British Journal of Medicine & Medical Research
11(5): 1-11, 2016, Article no.BJMMR.19844
ISSN: 2231-0614, NLM ID: 101570965

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Ultrasound Examination of Cardiovascular Profiles of Runners Participating in High Altitude Race and their Possible Influence on Performance: A Randomized Cross-sectional Study

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Authors' contributions

This work was carried out in collaboration between all authors. Author OSMB conceived and designed the study, analysed the data, recorded blood pressure and heart rate of some athletes; he also wrote the manuscript. Author MAS contributed in designing the study and proof read the manuscript. Author VSV enrolled the athletes, recorded their anthropometric parameters, blood pressure and heart rate; he also proof read the manuscript. Author CT recorded the anthropometric parameters of athletes, did the major part of the statistical analyses, contributed in writing the discussion section and proof read the manuscript. Author JCTT recorded and interpreted the haemodynamic parameters; he also proof read the manuscript. All authors have approved the final version of the article.

Article Information

DOI: 10.9734/BJMMR/2016/19844
Editor(s):
(1) Rakesh Garg, Department of Anaesthesiology, Intensive Care, Pain and Palliative Care, Dr BRAIRCH, All India Institute of Medical Sciences, New Delhi, India.
Reviewers:
(1) Ivana Gritti, University of Milan, Italy.
(2) Stefani laura, University of Florence, Italy.
(3) Maria Estefania Otto, Instituto de Cardiologia do Distrito Federal, Brasília, Brazil.
Complete Peer review History: http://sciencedomain.org/review-history/11609

Original Research Article

Received 29th June 2015
Accepted 14th September 2015
Published 29th September 2015

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ABSTRACT

Objectives: This work was aimed at investigating, by means of ultrasonography, the impact of cardiovascular parameters on the physical endurance of runners participating in high altitude race.
Experimental Design: This was a cross-sectional study.
Place and Duration of the Study: The study was carried out in Cameroon. Anthropometric and cardiovascular 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, 69 who were at least at their second participation, had voluntarily participated in the study. Haemodynamic parameters were collected through 2D transthoracic ultrasonography. Mann-Withney or Kruskal-Wallis tests and linear regression were used for statistical analysis. The significance level was set at p-value<0.05.
Results: The mean LVEDD, LVDV, LVSV, LVMMI, SF/EF and TAPSE were 2.7±0.3 cm/m^2, 88.5±49.3 mL/m^2, 53.4±30.7 mL/m^2, 131.1±28.6 g/m^2, 69.3±9.4% and 1.7±0.3 cm/m^2 respectively. In males and females, LVDV (mL/m^2) was 98.6±55.3 vs. 64.2±12.6 (p=0.011) while LVSV (mL/m^2) was 61.6±33.2 vs. 33.9±6.2 (p=0.0004), respectively. The linear regression model revealed that the lower the altitude, the greater the race time i.e. the weaker the performance (p=0.005; r^2=0.12). In addition increase of LVDV related with increase of residential (p=0.025; r^2=0.12) and training (p=0.021; r^2=0.13) altitudes.
Conclusion: Optimal values of haemodynamic parameters and/or high training altitude could be boosters of performance in endurance race at high altitude.

Keywords: Runners; cardiovascular ultrasonography; haemodynamic parameters; performance; endurance; altitude.

ABBREVIATIONS

BMI: body mass index; CE: centre; CM: Cameroon; FRA: France; DBP: diastolic blood pressure; LVDV: left ventricle diastolic volume; LVEDD: left ventricle end diastolic diameter; LVMMI: left ventricle mass/body surface area; LVSV: left ventricle systolic volume; NW: North-West; SBP: systolic blood pressure; SF/EF: systolic function/ejection fraction; SW: South-West; TAPSE: tricuspid annular plan systolic excursion; TTE: transthoracic echocardiography; USA: United States of America.

