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ORIGINAL

MAXIMAL OXYGEN CONSUMPTION IN MEXICAN UNIVERSITY STUDENTS: COMPARING FIVE PREDICTIVE TEST

CONSUMO MÁXIMO DE OXÍGENO EN ESTUDIANTES UNIVERSITARIOS MEXICANOS: COMPARANDO CINCO PRUEBAS PREDICTIVAS

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ABSTRACT

The objective of this study was to determine whether there are differences in the measurement of indirect $\dot{V}O_2\text{max}$ among five different physical tests: UMTT, VAM-EVAL, 20 MST, 1000 m and Ramsbottom. The subjects were Mexican college-age men without previous training and without sport experience with the following parameters (mean \pm 1 standard deviation): age $19,33 \pm 1,09$ years, weight $68,47 \pm 9,93$ kg, height $1,71 \pm 0,06$ m, and body mass index $23,62 \pm 2,82$. Indirect $\dot{V}O_2\text{max}$ (ml/kg/min, average \pm 1 standard error) by test were: $44,26 \pm 3,74$ for UMTT, $44,14$

$\pm 3,01$ for VAM-EVAL, $42,78 \pm 2,80$ for 20 MST, $44,92 \pm 2,33$ for 1000 m and $42,67 \pm 2,96$ for Ramsbottom. We did not detect significant differences in indirect $VO_2\max$ obtained by the five tests. We conclude that the five tests are equivalent and can be used interchangeably to assess indirect $VO_2\max$.

KEY WORDS: College students, $VO_2\max$, UMTT, VAM-EVAL, 20-MST, Ramsbottom.

RESUMEN

El objetivo de este estudio fue determinar si existen diferencias en los valores de $VO_2\max$ indirecto obtenido con cinco pruebas físicas: UTMM, VAM-EVAL, Ida-Vuelta, 1000 m y Ramsbottom. Los sujetos fueron hombres mexicanos en edad universitaria sin entrenamiento previo y sin experiencia en deportes, con los siguientes parámetros: edad $19,33 \pm 1,09$ años (media ± 1 desviación estándar), peso $68,47 \pm 9,93$ kg, estatura $1,71 \pm 0,06$ m e IMC $23,62 \pm 2,82$. El $VO_2\max$ indirecto (ml/kg/min, media ± 1 error estándar) por prueba fue de: $44,26 \pm 3,74$ para UMTT, $44,14 \pm 3,01$ para VAM-EVAL, $42,78 \pm 2,80$ para Ida y vuelta, $44,92 \pm 2,33$ para 1000 m y $42,67 \pm 2,96$ para Ramsbottom. No se encontraron diferencias significativas entre el $VO_2\max$ indirecto obtenido por los sujetos de estudio en las cinco pruebas. Concluimos que las cinco pruebas son equivalentes y pueden ser usadas indistintamente para evaluar el $VO_2\max$ indirecto.

PALABRAS CLAVES: Jóvenes universitarios, $VO_2\max$, UMTT, VAM-EVAL, Ida-Vuelta, 1000 m y Ramsbottom.

INTRODUCTION

Maximum oxygen consumption ($VO_2\max$) is a measurement that quantifies a subject's maximum aerobic capacity (1,2). It is useful because based on these data, physical exercise can be prescribed (3).

Currently, $VO_2\max$ can be evaluated both in the laboratory and in the field (4,5,6). In the laboratory, the measurement is more exact, but is more expensive, more time-consuming, and requires more personnel training than field measurement (7,8,9). As such, it is much more economical to measure $VO_2\max$ indirectly using different field tests. Among these indirect tests are the University of Montreal Track Test (UMTT), Maximum Aerobic Speed (VAM-EVAL), 20-m multistage shuttle run test (20-MST), the 20-MST applying the correction proposed by Ramsbottom et al. (14), and the 1000 m flat test (1000 m) (10,11,12,13,14,15,16,17).

