ORIGINAL ARTICLE

Aortic Diameters in Elite Athletes

Dimensiones aórticas en deportistas de elite

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ABSTRACT

Background: Some authors suggest that aortic dilatation is part of the athlete's heart. The recent guidelines recommend indexing aortic diameters by body surface area (BSA). This variable can be greater in athletes due to increased muscle mass, and indexing for this parameter might underestimate the measurements.
Objective: The aim of this study was to compare aortic dimensions between elite rugby athletes and controls, evaluating different methods of quantification.
Methods: Maximum aortic diameter (MAD) and maximum diameter indexed by BSA (MAD-BSA) were quantified by echocardiography. The expected ideal weight was calculated for each individual and MAD was indexed by the expected body surface area (eBSA). Aortic dilatation was defined as MAD >40 mm or MAD-BSA to MAD-eBSA ratio >21 mm/m^2.
Results: Maximum aortic diameter was greater in athletes (34.9±2.6 mm vs 32.4±2.9 mm; p <0.01). Body surface area was significantly increased in athletes and, in this setting, MAD-BSA was lower (15.6±1.2 mm/m2 vs. 16.2±1.6 mm/m2; p=0.02).
After estimating the ideal weight, MAD-eBSA was not significantly different in both populations (16.3±1.3 mm/m2 vs. 16.6±1.3 mm/m2; p=0.2)
The percentage of patients with MAD >40 mm was similar in controls and athletes (2.3% vs. 1.7%, respectively; p=NS). None of the patients presented indexed diameters above the normal ranges.
Conclusions: Elite rugby players present larger maximum aortic diameters in absolute values in the context of greater BSA. Due to increased muscle mass, indexing by BSA could underestimate the measurements. The MAD-eBSA ratio could be a useful parameter. Aortic diameters above reference values should be considered abnormal.

Key words: Athlete's heart - Aortic dilatation – Echocardiography

RESUMEN

Introducción: Algunos autores sugieren que la dilatación aórtica forma parte del corazón de atleta. Guías recientes proponen indexar los diámetros aórticos por superficie corporal (SC). En deportistas, esta variable puede aumentar solo a expensas de la masa muscular y la indexación podría subestimar las dimensiones.
Objetivo: El objetivo del estudio fue comparar los diámetros aórticos en jugadores de rugby de elite vs controles, evaluando distintas formas de cuantificación.
Materiales y Métodos: Se cuantificó mediante ecocardiografía el diámetro aórtico máximo (AoMax) y el diámetro máximo indexado a SC (AoSC). Se calculó en forma adicional el peso ideal esperado para cada individuo y se estableció el diámetro aórtico indexado por SC esperada (AoSCe). Se definió como dilatación un AoMax mayor a 40 mm o un AoSC/AoSCe mayor a 21 mm/m^2.
Resultados: El AoMax fue mayor en deportistas (34,9±2,6 vs 32,4±2,9 mm; p<0,01). Los atletas tuvieron una SC significativamente mayor y, en este contexto, presentaron menor AoSC (15,6±1,2 vs 16,2±1,6 mm/m2; p=0,02).
Al realizar el cálculo del peso ideal y comparar el AoSCe, no se observaron diferencias (16,6±1,3 vs 16,3±1,3 mm/m2; p=0,2).
El porcentaje de pacientes con AoMax mayor a 40 mm fue similar en controles y deportistas (2,3% y 1,7%; p=NS). Ningún paciente presentó diámetros indexados en rango patológico.
Conclusiones: Los deportistas presentan mayores diámetros aórticos en términos absolutos, en contexto de una mayor SC. Debido al desarrollo muscular, la indexación por SC podría subestimar las dimensiones. El cálculo del AoSCe podría ser un parámetro útil. Dimensiones aórticas en rango patológico debe ser considerado anormal.