1. INTRODUCTION

Performance in endurance race can be influenced by several factors including the cardiovascular profile of athletes [1-3]. Trained athletes do adapt by developing the athlete's heart [4-7], an exercise-induced cardiac remodeling, which refers to cardiac structural and functional adaptations to exercise training [7], such as enlargement of chambers and ventricular hypertrophy [4,6,7]. This physiological hypertrophy can be concentric (growth in width of cardiomyocytes) or eccentric (growth in length of cardiomyocytes) [5].

The Mount Cameroon Race of Hope is a very difficult endurance race as runners have to climb at 4,095 m altitude while covering a 42,000 m distance [8,9]. A well trained or well profiled heart might be advantageous for a better performance of athletes. Before 2014, there has been a pre-participation screening of athletes. For the cardiovascular part of it, only blood pressure recording and electrocardiography had been done but not cardiac ultrasonography. It is relevant to know precisely which of the haemodynamic parameters influences athletic performances the most and ultrasonography technique can be very useful. It is also important to know how altitude can impact on the performances of runners, in this forest environment.

From their work on anthropometric and haemodynamic profiles of runners participating in this race, some researchers [10] found significant influences of gender, male body mass index and training altitude on performance. However, no clear influence of the cardiovascular profiles of runners on their performances was found.

Baggish et al. [11] equally reported on the impact of the residential altitude en route to high altitude on the physiology of individuals. We hypothesized that haemodynamic parameters and training altitude impact the performances of such runners. Therefore, the current work was aimed at either confirming or invalidating the above findings and investigating, using echocardiography, the impact of haemodynamic parameters on the performances of runners participating in endurance races at high altitude.

2. MATERIALS AND METHODS

2.1 Study Area

Mount Cameroon is situated at Longitude 9°170' East and Latitude 4°203' North [12]. The main race covers a marathon distance of 42,000 m, to the 4,095 m summit [9] and back to the Molyko stadium, corresponding to a 6,096 m vertical round-trip [13].

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, 69 (53 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 Cameroonians (from North-West, West, South-West, Centre regions) and of different nationalities (from USA and France). But 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. Associations between echocardiographic indices, gender, 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. Futhermore, they had to be adults, not presenting any cardiovascular disease nor being under medication.

2.4 Recordings and Calculations

After their recruitment, all runners had their anthropometric and physiological 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 residence and training areas.

2.4.1 Anthropometric parameters

Height and weight were measured using a SECA® 755 (Germany) dial column mechanical scale with included SECA® 220 height rod; the body mass index (BMI) was automatically calculated and runners were classified as underweight (BMI<18.5), normal (18.5≤BMI<25) and overweight (BMI≥25) according to the WHO classification [14]. This was done in view to assess the influence of BMI on the athletic performance.

2.4.2 Blood pressure and heart rate

An automatic arm sphygmomanometer (Pic indolor Diagnostic, CS410-23154®, ARTSANA, Italy) was used for non-invasive recording of blood pressure (in mmHg) and heart rate (in beats per min). The resting Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) were measured on the right arm of each participant using an inflatable cuff of appropriate size. Optimal blood pressure was defined as a SBP<120 mmHg and DBP<80 mmHg. Pre-hypertension was defined at a SBP of 120 to 139 mmHg and/or DBP of 80 to 89 mmHg and hypertension was diagnosed at a SBP≥140 mmHg and/or DBP≥90 mmHg, according to international guidelines [15]. The measurements were taken on seated athletes after they had rested for 15 minutes, in a calm and quiet environment.

2.4.3 Ultrasound cardiography

Using an echocardiograph (Siemens-Acuson Cypress Plus ultrasound™, Germany) 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 left heart were assessed through the left ventricle end diastolic diameter (LVEDD), the left ventricle diastolic volume (LVDV), the left ventricle systolic volume (LVSV), the left ventricle mass/BSA (LVMMI) and the systolic function/ejection fraction (SF/EF). The Tricuspid annular plan systolic excursion (TAPSE), the only parameter of the right heart, was used as a mean for investigating the existence of chronic pulmonary diseases that might occur in such runners.

2.4.4 The race and recording of performances

The race took place on the 15th February 2014. The race 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.