Each of these field tests has its own characteristics. The UMTT is a maximum progressive indirect test of continuous running, based on the energetic cost to the individual of increasing velocity every 2 minutes (10,18). This test has been used to evaluate more than 3000 students in the physical conditioning classes at the University of Montreal (10), young students in physical education classes (19,20,21,22) moderately trained athletes (23), moderately trained subjects (18), and soldiers (24). The VAM-EVAL is a continuous progressive running test with velocity increases every minute (25), which has been used to evaluate young physical education students (26,27) and compare physiological responses in healthy subjects (28). The 20-MST has intermittent and incremental characteristics, with an increase in velocity each minute, and consists in 20-m shuttle-runs (12,13). This test has been used to evaluate university students in India (29) and Kenya (30). The 1000 m test is a linear or continuous test (31,15,16,17) and has been used on a sample of Mexican youths (15) and male university students in China (16), as well as to describe physical aptitude profile in the school population (32), sport habits, motor and cardiorespiratory physical aptitude in 7-9 year old schoolchildren (33), and to describe the influence of aerobic resistance in young volleyball players (34) and identify and evaluate youths with talent for football-soccer (17). Results for the Ramsbottom test can be obtained by using special tables to interpret data from the 20-MST (14).

To date, the UMTT, VAM-EVAL, 20-MST, and 1000 m, but not the Ramsbottom test, have each been validated separately against laboratory tests (10,14,35,25,36,15,37,38). In general, the comparison of results between one field test and one laboratory test have shown no difference in results (19,15,39). However, to date there is no comparison of the five aforementioned field tests in the same group of human subjects. In the present study we compare the $VO_2\max$ results obtained from the five tests (UTMM, VAM-EVAL, 20-MST, 1000 m and Ramsbottom), using the same group of healthy university students with no sports experience. Our objective using these data is to test whether the results of these tests are equivalent. In addition, given that in three of these tests (UMTT, VAM-

EVAL, 20-MST) it is possible to measure the distance covered in m by the subjects, we will compare the tests to see if these distances are equivalent among tests and can be used interchangeably to catalogue the physical performance of the subjects analyzed.

METHODS

The study was carried out during the months of February and May of 2014. The subjects in the study were 71 male university student volunteers without previous sports training living in the city of Xalapa, Veracruz, México (19°32' N, 96°54' O; 1460 masl). None of the study participants took medication or was a smoker. In addition, the subjects did not carry out any organized physical activity the six months prior to the study. The participants continued their normal activities during the data collection period. The group had the following parameters (mean \pm 1 SD): age 19,33 \pm 1,09 years, weight 68,47 \pm 9,93 kg; height 1,71 \pm 0,06 m, body mass index (BMI) 23,62 \pm 2,82.

The participants considered in the study were students enrolled in the Universidad Veracruzana, and had previously and electively chosen to take a class in the Sports Activities Department (*Dirección de Actividades Deportivas*) at the University. The inclusion criterion for the subjects was no physical activity (i.e. they were sedentary). Subjects who carried out light, moderate, or intense physical activity (40), or had been selected to compete in any sport in childhood or adolescence or that participated in any sports team at the Universidad Veracruzana were excluded from the sample.

All of the subjects were informed about the different indirect VO_2max tests and the objective of the study prior to beginning data collection. After it, they gave signed consent following the Helsinki declaration procedures to participate in all evaluations.

The subjects were familiarized with the tests during the four weeks prior to the evaluation. For this, a specific calendar was followed (Tables 1 and 2). The first day of the first week, the subjects ran on a 400 m synthetic (Tartan®) athletic track with a soccer field in the center. Then, the procedure for each test was explained to them (see details below). Over the following days, before beginning the specific exercises adapted to each of the different indirect VO_2max measurement tests, they carried out a 15-20 minute warm-up and stretch exercise. Once concluded, the subjects carried out the exercises described in Tables 1 and 2. During the first four weeks the subjects were instructed in how to take their heart rate (HR) manually. To do this, they applied their index and middle fingers to the neck region, where the pulse of the carotid artery can be felt. Once they perceived the pulse they recorded the number of pulses for 15 seconds, then multiplied this number by four to obtain the HR per minute (41,7). The practice of taking their HR was done five times per day, before and immediately after the exercises proposed in Tables 1 and 2.

