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The 20 m^2 VAMEVAL Test: A Reduced Space Approach to Determine the Maximum Oxygen Consumption of Young Cameroonians

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Abstract: This study aimed at comparing physiological variables measured during a modified 20 m^2 VAMEVAL test with that of its predecessor, the classical VAMEVAL test. Thirty volunteers moderately-trained sport students (14 males, 25.7 ± 3.4 years, and 16 females, 25.0 ± 2.5 years) specialized in running sport disciplines, randomly underwent three maximal oxygen uptake assessment using the classical VAMEVAL test in a 400m track (VAM400), the modified VAMEVAL test in a reduced space of 20 m^2 (VAM20) and, the ergometer test (ERG) as standard test. Results revealed significant differences between the two sexes in the VAM400 and VAM20 over VO_{2max} ($P< 0.01$), maximal heart rate ($P< 0.05$) and rating of perceived exertion ($P< 0.001$). No significant difference was noted in lactatemia (La) during VAM400 and VAM20. VO_{2max} variations of 6.8% in females and 8% in males were recorded when moving from VAM400 to VAM20. The VAM20 test is valid to estimate cardiorespiratory fitness of young Cameroonians in absence of appropriated infrastructures.

Keywords: VAMEVAL Test, Reduced Space, Maximum Oxygen Consumption, Young Cameroonians

1. Introduction

According to various researchers, maximum oxygen uptake (VO_{2max}) is the physiological parameter that plays an important role in the determination of physical capacity and fitness in aerobic situation [1, 2]. This measurement can be realized in a direct manner using a laboratory based double labeled water calorimetric [3], which is time consuming and requires expensive equipment as well as trained technicians, and is further not suitable for use with large groups [4]. Alternatively, indirect methods based on the correlations between measured parameters and oxygen consumption are also used, because they do not usually require sophisticated equipment or trained technicians, and are relatively less expensive, time efficient and easily administered to large numbers of subjects at the same time [4]. This second option seems more accessible because of its relatively low cost of realization [5].

Then, many field tests have been developed and each presents its characteristics [6–9]. However, their realization is limited to infrastructural difficulties which often oblige practical contextual adaptation. Some studies have been carried out in order to validate established original field tests adaptations [10, 11]. For example, Metsios et al. [12] and Flouris et al. [13] assessed the reliability and validity of the shuttle run test on areas of 20 m^2 and 15 m^2 respectively, in the prediction of maximal oxygen consumption. These different adaptations aimed at reducing the 180° directional changes in the classical space to 90° directional changes in a 20 m^2 area, directional changes which induce great energy depletion and low correlations with direct tests. They equally take into consideration the shape and the dimension of the layout, and it has been demonstrated that the shape of the layout as well as its perception influence the measurement of the subjects' aerobic capacities when using field tests [5, 14]. Furthermore, many studies supported that 20m shuttle tests could be adopted as a diagnostic mean of cardiovascular diseases, because of high correlations observed between onset values of estimated VO_{2max} and the occurrence of certain diseases [15–17].

Looking at the literature, the VAMEVAL test which was elaborated by Cazorla and Leger [18] is the more progressive test in the subjects' VO_{2max} estimation in sport context. This test is completed in a 200 m, 300 m or 400 m athletic tracks with 20m shuttles. Its validation in a reduced space has not yet been carried out, since many schools and training centers of developing countries do not always dispose appropriate spaces for its realization. Then, there is a problem of contextualization of originally elaborated tests, and no similar study has already been realized in the African context. The aim of the present study is to compare physiological variables measured during a modified 20 m^2 VAMEVAL test with that of its predecessor, the classical VAMEVAL test of Cazorla and Leger [18].

2. Material and Methods

2.1. Participants

Thirty non-smokers and moderately trained students, of the National Institute of Youth and Sports of Yaounde (Cameroon) (14 males, 25.7 ± 3.4 years, and 16 females, 25.0 ± 2.5 years), specialized in running sport disciplines volunteered to take part in the present study. The baseline biodemographic parameters of the participants are presented in table 1. Written consent was received from all participants after a detailed explanation about the benefits and risks involved with this investigation. Participants were told they were free to withdraw from the study at any time without penalty. The study was conducted according to the Declaration of Helsinki of 1975, and the protocol was fully approved by the national ethics committee for scientific research of the Republic of Cameroon, before the start of the assessments.

