Evaluation of aerobic endurance through time limit measured in the field in both sexes

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Summary

Introduction: The main objective of this paper was to compare the aerobic resistance in both sexes through the use of limited time (T-Lim) and the limit distance (D-Lim) measured in the field. In second place was to analyze the relationship between the VFA and the T-Lim.
Material and methods: 39 physical education students (27 men and 12 woman) were measured in 3 sessions. In the first session, anthropometric measurements were registered: size, body weight, perimeters and skin folds. In the second session the UNCa test was evaluated. This test was recently designed to estimate the maximum aerobic speed from the final speed reached (FSR). The FSR is defined as the speed reached in the last complete stage. In the last session, to measure the T-Lim the subjects ran to the endurance capacity in a track of 400 m next to a bicycle previously calibrated. The D-Limit refers to the total meters run during the T-Lim test. Differences between sexes were analyzed with the T test for independent samples. The relationships between FSR and T-Lim were determined using the Pearson correlation coefficient.
Results: In the UNCa test, FSR was was 14.8±1.4 km•h^{-1} and 12.0±1.0 km•h^{-1} for men and women respectively ($p<0.05$). The T-Lim was 385.0±99.3 and 351.0±79.6 seconds, without significant differences between groups. The D-Lim was 1589.5±485.7 meters for men and 1175.7±304.4 meters for women, being significant among groups ($p<0.05$). The correlations were: FSR and T-Lim; $R = 0.29$ ($p<0.035$) for all the cases, $r = 0.24$ ($p<0.112$) for males, and $r = 0.27$ ($p<0.196$) for females.
Conclusion: In physical education students, no significant differences were found among men and women as regards T-lim. The low correlation found between VFA and T-Lim leads us to conclude that both indicators define different variables.

Key words:
Aerobic training. Endurance capacity. Time limit. Maximal aerobics speed. Field test.

Evaluación de la resistencia aeróbica a través del tiempo límite medido en campo en ambos sexos

Resumen

Introducción: El propósito principal fue comparar la resistencia aeróbica entre los sexos a través del tiempo límite (T-Lim) y la distancia límite (D-Lim) medido en campo. En segundo lugar se analizó la relación entre la VFA y el T-Lim.
Material y método: 39 estudiantes de educación física (27 hombres y 12 mujeres) fueron medidos en 3 sesiones. En la primera sesión se registraron medidas antropométricas: talla de pie, masa corporal, perímetros y pliegues cutáneos. En la segunda sesión se evaluó el UNCa test. Este fue confeccionado recientemente para estimar la velocidad aeróbica máxima a partir de la velocidad final alcanzada (VFA). La VFA es definida como la velocidad alcanzada en la última etapa completa. En la última sesión, para medir el T-Lim los sujetos corrieron a la VFA en una pista de 400 m junto a una bicicleta previamente calibrada. La D-Lim es la cantidad total de metros recorridos durante la prueba de T-Lim. Las diferencias entre sexos fueron analizadas con la prueba T para muestras independientes. Las relaciones entre la VFA y el T-Lim fueron determinadas con el coeficiente de correlación de Pearson.
Resultados: La VFA en el UNCa test fue de 14,8±1,4 km•h^{-1} y 12,0±1,0 km•h^{-1} para hombres y mujeres respectivamente ($p<0,05$). El T-Lim fue de 385,0±99,3 y 351,0±79,6 segundos, sin diferencia significativas entre los grupos. La D-Lim fue de 1589,5±485,7 metros para los hombres y 1175.7±304,4 metros para la mujeres, siendo significativa la diferencia entre los grupos ($p<0,05$). Las correlaciones encontradas entre la VFA y el Tlim fue: para el grupo total $r=0,29$ ($p>0,035$), para los hombres $r=0,24$ ($p>0,112$) y para las mujeres $r=27$ ($p>0,196$).
Conclusión: En estudiantes de educación física no se encontraron diferencias significativas en el T-Lim entre hombres y mujeres. La baja correlación encontrada entre la VFA y el T-Lim nos lleva a concluir que ambos son indicadores de variables diferentes.

