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Can Right Heart Parameters of Runners Participating in High Altitude Race be Influenced by Training Altitude or Have Any Impact on Their Performances?

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Authors' contributions

This work was carried out in collaboration between all authors. Author OSMB conceived and designed the study; he also did part of the statistical analysis and wrote the manuscript. Author VSV enrolled the athletes and proof read the manuscript. Author MAS contributed in designing the study and proof read the manuscript. Author JCTT recorded and interpreted the echocardiographic parameters; he also proof read the manuscript. Author CT did part of the statistical analyses and proof read the manuscript. All authors have approved the final version of the article.

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ABSTRACT

Objectives: This work was aimed at investigating, by means of ultrasonography, the influence of training altitudes on haemodynamic parameters of the right heart and the impact of these parameters on the performances of runners participating in endurance races.
Experimental Design: This was a cross-sectional study.
Place and Duration of the Study: The study was carried out in Cameroon. Echocardiographic parameters were recorded at the Regional Hospital annex of Buea (Cameroon) on the 12th and 13th February while race times were recorded at Molyko Stadium of Buea, on the 15th February 2014.
Methodology: Out of 241 runners who finished the senior Mount Cameroon Race of Hope, 68 who were at least at their second participation, had voluntarily participated in the study. Right heart parameters such as the Mid Right Ventricle Diameter (MRVD), the right ventricle Base-To-Apex Length (BAL), the Right Wall Motion (RWM), the Free Wall Thickness (FWT), the tricuspid annular plan systolic excursion (TAPSE) were collected through 2D transthoracic ultrasonography. Mann-Withney or Kruskal-Wallis tests and Spearman's correlation were used for statistical analysis. The significance level was set at p-value<0.05.
Results: Performances improved with the increasing number of participation in the race. From all the above echocardiographic parameters only the values of TAPSE were significantly different (p=0.035), with respect to genders (1.8±0.3 vs. 1.6±0.3 cm/m^2, for males and females respectively). The Spearman's correlation analysis did not show any relationship between training altitude and MRVD (r=-0.19; p=0.19), TAPSE (r=0.14; p=0.35) or FWT (r=-0.04; p=0.77). However, there was a correlation, although weak, between training altitude and BAL (r=-0.33; p=0.02). BAL decreased as training altitude was getting higher. None of these haemodynamic parameters seemed to impact the performances of runners.
Conclusion: The training altitudes can impact right ventricle BAL, but not TAPSE and the latter is affected by gender. However, these parameters seem not to impact the performances of high altitude endurance runners.

Keywords: Altitude; echocardiographic parameters; endurance; right heart; runners; performance.

ABBREVIATIONS

BAL, base-to-apex length; RA/IVC/A, right atrium/inferior vena cava/area; RA/IVC/D, right atrium/inferior vena cava/diameter; RA/IVC/RV, right atrium/inferior vena cava/respiratory variability; MRVD, mid right ventricle diameter; RWM, right wall motion; FWT, free wall thickness; LA, the local aneurism; TAPSE, tricuspid annular plan systolic excursion;2D TTE, two dimensional transthoracic echocardiography.

1. INTRODUCTION

Performance in high altitude endurance race can be influenced by factors such as training altitude [1,2] and cardiovascular profile of athletes [3-5]. Trained athletes do adapt by developing the athlete's heart [6-9], an exercise-induced cardiac remodelling, which refers to cardiac structural and functional adaptations to exercise training [9,10], such as enlargement of chambers and ventricular hypertrophy [6,8,9]. This physiological hypertrophy can be concentric (growth in width of cardiomyocytes) or eccentric (growth in length of cardiomyocytes) [7]. Several studies have been carried out on the left heart parameters while fewer are concerned with the right heart. The Mount Cameroon Race of Hope is a tough endurance race as runners have to climb at 4,095 m altitude while covering a 42,000 m distance [11,12]. A well trained heart might present some advantages for a better performance of athletes. Although this is marked with the left side of the heart, one would like to know what can be the contribution of changes in the values of the right heart parameters on the performances of athletes. Of recent, we published a paper displaying the influence of the left heart parameters on performance, and it was also observed that the tricuspid annular plan systolic excursion, TAPSE, a right heart parameter, could help detect pulmonary hypertension (PH) associated with high level of training and performance of athletes at high altitude [2]. According to Cioffi et al. [13] chronic PH determines various adaptive changes in right ventricular (RV) geometry which can

progressively result in hypertrophy, mechanical dysfunction and dilatation with pump failure.