2.2. Study Protocol

The investigation started after a 10-min resting on a sitting position during which anthropometric and resting cardio-respiratory parameters of participants were determined. Weight and fat mass (FM) were measured using a bio-impedance-meter scale TANITA BC 532 (Tokyo, Japan), and the height was measured with height meter. Oxygen saturation (SpO_2) and resting heart rate (HRr) were determined using a pulse oximeter (OxyWatch^{TM}C20, China). Maximal expiratory volumes in 1st (FEV_1) and 6th (FEV_6) seconds as well as the FEV_1/FEV_6 ratio were obtained using an electronic peak-flow meter (Piko 6; nSpire Health, Inc., 1830 Left hand Circle, Longmont, CO, USA).

Each participant performed alone 3 maximal tests in a random manner:

1. classical VAMEVAL of Cazorla and Leger (1993) in a 400 m track (VAM400),
2. modified VAMEVAL test to a reduced space of 20 m^2 (VAM20) and,
3. ergometer test (ERG) as standard test.

The VAM400 test, similar to the classical VAMEVAL test of Cazorla [19] consisted in running in a 400 m athletic track, with cones placed on each 20 m, using pre-recorded sound signals to dictate the running speed. The participant should be in the level or near the following cone in the time of the beep. The test started with a speed of 8 km/h and the speed is increased by 0.5 km/h each shuttle of 1 minute. The test ends when the participant is unable to follow the imposed sound beeps, and the aerobic maximal speed (VMA) of the last shuttle achieved is recorded. The maximal oxygen consumption (VO_{2max}) is estimated by the formula: VO_{2max} (ml/min/kg) = 3.5*VMA (Km/h).

The VAM20 test is completed according to the same principle but, consisted in running on the four 20m long sides of a square marked on the floor with cones, and the VO_{2max} is also estimated.

The ERG test was performed on a cycloergometer (Monark Ergomedic 828E GHI, Sweden) and acted as a gold standard. The test started with 5 min warm up at around 90 watts (1.5 kilo pounds, Kp) in order to get the participants used to pedaling frequency between 60 and 70 rotations per minute (rpm). The starting load was fixed at 90 watts and was increased by 30 watts (0.5 Kp) after each minute. When the participant was not able to maintain the pedaling frequency beyond 60 rpm, the test was stopped and the last completed step was recorded. Then, we obtained the maximal aerobic load developed (PMA) and the VO_{2max} was estimated by the formula: VO_{2max} (ml/min/kg) = [13.5*PMA (Watts) +100]/weight (kg). However, participants were allowed to stop if symptoms of significant distress occurred. They were not informed of the aim of the study in order to avoid possible bias.

During tests, heart rate (HR) was continuously measured using a heart rate monitor Polar RS800CX (Polar electro Oy, Finland). At the end of each test, the Borg score (Rating of Perceived Exertion, RPE) was determined using the CR-10 scale of Foster et al. [20]. Blood lactate concentration [La] was determined after each test at the 5th minute of recovery using the blood lactate analyzer Lactate Scout (Barleben, Germany).

2.3. Statistical Analysis

All statistical analyses were conducted using Statview 5.0

software (SAS Institute Inc., Cary, NC, USA) and data were expressed as mean values (standard deviations). The repeated measures analysis of variance was realized to compare mean values obtained during the 3 tests. When necessary, the Tukey *post hoc* test was performed to locate this difference. Inter-sex comparison was conducted with the non-parametric U-Mann Whitney test, and the Pearson correlation test was used to determine associations between variables. The level of significance was set at $P < 0.05$.

3. Results

The baseline anthropometric and physiological characteristics of participants are summarized on Table 1. (Table 1 here). Significant differences were recorded on parameters between boys and girls, with exception of age (25.7 *vs* 25.0), the SpO_2 (98.0 *vs.* 98.4) and $VEMS_1/VEMS_6$ ratio (0.9 *vs.* 0.9).