Palabras clave:
Entrenamiento aeróbico. Resistencia aeróbica. Tiempo límite. Velocidad aeróbica máxima. Test de campo.

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Introduction

Maximal oxygen uptake (VO_2max) has traditionally been used to study the cardiorespiratory component of fitness in different health- and sport-related populations[1]. VO_2max can be improved in both men and women through aerobic training programmes[2]. Improvements depend on multiple factors: level of the subject, initial VO_2max, duration of training (weeks, months, years), training load (intensity, volume of work, frequency, density), sex, age, genetics, etc.[3,4]. Increases in VO_2max, however, have a genetic limit[4,5] and even in highly trained individuals run performance improves without observing increases in VO_2max[6]. It is, therefore, important to monitor other variables related to the cardiorespiratory component[7], such as maximal aerobic speed (MAS) and time to exhaustion (T-Lim).

Billat defines T-Lim as a subject's ability to sustain exertion at 100% MAS for as long as possible. The interest in studying T-Lim lies in validating a criterion for aerobic endurance[8]. The parameter expresses the amount of work carried out over time (seconds or minutes) and also in metres, called distance to exhaustion (D-Lim). The two variables (T-Lim and D-Lim) have shown themselves to be acceptably reproducible in testing and retesting (r=0.86), and there is great variability between subjects, even when VO_2max and MAS are similar[9,10]. According to a review of the literature, field-measured T-Lim averages between 5 and 7 minutes[9-16], regardless of MAS and VO_2max, although the value ranges from 3 to 10 minutes, and even greater times have been registered in some cases[9].

Another aim of T-Lim is to establish a framework with which to choose the duration of training at and near VO_2max. This means that the trainer can dose training volumes more precisely, obtaining improvements in VO_2max, MAS, high-intensity submaximal aerobic capacity, the anaerobic threshold and run performance[9,12-14].

The literature includes two studies which measured T-Lim in men and women[15-16]. Demarie *et al.*[15] measured T-Lim in both sexes, although mean values were presented in their results without differentiating between the two. Bherthoin *et al.*[16] compared the sexes, but the subjects in the study sample were children and adolescents aged between 6 and 17. The authors found differences in T-Lim from 12 years of age up to 17, inclusive.

Several studies have observed differences between men and women when measuring, directly or indirectly, VO_2max and MAS[4,17-20], but whether the same occurs with T-Lim in adults is unknown.

The main purpose of this study was to field-evaluate T-Lim to identify differences in endurance capacity between young physically active male and female adults. The second aim was to analyse the relationship between Final Speed Reached (V(max)) and T-Lim.

Material and method

All the evaluations were conducted in the morning between 9 and 11 a.m., with two hours without food intake. The UNCa test[21], recently validated through the final field speed reached (V(max)), was used to estimate MAS. The measurements were taken in three sessions. Anthropometric measurements were taken in the first session. In the second session, field measurements were taken using the UNCa test. The evaluations were carried out with groups of up to 6 subjects. In the third session, T-Lim was measured grouping the subjects together by speed, regardless of sex, with a maximum of 6 subjects. There was a rest period of 120 hours between the 2nd and 3rd sessions. The subjects wore the same clothes and footwear in all the evaluations. The evaluations were conducted in the field on natural grass. The subjects did not do any exercise in the 48 hours prior to the evaluations.

Subjects

39 voluntary subjects, all physical education students (27 men and 12 women), were evaluated. The general characteristics of the sample are shown in Table 1. The following were excluded from the study: a) under-18s, b) subjects with any type of neuromuscular lesion and/or cardiorespiratory disease, c) subjects without experience in the two field tests (UNCa test and T-Lim) and d) those who did less than 1 hour of physical activity at least three times a week. Before signing the informed consent form, the subjects were informed about the procedures involved in the study and the benefits and risks of taking part in it both verbally and in writing.