2.5 Statistical Analyses

Data are expressed as means ± standard deviation. Directly measured anthropometric parameters (body mass, height), haemodynamic data (resting Systolic BP, resting Diastolic BP, resting Heart Rate, LVEDD, LVDV, LVSV, LVMMI, SF/EF and TAPSE) and calculated data (BMI) were compared using the Mann-Withney or Kruskal-Wallis statistical tests, where appropriate. Associations between various parameters (anthropometric, haemodynamic, training altitudes) and race times were assessed using the linear regression 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

3.1 General Profile and Performances of Runners

In the global population of participants, the mean values of age, weight, height and BMI were 29.37±6.23 years, 65.04±9.64 Kg, 168.2±6.6 cm and 22.84±2.65 Kg/m^2 respectively. Mean systolic blood pressure, diastolic blood pressure and heart rate were 128±12 mmHg, 73±9 mmHg and 69±11 bpm respectively. Overall mean race time was 23765±3733 sec. Males and females showed significant differences for weight ($p<0.001$), height ($p<0.001$), BMI ($p=0.024$) and systolic blood pressure ($p=0.036$). Overall, there was no significant difference between performances of males and females (Table 1). The linear regression model did not show association of race times with anthropometric indices (age, weight, height, BMI), nor with cardiovascular parameters (systolic blood pressure, diastolic blood pressure and heart rate) (Table 1). There was no significant difference between the performances of runners in relation to their BMI. However, overweight runners were a bit slower than those with normal weight (race time=24125 sec vs. 23556 sec, $p=0.88$, Kruskal-Wallis H test).

3.2 Influences of Training Altitudes and Gender on Race Times of Athletes

The influence of training altitude and gender on performances of runners was assessed. The lowest and highest altitudes were 750 m (in the Centre region) and 1615 m (in the North-West region) respectively. The performances of male runners coming from the North-West region were highest, though not significantly different from those of runners who trained elsewhere. These performances were significantly different from those of females training in the same region (Table 2).

3.3 Relationship between Echocardiographic Parameters, Altitudes and Performances in Both Genders

In the global population of participants, the mean values of LVEDD, LVDV, LVSV, LVMMI, SF/EF and TAPSE were 2.7±0.3 cm/m^2, 88.5±49.3 mL/m^2, 53.4±30.7 mL/m^2, 131.1±28.6 g/m^2, 69.3±9.4% and 1.7±0.3 cm/m^2 respectively. Males and females showed significant differences for LVDV, LVSV, LVMMI and TAPSE (Table 3). A case of pulmonary hypertension with tricuspid impairment at a gradient of 41 mmHg was diagnosed in one female athlete. Furthermore, the athlete displayed a dilation of heart chambers, in apical 4-chamber view. She had very big left ventricle end systolic dimensions (volume = 68.6 mL, end systolic diameter = 6.8 cm, area= 23.4 cm^2) and atrium dimensions (long axis up-down distance = 4.3 cm and short axis left to right = 3.3 cm).

As shown in Fig. 1, the linear regression model revealed a significant association of race times with training altitudes ($p=0.005$; $r^2=0.12$). The lower the altitude, the greater the race time i.e. the weaker the performance. Similarly, there was an association between race times and residential altitudes. As shown in Table 4, there was also a significant relationship between LVDV and altitudes of residence (p=0.025; r^2=0.12) and training (p=0.021; r^2=0.13). LVDV actually increased with the altitudes. Finally, there was also a significant association of LVSV with residential altitudes (p=0.011; r^2=0.15) and training altitudes (p=0.012; r^2=0.15).