Table 1. *Baseline biodemographic characteristics of participants.*

Variables	Boys (n=14)	Girls (n=16)	Total (30)
Age (years)	25.7 (3.4)	25.0 (2.5)	25.8 (3.4)
Weight (Kg)	78.5 (6.9)**	54.8 (3.1)	63.7 (13.0)
Height (cm)	176.7 (7.2)**	160.4 (5.9)	166.5 (10.3)
BMI ($kg.m^{-2}$)	25.1 (0.6)***	21.3 (0.5)	22.7 (2.0)
HRr (bpm)	67.3 (2.5)*	74.4 (5.9)	71.8 (5.9)
SpO_2 (%)	98.0 (1.0)	98.4 (0.5)	98.3 (0.7)
FM (kg)	9.6 (1.7)***	18.9 (2.9)	15.4 (5.4)
FEV_1 (L)	3.9 (0.3)**	2.3 (0.3)	2.9 (0.9)
FEV_6 (L)	4.5 (0.3)**	2.5 (0.3)	3.3 (1.1)
FEV_1/FEV_6	0.9 (0.0)	0.9 (0.1)	0.9 (0.1)

BMI= Body Mass Index; HRr= Resting Heart Rate; SpO_2= Oxygen Saturation; FM= Fat Mass; FEV_1= Forced Expiratory Volume at the 1st second; FEV_6= Forced Expiratory Volume at the 6th second. *, **, ***: Significant Differences between boys and girls at p< 0.05, p< 0.01, and p< 0.001 respectively. Values are presented as Mean (Standard Deviation).

Table 2 presents the VO_{2max}, the [La], the maximal heart rate (HRmax) and the RPE obtained during the 3 tests. (Table 2 here). The [La] obtained during the VAM400 and VAM20 tests are not significantly different. Significant differences were perceived between the two sexes in the VAM400 and VAM20 over the VO_{2max} ($P < 0.01$), HRmax ($P < 0.05$) and RPE ($P < 0.001$). Variations of 6.8% for females and 8% for males were recorded when moving from VAM400 to VAM20. Consequently, determination equations of real VO_{2max} using the VAM20 are presented as follows:

Males: VO_{2max} (real) = VO_{2max} (estimated) + [8VO_{2max} (estimated)/100].

Females: VO_{2max} (real) = VO_{2max} (estimated + [6.8VO_{2max} (estimated)/100].

VO_{2max}ERG in boys and girls (56.7 ± 3.9 and 54.1 ± 3.3 respectively) were always more elevated than that of VAM400 and VAM20.

Table 2. *Performance and physiological characteristics during tests.*

Tests	VO_{2max}	[La]	HRmax	RPE
Boys				
VAM400	56.3 (1.0)***	9.8 (1.9)	189.9 (12.6)*	6.6 (0.8)***
VAM20	51.8 (1.5)	10.1 (2.3)	196.9 (8.9)	7.7 (0.9)
ERG	56.7 (3.9)***	10.5 (1.3)*	187.0 (3.8)***	7.5 (0.7)
Girls				
VAM400	52.6 (2.7)**	8.9 (1.4)	190.4 (9.5)*	6.4 (0.6)***
VAM20	49.0 (2.2)	8.8 (1.2)	193.3 (6.7)	8.1 (0.8)
ERG	54.1 (3.3)***	9.9 (2.1)*	171.1 (5.6)**	8.3 (0.9)
P value	0.0004	0.0587	0.0007	0.0248

*, **, ***: Significant differences compared to VAM20 at p< 0.05, p< 0.01 and p< 0.001 respectively; *P* value compares boys and girls; VO_{2max}: maximal oxygen Consumption; HRmax: Maximum Heart Rate; [La]: Blood lactate concentration; RPE: Rating of Perceived Exertion. Values are presented as mean (Standard deviation).

