

Normative Values of Cardio-Respiratory Endurance in Adults in Benin

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Abstract

Cardiorespiratory endurance is a determining factor in the assessment of the state of health of a person. Objective: To determine the reference values for cardiorespiratory endurance in Beninese adults. Methods: Prospective transversal study, with a descriptive and analytical aim. It was carried out on healthy adult subjects (18 to 50 years old), of Cotonou and Abomey cities, from October 2017 to May 2018, without clinically identifiable orthopedic, cardiorespiratory, osteoarticular or neuromotor impairment. These subjects performed three different cardio-respiratory endurance tests: The six-minute walk test (WT6), cycloergometer test (CT) and the step test (ST). Data processing and analysis were done using SPSS version 22 software. A linear regression model was used to establish the prediction equation of maximal oxygen uptake (VO_2 max) with the WT6 data. The significance level chosen was 5%. Results: Subjects average age was 30.0 ± 9.8 years. It was especially men (54.20%), students (42.13%), with a normal corpulence (69.91%). At WT6, they walked 365 m to 798 m (557.1 ± 93.6 m) with extreme heart rates (EHR) of 67 to 189 (136.7 ± 19.0) beats per minute. At ST, the extreme powers developed were 2.7 watts/kg and 11.8 watts/kg (6.4 ± 1.8 watts/kg), with EHR of 99 to 204 (168.4 ± 15.4) beats per minute. The predictor equation of VO_2 max by WT6 was function of the subject's weight, age and sex ($R = 0.73$). Conclusion-Discussion: These normative values of cardio-respiratory endurance of Beninese subjects seem to be specific to them. An extension of the present study to a larger sample nevertheless seems desirable.

Keywords

Cardio-Respiratory Endurance, 6-Minute Walk Test, Step Test, VO_2 Max, Benin

1. Introduction

Cardiorespiratory endurance (RCT) is the ability of the heart, lungs, and circulatory system to efficiently deliver oxygen and nutrients to muscle mass required during prolonged physical exertion [1]. This is a very important piece of information about the state of health of a person [2]-[13]. Its assessment is therefore decisive during the examination of any patient, in order to adapt the level of activity during patient rehabilitation sessions. VO₂ max is the parameter of choice for this assessment [14]. Its estimate is made, based on various tests including the 6-minute walk test [15]. So it requires reference to normative values [16] [17]. The latter is not currently being available in Benin. It is for this purpose that we initiated this study, which objective is to determine reference values of cardiorespiratory endurance in Beninese adults.

2. Methods and Materials

2.1. Type and Period of Study

This is a cross-sectional prospective study with a descriptive and analytical aim. It was done from October 06, 2017 to May 25, 2018, *i.e.* over a period of eight (08) months.

2.2. Study Population and Sampling

Our study population took into account healthy adult subjects from Cotonou and Abomey cities. A healthy subject was defined as any person having no apparent orthopedic impairment objectified on examination and having no impairment of cardiorespiratory, osteoarticular, and neuromotor function. The sampling was carried out taking into account healthy adult subjects, aged 18 to 50 years, living in Cotonou or Abomey (or in one of their neighboring municipalities) and having consented to participate to the study. Pregnant women (female) were excluded.

The list of subjects was made by raising awareness in public places (churches, market, sports ground, schools, workshops, etc.). An appointment was made with the consenting subjects, either at the University Clinic of Physical Medicine and Rehabilitation of the National Hospital and University Center (CNHU-HKM) of Cotonou or the functional rehabilitation service of the Departmental Hospital of Abomey, to carry out their cardio-respiratory endurance tests.

2.3. Cardio-Respiratory Endurance Tests Done

For the evaluation of cardio-respiratory endurance, subjects had in two separate sessions of at least one week, three different tests: The six-minute walk test and the cycloergometer test at the first session and the step test during the second session.

- For the six-minute walk test (6 MWT), subjects did not perform vigorous exercise within two hours of testing. They seated and were at complete rest for

ten minutes before the 6 MWT. They wore sportswear to be comfortable during the exercise. The test was done in a flat linear corridor, marked every 1 meter over a distance of 20 meters with a stud placed at each end. Instructions given to the subjects were: “The objective of this test is to walk as far as possible in six minutes. You will go back and forth by going around the studs and keeping a straight trajectory”. Encouragement given was standardized, every minute. Fifteen (15) seconds before the end of the test, subject was notified that the test was about to be completed.

