Ultrasonographic study of left ventricular function at rest in a group of highly trained black African handball players

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KEYWORDS
Black African; Echocardiography; Handball; Left ventricle; Sport

Abstract
Aims: Most of the studies of athlete’s heart have been performed on Caucasian and yet, evidence suggests that there are racial differences in the response of the heart to certain pathological conditions such as hypertension. This study aimed to evaluate the morphologic cardiac changes in a group of highly trained Cameroonian handball players.

Methods and results: We studied cardiac morphology and function as assessed by echocardiography at rest in 21 asymptomatic international level handball players and 21 age-, sex-, height- and weight-matched sedentary controls. Echocardiographic variables were compared between groups using unpaired t-test.

Compared with controls, wall thickness, relative wall thickness (h/R), left ventricular (LV) mass, LV end diastolic diameter (LVEDD) and left atrial diameter were significantly greater in athletes. None of the athlete exhibited a wall thickness above 12 mm. The ejection fraction (EF) and the mitral pattern on pulsed wave Doppler did not differ in the two groups.

Abbreviations: LV, left ventricular; SWT, septal wall thickness; PWT, posterior wall thickness; LVEDD, LV end diastolic diameter; LVESD, LV end systolic diameter; EF, ejection fraction; WT, wall tension; MWS, meridional wall stress.

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Introduction

Long-term athletic training is associated with cardiac changes, including increased left ventricular (LV) cavity dimension, wall thickness, and calculated mass, that have been extensively studied and are commonly described as ‘‘athlete’s heart’’. The extent of these changes varies between sports and complicates the differentiation between these normal physiologic changes and hypertrophic cardiomyopathy. Almost all studies of athlete’s heart have been performed on Caucasian individuals; hence there is limited data on the cardiac response to exercise in black African individuals. There is evidence suggesting that there are racial differences in the response of the heart to certain pathological conditions such as hypertension. For example, it is well recognized that Afro-Caribbean patients with systemic hypertension demonstrate a more significant increase in LV mass than Caucasian individuals. Therefore it seems possible that the increased preload and/or afterload or the increased in systolic blood pressure during prolonged exercise in black African individuals may give rise to more marked morphological changes as part of the normal physiological adaptation process. These considerations prompted us to use echocardiography to evaluate the left ventricular function at rest in a group of highly trained Cameroonian handball players.

Methods

Subjects

From January to June 2003, all the handball players from the team of the Cameroon’s armed forces and police were invited to take part in the study. This team plays at an international level and is the year 2000 African champion and the 2003 national titleholder. During their competitive season, 21 men out of 22 athletes (participation rate 95.4%) aged 21 to 32 years with handball as their main training modality gave their written informed consent and joined the study. The control group consisted of 21 age-, sex-, height- and weight-matched sedentary men, students, shopkeepers or unemployed, none of whom exercised over 2 h per week, selected after their written inform consent. All athletes and control subjects were asymptomatic black Africans living in Yaoundé and free of known cardiac disease. None of these subjects was known to be using anabolic steroids or any other medications that may cause cardiac muscle hypertrophy.

Study protocol

The study protocol was approved by the ethics committee of Yaoundé General Hospital (Yaoundé, Cameroon). At an initial fitness and familiarization session, each subject completed a general health questionnaire and was then assessed for age, weight, height, blood pressure (BP), training hours per week, and length of training (years). BP was measured at the right upper arm in a seated subject after 5 min resting using an automated blood pressure device. The average of two consecutive readings taken 3 min apart was considered. All anthropometric and blood pressure measurements were performed by the same qualified observer. The subject then participated in echocardiography and Doppler echocardiography at rest. All tests were done between 08:00 and 12:00 h on the same day for each individual.

Echocardiographic measurements

Echocardiographic and Doppler studies were performed with a Sonoline CD Siemens instrument equipped with a 2.5 MHz transducer. At rest, subjects were positioned at 30° left lateral position. An integrated M-mode and two-dimensional study was done to determine septal wall thickness (SWT), posterior wall thickness (PWT), LV end-diastolic diameter (LVEDD) and LV end-systolic diameter (LVESD), consistent with the recommendations of the American Society of Echocardiography. Particular effort was made not to include overlying trabeculations in the ventricular septum or posterior wall measurements, which may overestimate wall thickness. The LV mass was calculated using the formula