Figure 1 illustrates the kinetic of the HR for the different tests. (Figure 1 here). No HR difference has been observed all through tests between the VAM400 and the VAM20 ($P > 0.05$). We have noticed a significant difference of HR between the VAM20 and ERG during the entire test ($P < 0.05$), and between the VAM400 and ERG from half of the tests ($P < 0.05$). The intermediary HR obtained during ERG is lower than those obtained in VAM400 and VAM20.

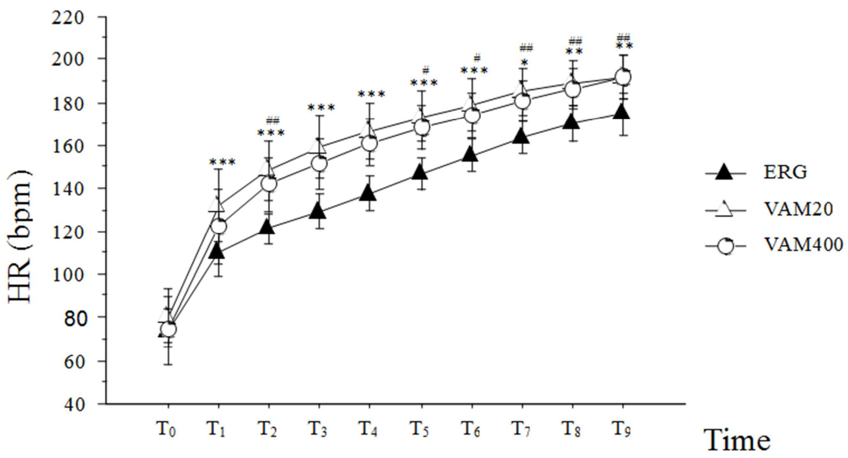

Figure 1. *Heart rate kinetic during tests.*

*, ** and***: Differences between VAM20 and ERG at $P < 0.05$, p< 0.01 and $P < 0.001$ respectively; # and ##: Differences between VAM400 and ERG at $P < 0.05$ and $P < 0.01$ respectively; NS: Non significant; HR: Heart rate.

Correlations between the measured VO_{2max} in the different tests are presented in table 3. (Table 3 here). We observed strong correlations between the VO_{2max} 400 and VO_{2max} 20 ($P< 0.01$; r= 0.608) and, VO_{2max} 20 and VO_{2max} ERG ($P< 0.01$; r= 0.685), but an average correlation between VO_{2max} 400 and VO_{2max} ERG ($P< 0.05$; r= 0.475).

Table 3. *Correlations between VO_{2max} of different tests.*

	VO_{2max}400	VO_{2max}20	VO_{2max}ERG
VO_{2max}400	1	0.608**	0.475*
VO_{2max}20		1	0.685**
VO_{2max}ERG			1

VO_{2max}400, VO_{2max}20, and VO_{2max}ERG: maximal oxygen consumptions obtained during the VAM400, VAM20 and ERG respectively.* and **: Significant Correlations at $P< 0.05$ and $p< 0.01$ respectively.

4. Discussion

The objective of this study was to compare the physiological parameters measured during a modified VAMEVAL test on 20 m^2 to those of its predecessors, the VAMEVAL test by Cazorla and Leger [18], so as to have a variant of the VAMEVAL test that can be applied to young Cameroonian sport students in a context of appropriate sport infrastructure scarcity.

In terms of aerobic capacity, results revealed differences of 6.8% for girls and 8% for boys when we move from VAM400 to VAM20. In fact, estimated VO_{2max} on a 400 m track (56.3 for boys and 52.6 for girls) are higher (P< 0.01) than those obtained on a reduced space of 20 m for each side (20m^2) (51.8 for boys and 49.0 for girls) (Table 2). These results met those of Assomo-Ndemba et al. [5] that showed that the estimated VO_{2max} during a twelve-minute run test in a larger space (track of 400 m) was higher than that estimated on a reduced space (200m). Moreover, the percentage gap observed in the two conditions during our study (~ 8%) is close to the 9.3% observed by Assomo-Ndemba et al. [5]. Consequently, we proposed correction factors as well as predictive equations to apply so as to get the real value of aerobic aptitude.

