves many professional sporting organizations in the United Kingdom. Up to 1,000 athletes from numerous regional or national sporting squads are assessed annually. Most preliminary evaluations, including electrocardiogram (ECG) and echocardiography, are performed at training centers by experienced cardiologists through a mobile investigations unit and supervised by the principal investigator (S.S.). Between 2010 and 2013, a total of 1,364 elite athletes age 14 to 35 years were assessed with a health questionnaire, ECG, and echocardiogram. Of these, black females comprised only 40 (3%) athletes. Given that the aim of this study was to specifically assess sex differences in LV geometry in a large cohort we confined our analysis only to white athletes. The final study group consisted of 1,083 consecutive elite athletes of which 40% were female. The mean age of the cohort was 22 ± 6 years of age.

ECOCARDIOGRAM. Two-dimensional echocardiography was performed using either a GE Vivid I (GE Healthcare, Tirat, Israel), Philips Sonos 7500, Philips iE33, or Philips CPX50 (Philips Healthcare, Bothell, Washington). Standard views were obtained as previously described (13). Assessment of diastolic function included traditional pulsed-wave Doppler across the mitral valve and tissue Doppler velocity imaging of the septal and lateral mitral valve annulus (14). Digitized images of 2 beats were stored and analyzed by cardiologists and expert sonographers blinded to the clinical characteristics offline in accordance with the European Society of Echocardiography guidelines.

Left ventricular (LV internal diameter, septal wall thickness, and posterior wall thickness were measured from 2-dimensional images in the parasternal long-axis view in end-diastole. When measuring septal thickness, care was taken to exclude right ventricular septal bands. In measuring the LV posterior wall thickness, care was taken to exclude posterior wall chordae. Indexed LV cavity size was considered increased if >31 mm/m². RWT was defined as the ratio of the sum of the interventricular septum and posterior wall thickness in end-diastole to the left ventricular end-diastolic diameter (LVEDD). A RWT was considered to be abnormal if >0.42 (13). LVM calculation was based on a prolate ellipse model of the left ventricle in accordance with American Society of Echocardiography formula: $LVM = \frac{0.8 \times 1.04 ((LVEDD + interventricular septum + posterior wall thickness)^3 - (LVEDD)^3)}{1.6}$. An abnormal LVM was defined as >95 g/m² in women and >115 g/m² in men (13). LV volumes and LV ejection fraction were assessed from the apical views, using the biplane method of discs. LV systolic function was considered to be reduced if the ejection fraction was <50% (15).

Based on the guidelines from the European and American Society of Echocardiography (13,15), LV geometry was classified into 4 groups based on the RWT and LVM as represented in Figure 1: 1) normal...
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