Conclusions: Both LVEDD and wall thickness of elite Cameroonian handball players are increased. There is an increased h/R. The LV EF was normal and not supranormal, as is sometimes believed. These cardiac changes are consistent with cardiac adaptation required in this type of sportsmen who are submitted both in endurance and resistance training.
Measurements were quoted with body surface area (BSA) calculated with the formula of Dubois and Dubois. Relative wall thickness in diastole (h/R) was calculated by dividing the sum of the septal and posterior wall thickness at end-diastole (h) by the LVEDD. LV afterload was estimated as end systolic LV meridional wall stress (MWS), calculated using the following formula: 

$$\text{MWS (dyn/cm}^2\text{)} = \frac{0.334 \times \text{systolic BP} \times \text{LVESD}}{(\text{PWT} \times (1 + \text{PWT}/\text{LVESD}))}.$$ 

LV wall tension (WT) was calculated using the following formula: 

$$\text{WT (dyn/cm)} = \frac{1.33 \times \text{systolic BP} \times \text{LVESD}/2.}$$

Measurements of LV diastolic filling velocities were obtained in an apical four-chamber view by positioning the pulsed Doppler volume sample just below the mitral annulus. Early peak flow velocity ($V_E$), peak atrial flow velocity ($V_A$) and deceleration time were measured. The ratio $V_E/V_A$ was then calculated. The aortic flow velocity was also recorded.

All echocardiographic measurements were performed by the same experienced observer and obtained directly from the screen monitor with the aid of calipers and the instrument’s trackball. Each measurement was made on three consecutive cardiac cycles and an average of the three values was considered.

**Statistical analysis**

All statistical analyses were performed with SPSS for Windows release 9.0 (SPSS, Chicago, IL, USA). Results are expressed as means ± standard deviation (SD) when appropriate. Normal distribution of variable was checked using the Kolmogorov–Smirnov test. The comparison of means of quantitative variables between athletes and control subjects was performed using the two-tailed Student $t$-test for unpaired variables. A $P$ value less than 0.05 was considered significant.

**Results**

**Clinical characteristics of handball players and control subjects**

Characteristics of the athletes and control subjects at rest are given in Table 1. The athletes had much lower heart rates, but resting BP was similar between the two groups. There was no statistically significant difference elsewhere.

**Doppler echocardiographic left ventricular measurements in handball players and control subjects**

Table 2 depicts LV measurements at rest in control subjects and athletes. The PWT, the LVEDD and the atrial dimension were significantly larger in handball players, but the LVESD was similar in both groups. The maximal value of LVEDD in our athletes was 58 mm and none of them had a septal or posterior wall thickness above 12 mm. The indexed LV mass was 36.9% larger on average in the athletes. Shortening and ejection fraction were similar in both groups. There was a significant increase in h/R ratio in athletes compared to controls. Wall stress and wall tension was similar in

<table>
<thead>
<tr>
<th>Variable</th>
<th>Handball players (n = 21)</th>
<th>Control subjects (n = 21)</th>
<th>% Difference</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25.1 ± 3.1</td>
<td>25.43 ± 3.4</td>
<td>−1.2</td>
<td>NS</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.9 ± 6.9</td>
<td>177.7 ± 6.9</td>
<td>+0.1</td>
<td>NS</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.8 ± 11.1</td>
<td>77.9 ± 11.1</td>
<td>−0.1</td>
<td>NS</td>
</tr>
<tr>
<td>Body surface area (m$^2$)</td>
<td>1.95 ± 0.16</td>
<td>1.96 ± 0.16</td>
<td>−0.5</td>
<td>NS</td>
</tr>
<tr>
<td>Body mass index (kg/m$^2$)</td>
<td>24.5 ± 2.6</td>
<td>24.6 ± 2.6</td>
<td>−0.0</td>
<td>NS</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>59 ± 12</td>
<td>70 ± 4</td>
<td>−15.7</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>125 ± 8</td>
<td>126 ± 7</td>
<td>−0.8</td>
<td>NS</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>79 ± 7</td>
<td>77 ± 7</td>
<td>+2.6</td>
<td>NS</td>
</tr>
<tr>
<td>Training (h/week)</td>
<td>11 ± 2</td>
<td>&lt;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of training (years)</td>
<td>10 ± 3</td>
<td>3 ± 11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are means ± SD (standard deviation) and range, for 21 handball players and 21 control subjects. NS, not significant.
as a moderate static and high dynamic sport, 15 ing in African handball.