- Cycloergometer test was performed after a minimum of thirty to forty-five minutes of rest after the six-minute walk test, after that the heart rate had returned to its resting value or very close to it and the subject felt ready to start. Therefore, we comfortably install subject on the bike (adjusting the height of the seat so as to avoid a flexion of more than 90° of the knee during pedaling). Subject is pedaling at free pace for three minutes as a warm-up. The test began really when the bike power is reached to 50 watts, that was increased by 15 watts every minute. Subject was allowed to pedal upright when the working power became greater. Instructions given to the subject were: “Pedal at a speed between 60 and 70 revolutions/minute; do not speak during the test; pedal as long as possible”. Standard encouragement was given during the test.

- For the step test, subject was first installed in a seated position on a chair so as to be put to rest for 2 minutes. After that, the resting heart rate (HR_0) was recorded and noted (step 0). Then, the subject started the test with the first board 0.1 m high corresponding to the first level. For 2 minutes he went up and down the board at a constant speed of 84 steps/min (step 1). At the end of this step, the heart rate (HR_1) was also recorded. The subject rested for 2 minutes, to repeat the same test, at the same pace with a board 0.2 m high, for 2 minutes after which the heart rate (HR_2) was recorded. The same scenario was continued with boards of increasingly higher heights (incrementing 0.1 meter per step), until the subject was unable to follow the rhythm imposed by the metronome to ascend and descend.

2.4. Parameters Collected

On the 6-minute walk test, the total distance traveled and the heart rate immediately when stopped were recorded using the heart rate monitor worn by the subject. The maximum oxygen consumption (VO_2 max) was calculated, from the data of the cycloergometer test, according to the gender-specific formulas established by Thomas W. Storer:

$$VO_2 \text{ max (male)} = 10.51 (w) + 6.35 (kg) - 10.49 (age) + 519.3 \text{ ml}\cdot\text{min}^{-1},$$

$$VO_2 \text{ max (female)} = 9.39 (w) + 7.7 (kg) - 5.88 (age) + 136.7 \text{ ml}\cdot\text{min}^{-1}.$$

Relative VO_2 max (ml/kg/min) was obtained by dividing these absolute values by body weight. Also, as soon as the cycloergometer test was stopped, the heart rate (HR) was taken on the heart rate monitor by the subject. During the step test, the developed power (watts) was calculated according to the formula used

by Nielens H. and Plaghki L: Power = weight (in kg) \times acceleration due to gravity (9.8 m/S^2) \times climb frequency/second (84 steps/minute) \times height of the last plank with which the two minutes of ascent/descent were completed. Power relative to body weight was the ratio of absolute power to subject weight.

2.5. Statistical Analysis and Data Processing

Encoding and processing of data were done in Microsoft office Excel version 2007 and SPSS software version 22, respectively. A descriptive analysis of the study variables was done. A correlation between VO_2 max and the distance covered on the six-minute walk test was sought. A linear regression model was used to establish the predictive equation for VO_2 max with the data from the six-minute walk test. The significance level chosen was 5%.

3. Results

3.1. Characteristics of the Study Population

The extreme ages were 18 and 50 with a median of 28. The mean age was 30.0 ± 9.8 years. Subjects were especially men (54.20%), students (42.13%), with a normal corpulence (69.91%). According to their allegations, 23.61% of them consume alcohol occasionally and 21.30% have a fairly regular practice of sport. **Table 1** shows other characteristics of the study population and **Figure 1** shows data on the lifestyle of study subjects.

Table 1. Distribution of study subjects, according to their socio-demographic characteristics.

		Number	Percentage (%)
Gender	Male	117	54.20
	Female	99	45.80
Professional status	Student	91	42.13
	Artisan	43	19.91
	Civil servant	24	11.11
	Others	58	26.85
Marital status	Single	109	50.46
	Married	104	48.15
	Widower	3	1.39
Level of study	University	84	38.89
	Secondary	53	24.54
	Primary	52	24.07
	Unschoolled	27	12.50
Corpulence	Thinness	36	16.67
	Normal	151	69.91
	Obesity	29	13.42