In order for the subjects to know how to determine their rating perceived effort (RPE) (42) it was explained to them, the first day of week 1 before beginning the exercises, what the Borg scale (CR 10) consists of, so that they would relate each of the numbers on the scale with the energy demand required. Each day, ten minutes after concluding the exercises indicated in tables 1 and 2 each subject reported his RPE.

All of the subjects were able to report their HR and RPE at the end of the fourth week of the study. The accuracy of the HR measurement was evaluated for each subject. This was done during the fourth week by verifying three times that the HR reported by the subject coincided with that taken simultaneously by the study authors.

Table 1. Exercises carried out by study participants during week 1. During this week the subjects were familiarized with the different VO₂max tests. The day, test worked, and running time, distance, and intensity are indicated.

Day	Test	Time (minutes)	Distance (m)	Intensity (km/h)
Monday	UMTT	2	280	8
Tuesday	VAM-EVAL	1	140	8,5
		1	160	9,0
Wednesday	20-MST	1	140	8,5
		1	160	9,0
Thursday	1000 m	1	200	10

Table 2. Exercises carried out during weeks 2, 3, and 4 by study participants. During these weeks the subjects were familiarized with the VO₂max tests used. Note that the practice of the of the UMTT, VAM- EVAL and 20-MST were repeated each week, while for the 1000 m test there was an increase of 100 m each week. The rest of the table is similar to Table 1.

Day/week	Test	Time (minutes)	Distance (m)	Intensity (km/h)
Monday/weeks 2, 3, 4	UMTT	2	280 m	8
			600 m	9
Tuesday/weeks 2, 3, 4	VAM-EVAL	1	140 m	8,5
			160 m	9,0
Wednesday/weeks 2, 3, 4	20-MST	1	140 m	8,5
			160 m	9,0
Thursday/week 2	1000 m	No time	200 m	-----
Thursday/week 3	1000 m	No time	300 m	-----
Thursday/week 4	1000 m	No time	400 m	-----

During the last four weeks of the study (weeks 5, 6, 7, and 8) four VO₂max test were carried out, evaluating subjects on each Tuesday, carrying out one test per

week (43): week 1 UMTT, week 2 VAM-EVAL, week 3 20-MTS, and week 4 1000 m.

The subjects were given a physical prior to the tests by the University medical team to certify that they could exercise without issues. In addition, the subjects abstained from vigorous exercise during the 48 h prior to each test. During the evaluations participants were responsible for bringing sufficient water to freely hydrate as long as they wished or as they were instructed. The subjects that completed 100% of the evaluation were included in the study. Twelve subjects abandoned the study due to illness (n=4), injury (n=3) or absence (n=5) from one or more of the test protocols. In figure 1 a flow chart of the process described is presented.