It has been also observe that VO_2max estimated values obtained in the present study are slightly higher than those usually brought out in the validity study of the shuttle test on 20 meters [9, 12, 21]. This ascertainment should spark studies at a higher scale to define the values that are proper to our context and propose useful norms for a comparison with those Caucasians.

However, the results of the present study are not in agreement with those of Flouris et al. [9, 13, 21] who had instead obtained higher VO_{2max} during tests realised on a modified space than that of their predecessors. They had investigated on the 20m shuttle test which requires the students to carry out semi rounds on 180°, leading to deceleration periods before accelerations. As for the modified variant, it was realised on a squared track of 20m by the side imposing 90° turns to athlete enabling the maintenance of the maximum speed race imposed by the test. In the present experiment, the VAM400 was carried out on a continuous athletic track of 400 m. This way supposes that the participants covered a race on a 0° angle. In the modified version during our experiment, the track was that of a square of 20 m side, which has increased the difficulty that has been the cause of the falling of the VO_{2max}. Assomo-Ndemba et al. [5] equally observed the reduction of the VO_{2max} of sport athletes from a Cooper test carried out on a reduced track of 200 m.

This study revealed no difference on the concentrations of lactate produced during the three effort tests (Table 2). In general, measured values are all superior to 9 Mmol/L. This result supposes that, from this parameter, subjects were at the maximum of their effort [19]. The [La] during VAM20 (10.1 Mmol/L) is superior to those obtained by Assomo-Ndemba et al. [5] on a reduced space (8.1 Mmol/L). On the other way, this value is close to those obtained by Flouris et al. [13] (10.3 Mmol/L) during the shuttle test of 15 m^2. On the physiological view, this result suggests that muscle solicitation through lactic anaerobic metabolism looks alike during the shuttle tests of 20 m^2 and of 15 m^2. It is suggested that the variant of the VAMEVAL test realised on a reduced space of 20 m by the side can enable to determine the maximum aerobic speed of athletes.

The present study has revealed no difference in the HR kinetic between the VAM400 and the VAM20. This result suggests a similar cardiac response during the two tests (Figure 1). The recorded HRmax during these two tests are close to their estimated theoretical maximum HR (220-age), and suppose that subjects are equally at the maximum of their effort during tests. In fact, the energic need fit for a good output of muscles induces a higher blood gain that increases the VO_{2max} and thus, the rhythm of the heart, which is put to contribution for a good flow [22]. Dellal et al. [23] have already noticed that change of direction in athletic task of adult footballers brought about a prompt response of the HR, alongside an increase of lactatemia and the perceived exertion.

Concerning the rating of perceived exertion, results revealed significant difference (P< 0.001) between the RPE obtained in VAM400 and VAM20 tests, with significant intersexual differences (P= 0.0248) (Table 2). As mentioned above, the modification of the track has caused an increase of the angle of the curve (0° to 90°). This has induced an increase of the difficulty that caused the falling of the performance justified by weaker VO_{2max} during the modified test. This result is in line with the conclusions of Assomo-Ndemba et al. [5] which stipulate that an increase of the RPE is related to the reduction of the oxygen maximum consumption having as direct consequence the reduction of the performance.

During this study, the correlations that may exist between the estimated VO_{2max} in the various tests were determined (Table 3). Strong correlations between VO_{2max}20 and VO_{2max}400 on one hand (r=0.608; P< 0.01), and between

$VO_{2max}20$ and $VO_{2max}ERG$ on the other hand (r= 0.685; P< 0.01) were observed. This result suggests that the VAM20 test is the one that permits to estimate in a most reliable way the aerobic endurance of the subjects of our study.

5. Conclusion

The adaptation of aerobic endurance tests context as well as the validation of these ones constitutes a necessity in the optimal determination of the physical condition of athletes. Measured physiological responses during the modified VAMEVAL test on a square of 20m by the side (VAM20) present more maximal values, compared to those taken during that of its predecessor, the classical VAMEVAL test (VAM400). The VAM20 test is valid to estimate the aerobic aptitude of young Cameroonians in absence of appropriate infrastructures. The increase of the sample size and the comparison of the data obtained from other direct measurements might permit the validation of the present conclusions.

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