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Study of the Right Heart of High-Level African Adult Athletes: Electrocardiographic and Echocardiographic Aspects

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Abstract

Despite the growing interest in athlete's right ventricle and various work carried out, many uncertainties are remaining. The interest of this work resides in the determination of the particularity in right heart of the black athlete subject. We conducted a prospective study from August to October 2016 in the cardiology department of Aristide Le Dantec University Hospital in Dakar. The included patients were divided according to the sporting practice as enduring, resistant and non-athletes. The parameters studied were electrocardiographic (atrial or ventricular hypertrophies), echocardiographic: dimensions of the right cavities, systolic and diastolic functions of the right ventricle. We included 58 subjects: 38 athletes including 28 endurance and 10 resistance and 20 non-athletes. The average age of the endurance athletes was 21.9 ± 3, 75 years, 26.30 ± 4.64 in resistance ones and 24.10 ± 1.89 in the non-athletic group. Two cases of first-degree atrioventricular block were recorded in athletes. On the echocardiographic point, the atrium surfaces, as well as the transverse diameter, were greater in athletes, especially in the endurance group. The mean diameters of the admission chamber and those of the right ventricular flush chamber were larger in the group of endurance athletes. It was the same for the annular and sagittal basal mean diameters of the RV as well as the RV/LV ratio. The anterior wall of the right ventricle was larger in athletes compared to non-athletes. The vena cava was greater in athletes, the pulmonary arterial pressure higher in resistance ones.

Keywords

Right Ventricle, Black African Athletes, Dilation, Endurance

1. Introduction

Athlete's heart consists of all cardio-circulatory adjustments related to the practice of a physical activity equivalent to a high level of training. These result from neuro-hormonal and hemodynamic changes. Hemodynamic overload due to the long-term consequences of physical exercise usually concerns both ventricles [1] [2] [3].

Historically, research on cardiovascular adaptation in athletes focused on the left heart. Recently, the right ventricle is of increasing interest to authors, and publications continue to increase, explaining the remodeling of the right ventricle associated with physical exercise [4] [5].

Authors report an acute particular effect of exercise on the right ventricle, particularly its function, compared to the left ventricle [6]. Many uncertainties remain as to the characteristics of the athlete's heart right ventricle. This is even truer for Africans when we know the racial particularities that there may be in this matter.

The interest of our work resides in this insufficiency of data on the morphology and the function of right ventricle of African athletes practicing sports. The main objective was to study particularities of the right heart of subjects practicing endurance or resistance sports of high level of training compared to the right heart of non-athlete subjects.

Specifically, it was:

- to compare electrocardiographic data between three subgroups (endurance athletes, resistance ones, and non-athletes),
- to compare the right cavity dimensions,
- to clarify the difference in regards to the systolic and diastolic function data.

2. Methodology

We conducted a prospective study from August to October 2016 in the cardiology department of Aristide Le Dantec University Hospital in Dakar. The included patients were divided according to the sporting practice in enduring, resistant and non-athletes.

2.1. Inclusion Criteria

Athletes: male subjects performing sports and who agreed to participate in the study, with a minimum of 8 hours of weekly training and who have been playing sports for more than two consecutive years selected from a national sports federation.

Non-athletes: Men who do not play sports or whose weekly volume does not reach 8 hours.

2.2. Exclusion Criteria

Congenital heart disease, valvulopathy or any other acquired cardiomyopathy.

2.3. Ethical Considerations

After explaining the study protocol, the participants were informed of the progress and obtaining their consent was mandatory.

2.4. Studied Parameters

At the interrogation: age, type, number of hours

Clinical parameters: blood pressure (BP), heart rate (HR), body surface area (BSA) and body mass index (BMI).

12-Lead Surface ECG: All subjects had a standard 12-lead resting electrocardiogram on a CardiMax Fx 7102 device. These plots were interpreted by a single senior cardiologist. The study included: rhythm, heart rate, PR interval, P wave, QRS complex, repolarization (inversion of the T wave, loose T wave, ST shift, early repolarization), and ventricular overload (Lewis index [(RI-RIII) + (SIII-SI)]), and Sokolow-Lyon index (RV1 + SV5 > 1.04 mV) Sokolow-Lyon index of the right ventricle ≥ 10.5 mV and/or Lewis < 14 index showed right ventricular hypertrophy.