Procedure

Anthropometry: Body mass, standing height, 3 girths (relaxed arm, minimum waist and maximum calf) and 3 skinfolds (triceps, abdomen and cal f) were measured. The skinfolds were measured using Rosscraft

Table 1. Characteristics of the sample and field-measured variables.

	All N= 39	Men N= 27	Women N= 12
Anthropometric variables and indexes			
Age (years)	24.5 ± 6.4	25.4 ± 7.3	22.9 ± 4.1
Height (m)	1.70 ± 0.08	1.76 ± 0.05	1.60 ± 0.07#
Body mass (kg)	71.2 ± 11.2	77.6 ± 9.2	63.7 ± 8.2#
CG Arm (cm)	24.0 ± 17.6	27.4 ± 2.3	21.3 ± 3.4#
CG Waist (cm)	70.9 ± 7.7	75.9 ± 6.5	67.0 ± 6.2#
CG Calf (cm)	32.3 ± 5.2	34.9 ± 2.3	30.4 ± 6.0#
BMI (kg/m^2)	24.6 ± 3.1	25.2 ± 2.8	23.9 ± 3.2
Σ 3 skinfolds (mm)	46.7 ± 17.6	36.5 ± 14.7	54.6 ± 15.8#
Fields variables			
V(max) (km•h^{-1})	13.9 ± 1.8	14.8 ± 1.4	12.0 ± 1.0#
T-Lim (s)	374.5 ± 94.0	385.0 ± 99.3	351.0 ± 79.6
D-Lim (m)	1462.2 ± 475.0	1589.5 ± 485.7	1175.7 ± 304.4#

CG: corrected girth. BMI: body mass index. Σ: Sum of 3 skinfolds (triceps, abdomen and calf). V(max): final speed reached in the last complete stage of the UNCa test. T-Lim: time to exhaustion. D-Lim: distance to exhaustion.
# p< 0.05 significant differences with respect to the male group.

Slim Guide callipers and the girths with a Lukfin metal tape measure. The measurements and calculations of the body mass index and corrected girths were made according to the guidelines of the ISAK (International Society for the Advancement of Kinanthropometry)[22].

UNCa Test: The subjects run the perimeter of a hexagon. Each side of the hexagon is 20 metres long (Figure 1). Each interior angle is 120º. The speed is set by a beep. At each vertex of the hexagon, there is a 2-metre area where the subject should be located when the beep sounds (Figure 1). The initial speed in the test is 8.0 km•h^{-1} and the stage lasts 3 minutes. It then increases to 10.0 km•h^{-1} for 2 minutes. The aim of these first two stages is to standardise a specific warm-up. Without a break, the speed then increases by 1 km•h^{-1} every 1 minute until exhaustion.

Given that a portable gas analyser was not used, the Final Speed reached (V(max)) was monitored in the last complete stage as recommended in the literature[23].

The audio was downloaded from: http://g-se.com/es/entrenamiento-en-rugby/blog/audio-del-unca-test[24].

Time to exhaustion (T-Lim). A 400-metre athletics track was used. A bicycle with a digital speedometer was used to register the speed of the subjects. The speedometer was calibrated as explained in the manual: the circumference of the tyre and the radius need to be loaded into the device. As a second method of calibration, the speed recorded by the speedometer was compared with the speed determined by the UNCa test audio over a distance of 100 metres with cones every 20. The warm-up consisted of 10 minutes at 60% V(max) in the UNCa test. Then there was an active 10-minute break for joint mobility, flexibility and hydration. Immediately afterwards, the runner started to run alongside the bicycle, always between its two wheels and on the inside lane of the athletics track. When the speed corresponding to 100% V(max) in the UNCa test was reached, the stopwatch was started and that speed was maintained for as long as possible. The test ended when the subject could not maintain the speed imposed by the bicycle (between its two wheels) or when he/she stopped through exhaustion. This method to field-measure T-Lim is described in the literature[11].