Palabras clave: Corazón de atleta - Dilatación aórtica – Ecocardiografía

Abbreviations

eBSA	Expected body surface area	MAD-eBSA	Maximum aortic diameter indexed by expected body surface area

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INTRODUCTION

Over a century ago, Henschen described cardiac enlargement in cross-country skiers by precordial percussion. (1) Years later, at the 1928 Olympic Games in Amsterdam, a group of German cardiologists performed a thorough evaluation and accurate description of the clinical and electrocardiographic characteristics of highly competitive athletes. (2)

Sports cardiology is a discipline that has developed significantly and exponentially up to the present day. There is a greater understanding of the "athletic heart syndrome" or "athlete's heart" as an entity and greater knowledge about the role of training in different clinical settings. Many of these advances developed during the 1970s and 1980s, with the introduction of complementary imaging tests such as echocardiography, nuclear medicine and magnetic resonance imaging.

Sinus bradycardia, increased stroke volume, improved myocardial perfusion and greater wall thickness and dimensions of the cardiac chambers are the main cardiovascular adaptations to training. (3, 4) Cardiac remodeling has proved to be a global process, affecting all the heart chambers. (5, 6)

The intensity and type of training are the most important variables that determine the development of these adaptations, and are more prevalent in those who perform high intensity isometric exercise. (7) According to Mitchell's sports classification, rugby has at least a moderate isometric and isotonic component. (8) Previous studies have demonstrated that rugby players develop athlete's heart. (9)

Some authors suggest that the aorta takes part in this clinical scenario, (10, 11) as aortic dilatation was found in athletes as a consequence of the hemodynamic changes that take place during exercise. (12) Different small sample size studies have evaluated aortic diameters without reaching significant conclusions. In addition, the interest of aortic diseases in athletes, although infrequent, has increased due to the association of sudden death with sports practice. (13)

Finally, transthoracic echocardiography is the first line test for assessing aortic size. The results are commonly expressed in absolute values; yet, recent guidelines recommend the use of indexed values due to the direct correlation between aortic dimensions and body surface area (BSA). (14-15) Athletes constitute a population with anthropometric characteristics very different from those of the general population, and also differ from one sport to another. In some cases, as this variable may increase due to greater muscle mass, indexing using this parameter might underestimate the measurements in this population. Rugby players are a good example of muscle building. In this setting, the estimation of the ideal weight and indexing aortic diameters by the expected body surface area (eBSA) results in a novel parameter that could overcome these difficulties.

Therefore, the aim of our study was to compare aortic dimensions between elite rugby athletes and a healthy population of non-athletes, evaluating different methods of quantification.

METHODS

From January 2017 to February 2018, we prospectively included elite rugby players and male non-athletes (controls) between 18 and 35 years of age who attended our center. Patients with a history of any disease, bicuspid aortic valve or family history of aortic diseases were excluded.

The aorta was evaluated by transthoracic echocardiography using an ultrasound machine with a 2-4 MHz transducer (Vivid S5; GE Vingmed Ultrasound, Israel). Five university cardiologists specialized in echocardiography and trained in assessing the aorta (level III) performed the tests. The aortic diameters were measured at the levels of the aortic annulus, sinuses of Valsalva, sinotubular junction, tubular ascending aorta, aortic arch and descending thoracic aorta. The diameters were measured at end-diastole from leading edge to leading edge, except for the aortic annulus which was measured at midsystole from inner edge to inner edge, following current international recommendations.

Body surface area was calculated using the DuBois formula [BSA (m^2) = 0.007184 x height (cm)0.725 x weight (kg)0.425]. The maximum aortic diameter (MAD) and the maximum diameter indexed by BSA (MAD-BSA) were established. As rugby players have higher weight due to increased muscle mass, we also calculated the ideal weight. Many formulas are available for such estimation, but due to the lack of bibliography recommending one over the other, we used the one designed by the World Health Organization (WHO) in 1985 {ideal weight = [height (cm)/100]2 x 23 ± 10%} and the Broca index [ideal weight = height (cm) - 100 ± 10%]. (16) Maximum aortic diameter indexed by the expected BSA (MAD-eBSA) was determined for each of these results. Aortic dilatation was defined as MAD >40 mm or MAD-BSA to MAD-eBSA ratio >21 mm/m^2.