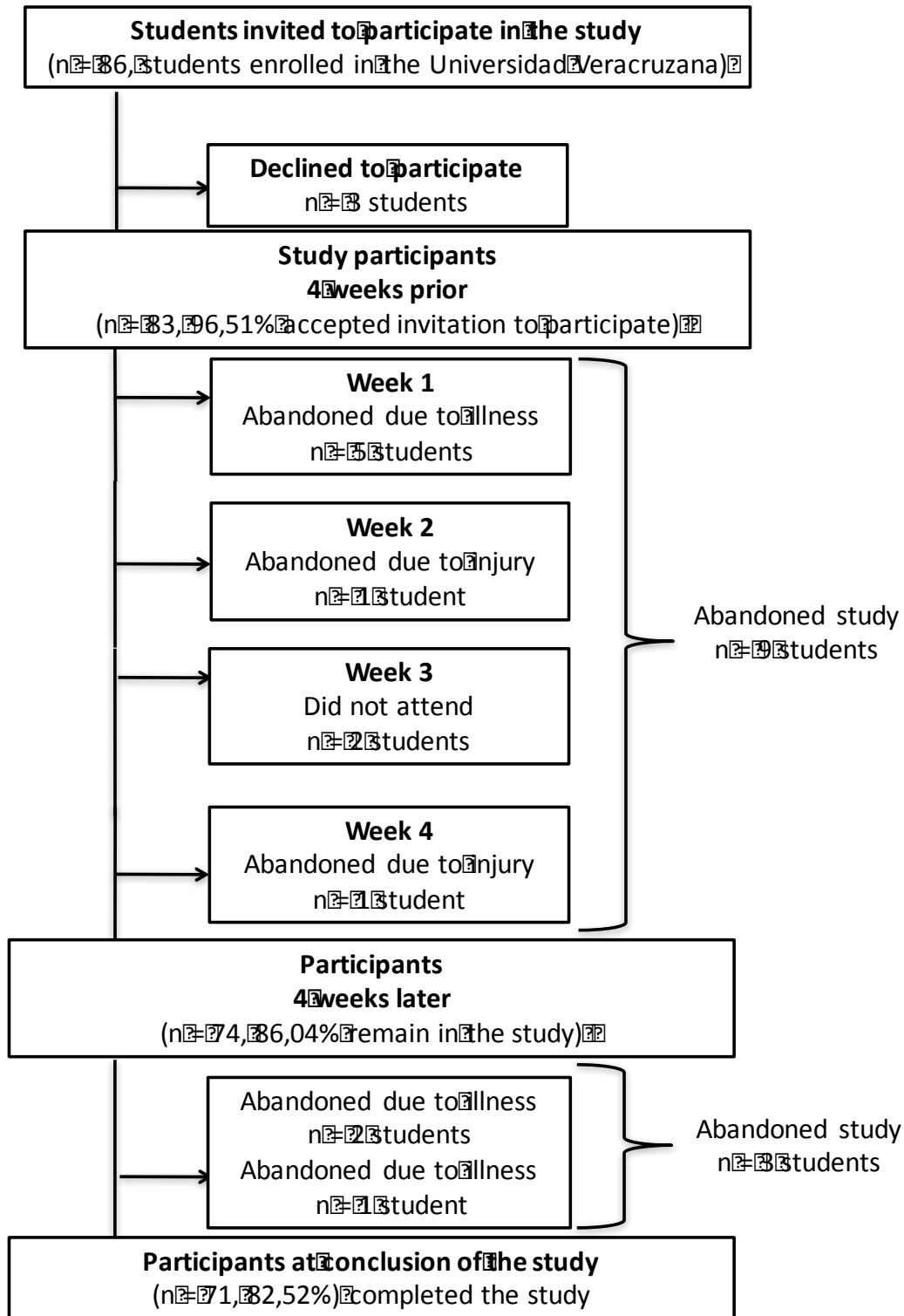


Figure 1. Flow chart of the process followed to determine subject participation in the study. The number of participants for each phase is indicated.

For the UMTT, VAM-EVAL, and 1000 m tests, a 400 m flat Tartan® track was used with cones placed every 20 m, while for the 20-MST test the soccer field in the

center of the same track was used. This field was covered with natural grass, on which a 20-m long, 1,20-m wide lane was marked. During the UMTT, VAM-EVAL, and 20-MST tests a loudspeaker was used to indicate the running pace of the subjects. For the UMTT the subjects began running at a speed of 8,0 km/h. After each 2-minute period, they were asked to increase their running speed by 1 km/h. For the VAM-EVAL and 20-MST, subjects began running at 8,5 km/h upon hearing an auditory signal they were asked to increase their speed by 0,5 km/h each minute. For the 20-MST subjects ran only within the lane described above, running back and forth within it. In the 1000 m test, participants ran the 400 m track. In the UMTT, VAM-EVAL, and 20-MST the test ended when on two occasions the subject was unable finish the 20 m in the time required by the auditory signal. For each subject during each test, the total distance run, time run, maximum heart rate (HRmax) and RPE were recorded.