Cardiac dimensions found in our study of handball players are globally similar to average values reported among Caucasian athletes pursuing a variety of other sports: increased left atrial diameter, LV septal and posterior wall thickness, LVEDD, and indexed LV mass whereas LV end systolic diameter was similar in both athletes and controls. Blaire et al. 16 reported similar findings in a variety of sports such as cycling and football. Compared to controls, increased LVEDD in this study was 54.1 mm in athletes with an increased percentage 8.6%. This result correlates with the findings of Cohen and co-workers in Caucasian well-trained judokas. 17 Kingue and co-workers also reported similar findings in black African judokas. 18 None of our athletes showed a LVEDD above 60 mm. Douglas et al. 19 also reported an increased LVEDD (50.1 mm) in Caucasian football players with no value above 60 mm. According to the literature, LVEDDs above 60 mm are exceptional and only reported in cycling. 1

Wall thickness in our study athlete group is 9.2 mm (difference +13.6%) for the posterior wall

Discussion

In general, studies have proven that athletes participating in purely endurance sports such as long distance running and tennis are subject to chronic increases in cardiac preload, while those participating in purely resistance sports such as weightlifting and body-building tend to develop a large increase in LV wall thickness to normalize wall tension but without much increase in left ventricular cavity size. 3,4,13 This variation of change in cardiac dimensions between athletes and training methods complicates the distinction between physiological athlete’s heart and pathological conditions with possible critical implications for professional athletes. 13,14 Handball has been recently classified as a moderate static and high dynamic sport, 15 therefore involving a combination of resistance and endurance training. It is a popular sporting discipline in sub-Saharan Africa, and cardiac adaptations peculiar to training for this sport in black Africans have not been described. We intended to assess the cardiac structural changes commonly seen among athletes intensely training and competing in African handball.

Our findings suggest that: (i) there is increased LV mass in handball players; (ii) this increased mass is predominantly due to increased LVEDD but there is also an increased in sum of wall thickness and relative wall thickness; (iii) the LV EF was normal.

LV morphology and type of athlete’s heart

The cardiac morphologies found in our study of handball players are globally similar to average values reported among Caucasian athletes pursuing a variety of other sports: increased left atrial diameter, LV septal and posterior wall thickness, LVEDD, and indexed LV mass whereas LV end systolic diameter was similar in both athletes and controls. Blaire et al. 16 reported similar findings in a variety of sports such as cycling and football. Compared to controls, increased LVEDD in this study was 54.1 mm in athletes with an increased percentage 8.6%. This result correlates with the findings of Cohen and co-workers in Caucasian well-trained judokas. 17 Kingue and co-workers also reported similar findings in black African judokas. 18 None of our athletes showed a LVEDD above 60 mm. Douglas et al. 19 also reported an increased LVEDD (50.1 mm) in Caucasian football players with no value above 60 mm. According to the literature, LVEDDs above 60 mm are exceptional and only reported in cycling. 1

Wall thickness in our study athlete group is 9.2 mm (difference +13.6%) for the posterior wall

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Echocardiographic left ventricular measurements in handball players and sedentary control subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Handball players (n = 21)</td>
</tr>
<tr>
<td>Aortic root (mm)</td>
<td>29.6 ± 3.6</td>
</tr>
<tr>
<td>Left atrium, diameter (mm)</td>
<td>38.2 ± 4.6</td>
</tr>
<tr>
<td>LV, end diastolic diameter (mm)</td>
<td>54.1 ± 4.2</td>
</tr>
<tr>
<td>LV, end systolic diameter (mm)</td>
<td>32.6 ± 4.1</td>
</tr>
<tr>
<td>Posterior wall thickness (mm)</td>
<td>9.2 ± 1.2</td>
</tr>
<tr>
<td>Septal wall thickness (mm)</td>
<td>10.6 ± 1.2</td>
</tr>
<tr>
<td>Sum of LV wall thickness (mm)</td>
<td>20.1 ± 1.4</td>
</tr>
<tr>
<td>Relative wall thickness (h/R)</td>
<td>0.38 ± 0.03</td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>261 ± 28</td>
</tr>
<tr>
<td>Indexed LV mass (g/m²)</td>
<td>133.1 ± 26.7</td>
</tr>
<tr>
<td>Meridional wall stress (dyn/cm²)</td>
<td>40.4 ± 1.3</td>
</tr>
<tr>
<td>Wall Tension (dyn/cm)</td>
<td>1.67 ± 0.3</td>
</tr>
<tr>
<td>Shortening fraction (%)</td>
<td>40 ± 5.0</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>63.7 ± 5.6</td>
</tr>
<tr>
<td>Aortic flow velocity (m/s)</td>
<td>113.2 ± 14.8</td>
</tr>
<tr>
<td>Transmitral V₆ (cm/s)</td>
<td>82.6 ± 23.9</td>
</tr>
<tr>
<td>Deceleration time (DT) (s)</td>
<td>145 ± 30</td>
</tr>
<tr>
<td>Transmitral V₆ (cm/s)</td>
<td>53.3 ± 24.1</td>
</tr>
<tr>
<td>Vₑ/V₆</td>
<td>1.66 ± 0.44</td>
</tr>
</tbody>
</table>