Distance to exhaustion (D-Lim). This is the number of metres covered in the T-Lim test.

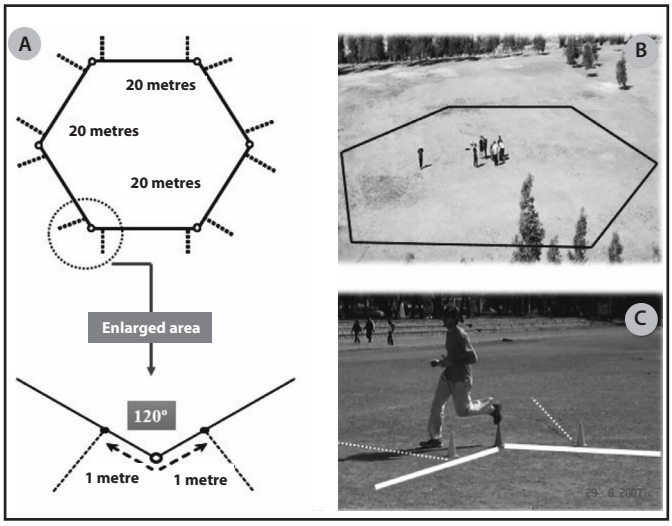
The distance is obtained by multiplying the time to exhaustion in seconds by the speed in metres per second.

$$\text{D-Lim} = \text{T-Lim (s)} \cdot \text{Speed (m} \cdot \text{s}^{-1}\text{)}$$

Statistical Analysis

The data are presented as mean values with standard deviation, unless otherwise specified. They were analysed using SPSS 18.0. The Kolmogorov-Smirnov test and Levene's test were used to test the normality and homoscedasticity of the study sample. After corroborating the normality of the data, the independent samples t-test was used to determine statistically significant differences between the sexes in terms of V(max), T-Lim, D-Lim and other descriptive variables. The relationships between T-Lim, D-Lim and V(max) were calculated using the Pearson correlation coefficient, applying the following criteria: 0.1 very low; 0.1-0.3, low; 0.3-0.5, moderate; 0.5-0.7, good; 0.7-0.9, very good; and 0.9-1.0, perfect[25]. An alpha level of p <0.05 was accepted in all cases..

Figure 1. UNCa test; a) graphic design of the hexagon, with one of its vertices enlarged. b) Aerial photograph of the hexagon. c) One of the vertices of the hexagon.



Results

Table 1 shows the characteristics of the sample and the field values obtained. In the male group, V(max) ranged between 13 and 18 km•h^{-1}, for T-Lim from 213.0 to 661.0 seconds, and D-Lim between 828.3 and 3121.0 metres. In the female group, V(max) ranged between 10 and 14 km•h-1, for T-Lim from 217.0 to 523.0 seconds, and D-Lim between 769.4 and 1743.3 metres.

Statistically significant differences were observed between the sexes in all the variables measured except age, body mass index and T-Lim (Table 1).

The correlations found between V(max) and T-Lim were: for all the cases r= 0.29 (p>0.035), for the men r= 0.24 (p<0.112) and for the women r= 0.27 (p<0.196). The correlations found between V(max) and D-Lim were: for all the cases r= 0.64 (p>0.001), for the men r= 0.53 (p<0.002) and for the women r= 0.56 (p<0.027). The correlations found between T-Lim and D-Lim were: for all the cases r= 0.92 (p>0.001), for the men r= 0.95 (p<0.001) and for the women r= 0.95 (p<0.001). Such a high correlation is because D-Lim is dependent on T-Lim; the longer the subjects kept running, the greater the distance covered, regardless of V(max).

Figure 2 shows the individual values of V(max) and T-Lim. Several subjects share the same V(max), but differ in terms of T-Lim. The same can be observed between D-Lim and V(max) in Figure 2.