The following formulas were used to calculate $VO_2\max$ from each test. For the UMTT and VAM-EVAL: $VO_2\max=3,5(v)$, where v = velocity reached in the last period completed (12). For the 20-MST: $VO_2\max=(6(v))-27,4$ (13). For the 1000 m $VO_2\max = 71,662-(5,850 (t))$, where t = time in seconds (15). For the Ramsbottom test, the table from (14) was used.

At the end of each test, each subject was instructed to take the HRmax between 5 and 20 seconds of the recovery period. These 15 seconds were converted into pulse rate per minute and recorded manually (41,7). Each individual's RPE (44) was recorded 10 minutes after each test.

Analysis. To test for differences with respect to $VO_2\max$ and distance run, a one-way ANOVA was used. In the first case, $VO_2\max$ had five levels (i.e. UMTT, VAM-EVAL, Ida-Vuelta, 1000 m and Ramsbottom), and in the second, distance run had three levels (i.e. UMTT, VAM-EVAL, and 20-MST). In both cases the response variable ($VO_2\max$ and distance run) was normally distributed (checked using a Q-Q plot with 95% confidence limits of the distribution marked). In the ANOVAs an offset variable (called PC1) was used to standardize subjects by removing variance associated with age, height, weight, and BMI. PC1 was obtained using a main components analysis, which considered the following base variables: age, weight, height, and BMI of each subject measured. With these variable PC1 was constructed and explained 96% of the variance in the variables used for its construction. In the case of the ANOVA, if the data presented overdispersion, this was corrected by adjusting the scaling parameter (45).

When there were significant differences among treatments in an ANOVA, a Holm-Sidak *a posteriori* test was used to determine among which pairs of tests the differences occurred. In all cases $P<0.05$ was used to reject H_0 , and unless otherwise indicated mean ± 1 standard error is reported.

RESULTS

We found no statistically significant differences among the five indirect VO₂max tests recorded (F=0,34, df= 1, 353, P=0,56; Table 3a). The VO₂max values obtained were: 44,26 ± 3,74 for the UMTT, 44,14 ± 3,01 for the VAM-EVAL, 42,78 ± 2,80 for the 20-MST, 44,92 ± 2,33 for the 1000 m and 42,67 ± 2,96 for the Ramsbottom.

We detected statistically significant differences among the distances among the three tests for which this measure could be determined (F=111,2, df= 2, 210, P<0,001; Table 3b). In the UMTT subjects ran 2140,3 ± 425,4 m, in the VAM-EVAL 1717,5 ± 332,9 m, and in the 20-MST 1335,9 ± 135,4 m. The multiple comparisons indicated that the distance ran differed significantly between all pairs of tests (in all cases, Holm-Sidak >7, P<0,001).

We did not find significant differences in HRmax or RPE recorded by the subjects following the tests.

Table 3. Results of one-way ANOVAs with response variables (a) indirect VO₂max, with five levels (UMTT, VAM-EVAL, 20-MST, 1000 m and Ramsbottom), and (b) total distance run in meters, with three levels (UMTT, VAM-EVAL and 20-MST). Before running ANOVAs the response variables were standardized to eliminate variance due to differences in subject age, weight, height, and BMI.

