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ORIGINAL RESEARCH

Left Atrium Size in Elite Athletes

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ABSTRACT

OBJECTIVES The goal of this study was to perform a meta-analysis of the published literature to investigate the relationship of high levels of exercise training to left atrial (LA) size.

BACKGROUND The "athlete's heart" is a series of cardiac adaptations to systematic exercise training and may include LA enlargement.

METHODS We conducted a systematic review of English-language studies in MEDLINE and Scopus from inception through April 29, 2014, that reported LA size in elite athletes.

RESULTS A total of 54 studies comprising 7,189 elite athletes and 1,375 controls were included. Forty-eight of the 54 studies reported absolute LA diameter in 7,018 athletes and 1,044 controls. Nine of the 54 studies (including 992 athletes and 426 controls) presented LA volume corrected for body surface area. The adjusted weighted mean LA diameter was 4.1 mm greater in athletes overall compared with sedentary controls ($p < 0.0001$), and LA volume index was 7.0 ml/m^2 greater in athletes than controls ($p < 0.01$). Compared with controls, LA diameter was 4.6 mm greater in endurance-trained athletes ($p < 0.0001$), 2.9 mm greater in strength-trained athletes ($p < 0.03$), 3.5 mm greater in combined strength- and endurance-trained athletes ($p < 0.0001$), and 4.2 mm greater in athletes with unspecified training ($p < 0.02$).

CONCLUSIONS To our knowledge, this is the largest compilation of studies documenting that elite athletes have larger LA dimensions compared with controls when evaluated by either LA diameter or LA volume corrected for body surface area. The largest average LA diameters were reported in endurance athletes. Physicians evaluating athletes should be aware that the LA is increased in both strength- and endurance-trained elite athletes. (J Am Coll Cardiol Img 2015;8:753–62) © 2015 by the American College of Cardiology Foundation.

Athletic training produces multiple cardiac adaptations that constitute the "athlete's heart." This exercise-induced cardiac remodeling is considered a benign physiological adaptation to the hemodynamic load of systemic training and is characterized by an increase in cavity diameters, wall thickness, and left ventricular (LV) mass (1).

Increase in left atrium (LA) size has been proposed as a component of "athlete's heart" (1). The LA is not a symmetrical, 3-dimensional structure, and LA enlargement may not occur uniformly (2). The American Society of Echocardiography (ASE) recommends using LA volumes indexed for body surface area (BSA) as a more accurate and reproducible measure of LA size than diameter alone (3), but few studies of athletes have followed this recommendation. This may be especially important when LA size is evaluated in elite athletes because

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ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

AP = anterior-posterior

ASE = American Society of Echocardiography

BSA = body surface area

CMR = cardiac magnetic resonance

LA = left atrial/atrium

LV = Left ventricular/ventricle

larger body dimensions could increase both athletic performance and LA size.

LA enlargement is associated with an increase in adverse cardiovascular outcomes even in subjects without a history of atrial fibrillation (AF) or significant valvular disease (2). LA enlargement increases the risk of AF, which may explain recent data supporting an increase in AF incidence among middle-aged competitive athletes after many years of sport practice (4).

Consequently, we performed a systematic review of the available data to evaluate the association and to quantify the magnitude of the effect of exercise training on LA size. We also sought to determine if LA size remained greater in elite athletes after adjustment for body size.

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METHODS

DATA SOURCES AND SEARCHES. We conducted a systematic literature search of MEDLINE and Scopus databases from inception to April 29, 2014, using combinations of the following terms: "heart," "echocardiography," and "athlete." Additionally, we manually searched references from papers about included studies, review articles, and meta-analyses.

STUDY SELECTION. We assessed studies for inclusion by using the following a priori defined criteria: 1) the study explicitly stated that the evaluated athletes were elite, competing at international or national level (including National Collegiate Athletic Association); 2) the study reported absolute mean LA diameter or LA volume indexed for BSA measured by echocardiography according to current clinical standards (3); 3) the mean age of the study cohort was between 18 and 40 years; and 4) a measure of statistical variance was reported. Study arms that reported populations that potentially overlapped with other studies were excluded.

DATA EXTRACTION. Two reviewers independently extracted the data, with discrepancies resolved by consensus. We classified the athletes into strength, endurance, and combined groups based on the intensity level of the static and dynamic components (5). Heterogeneous groups of athletes of different sports classifications were categorized as mixed. In longitudinal exercise training studies, the LA measurements after the longest exercise exposure were used.

DATA SYNTHESIS AND ANALYSIS. LA dimensions were pooled using meta-analytic methods. Random-effects meta-analysis and meta-regression analyses were conducted to determine how exercise and other important study characteristics influenced LA size. A multivariate linear mixed model was used to conduct meta-regression analyses. Both random and fixed effects were used for meta-regression, which was weighted by the inverse of the variance of the aortic root diameter (6). Fixed effects were assumed for study-level factors, including participant type (athlete or control) and sex. When sample size permitted, we performed subgroup analyses of studies to determine the effect of sex and the type of exercise training on LA dimensions. We constructed 2 funnel plots of the SE versus the LA diameter and indexed LA volume, respectively, to evaluate publication bias using StatsDirect version 2.7.9 (StatsDirect Ltd., Cheshire, United Kingdom). The funnel plot was examined visually and tested for asymmetry using the Egger test. Heterogeneity across studies was assessed by calculating the I statistic, which measures the proportion of overall variation that is attributable to between-study heterogeneity rather than chance. I^2 statistic >50% was defined as significant. Statistical analysis was performed using SAS (PROC MIXED) version 9.2 (SAS Institute, Cary, North Carolina) with statistical significance set at 0.05.

RESULTS

Our search of the literature identified 1,546 nonduplicate citations (**Figure 1**). Of these, 54 studies (7–60) met the inclusion criteria for this analysis. Forty-eight of the 54 included studies reported absolute LA diameter in 2,626 endurance-trained athletes; 411 strength-trained athletes; 875 combined endurance- and strength-trained athletes; 3,106 athletes for whom pure exercise classification was not possible, which we labeled "mixed trained athletes"; and 1,044 controls (**Table 1**). Nine of the 54 studies presented LA volume corrected for BSA in 552 endurance-trained, 255 strength-trained, and 185 combined trained athletes and 426 controls (**Table 2**). Across all studies, mean age of the athletes and controls ranged from 18.9 to 36 years.

Meta-regression analysis demonstrated that pooled mean LA diameter was 4.1 mm (95% confidence interval [CI]: 2.8 to 5.4) greater in athletes overall compared with sedentary controls ($p < 0.0001$) (**Table 3**), and LA volume index was 7.0 ml/m^2 (95% CI: 2.3 to 11.6) greater in athletes compared with controls ($p < 0.01$) (**Table 4**). These increases correspond to a 13% increase in LA diameter and a 30% increase in indexed LA volume.

LA diameter compared with controls was 4.6 mm (95% CI: 3.2 to 6.0) greater in endurance-trained