Therefore, one would like to know if the other parameters of the right heart (more precisely the right ventricle) undergo changes under high altitude training conditions. Furthermore, it is relevant to know if some haemodynamic parameters of the right heart could influence athletic performances. It has been reported that residential and training altitudes impact on the physiology of individuals [2,14]. Therefore, this work was aimed at investigating, using echocardiography, the influence of gender and training altitudes on haemodynamic parameters of the right ventricle and the impact of these parameters on the performances of runners participating in endurance races.

2. MATERIALS AND METHODS

2.1 Study Area

Mount Cameroon is situated at Longitude 9°170' East and Latitude 4° 203' North [15]. The main race covers a marathon distance of 42,000 m, to the 4,095 m summit [12] and back to the Molyko stadium, corresponding to a 6,096 m vertical round-trip [16].

2.2 Study Participants

Two hundred and forty one runners finished the race to the summit in the official records. Out of this number of athletes, 68 (52 males and 16 females) who were at least at their second participation, had voluntarily taken part in the study. This condition of being at the second participation or more was to ensure that runners were aware of difficulties they were going to face and would have potentially developed physiological adaptations to strenuous exercise at high altitude, since they would have been training for more than a year and competed under harsh environmental conditions at such altitude. They were sixty six Cameroonians and two with different nationalities. All of them were residents of Cameroon.

2.3 Study Design

The present work is a cross-sectional study carried out in February 2014 in the framework of the Mount Cameroon Race of Hope. Correlations of echocardiographic indices with altitude and race time were assessed. Participation was voluntary. Runners who were disqualified at the medical check-up or in the course of the race were not included in the study. Furthermore, they had to be adults, not presenting any cardiovascular disease nor being under medication. They also had to be at least at their second participation, and the influence of the number of participations on performance was assessed.

2.4 Recordings and Calculations

All runners had their echocardiographic measurements recorded during the medical fitness check-up by the appointed health crew based in the Regional Hospital annex in Buea (Cameroon), on the 12th and 13th February 2014. Information was also recorded on their training altitudes [2] which varied from 750 to 1615 m.

2.4.1 Ultrasound cardiography

Using an echocardiograph (Siemens-Acuson Cypress Plus ultrasound^{TM}) with the 3V2c - 3.5/3.0/2.5/2.0 MHz – Cardiac probe, the cardiologist and his assistants collected important haemodynamic parameters by two dimensional transthoracic echocardiography (2D TTE) performed at rest. Bi-dimensional measurements were used for dimensions and volumes with Simpsons. Observations were done by the parasternal and apical four-chamber (4C) views [16,17]. The structure and function of the right atrium were assessed by measuring the right atrium/inferior vena cava/area (RA/IVC/A), the right atrium/inferior vena cava/diameter (RA/IVC/D) and the right atrium/inferior vena cava/respiratory variability (RA/IVC/RV). The structure and function of the right ventricle were assessed through the mid right ventricle diameter (MRVD), the right ventricle base-to-apex length (BAL), the right wall motion (RWM), the free wall thickness (FWT), the local aneurism (LA), the state of tricuspid valve, the state of pulmonary valve and the tricuspid annular plan systolic excursion (TAPSE).

2.4.2 The race and recording of performances

The race took place on the 15th February 2014. It was launched at 7:30 am and the last official finisher arrived at 4:23 pm. Official race times were collected a few days after the race, from the Cameroon Federation of Athletics.

