investigators underlined in their limitations the significance of scaling cardiac dimensions to other, potentially more appropriate parameters of body composition, including allometric approaches. The latter take into account the different geometric dimensions of body size variables, challenging the concept of scaling 1-dimensional variables such as LVEDD to 2- or 3-dimensional parameters such as body surface area or fat-free mass (FFM) in a simple, linear fashion.

In this regard, our group published a similar study on 1,051 competitive athletes several years ago, in which we demonstrated that scaling to body size using geometrically adjusted variables enabled a much better understanding of the adaptation of athlete hearts to different types of exercise (4). In this study, we also included a substantial number of Caucasian female athletes (n = 271; >18 years of age); we compared them not only with male athletes but also to age-matched control subjects. The same classification regarding the proportion of dynamic exercise was applied, with even more female athletes included in the dynamic group (n = 153) than in the current study (n = 131). Similarly, no female athlete exceeded a maximal WT of 12 mm, only 1.6% had LVEDDs of >54 mm, 5.2% exceeded a relative WT of 0.42, and no female athlete showed a LVM >145 g/m^2. Absolute cardiac dimensions were comparable to the current analysis, and scaling LVEDD to BSA also resulted in greater values in female athletes versus male athletes, but when allometrically scaling to BSA$^{0.5}$, female athletes again demonstrated lower values. Scaling LVEDD to height$^{2.7}$ consistently eliminated differences between types of exercise, and sex differences disappeared when scaling LVEDD to FFM$^{0.33}$ and WT to BSA. Only LVM was consistently greater in both male and female athletes performing dynamic disciplines, and we demonstrated, on a mathematical basis in both genders, that adaptation of LVM to exercise apparently exceeded the sole influence of concomitant changes in body composition. We finally provided reference values for cardiac dimensions scaled to various body size parameters, which aid in clarifying borderline findings in female athletes detected during pre-participation screening.

I agree with the investigators that, particularly in female athletes, a better understanding of cardiac adaptations is still needed. However, adaptation to intensive exercise does not only affect the heart, but body composition as well, and we thus recommend appropriate scaling to body size in case of borderline findings before proceeding to potentially equivocal further investigations.

Axel Pressler, MD*

*Department of Prevention, Rehabilitation and Sports Medicine
Klinikum rechts der Isar
Technical University of Munich
Ismaninger Strasse 22
81675 Munich
Germany
E-mail: axel.pressler@mri.tum.de

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THE AUTHORS REPLY:

We are grateful to Dr. Pressler for his interest in our paper (1). We would like to start by disagreeing that there is a wealth of data on cardiac dimensions in female athletes and would argue the opposite especially when comparisons are made with data on male athletes. The issue of scaling metrics and sex differences in body size composition is challenging, and its application is a source of contention. Our study relates to the effects of sex and sporting discipline on left ventricular (LV) geometry, a parameter without a dimension (1). According to international guidelines (2), LV geometry is calculated using an equation that includes the LV end-diastolic diameter, LV wall thickness, and LV mass. The LV mass is indexed for body surface area (BSA) with different cutoff values for males and females. LV geometry is neither a description of a dimension or a numerical parameter, but it simply defines a shape; therefore, the issue of appropriate scaling is less relevant in this setting. We concede that LV mass indexed for BSA is part of LV geometry calculation, but an intrinsic correction for sex, with different cutoff values is also factored into the formula. Interestingly, in our cohort, the proportion of athletes exceeding LV mass/BSA was 24% both in males and females. The lack of difference between the sexes suggests that scaling LV mass for BSA using the cutoff values of 95 g/m^2 in females and 115 g/m^2 in males is a reliable method of identifying individuals with truly increased LV mass. This information can be derived easily and applied in day-to-day clinical practice.

Pressler et al. (3) studied 1,051 competitive athletes, including 271 female athletes, and reported that LV mass scaled for fat-free mass (FFM) was higher in male athletes compared with female athletes. However, because of the lack of established cutoff values for LV mass and/or FFM, the investigators were unable to determine the proportion of males and females with increased LV mass. The absence of defined and agreed cutoff values for scaling methods different from BSA are due to the paucity of robust studies in large populations. Moreover, the methods to calculate the FFM varies considerably, from skinfold thickness measurements to dual energy x-ray absorptiometry or use of magnetic resonance, with differing results according to the modality used (4). Finally, there is no solid consensus that FFM is the best method to scale cardiac dimensions. With this degree of uncertainty, we believe that the enthusiasm for using FFM should be moderated until large studies confirm its potential value.

We believe that our study provides an intriguing perspective on sex differences in LV geometry in athletes, suggesting that cardiac adaptation to exercise is different in males and females, particularly those engaged in dynamic sports. Because this may be a key to understanding the strikingly higher prevalence of sudden cardiac death in male athletes, further studies should be focused on this concept.

Gherardo Finocchiaro, MD
Harshil Dhutia, BSc, MBBS
Andrew D'Silva, MBBS
Aneil Malhotra, MBBS, PhD, MSc
Alexandros Steriotis, MD, PhD
Lynne Millar, MBBS
Keerthi Prakash, MBBS
Rajay Narain, MBBS
Michael Papadakis, MBBS
Rajan Sharma, BSc, MBBS, MD
Sanjay Sharma, BSc, MBChB, MD*

*St. George's University of London
Cardiovascular Sciences
Cranmer Terrace
London SW17 0RE
United Kingdom
E-mail: sasharma@sgul.ac.uk

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