Values are means ± SD (standard deviation), for 21 handball players and 21 control subjects. LV, left ventricular; Vₑ, early peak flow velocity; V₆, peak atrial flow velocity; NS, not significant.
and 10.6 mm (difference $+10.1\%$) for the SWT. There is an increase in indexed LV mass among our group of handball players compared to control subjects; however, none of our athletes had a wall thickness above 12 mm. These findings are similar with previously reported populations of other athletic disciplines including basketball and football.\textsuperscript{4,19,20}

Morganroth et al.\textsuperscript{21} were the first to postulate that two different morphological forms of athlete’s heart can be distinguished: a strength-trained and an endurance-trained. Since then several studies\textsuperscript{2–4,20} have evidenced the two distinct models cardiac adaptation to training. Endurance athletes involved in training with high dynamic aerobic component develop predominantly increased in LV chamber size, with proportional increase in wall thickness and LV stroke volume caused by volume overload, thus showing an eccentric LV hypertrophy. On the other hand, strength-trained athletes, mainly involved in static isometric anaerobic exercise, show increased LV sum of wall thickness and relative wall thickness (usually above 0.45), with a pattern of LV concentric geometry caused by pressure overload specific to this kind of effort.\textsuperscript{21} In the present study, we found an increase LVEDD but also a significant increase in wall thickness and h/R ratio in athletes compared to controls. However, the mean value did not reach the diagnostic cut-off for concentric LV hypertrophy. Moreover, wall tension and wall stress at rest were similar in the two groups. Difference in the training regiments is likely to provide an explanation to the observed increase in h/R ratio with more emphasis on resistance training. However, objective information gathered from the training staff ague against such an explanation, since all players are said to have been submitted to four to five sessions per week of handball training. A potential limitation of this study comes from the fact that we did not study LV function during exercise. But it is possible as proven elsewhere\textsuperscript{20} that sustained episodes of high cardiac output and volume overload that occur in handball matches are responsible for preferential increase LV chamber size in our athletes with less effect on wall thickness. This is in line with the previous demonstration by Spirito et al.\textsuperscript{4} in the largest study in athletes to date that sports differ greatly with regard to their impact on LV dimensions. They also reported that in general, athlete training in sports associated with large diastolic cavity dimension also have relatively high values for wall thickness. Therefore in our group of handball players with an increase in both LV internal dimension and wall thickness, a classification as endurance or strength-trained heart seems not to be appropriate.

Left ventricular systolic function is commonly assessed by ejection fraction (EF)\textsuperscript{6} and there is a perception among some that the EF of a well-trained athlete should be supranormal. However, some studies prove this to be unlikely. Our results are similar to those of Pluim and co-workers\textsuperscript{20} who reported from a large meta-analysis of 59 echocardiographic studies on 1451 athlete’s findings that LV systolic function at rest as assessed by EF or fractional fiber shortening is similar to findings in sedentary control subjects.

The mean left atrial dimension in our study athletes was similar to the value reported by Pellicia and colleagues\textsuperscript{22} in Italian competitive athletes. This left atrial remodeling in athletes may be regarded as a physiologic adaptation to exercise conditioning, largely without adverse clinical consequences.\textsuperscript{22}

**Physiologic vs. pathologic LV hypertrophy**

Differentiating physiologic from pathologic LV hypertrophy is an important challenge, as highly trained competitive athletes without apparent heart disease can develop markedly thickened ventricular walls that may resemble hypertrophic cardiomyopathy.\textsuperscript{3,4,14} Among the criteria used to differentiate between the pathological LV hypertrophy and the adaptive hypertrophy of athletes, LV diastolic filling is a valuable tool. Several authors\textsuperscript{2,4,18,20} have reported a normal diastolic filling in physiological hypertrophic states, whereas pathologic LV hypertrophy such hypertrophic cardiomyopathy or aortic stenosis affects diastolic filling. In the present study, in spite of the difference in wall thickness, LVEDD and LV mass, LV diastolic filling assessed by pulsed Doppler studies of early peak flow velocity ($V_e$) and peak atrial flow velocity ($V_A$) and the ratio $V_e/V_A$ showed no difference between handball players and control subjects, suggesting a normal diastolic filling. It is therefore very unlikely that someone among our athletes had hypertrophic cardiomyopathy.

In conclusion, this study shows that highly trained Cameroonian handball players have increased LV indexed mass, LVEDD, sum of wall thickness and relative wall thickness, similar to previous reports in several Caucasian athletic populations. The increased LV mass in handball players is predominantly due to increased preload. Unlike the common belief, the LV EF is normal and not supranormal. These morphological cardiac changes are the result of the adaptation required in this type of sportsman who are submitted both to endurance and resistance training. In screening a black African athletic population, wall thickness above 12 mm or LV end
diastolic diameter above 60 mm should urge the clinician to rule out hypertrophic cardiomyopathy. However, because our study population was only male, caution should be exercised in extrapolating our findings to female athletes.

References