2.4.3 Statistical analyses

Data are expressed as means ± standard deviation. Haemodynamic data (RA/IVC/A, RA/IVC/D, RA/IVC/RV, MRVD, BAL, RWM,

FWT, LA and the TAPSE) were compared using the Mann-Withney or Kruskal-Wallis statistical tests, where appropriate. Correlations between haemodynamic parameters and training altitudes or race times were assessed using the Spearman's correlation model. Statistical analysis was performed using Epi info software (Epi Info™ 7.1.1.14, CDC Atlanta, USA). The significance level was set at p-value <0.05.

3. RESULTS

In the general study population, age (year), weight (kg), height (cm) and race time (s) were 29.37±6.23, 65.04±9.64, 168.2±6.6 and 23765.3±3732.9 respectively.

3.1 Influence of the Number of Participations in the Race on Performance

Fig. 1 displays the relationship between the number of participations in the race and the race time of runners. The more the number of participations, the lower the race time; i.e the higher the performance.

The number of participations is categorised as: <4; 4-7; ≥8

In the general population of participants, it was observed that the performance of those participating at least for the eighth time, was significantly highest (p=0.02) compared to those who had participated less. When looking at the gender, this variation of the race time in the general population was similar in females (p<0.05) but not in males (p>0.05) (Table 1).

3.2 Influence of the Gender on the Echocardiographic Parameters

From all echocardiographic parameters investigated (RA/IVC/A, RA/IVC/D, RA/IVC/RV, MRVD, BAL, RWM, FWT, LA, TAPSE, the state of tricuspid valves and the state of pulmonary valves) only the values of TAPSE were significantly different (p=0.035) with respect to genders (Table 2).

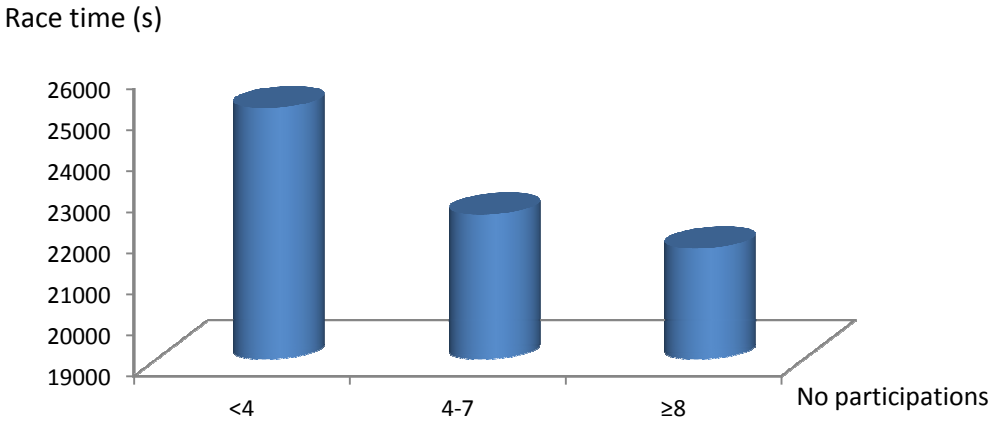

Fig. 1. Relationship between number of participations in the race and race time in the general population

Table 1. Race times with respect to the number of participations in males and females

	Number of participations	N	Mean race time (s)	StdDev	p-value
Females	<4	10	26261	3036	
	4 – 7	4	21586	2750	0.04[a]
	≥8	2	21317	2340	
Males	<4	21	24761	3237	
	4 – 7	22	22881	3604	0.17
	≥8	9	21781	4570	

[a]p<0.05, significant difference between participation categories (number of participations) (Kruskal-Wallis test was used)

3.3 Influence of Echocardiographic Parameters on Performance

The Table 3 shows the correlations between echocardiographic parameters on the one part and between these parameters and the performances (through race times) on the other part. MRVD was correlated with BAL. None of the echocardiographic parameters correlated with race time.

The Spearman's correlation analysis did not show any relationship between training altitude and MRVD(r=-0.19; p=0.19), TAPSE (r=0.14; p=0.35) or FWT (r=-0.04; p=0.77). However, there was acorrelation, although weak, between training altitude and BAL (r=-0.33; p=0.02). BAL decreased as training altitude was getting higher).