Table 1. Anthropometric parameters, blood pressure, heart rate and race time of the participants

Parameter	Gender (N=69, 53 males and 16 females)	Mean (SD)	95% confidence interval on mean		p-value (U)	Linear regression model between race time and parameters (r^2 / p-value)
			Lower bound	Upper bound		
Age (year)	Male	29.85 (5.46)	28.33	31.37	0.343	0 / 0.82
	Female	27.73 (8.39)	23.09	32.38		
	Total	29.37 (6.23)	27.85	30.89		
Weight (Kg)	Male	67.69 (8.65)	65.28	70.10	<0.001[a]	0.17 / 0.18
	Female	55.87(7.04)	51.97	59.77		
	Total	65.04(9.64)	62.69	67.40		
Height (cm)	Male	170.3(5.3)	168.8	171.8	<0.001[a]	0 / 0.65
	Female	160.6(5.4)	157.5	163.8		
	Total	168.2(6.6)	166.5	169.8		
Body Mass Index (Kg/m^2)	Male	23.16(2.66)	22.40	23.93	0.024[a]	0.14 / 0.28
	Female	21.71(2.39)	20.33	23.09		
	Total	22.84(2.65)	22.17	23.51		
Systolic Blood Pressure (mmHg)	Male	130 (12)	127	133	0.036[a]	0 / 0.89
	Female	122 (9)	117	127		
	Total	128 (12)	125	131		
Diastolic Blood Pressure (mmHg)	Male	74(9)	71	76	0.361	0 / 0.79
	Female	71(10)	65	76		
	Total	73 (9)	71	75		
Heart Rate (bpm)	Male	69(12)	66	72	0.393	0.14 / 0.28
	Female	72(11)	66	77		
	Total	69 (11)	67	72		
Race time (s)	Male	23673.3 (3854.4)	22600.3	24746.4	0.771	
	Female	24084.8 (3381.1)	22211.7	25956.5		
	Total	23765.3 (3732.9)	22854.8	24675.8		

95% CI, 95% confidence interval; [a]p<0.05, significant difference between genders; r^2, regression coefficient; SD, standard deviation; U, Mann-Whitney test was used

Table 2. Performance of runners (69 individuals) from various training areas

Origin, training region	Mean altitudes of the training area (m)	Number of athletes (males, females)	Race time (s)			
			Males		Females	
			Mean (SD)	Range	Mean (SD)	Range
CM, NW	1615	24 (13, 11)	20367 (2577)	16064-25590	24122 (3519)[a]	19408-29831
CM, West	1390	1 (1, 0)	25243 (0)	--		
CM, SW	1000	34 (32, 2)	24789 (3686)	18474-30913	25402 (4130)	22481-28322
CM, CE	855	8 (6, 2)	23934 (2974)	18259-26327	21187 (417)	20892-21482
USA, NW	1615	1 (0, 1)			25225 (0)	--
FRA, CE	750	1 (1, 0)	29069 (0)	--		

N=69 (53 males and 16 females); [a]p=0.006, Significant difference (Mann-Whitney U-test) between performances of male and female NW runners CE, Centre; CM, Cameroon; FRA, France; NW, North-West; SD, Standard deviation; SW, South-West; USA, United State of America