Statistical analysis

A two-tailed Student's t test was used to compare the diameters of both populations. The chi-square test with Yates correction or Fisher's exact test were used to analyze the proportions of patients with aortic dilatation. Continuous variables were expressed as mean ± standard deviation and qualitative variables as percentage. A p value <0.05 was considered statistically significant.

All the statistical calculations were performed using STATA software package.

Ethical considerations

The study was conducted following the medical research recommendations suggested by the Declaration of Helsinki, Good Clinical Practice Guidelines and ethical principles in force.

RESULTS

A total of 58 athletes and 87 controls were included. Mean age was 24.2±3.4 years and 25.6±5.9 years, respectively (p=NS). Compared with controls, athletes were taller (184.5±7.8 vs. 177.7±7.4 cm; p <0.01), had higher weight (98.6±13.6 kg vs. 82.9±14.3 kg; p <0.01) and, thus, greater BSA (2.24±0.19 vs. 2.02±0.19; p <0.01). The echocardiogram showed the typical adaptations to exercise, with increased left ventricular diastolic dimension (56.2±4.1 vs. 51.6±4.4 mm; p <0.01), indexed left ventricular mass (99.9±14.3 vs. 82.7±16.5 g/m^2; p <0.01) and indexed left atrial volume (32.1±5.6 vs. 27.2±8.3 ml/m^2; p <0.01). The clinical and echocardiographic characteristics of the population are described in Table 1.

Athletes presented greater absolute aortic diameters in four of the six aortic segments evaluated, with no significant differences in the aortic annulus diameter and descending thoracic aorta diameter (Figure 1).

Mean aortic diameter was greater in athletes (34.9±2.6 mm vs. 32.4±2.9 mm; p <0.01) but within normal ranges. When MAD was indexed by BSA, this difference was reversed and controls had the largest diameters (16.2±1.6 2 mm/m^2 vs. 15.6±1.2 mm/m^2; p=0.02), reflecting the limitations of indexing by BSA in patients with increased muscle mass (Figure 2).

The ideal weight estimated by the WHO formula was 80.1±6.6 kg in controls and 86.3±7.3 kg in athletes. This represented a mean decrease of 2.8 kg in controls and 12.3 kg in athletes compared with the real weight, with expected body surface area (eBSA) of 1.99±0.12 m2 and 2.10±0.13 m2, respectively (p <0.01). The eBSA was significantly lower than the real BSA in athletes, with a decrease of 0.14 m^2 (p <0.01), but was not different in controls (p=NS). In this setting, MAD-eBSA was not significantly different in both populations (16.3±1.3 mm/m^2 vs. 16.6±1.3 mm/m2; p=NS) (Figure 2). The results were similar when the Broca index was used (15.8±1.3 mm/m^2 vs. 16±1.2 mm/m^2; p=NS) (Table 2).

The percentage of patients with aortic root dilatation was low and similar in both groups in absolute

Table 1. Clinical and echocardiographic characteristics of the population

	Controls	Athletes	p
Age (years)	25.6 ± 5.9	24.2 ± 3.4	NS
Height (cm)	177.7 ± 7.4	184.5 ± 7.8	< 0.01
Weight (kg)	82.9 ± 14.3	98.6 ± 13.6	< 0.01
BSA (m2)	2.02 ± 0.19	2.24 ± 0.19	< 0.01
eBSA-Broca (m2)	2.05 ± 0.14	2.18 ± 0.15	< 0.01
eBSA-WHO (m2)	1.99 ± 0.12	2.10 ± 0.13	< 0.01
LVDD (mm)	51.6 ± 4.4	56.2 ± 4.1	< 0.01
LVSD (mm)	31.2 ± 4.1	34.2 ± 4.2	< 0.01
Septal thickness (mm)	9.3 ± 1.3	10.5 ± 0.8	< 0.01
Posterior wall thickness (mm)	8.6 ± 1.3	9.6 ± 0.9	< 0.01
LVMI (g/m2)	82.7 ± 16.5	99.9 ± 14.3	< 0.01
RWT	0.33 ± 0.05	0.34 ± 0.03	NS
LVEF (%)	63.1 ± 4.6	62.1 ± 3.9	NS
LA volume index (ml/m2)	27.2 ± 8.3	32.1 ± 5.6	< 0.01
E/A ratio	1.7 ± 0.6	1.8 ± 0.4	NS

BSA: Body surface area. eBSA; Expected body surface area estimated by the Broca method and the WHO (World Health Organization) formula. LVDD: Left ventricular diastolic dimension. LVSD: Left ventricular systolic dimension. LVMI: Left ventricular mass indexed by body surface area. RWT: Relative wall thickness. LVEF: Left ventricular ejection fraction, LA: Left atrial.