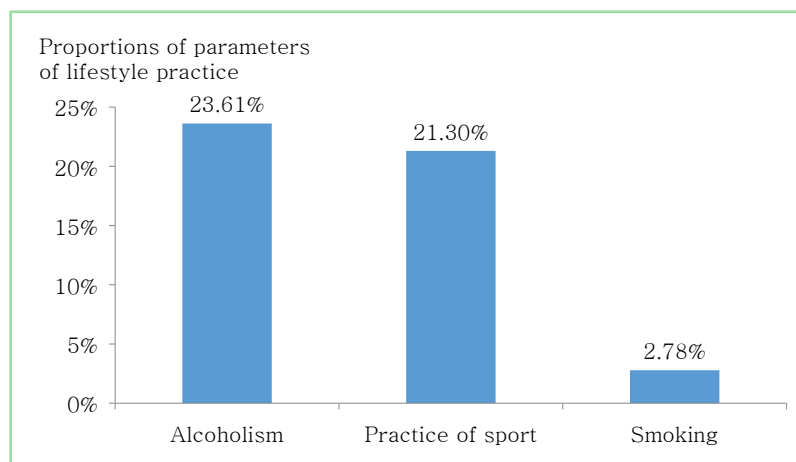


Figure 1. Distribution of subjects according to their lifestyle practices.

3.2. Cardio-Respiratory Endurance Performance

3.2.1. Six-Minute Walk Test Performance

On the 6-minute walk test, distances covered by subjects ranged from 365 m to 798 m with an average of 557.1 ± 93.6 m. The extreme heart rates were 67 and 189 beats per minute. The average HR was 136.7 ± 19.0 beats per minute. **Table 2** shows the percentiles of the subjects' performance on the 6-minute walk test, for distance traveled and heart rate, by sex and age groups.

3.2.2. Step Test Performance

During the step test, the extreme powers developed by the subjects were 2.7 watts/kg and 11.8 watts/kg with an average of 6.4 ± 1.8 watts/kg. The extreme heart rates were 99 and 204 beats per minute with an average of 168.4 ± 15.4 beats per minute. **Table 3** presents the percentiles of the developed power and the heart rate of the subjects by sex and age groups.

3.2.3. VO₂ Max on the Cycloergometer

The extreme VO₂ max of the subjects was 15.7 ml/kg/min and 68.7 ml/kg/min with the mean (standard deviation) of 33.4 ± 9.3 ml/kg/min. It was 38.3 ± 9.6 ml/kg/min for men and 27.6 ± 4.5 ml/kg/min for women. **Table 4** presents the percentiles of VO₂ max by sex and age groups.

3.2.4. Prediction of VO₂ Max with the Cycloergometer

The equation for predicting peak oxygen uptake by the six-minute walk test is as follows: $VO_2 \text{ max (ml/kg/min)} = [53.906 + 0.026 D - 0.395 \text{ Weight} - 0.257 \text{ Age} - 9.204 \text{ Sex}] \pm 4.1 \text{ ml/kg/min}$ ($R = 0.73$). **Table 5** shows the correlation data of VO₂ max with the distance covered on the 6-minute walk test.

4. Discussion

4.1. Six-Minute Walk Test Performance

The average distance covered by subjects of our sample was 557.1 ± 93.6 m. This mean distance is greater than what was reported in the Arab population, by

Table 2. Percentiles of distance traveled and heart rate of subjects on the 6-minute walk test according to age and gender.

		5th	10th	25th	50th	75th	90th	95th
		<i>Distance traveled</i>						
Male	All ages	424.7	459.0	526.0	600.0	682.9	711.0	730.1
	<20	568.6	580.4	601.5	644.5	685.0	713.5	738.8
	20 - 30	519.6	549.9	602.0	660.0	699.0	722.7	772.8
	30 - 40	414.2	445.1	485.5	542.5	602.5	655.0	735.5
	40 - 50	410.0	414.0	443.0	490.0	529.0	539.6	559.2
Female	All ages	405.0	411.8	460.0	513.8	558.5	610.0	660.0
	<20	499.0	525.4	540.0	558.0	596.0	649.8	.
	20 - 30	423.7	453.7	491.5	543.0	583.5	660.0	669.1
	30 - 40	393.8	407.5	425.5	485.0	517.5	556.5	600.0
	40 - 50	376.7	404.6	420.0	555.0	491.0	524.1	552.1
		<i>Cardiac frequency</i>						
Male	All ages	107.5	114.0	124.5	137.0	150.0	160.2	170.4
	<20	127.1	128.0	137.3	144.0	151.8	173.5	179.7
	20 - 30	100.8	108.0	126.0	140.0	152.5	161.5	173.3
	30 - 40	97.5	116.0	127.3	132.5	148.0	161.5	167.6
	40 - 50	108.8	112.0	120.0	124.0	133.0	154.0	175.6
Female	All ages	109.5	113.8	126.0	137.0	145.3	158.3	170.2
	<20	67.0	75.0	130.0	145.0	161.5	172.4	.
	20 - 30	107.8	116.4	130.5	139.5	149.8	170.7	182.5
	30 - 40	110.5	112.0	122.5	131.0	140.8	149.5	154.0
	40 - 50	111.5	115.0	122.0	133.0	141.0	149.2	154.5

Table 3. Percentiles of power developed and heart rate of subjects in the step test according to age and gender.