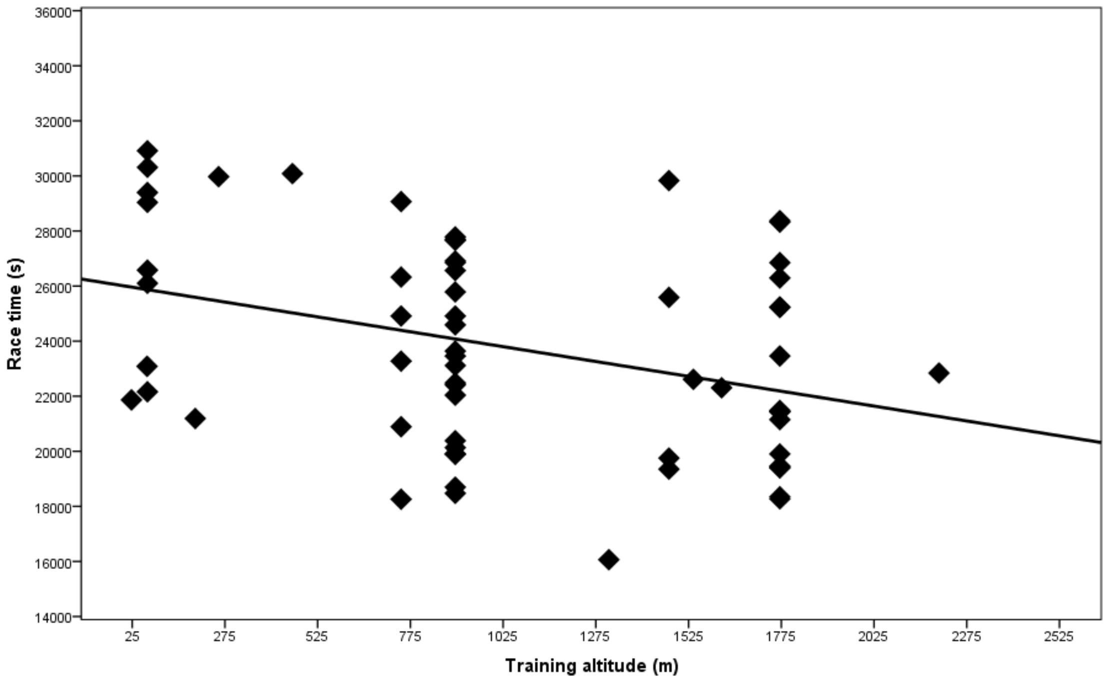

Fig. 1. Relationship between training altitude and race time (p=0.005, r^2=0.12)

This figure represents the association between race times (Y axis) and training altitude (X axis). The decrease in the race time (i.e. increase in performance) is associated with the increase in training altitude

Table 3. Haemodynamic parameters recorded by ultrasound in runners

Parameter	Gender	Mean (SD)	95% CI on mean		p-value
			Lower	upper	
LVEDD (cm/m^2)	Male	2.7 (0.3)	2.2	3.4	0.716
	Female	2.7 (0.3)	2.2	3.4	
	Total	2.7 (0.3)	2.2	3.4	
LVDV (mL/m^2)	Male	98.6 (55.3)	47.2	270.3	0.011[a]
	Female	64.2 (12.6)	47.9	88.6	
	Total	88.5 (49.3)	47.2	270.3	
LVSV (mL/m^2)	Male	61.6 (33.2)	23.6	180.9	0.0004[a]
	Female	33.9 (6.2)	24.4	44.4	
	Total	53.4 (30.7)	23.6	180.9	
LVMMI (g/m^2)	Male	136.4 (28.6)	74.0	236.3	0.004[a]
	Female	112.8 (20.0)	78.5	141.3	
	Total	131.1 (28.6)	74.0	236.3	
SF/EF (%)	Male	69.5 (9.1)	49.0	86.0	0.78
	Female	68.5 (10.8)	47.0	90.0	
	Total	69.3 (9.4)	47.0	90.0	
TAPSE (cm/m^2)	Male	1.8 (0.3)	1.4	2.4	0.035[a]
	Female	1.6 (0.3)	1.2	2.0	
	Total	1.7 (0.3)	1.2	2.4	

95% CI, 95% Confidence interval; LVEDD, left ventricle end diastolic diameter; LVDV, left ventricle diastolic volume; LVMMI, left ventricle mass/BSA; LVSV, left ventricle systolic volume; SD, Standard deviation; SF/EF, systolic function/ejection fraction; TAPSE, tricuspid annular plan systolic excursion. n=69 (53 males and 16 females); [a]P<0.05, Significant difference between genders (mann-whitney U-test)

Table 4. Relationship between haemodynamic parameters and altitudes of residence and training site of runners

Dependent variable	Independent variable	p-value	r^2
LVEDD (cm/m^2)	Residential altitude	0.996	0
	Training altitude	0.969	0
LVDV (mL/m^2)	Residential altitude	0.025[a]	0.12
	Training altitude	0.021[a]	0.13
LVSV (mL/m^2)	Residential altitude	0.011[a]	0.15
	Training altitude	0.012[a]	0.15
LVMMI (g/m^2)	Residential altitude	0.17	0.03
	Training altitude	0.226	0.03
SF/EF (%)	Residential altitude	0.28	0.02
	Training altitude	0.437	0.01
TAPSE (cm/m^2)	Residential altitude	0.26	0.03
	Training altitude	0.422	0.02