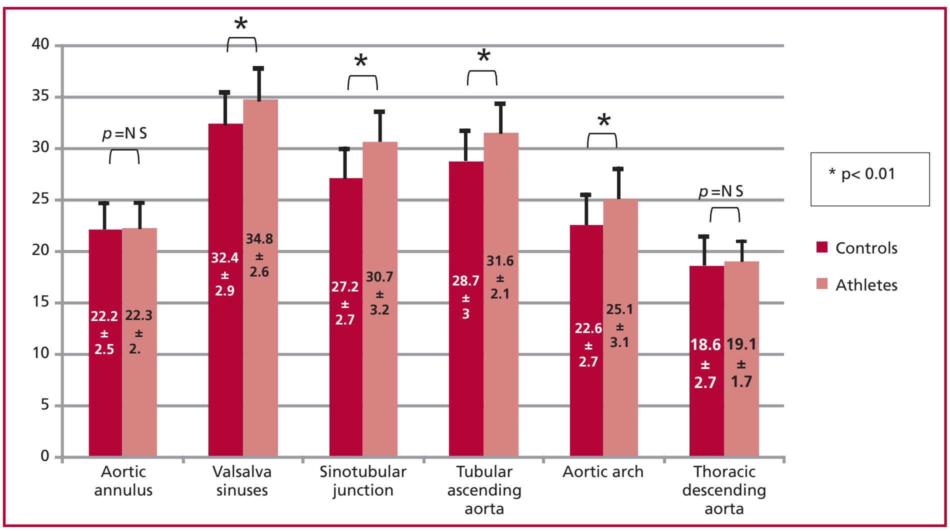


Fig. 1. Comparison of aortic diameters in controls and elite athletes evaluated at six levels, expressed in absolute terms.

terms (2.3% in controls and 1.7% in athletes; p = NS). The aortic diameter indexed by BSA or eBSA did not exceed 21 mm/m² in any of the patients.

DISCUSSION

To our understanding, this is the first study introducing a new method of aortic diameter assessment in patients in whom the disproportionate increase in muscle mass results in underestimation of the diameters indexed by BSA. The estimation of the ideal weight and MAD indexed by eBSA is a novel parameter that could overcome these difficulties.

In our study, elite athletes presented greater MAD; however, they were within the normal range. Therefore, diameters above reference values should suggest the presence of an aortic disorder. Body surface area was also greater in athletes, mostly due to increased weight as a consequence of greater muscle mass. In this setting, after indexing by this variable, the difference between both populations not only disappeared but also reverted, resulting in higher MAD-BSA in controls. This demonstrates the underestimation generated when indexing this variable in athletes with these anthropometric characteristics.

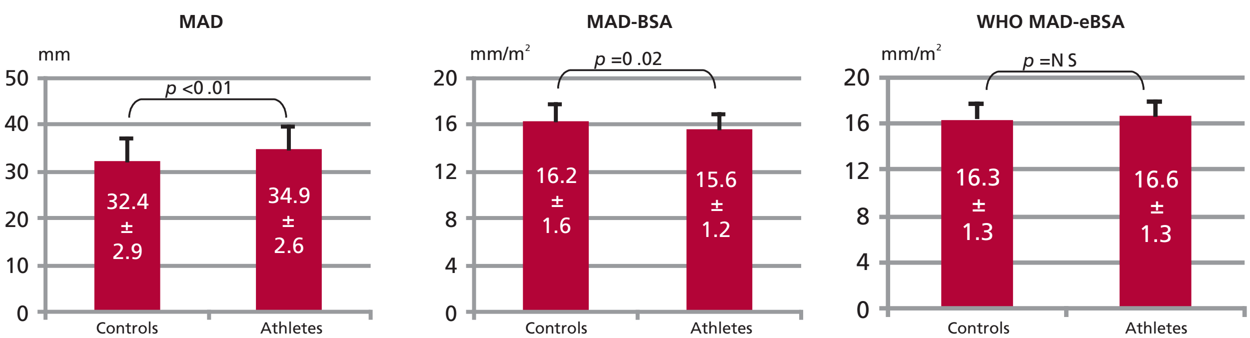
According to our results, a significant decrease was observed in the eBSA compared with BSA in the group of athletes, without differences in the control group. This change was notably reflected when the two populations were compared, resulting in similar dimensions of MAD-eBSA, with any of the two formulas proposed. According to this variable, rugby per se would not generate a significant aortic dilatation.