		5th	10th	25th	50th	75th	90th	95th
		<i>Power developed</i>						
Male	All ages	4.97	5.49	6.17	6.86	8.23	9.60	9.60
	<20	6.86	6.86	7.55	8.23	8.92	9.60	-
	20 - 30	6.11	6.86	7.20	8.23	9.60	9.60	9.60
	30 - 40	4.22	5.07	5.49	6.86	6.86	8.23	8.23
	40 - 50	4.05	5.12	5.49	5.49	6.86	6.86	7.95
Female	All ages	2.74	4.12	4.12	5.49	6.75	6.86	7.99
	<20	4.12	4.12	5.49	6.12	6.86	7.07	.
	20 - 30	4.12	4.12	5.49	6.50	6.86	8.23	8.71
	30 - 40	2.94	4.12	4.12	4.12	5.49	5.49	5.49
	40 - 50	2.74	2.74	3.23	4.12	4.12	4.26	5.22
		<i>Cardiac frequency</i>						
Male	All ages	155.0	156.0	163.0	173.0	181.5	193.0	196.0
	<20	167.0	167.4	173.5	180.0	194.0	201.2	.
	20 - 30	156.0	163.8	173.0	180.0	188.0	195.1	196.0
	30 - 40	153.9	157.2	160.5	166.0	171.0	177.4	187.3
	40 - 50	148.6	151.8	156.0	163.0	168.0	172.8	174.8
Female	All ages	141.2	146.0	155.0	159.0	173.0	188.8	192.0
	<20	148.0	156.0	168.0	177.0	185.0	193.2	.
	20 - 30	121.8	149.9	156.3	169.0	179.5	192.0	197.5
	30 - 40	138.6	143.8	154.0	158.0	160.0	164.7	168.4
	40 - 50	133.0	142.0	146.3	155.0	158.0	160.0	161.5

Table 4. Percentiles of the subjects' VO₂ max and heart rate during the cycloergometer test according to age and gender.

		5th	10th	25th	50th	75th	90th	95th
		<i>VO₂ max</i>						
Male	All ages	24.6	28.6	31.3	36.4	44.6	52.6	55.92
	<20	31.9	32.6	37.4	42.2	52.7	60.1	68.3
	20 - 30	29.8	33.0	35.2	40.2	48.6	53.9	56.7
	30 - 40	25.0	27.1	29.4	32.0	35.1	39.4	43.3
	40 - 50	22.3	23.6	26.4	29.8	32.9	34.3	38.6
Female	All ages	20.4	22.0	25.0	27.3	30.3	33.4	35.4
	<20	23.8	24.1	27.3	28.6	31.8	35.4	-
	20 - 30	23.1	24.6	25.7	28.5	31.4	35.0	37.4
	30 - 40	24.4	24.8	26.0	28.4	31.0	34.0	36.9
	40 - 50	16.2	17.8	20.8	22.8	25.3	28.1	31.5
		<i>Cardiac frequency</i>						
Male	All ages	166.0	169.6	174.0	180.0	186.0	194.0	197.1
	<20	166.4	173.1	176.3	183.5	191.8	193.8	197.8
	20 - 30	168.0	169.8	178.0	185.0	192.0	197.1	200.0
	30 - 40	155.6	168.2	174.0	178.0	181.0	182.6	184.7
	40 - 50	162.8	166.4	170.0	172.0	178.0	181.2	182.8
Female	All ages	166.0	170.0	172.0	178.0	183.0	188.0	189.0
	<20	176.0	177.8	184.0	186.5	188.3	192.2	.
	20 - 30	171.3	173.6	178.0	180.0	184.0	188.7	192.8
	30 - 40	168.5	170.0	174.3	177.0	178.8	182.0	182.8
	40 - 50	162.2	165.0	167.5	170.0	174.0	178.0	179.4

Table 5. Correlation between VO₂ max and traveled distance to 6-minute walk test.