LVEDD, left ventricle end diastolic diameter; LVDV, left ventricle diastolic volume; LVMMI, left ventricle mass/BSA; LVSV, left ventricle systolic volume; r^2, regression coefficient; SD, Standard deviation; SF/EF, systolic function/ejection fraction; TAPSE, tricuspid annular plan systolic excursion. n=69 (53 males and 16 females); [a]$p<0.05$, Significant association of the considered haemodynamic parameter with residential and training altitudes (linear regression model)

4. DISCUSSION

Following the preliminary findings by Salah et al. [10], the present work was carried out with the aim of using 2D TTE for a more precise assessment of the influence of cardiovascular profiles of athletes participating in Mount Cameroon race on their performances. TTE is known as the most suitable means of diagnosing normal and abnormal heart physiology and morphology in a single examination [18-20]. Endurance athletes can develop the athlete's heart [4-7] characterised by the dilation of chambers and the increase of cardiac mass (hypertrophy). Physiological hypertrophy can be concentric (growth in width of cardiomyocytes) or eccentric (growth in length of cardiomyocytes) [5,21]. In absolute terms, female athletes do not develop as marked left ventricular hypertrophy as male athletes. However, in relative terms, female athletes develop significantly greater left ventricular dilatation compared with male athletes [22]. Furthermore, because of the prognostic significance of left ventricular hypertrophy, gender-specific indexing techniques have been suggested to account for physiological variations due to the body size [23].

Anthropometric parameters were assessed and mean values of age, weight, height, BMI of participants were in line with those got by Salah et al. [10]. Males and females showed significant differences for weight, height, BMI and systolic blood pressure. These results are partly in line with the findings of some authors [10,24], who found a significant difference in systolic blood pressure between men and women. It is worth noting that there was no significant difference in age between males and females. Furthermore, male runners from the North-West region performed significantly better (i.e. they had lower race times) than female runners who trained in this same region. Such differences in performance have been reported by other researchers [4,25]. These differences in performances can be explained by the heavier muscular mass and distribution in males compared with females, a longer stride for males and/or the hormonal differences. In marathon race, the top female performer has a running speed that is 11% lower than that of the top male performer; as a result of the effect of the male hormone testosterone [25,26] and other androgens. Runners with normal sizes ran faster than the overweight. Excess fat has been reported over the years as detrimental to high level athletic performance in events in which performance depends on speed or on ratio of total body muscle strength to body weight. In women in particular, there is a greater tendency for fat to deposit under the skin than in men. Fat as adipose subcutaneous tissue might have a special influence on athletes [27,28], especially in black runners [28] like those who participated in the Mount Cameroon race.

On the other hand, race time was found to be associated with altitudes of residence and training. The lower the altitude, the greater the race time; this is a confirmation of the baseline findings by Salah et al. [10] clearly showing improvement of athletes performances from lower to higher altitude training sites.