Different studies with small sample size have described greater aortic diameters in athletes compared with controls. (17) As mentioned above, these studies included a low number of subjects, few studies analyzed the aorta at its different levels, and the method of measurement was not standardized. For these reasons, added to variations of their results, these group of studies as a whole are not conclusive.

The publications with the greatest number of patients, and perhaps the most relevant in the literature, are the cohort studies conducted by Pelliccia et al. (18) and Boraita et al. (19) These authors included 2,317 and 3,281 athletes, respectively, and although the aortic root diameters described were within the normal range, they did not use a control group. Therefore, the impact of exercise on the size of the aorta results difficult to infer.

One of the strengths of our study is that we measured the aortic diameters not only at the four levels of the aortic root, but also at the aortic arch and descending aorta, which had not been previously evaluated. On the other hand, the diameters were measured according to current recommendations, another aspect that provides additional value.

As observed in main cohort studies, only a small percentage of patients had abnormal diameters in



MAD: Maximum aortic diameter. MAD-BSA: Maximum aortic diameter indexed by body surface area. WHO MAD-eBSA: Maximum aortic diameter indexed by the expected body surface area estimated using the WHO (World Health Organization) formula.

Fig. 2. Ideal weight, expected body surface area and maximum aortic diameter indexed by the expected body surface area according to the Broca index and the World Health Organization formula.

Table 2. Ideal weight, eBSA and MAD-eBSA according to the Broca index and the WHO formula.

		Controls	Athletes	p
Broca index	Weight (kg)	85.6 ± 8.2	93 ± 8.6	< 0.01
	eBSA (m2)	2.05 ± 0.14	2.18 ± 0.15	< 0.01
	MAD-eBSA (mm/m2)	15.8 ± 1.3	16 ± 1.2	NS
WHO formula	Weight (kg)	80.1 ± 6.6	86.3 ± 7.3	< 0.01
	eBSA (m2)	1.99 ± 0.12	2.10 ± 0.13	< 0.01
	MAD-eBSA (mm/m2)	16.3 ± 1.3	16.6 ± 1.3	NS

eBSA: Expected body surface area. MAD-eBSA: Maximum aortic diameter indexed by the expected body surface area. WHO: World Health Organization absolute values, with no differences between both groups. The maximum diameter observed was 41 mm, just above the upper normal limit established. After indexing for BSA or eBSA, the highest value was 21 mm/m^2.

Among the limitations our study is the inclusion of a low number of patients, analyzing only one sport and not including female athletes. As with any cross-sectional study, we cannot draw conclusions about the long-term impact.

The concept of eBSA is an attractive variable that could be applied to other echocardiographic variables, in athletes from other sports, and extended to other populations, such as obese patients, where indexing by BSA underestimates different parameters.

CONCLUSIONS

Elite rugby players present larger MAD in absolute values in the context of a greater BSA. Yet, these values are within the normal range. Indexing by BSA could underestimate the dimensions as a result of the disproportionate increase in this variable due to muscle building. Maximum aortic diameter indexed by eBSA is a novel parameter that could overcome these difficulties.

Aortic diameters above reference values should be considered abnormal.

Conflicts of interest

None declared.

(See authors' conflicts of interest forms on the website/ Supplementary material).

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