2.5. Doppler Echocardiography

Echocardiographic examinations were performed by a single operator on a GE Vivid 7 ultrasound system. All measurements were performed according to the recommendations of the American Society of Ultrasound [7]. Several cuts were used: left parasternal long axis view, short axis, apical four chambers, two cavities and subcostal incidence. Seven cavity measurements of the right ventricle were performed (Figure 1).

Echocardiographic parameters measured were:

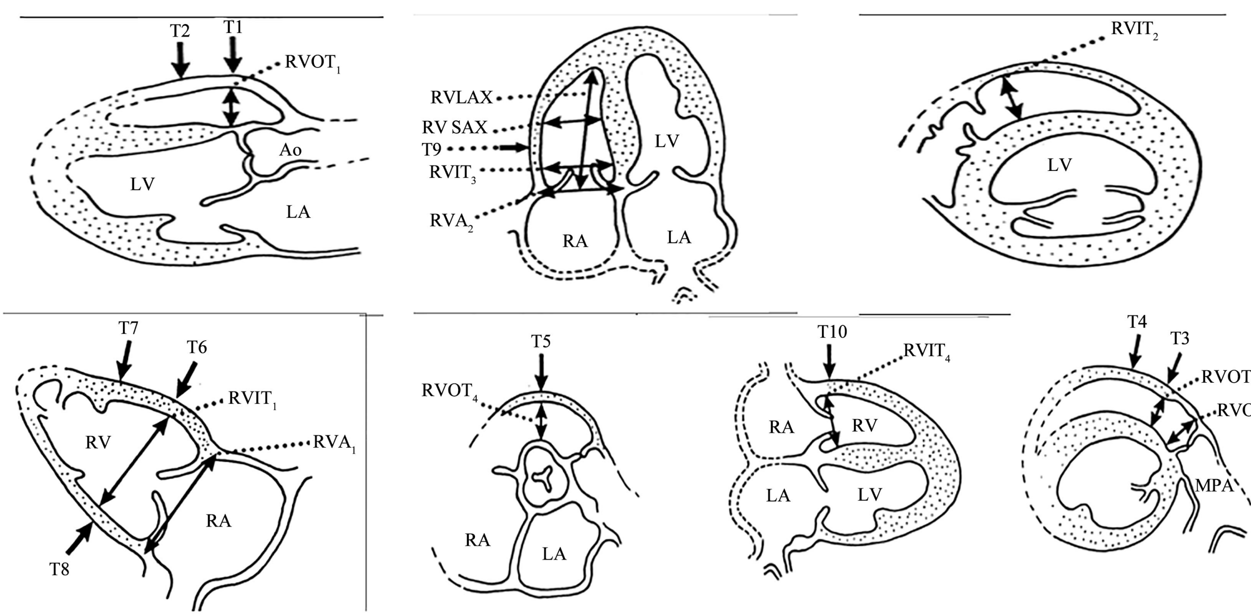

Figure 1. Scheme of different diameters of the right ventricle.

- Right atrium: surface, diameter, volumes
- Right ventricle: different diameters (Figure 1), surfaces, free wall, ratio RV/LV
- Systolic function of the right ventricle: TAPSE (tricuspid annular plane systolic excursion), Sa (S-wave from the tricuspid ring to tissue Doppler), Isovolumetric contraction peak, Fraction of surface shortening, Simpson RV
- Diastolic function of RV: tricuspid venous flow (E, A, E/A, E-wave deceleration time (TD), E, "E/E", Isovolumetric relaxation time, RV-RA systolic pressure gradient, pulmonary artery systolic pressure, supra-hepatic venous flow

Sociodemographic, clinical and paraclinical data were identified using a survey form designed for this study. Then they were captured and analyzed with the SPSS (Statistical Package for Social Science) software version 18. The averages and percentages were compared using the Student's test, the Chi-square test, and the exact Fischer test, according to their conditions of applicability. We compared proportions and averages in the three subgroups of subjects. A statistically significant difference was selected for a value of $p < 0.05$.

3. Results

We have enrolled 38 athletes including 28 from the Senegalese football federation, 10 from the martial arts and 20 non-athletes.

The average age of the enduring athletes (footballers) was 21.9 ± 3, 75 years, 26.30 ± 4.64 for the resistant ones (martial arts practitioners) and 24.10 ± 1.89 years old in the group of non-athletes. The average weekly volume in the endurance athletes group was 11.07 ± 2.12 hours per week and 10.70 ± 2.11 hours per week in resistance athletes. In the non-athletic group, there were less than 3 hours per week. Table 1 summarizes the characteristics of our population according to the sport and the type of sport performed.