Table 2. Influence of gender on echocardiographic parameters of the right heart

Parameter	Gender (N=68, 52males and 16females)	Mean	StdDev	p-value
	Male	17.53	3.19	
RA/IVC/A (cm^2)	Female	16.23	3.48	0.641
	Total	17.12	3.31	
	Male	1.94	0.39	
RA/IVC/D (cm)	Female	1.93	0.22	0.817
	Total	1.94	0.34	
RA/IVC/RV (%)	**> 50in all**			
	Male	2.82	0.46	
MRVD (cm)	Female	2.74	0.45	0.206
	Total	2.80	0.45	
	Male	3.96	0.63	
BAL (cm)	Female	3.90	0.58	0.454
	Total	3.94	0.62	
	Male	0.84	0.15	
FWT (cm)	Female	0.86	0.14	0.497
	Total	0.84	0.14	
	Male	1.8	0.3	
TAPSE (cm/m^2)	Female	1.6	0.3	0.035[a]
	Total	1.7	0.3	
Tricuspid valves	Normal in all			
Pulmonary valves	Normal in all			
RWM	Normal in all			
LA	Absent in all			

[a]p<0.05, significant difference between genders (U, Mann-Whitney test was used); BAL, base-to-apex length; RA/IVC/A, right atrium/inferior vena cava/area; RA/IVC/D, right atrium/inferior vena cava/diameter; RA/IVC/RV, right atrium/inferior vena cava/respiratory variability; MRVD, mid right ventricle diameter; RWM, right wall motion; FWT, free wall thickness; LA, local aneurism; TAPSE, tricuspid annular plan systolic excursion.

Table 3. Correlations between race time and some haemodynamic parameters

Parameter	Base-to-apex length (BAL)	Mid right ventricle diameter (MRVD)	Free wall thickness (FWT)	Tricuspid annular plan systolic excursion (TAPSE)	Race time
BAL	1.00	0.56[a](<0.001)	0.056(0.708)	-0.16(0.298)	-0.12(0.397)
MRVD	0.56[a](<0.001)	1.00	0.03(0.829)	-0.23(0.134)	-0.20(0.165)
FWT			1.00	-0.09(0.582)	-0.05(0.723)
TAPSE				1.00	0.17(0.263)
Race time					1.00

Values outside brackets represent Spearsman'scorrelation coefficient 'r' while the corresponding p-values are inside brackets

[a]p<0.001, significant positive correlation (r=0.56) between MRVD and BAL

4. DISCUSSION

The right heart is known to play a crucial role in the maintenance of adequate pulmonary perfusion pressures and maintenance of a low systemic venous pressure [17-19]. The echocardiographic examination of the right heart is increasingly drawing the attention of scientists. The aim of this work was to investigate, using echocardiography, the influence of gender and training altitudes on haemodynamic parameters of the right heart and the impact of these parameters on the performances of runners participating in endurance races.

It was found that the increase of the number of participations in the race was associated with a decrease of the race times of athletes. The results followed the same trend in both genders, but were significant only in females. These results bring about the adaptations of the heart, and the adaptations of the individual's body in general, to endurance exercise. Therefore, this might indirectly mean an increase of the heart capacity, with increasing number of participations, along with improvement of the capacities of other organs involved. These findings are in line with reports made by George et al. [20], Verkhoshansky [21] and d'Andreaet al. [22].