Discussion

The main purpose of this study was to examine gender differences in endurance capacity through field-evaluated T-Lim in physically active

Figure 2. Individual values:T-Lim vs. V(max).

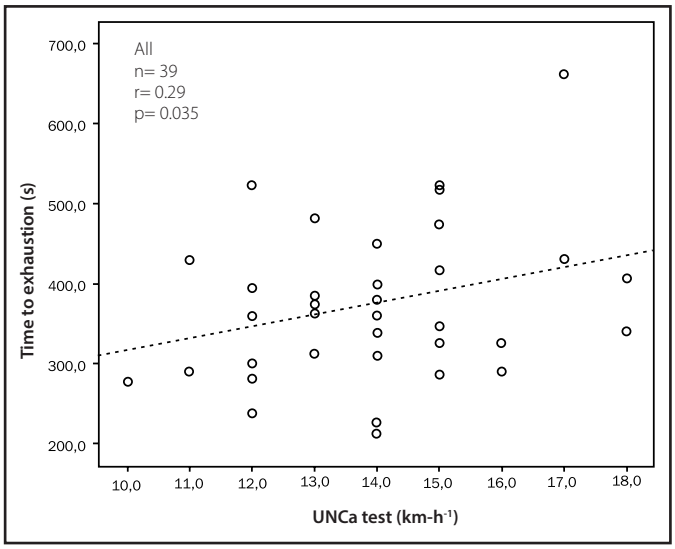


Figure 3. Individual values: D-Lim vs. V(max).

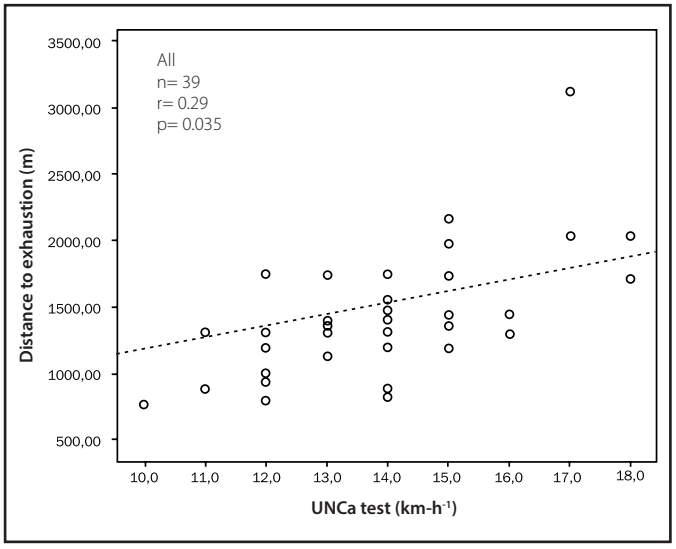


Table 2. Summary of research which has field-measured T-Lim using V(max) or MAS.