Source	df	SS	MS	F	P
a) VO2Max					
Regression	1	41	40,6	0,34	0,562
Residual	353	42486	120,4		
Total	354	42527			
b) Distance run (m)					
Regression	2	22987307	11493654	111,2	<0,001
Residual	210	21705947	103362		
Total	212	44693254			

DISCUSSION

Our results indicate that there are no significant differences among the VO₂max values obtained from the five tests (i.e. UMTT, VAM-EVAL, 20-MST, 1000 m and Ramsbottom). On the contrary, we did find differences in the total distance run in meters between three tests (i.e. UMTT, VAM-EVAL, and 20-MST).

The similarity in VO₂max values among tests has been found in other studies, though usually only in comparisons between pairs of test. For example, the UMTT has been compared, using different study subjects (e.g. with and without training,

men and women, youths and adults) with six tests: Balke's test, the inclined treadmill test, test-retest UMTT, stationary bike test, Canadian Home Fitness Test and Cooper's test (10). In all of these comparisons, no significant difference was found between tests (10). In addition, Berthoin *et al.* (19) contrasted the UMTT against a laboratory treadmill test and the 20-MST test in physical education students and found no significant differences.

The 20-MST test has been compared, using adult amateur football players, with the VAM-EVAL, laboratory test, intermittent test with recovery, and 10 km performance test (46,47). In all of these cases there were no significant differences. However, Bandyopadhyaya (39) compared $VO_2\max$ results in the laboratory ($39,80 \pm 4,06$ ml kg min) with the 20-MST test ($35,35 \pm 4,90$ ml kg min) in young male students from India and found a significant difference ($P < 0,001$). For this reason, this researcher suggested that the original formula used for the test could not be applied to this population, and he proposed a modification to the equation used to calculate indirect $VO_2\max$. Using this modification, no significant difference was found between the $VO_2\max$ obtained from the two tests.

The 1000 m test has been compared against itself (test-retest), a laboratory treadmill protocol, a stationary bike test, and a portable gas analyzer (15,16). These comparisons were made in Mexican students, except the last one, which was in Chinese students. Comparing these tests revealed no significant differences in $VO_2\max$ obtained.

Our results showed no significant differences in indirect $VO_2\max$ among the tests analyzed. However, we do not know if this result would hold if $VO_2\max$ were measured directly in the laboratory following each test. Obtaining direct $VO_2\max$ for each subject would allow us to better plan training for each subject (e.g. their workloads). In the future, it would be interesting to investigate whether laboratory tests are equivalent to indirect tests. In the past other studies have compared some of the indirect tests used here with one (12,7,39,9) or two (48) laboratory tests and have found no significant differences.

The differences we found between tests in the distance run may be due to the different characteristics of each test. For example, in the 20-MST the subjects ran less distance on average (1336 m) compared to the same subjects in the UMTT (2140 m) and VAM-EVAL (1718 m). The difference may be due to the fact that in the 20-MST, subjects must change direction every 20 m, which means that they must decelerate and accelerate during the entire test, limiting the distance run (49,28,21); while in the UMTT and VAM-EVAL the subjects run continuously, without decelerating, increasing the distance run (10,12). The difference in m run between the UMTT and VAM-EVAL can be explained by the fact that in the UMTT the subjects increase their velocity every two minutes, while in the VAM-EVAL velocity is increased every minute, possibly allowing them to run further in the UMTT than the VAM-EVAL. These results are similar to those found by (50), where in three tests, the 20-MST, UMTT and VAM-EVAL, physical education students in

Argentina ran $1339,2 \pm 370,5$ m, $2209,2 \pm 636,4$ m and $2229,2 \pm 648,5$ in the three tests, respectively. In this sense, the distance run is not equivalent between tests and should not be used to compare performance among subjects that completed different tests.

CONCLUSIONS

Our results allow us to say that the five tests used here are not different in terms of the calculation of indirect VO_2max in healthy Mexican university students. As such, it can be recommended to physical education teachers, coaches, or sports scientists that they use whichever of the tests works best with the infrastructure and space they have. On the other hand, we do not suggest using the total distance run, since the value is not equivalent among tests.

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