Table 1. Characteristics of study population and comparison between the 3 subgroups.

Parameters	Endurance athletes	Résistance athletes	Non-athletes
Age (years)	21.92 ± 3.75	26.30 ± 4.64	24.10 ± 1.89
SABP (mm Hg)	125.78 ± 13.21	121.40 ± 15.74	122.65 ± 11.33
DABP (mm Hg)	74.25 ± 9.34	73.80 ± 6.10	77.20 ± 11.23
HR (bpm)	63.85 ± 11.12	69.60 ± 9.33	73.30 ± 15.29
BSA (m^2)	1.90 ± 0.14	1.82 ± 0.13	1.84 ± 0.13
BMI (kg/cm^2)	21.42 ± 2.34	21.65 ± 2.16	20.47 ± 2.31
SPO_2	97.46 ± 1.37	98.20 ± 0.63	97.40 ± 1.14
Number of hours of training/week	11.07 ± 2.12	10.70 ± 2.11	<3

SABP: systolic arterial blood pressure DABP: diastolic arterial blood pressure, HR: heart rate BSA: body surface aera.

3.1. On Electrocardiographic Level

All subjects had a sinus rhythm. Two cases of atrioventricular block of first degree were registered in athletes (one case in the endurance group and one other case in the resistance athletes group). Two cases of intraventricular conduction disorder were noted: one case of complete right limb block and one of incomplete right limb block both in the group of resistant athletes.

There were 2 cases of right atrial hypertrophy in enduring athletes (7%). According to the Sokolow-Lyon index for right ventricular hypertrophy, 2 enduring athletes (7%) and one of the non-athletes group had a right ventricular hypertrophy. Using the Lewis index, 2 subjects in the control group had right ventricular hypertrophy.

Early repolarization appearance was observed in 3 cases from the group of endurance athletes in apical septal and apical lateral derivations; 5 cases in same area in the non-athlete group. In the resistant group, one case was observed in anteroseptal territory.

Seven subjects from the group of endurance athletes had an inversion of the T wave (associated with ST elevation) in the anteroseptal and two other in inferior territories.

A peaked T wave was found in 12 endurance athletes, 7 strength athletes and 12 individuals in the non-athletic control group. The presence of thin Q wave (duration less than 2 mm) was noted in 18 enduring athletes.

ST elevation was observed in 12 enduring athletes, 2 resistant athletes, and 7 subjects in the non-athletic group.

3.2. On Echocardiographic Level

The atrium surface as well as the transverse diameter were greater in athletes especially in the endurance group (p respectively at 0.002). The longitudinal diameter was greater in the resistant group ($p < 0.0001$).

The volume of the RA was larger in athletes group ($p = 0.04$).

The average diameters of the right ventricle admission chamber (RVIT1, RVIT3, and RVIT4) were greater in the group of enduring athletes with a statistically significant difference ($p < 0.0001$, respectively, at 0.002 and 0.01) except for RVIT2 ($p = 0.4$).

With regard to the mean diameters of the right ventricular flushing chamber (RVOT1, RVOT2, RVOT3 and RVOT4), there was no significant difference except for RVOT3 which was significantly greater in the enduring athletes ($p = 0.03$).

The mean annular and basal sagittal diameters of RV were greater in the group of enduring athletes ($p < 0.0001$). The longitudinal one was larger in the resistant ($p = 0.04$).

Compared with the left ventricle, the right ventricle was proportionally larger in enduring athletes with RV/LV ratio ($p < 0.0001$). The surface area of RV in end-diastole was significantly greater in enduring athletes ($p = 0.002$). The anterior wall of the right ventricle was larger in athletes compared to non-athletes ($p < 0.0001$).

Table 2 summarizes the dimensions and volumes of the right atrium and ventricle in the three subgroups.

Apart from the TAPSE which was larger in athletes, there was no significant difference between the subgroups with respect to the systolic function indices. Table 3 summarizes the data on systolic function.

The E/A ratio was positive in all subjects. This ratio, as well as the isovolumetric relaxation time, were significantly greater in the group of resistant athletes (p respectively 0.03).

The vena cava was greater in athletes. There was no significant difference in the hepatic venous flow. The RV-RA systolic gradient and pulmonary arterial pressure were greater in resistant athletes ($p < 0.0001$).

There was no significant difference in the Doppler parameters of the hepatic venous flow. In addition, the systolic fraction was normal in the different subgroups.