The recorded values of left ventricle end diastolic diameter (LVEDD), left ventricle diastolic volume (LVDV), left ventricle systolic volume (LVSV), left ventricle mass/BSA (LVMMI), systolic function/ejection fraction (SF/EF) and tricuspid annular plan systolic excursion (TAPSE) showed significant differences between males and females for LVDV, LVSV, LVMMI and TAPSE; with males having higher values than women. LVDV, LVSV and LVMMI are important haemodynamic parameters of the left ventricle function. The first two reflect the compliance of the left ventricle, i.e. its capacity to receive and store blood that will be ejected during the next systole, as stroke volume [29,30]. It is clearly known that the stroke volume is the difference between end diastolic volume and end systolic volume [29,30]. Increasing the end-diastolic volume and reducing the end-systolic volume can increase the stroke volume to more than double the normal [25]. From our findings stroke volume per body surface area is greater in males than females (37.02 vs. 30.28 mL/m^2). Stroke volume and heart rate are the two factors of the cardiac output (or cardiac index, if expressed per unit of body surface area) [28] and any of them can be influential in cardiac output/cardiac index. Around 50% of the VO_2 max during exercise of elite athletes can be attributed to an increase in stroke volume [2]; this is enabled in endurance runners by an enlarged left ventricle [2,31,32]. In endurance athletes, the heart improves its ability to pump blood, mainly by increasing its stroke volume [20,32], which occurs because of an increase in end-diastolic volume and a small increase in left ventricular mass [31]. According to the Frank-Starling Law, the more blood enters the heart, the more it will be ejected [25,31]. Therefore, the more compliant the heart, the greater the stroke volume and consequently the more elevated the cardiac output. From our results, the cardiac output should be higher in males than females because of the significantly higher stroke volume in males. This is supported by the fact that the body muscle mass in women is about two thirds of that in men [25]. LVMMI is the left ventricular muscle mass per unit of surface; it is directly related to the strength of the left ventricle and its capacity to contract powerfully. Endurance-trained athletes develop biventricular dilation with enhanced diastolic function [20]. Echocardiographic studies have suggested that the young female heart exhibits less enlargement in response to endurance training than the male heart [20,25,31]. Thus men hearts have greater capacity to contract and supply larger volumes of blood to their body than women's hearts do. All of the above strongly explain, at least in part, the better performance observed in men, compared to women. LVDV and LVSV were significantly associated with both residential and training altitudes. Left ventricle volumes, and more notably LVDV, increased with altitudes. Also, there was a linear relationship between these residential and training altitudes and race times of runners. These demonstrate that optimal values of LVDV and LVSV combined with increasing training altitude could be boosters of runners' performances. The lower race times (i.e. higher performances) recorded with NW male runners over females might therefore be explained by higher values of the above-mentioned cardiac parameters in men compared to women.

The TAPSE is a simple echocardiographic measure of the right ventricle ejection fraction [32,33]; this parameter was significantly higher in men than women. Therefore, males had a better right ventricle systolic function than women; this could have been another contributing factor to their better performance. The TAPSE can help detect heart failure and/or co-existing chronic pulmonary disease [33,34]. We actually detected a female presenting a pulmonary hypertension with tricuspid impairment and dilation of chambers, but the data are not taken into consideration in the statistical analysis in this manuscript. The athlete was indeed advised not to run, by our research team. Such dilation could be due to repeated and regular trainings and participations in this race, as reported by some researchers [20,25].

5. LIMITATIONS

Our 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, not all finishers volunteered to participate in the study. We ended up having a small sample size of 69 participants. This was detrimental to our statistical analysis. The weak coefficients of determination r^2 obtained actually reflect that the regression model can only moderately explain all the variability of the response data around the mean. This can be due to the small sample size. The study was done for the first time on endurance runners under the harsh conditions of

Mount-Cameroon Race of Hope, and even though this gives good insights to a very interesting group of high performance runners, the paucity of preliminary data was not advantageous for our discussion.

6. CONCLUSION

The present study globally confirmed the baseline study carried out by Salah et al. [6]. Also, it demonstrated that optimal haemodynamic ventricular parameters (LVDV, LVSV, LVMMI and TAPSE) are preponderant in influencing the athletic performances in runners participating in endurance races such as Mount Cameroon Race of Hope. LVDV increased as altitudes too increased. Furthermore, regular training at increasing altitudes might explain, at least partially, the improvement of athletic performances in high altitude race. A follow-up study by TTE should be carried out at meaningful periods of the year, so as to bring more information on the evolution of these parameters in 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 claerance was got from the Cameroon Federation of Athletics.

ACKNOWLEDGEMENTS

The authors are very grateful to the Sisters of the Cardiac Centre, St. Elizabeth Catholic General Hospital, Kumbo, Cameroon, for making provision of their echocardiograph (Siemens-Acuson Cypress ultrasound®) and for their tireless assistance in handling the runners during medical control. Likewise, we are grateful to the assistant of the cardiologist who worked all through with us.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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