However, when looking at the influence of the gender on the echocardiographic parameters (MRVD, BAL, RWM, FWT, LA, TAPSE, the state of tricuspid valves and the state of pulmonary valves) of the right heart, we did not find any significant difference between males and females for the majority of them. Only the tricuspid annular plan systolic excursion, TAPSE, Was significantly different between females and males. The TAPSE is a simple echocardiographic measure of the right ventricle systolic function [23,24]. The higher the TAPSE within normal range, the larger the right ventricle ejection fraction. The observed gender-difference of the TAPSE is actually the same result we previously reported, and we explained that this disparity could partially contribute to the difference observed in the performances of males and females in the North-West region of Cameroon [2]. Although in this current work, we did not find any significant difference, in the general population, between male and female performances, likely due to skewed data, it is known that they should logically be a difference [4,25-27], like it was the case in the above region of Cameroon. As we previously reported [2], the TAPSE helped us diagnose a moderate pulmonary hypertension (gradient 41mmHg) in a female. It appears the lady was in the ≥8 participation category. This can be looked at as a consequence of cardiac remodelling in the lady. According to George et al. [20] and d'Andrea et al. [22], endurance athletes are known to be more likely to experience such remodelling than age- and sex- comparable strength athletes. Also it is known that, when assessed at rest, echocardiographic parameters of global right systolic function are slightly reduced compared with nonathletic controls. We therefore believe that in the course of numerous participations in the race, this athlete would have move progressively towards a ladder of remodelling changes until exceeding her limits of physiological or athlete heart.

The state of tricuspid valves and pulmonary valves was not different between males and females. In the same line, local aneurism was absent in both genders. Local aneurism can be defined as a syndrome of arterial dilation and rupture, elastin degradation, inflammatory cell infiltration in the media, and up regulation of Matrix Metalloproteinases [28]. Therefore, we can allege that all the athletes in our sample population were safe of any of these pathological features. As shown in Table 3, there is a positive correlation between mid right ventricle diameter (MRVD) and right ventricular base-to-apex length (BAL). The BAL is the distance between the midpoint of tricuspid valve annular plane and the right ventricular apex at end diastole [29]. Thus this can be understood that when the chamber's volume increases, it is a resultant of both an increase of the mid right ventricular diameter and the base-to-apex length of the ventricular chamber. The training altitude was negatively associated with BAL. Therefore, when the training altitudes get higher, the base-to-apex length reduces and subsequently the volume of the right ventricular chamber also reduces. The shortening of the long axis of the right ventricle might likely be due to the contraction of the longitudinal cardiomyocytes [18]. However, such findings are quite paradoxical as one could have expected that the BAL instead increases as training altitude increases, i.e. the right ventricle chamber size would have increased with training altitude [30]. Further investigations on participants in this particular race, in the future, will enable us confirm or decline the above. It has been reported that the higher the altitude of training, the smaller the race time [1,2]. Thus, we could have hypothesized that right ventricular

BAL and race time of runners vary in the same direction. Conversely, this was not in line with our findings. The race time of athletes was not correlated with any of the right ventricular parameters studied, including BAL. One can therefore allege that the variation of these right ventricle parameters has no noticeable impact on the performances of runners. However, as we earlier mentioned training altitude can slightly influence right ventricle BAL and high level training and performance can impact the TAPSE; causing in some cases negative repercussions on the pulmonary circulation. As we cannot have the pretention of having done an exhaustive study of the right heart parameters, it is not impossible that further studies reveal an impact of some other right heart parameters on the performances of athletes at high altitude. In comparison with our findings on the left heart [2], we can argue that we found more parameters from the left side than the right side of the heart that influence athletic performance of high altitude endurance runners. However, long-term regular training does affect both sides of the heart.

5. LIMITATIONS

This study included finishers who were participating for at least a second time to the Mount-Cameroon race, therefore reducing the number of potential participants. Furthermore, participation was voluntary and not all finishers volunteered to participate in the study. We ended up having a small sample size of 68 participants. This was detrimental to our statistical analysis, as shown by the weak correlation coefficients observed in general.

6. CONCLUSION

The echocardiographic examination of the right heart is increasingly drawing the attention of scientists. Performances were found to be improved with the increasing number of participation in the race; this might indirectly mean an increase of the heart capacity with increasing number of participations. Values of TAPSE were significantly different, with respect to genders. None of the studied haemodynamic parameters seemed to impact the performances of runners.

INFORMED CONSENT

Authors declare that written informed consent was obtained from all participants after verbal explanation of the experimental design in the language they understood best.

ETHICAL CONSIDERATION

The study was approved by the Institutional Review Board of the Faculty of Health Sciences, University of Buea (Ref. UB-IRB-2014-01-0179). Also, administrative clearance was got from the Cameroon Federation of Athletics.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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