Table 4 summarizes the data described above.

Table 2. Measurement of right atrium and ventricle.

	Endurance athletes	Resistance athletes	Non-athletes
Right atrium			
Aera	16.36 ± 3.36	16.29 ± 3.34	12.83 ± 2.14
Transversal diameter	42.34 ± 5.22	38.6 ± 6.57	37.1 ± 3.44
Longitudinal diameter	46.39 ± 5.21	47.2 ± 4.07	41.09 ± 3.63
Volume	48.08 ± 17.40	46.44 ± 13.24	33.81 ± 8.64
Right ventricle			
Inflow tract			
RVIT1	42.44 ± 7.39	38.4 ± 5.75	32.65 ± 8.01
RVIT2	38.12 ± 6.29	35.8 ± 5.18	36.68 ± 4.37945
RVIT3	38.86 ± 5.62	34.6 ± 5.23	33.8 ± 3.18
RVIT4	35.98 ± 5.81	33.9 ± 2.68	31.55 ± 4.48
Outflow tract			
RVOT1	24.24 ± 3.47	22.68 ± 3.11	22.02 ± 2.52
RVOT2	24.38 ± 3.34	23.4 ± 2.17	24.255 ± 3.22
RVOT3	25.96 ± 2.85	23.1 ± 2.28	24.675 ± 3.30
RVOT4	25.10 ± 3.40	25.5 ± 2.12	24.2 ± 4.58
Other diameters			
RVA1 (mm)	49.67 ± 6.04	46.02 ± 7.38	42.05 ± 5.41
RVA2 (mm)	41.16 ± 5.22	38.2 ± 4.23	35.15 ± 3.82
RVSAX (mm)	32.13 ± 5.78	31.4 ± 5.62	29.75 ± 3.95

Continued

RVLAX (mm)	72.37 ± 5.92	75.4 ± 7.18	68.75 ± 8.29
End-diastolic aera	21.05 ± 4.28	18.71 ± 3.28	17.2045 ± 2.50
Free wall thickness	4.98 ± 0.93	4.94 ± 1.016	3.81 ± 0.64
Ratio RV/LV	1.05 ± 0.13	0.96 ± 0.09	0.93 ± 0.06

RV: right ventricle; LV: left ventricle; RVOT: right ventricle outflow tract; RVIT: right ventricle inflow tract.

Table 3. Mean values of different parameters of right ventricle systolic function.

Parameters	Endurance athletes	Resistance athletes	Non-athletes
TAPSE (mm)	24.41 ± 3.48	24.4 ± 4.50	21.08 ± 2.13
S wave (cm/s)	14.71 ± 1.86	15.7 ± 1.88	15.1 ± 2.44
Fraction area change (%)	45.39 ±1 0.44	47.79 ± 7.82	42.75 ± 8.09
Simpson RV (%)	55.18 ± 10.77	59.5 ± 10.49	58.55 ± 9.14
Isovolumetric contraction peak (m/s)	10.75 ± 3.06	11.9 ± 1.79	9.7 ± 2.32

TAPSE: tricuspid annular plane systolic excursion; RV: right ventricle.

Table 4. Comparative values of diastolic function right ventricle parameters and pulmonary artery systolic pressure.

Parameters		Endurance athletes	Resistance athletes	Non-athletes
Tricuspid flow	E wave (m/s)	0.54 ± 0.07	0.60 ± 0.12	0.57 ± 0.14
	A wave (m/s)	0.33 ± 0.05	0.31 ± 0.03	0 .31 ± 0.07
	Ratio E/A	1.67 ± 0.30	2.03 ± 0.54	1.82 ± 0.33
	A' wave (cm/s)	11.5 ± 3.56	14 ± 4.64	10.75 ± 3.33
	E' wave (cm/s)	13.57 ± 2.92	14.1 ± 4.30	14 ± 3.53
	Ratio E/E'	4.33 ± 1.30	4.471 ± 1.05	4.03 ± 1.09
	Deceleration time (ms)	250.92 ± 40.39	242.1 ± 68.40	254.6 ± 76.93
	Isovolumic relaxation time (ms)	92.60 ± 43.53	102.5 ± 25.31	70.25 ± 27.24
Inferior vena cava	IVC expiration (mm)	23.48 ± 3.19	23.1 ± 4.86	20.55 ± 3.21
	Index of distension IVC (%)	56.29 ± 13.94	59.66 ± 8.16	53.65 ± 19.52
Pulmonary pressure	Gradient RA-RV (mm Hg)	23.18 ± 3.84	25.9 ± 5.21	17.76 ± 7.26
	PASP (mm Hg)	29.79 ± 5.14	35.6 ± 3.34	24.46 ± 9.92
Supra-hepatic veinous flow	S wave (m/s)	0.49 ± 0.13	0.52 ± 0.19	0.46 ± 0.15
	D wave (m/s)	0.39 ± 0.14	0.41 ± 0.10	0.37 ± 0.10
	A wave (m/s)	0.36 ± 0.19	0.33 ± 0.10	0.30 ± 0.07
	Ratio S/D	1.32 ± 0.34	1.40 ± 0.49	1.25 ± 0.31
	Systolic fraction (%)	61.87 ± 7.71	57.83 ± 10.95	57.85 ± 8.93