		VO ₂ max (ml/kg/min)		Statistical test
		<33	>33	
Distance traveled during the 6-minute walk test	<557	91	24	R = 0.65
	>557	36	64	P < 0.00

Alameri *et al.* [18]. On the other hand, it is lower than what was found in the study of Chetta in 2001 and Prochaczek in 2007 [19] [20]. If we could evoke the question of age to explain the observed difference, it should be noted that our proportions remain lower than those of Chetta *et al.* in 2006, in a study population of identical age to ours (20 - 50 years) [19]. We can then simply make the assumption of the cultural question (sports practice, predominant mode of travel, etc.) to justify these noted differences. The average heart rate of subjects of our study was 136.7 ± 19.0 beats/minute, or 34.8% of the calculated theoretical maximum heart rate. This percentage shows that the test is submaximal. This average heart rate is higher than that found by some authors in the literature [20] [21] [22]. This difference may be related to reduced aerobic endurance in our cohort compared to these populations.

4.2. Step Test Performance

The average power of our subjects was 6.4 ± 1.8 watts/kg. This average exceeds

those found in a study carried out by Niens where the average power was 1.29 ± 0.39 W/kg and 1.01 ± 0.25 W/kg respectively for men and women with chronic pain. In healthy subjects, it was 1.74 ± 0.53 W/kg and 1.08 ± 0.40 W/kg respectively for men and women [23]. This higher value in our study would be related in the fact that our subjects went to exhaustion while in the study of Niens the test was stopped at a heart rate corresponding to 65% of the theoretical maximum heart rate calculated. The average heart rate was 168.4 ± 15.4 beats per minute, or 80.4% of the theoretical maximum heart rate. This percentage of FMT achieved shows that the test is under maximal despite the fact that subjects were allowed to go to exhaustion. This would be due to the discontinuous nature of the protocol. Indeed the two minutes of rest after each level allows a recovery and therefore a drop in heart rate.

4.3. Performance of the Cycloergometer Test

The mean maximum oxygen uptake (VO_2 max) of subjects of the study was 33.4 ± 9.3 ml/kg/min. Compared to other populations, the average VO_2 max of Beninese is lower than that of Japanese, Americans, Norwegians and Canadians [24] [25] [26] [27]. But these results are clearly superior to those reported by Shete *et al.* in subjects who are not known athletes [28]. The average maximum heart rate of our cohort was 179.4 ± 8.5 beats per minute, or $89.5\% \pm 7.1\%$ of the calculated theoretical maximum heart rate. This percentage shows that this is a peak test. This average heart rate is similar to that obtained by Loe *et al.* in a Norwegian population [26].

4.4. Correlation between the Distance Covered with a Six-Minute Walk and Maximum Oxygen Consumption

The maximum distance traveled on the six-minute walk test was correlated with the maximum oxygen consumption estimated from the cycloergometer test ($r = 0.65$; $p < 0.00$). Burr *et al.* found a moderate correlation ($r = 0.54$) in healthy subjects aged 20 to 59 years [29]. In populations suffering from respiratory pathologies, a correlation between distance travelled during the 6-minute walk test and VO_2 max has also been found [30]. It is therefore possible to predict a subject's maximum oxygen uptake from the six-minute walk test. The VO_2 max prediction equation shows that the latter evolves inversely with respect to body weight, age and gender. The influence of sex on VO_2 max is greater than that of others. Similar remarks were made by Burr *et al.* [29]. Also, Mänttari *et al.* had noted that the predictors of the subject's performance on the six-minute walk test varied by gender [15]. From their analysis, it emerged that for men, the best predictors for VO_2 max were walking distance, age, BMI, heart rate at the end of 6 MWT and height, and for women, walking distance, age and weight.

We can mention two main limitations to this study. This concerns the method of recruiting subjects and the taking into account of the heart rate as a parameter for assessing cardio-respiratory endurance. Indeed, a stratified cluster sampling would have been better. But, as we don't have specific motivating factors for the

subjects, such a recruitment method is difficult in our socio-cultural context. About the heart rate, it is well known that various other parameters such as tests examination conditions or stress, could lead to disturbances.

5. Conclusion

This study enabled the establishment of normative values for the parameters of cardiovascular endurance in young Beninese adults. It emerges from this study that the standards found are different according to gender and age, as well as those of several other countries, justifying the importance of this work. It is therefore urgent to extend this study to other age groups of the population and to consider looking for other factors that may influence these standards.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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