RA: right atrium; RV: right ventricle; PASP: pulmonary artery systolic pressure.

4. Discussion

Determining Factors

Cardiac changes related to sport are determined by several factors. One of these factors is sex [8] [9], the male predominance of these changes can be explained by a plasma concentration of testosterone, anabolic hormone higher in humans. It is also the age: the findings were more frequent in the subject of less than 20 years [10]. The role of genetics has been asserted, explained by individual susceptibility in the development of athlete's adaptive cardiac hypertrophy [11]. Race is also a determining factor with very marked findings in black athletes [12] [13].

Recently, a large number of researchers have focused on the response of the right ventricle to exercise and training.

Morphologically, several cardiac imaging studies using both ultrasound and magnetic resonance imaging, report a high prevalence of right ventricular dilation among the endurance athletes [14] [15] [16]. In our work, admission chamber measurements, basal and basal sagittal diameters, right ventricular surfaces as well as RV/LV ratio were more important in long-term athletes. Aerobic sports require a prolonged rise in cardiac output and concomitantly a reduced afterload. The decrease in peripheral vascular resistance, which characterizes this type of physical activity, can induce chronic venous overload, better diastolic filling of the right ventricle and an increase in the size of the right ventricle and atrium [4].

The increased volume of the right ventricle could, therefore, result in a more significant increase in the left ventricular end-diastolic volume and an earlier end-diastolic stretching of the myocardial fibers, probably in turn to improve systolic function through a better use of the Frank-Starling mechanism [4].

Literature data suggest that right ventricular hypertrophy is an unusual response to exercise and training in the absence of any form of concomitant pulmonary hypertension. The mean parietal thickness of the right ventricle in athletes is within normal range. However, compared to the average non-athletes, they are larger. Therefore, it is possible that the remodeling of the right ventricle in the black athlete also includes a singular increase in the parietal thickness. Much larger studies would be needed to more accurately assess this aspect. On the other hand, the left ventricle shows that black subject has a tendency to remodel marked by an increase in parietal mass and thickness [17].

The right ventricle is not a passive chamber, as previously thought, but plays a crucial role in cardiac adaptations to exercise. Exercise and intense endurance training lead to an acute right ventricular dysfunction that is restored in the short term, but chronic structural changes and reduced right ventricular function are evident in some athletes [18]. Hemodynamic imbalance may promote transient lesion of the right ventricle or incomplete recovery, with possible long-term structural consequences.

There is little data on the diastolic function of the right ventricle in athletes.

Andrew Owen and All reported a regression of diastolic function with age, not found in the sedentary control group [19]. But this hypothesis should be the subject of further studies. Another study did not show any difference between the different groups studied (sedentary active and athletes) regarding the diastolic function of the right ventricle [20]. We did not find any particular difference with respect to the various diastolic function parameters between the different subgroups.

The physiological increase in pulmonary artery systolic pressure is correlated with that of the stroke volume of the ventricle in endurance athletes [4]. The upper limit in our athletes was 40 mmHg, both for endurance athletes and resistance athletes. D'Andrea reported the same observation in endurance athletes [15] [18]. However, in well-trained athletes or those aged over 55, pulmonary artery systolic pressure can reach 55 to 60 mmHg during maximum effort.

5. Conclusion

The right ventricular changes related to sport are various and depending on the type of sport. It appears that endurance increases the cavity dimensions of both the filling chamber and the flushing chamber. There is no significant difference in systolic and diastolic functions. Athletes seem to have a greater parietal thickness than non-athletes. This has not been previously described and may be a singularity of black athlete.

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