Author	n=	Sex	MAS (km•h-1)	V(max) (km•h-1)	Evaluation Protocol	TLim (s)
Billat V. *et al.*[9]	10	M	21.6 ± 1.2	-	3 min * 1 km•h^{-1}	371.0 ± 120
Billat V. *et al.*[11]	7	M	-	20.1 ± 0.7	2 min * 1 km•h^{-1}	355.0 ± 55
Kachouri M. *et al.*[28]	14	M	-	17.8 ± 1.5	2 min * 1 km•h^{-1}	483.,0 ± 213.0
Berthoin S. *et al.*[29]	74	M	-	14.1 ± 1.6	2 min * 1 km•h^{-1}	365 ± 102
	65	W	-	11.4 ± 1.1	2 min * 1 km•h^{-1}	325 ± 93
Billat V. *et al.*[30]	6	M	17.0 ± 1.1	-	4 min * 2 km•h^{-1}	
					(1 min pausa)	333.0 ± 116
Demarie *et al.*[31]	15	M-W	16.6 ± 1.1	-	3 min * 1 km•h^{-1}	
					(20 s. pausa)	307.0 ± 183
Millet G. *et al.*[10]	8	M	19.9 ± 0.9	-	1 min * 0.5 km•h^{-1}	235.6 ± 49.2
Millet G. *et al.*[32]	7	M	19.8 ± 0.9	-	1 min * 0.5 km•h^{-1}	243.7 ± 39.5
Heurbert *et al.*[33]	8	M	16.1 ± 1.4	-	1 min * 3 km•h^{-1}	373 ± 111
Dupont G. *et al.*[34]	10	M	17.5 ± 1.3	-	2 min * 2 km•h^{-1}	350.3 ± 68.5
Dupont G. *et al.*[35]	9	M	16.7 ± 1.3	-	1 min * 1.5 km•h^{-1}	362.0 ± 109.0
Chtarra *et al.*[36]	10	M	-	16.1 ± 1.1		312.2 ± 68
	9	M	-	16.1 ± 0.5		280.9 ± 55
	10	M	-	16.2 ± 1.0	1 min * 0.5 km•h^{-1}	274.9 ± 63
	10	M	-	16.2 ± 0.9		312.7 ± 57
	9	M	-	16.1 ± 0.8		253.9 ± 51
Chaouachi *et al.*[37]	41		-	16.2 ± 1.0	1 min * 0.5 km•h^{-1}	307.2 ± 79.5
Presente	27	M	-	14.8 ± 1.4	1 min * 1 km•h^{-1}	385.0 ± 99.3
Trabajo	12	W	-	12.0 ± 1.0	1 min * 1 km•h^{-1}	351.0 ± 79.6

MAS: maximum aerobic speed. V(max): final speed reached. TLim: time to exhaustion. s: seconds. M: men. W: women. min: minutes.

young adults. The results showed that there existed no difference in T-Lim between men and women in a sample of physical education students. Due to the greater V(max) registered by the males, higher D-Lim for this group was to be expected. The low correlations between T-Lim and V(max) would seem to indicate that there is a very poor relationship between these two aerobic performance variables. This highlights the fact that subjects who reach higher speeds are not always those who can maintain or sustain those speeds the longest.

Table 2 shows how little research has involved female subjects. The table only shows research which field-measured T-Lim and excludes studies conducted with treadmills, because MAS and/or V(max) may be affected by the protocol and the place where measurement is taken (field or treadmill)[11,21,26,27]. Table 2 also shows how speed was arrived at in the different studies: by finding MAS directly (gas analyser) or using an indirect test to estimate MAS through V(max).

The T-Lim values registered in this study were similar to those reported in Table 2. The running speeds (MAS or V(max)), however, were appreciably lower. These differences may be due to the type of sample used. In most cases, the subjects were trained or highly trained. The only study which gave speeds similar to those in our study was that of Berthoin *et al*, although it should be pointed out that the sample consisted of 17-year-olds[16].

On analysing our subjects' physical performance and comparing it with the other studies, both differences and similarities in terms of aerobic performance can be observed: the former regarding "aerobic power", in this case determined by running speed, and the latter regarding "aerobic capacity", which has to do with the condition or ability to sustain the final speed reached in the test continuously until exhaustion, represented by T-Lim.

The most significant differences, therefore, are concerned with speed and not T-Lim. In other words, we can say that our subjects differ from those in other studies when aerobic power, expressed as speed, is compared, but give similar values when aerobic capacity, expressed as time, is compared.

Another point for discussion concerns the applicability of T-Lim in aerobic training. If the aim is to stress the cardiorespiratory component at and near VO_2max, Billat suggests that repetitions should last 60% T-Lim[8]. This means that if the subject keeps running for 200 seconds during the T-Lim test, the training repetitions should last 120 seconds. This is an interesting idea for trainers and fitness coaches. In both continuous and intermittent sports, the distances covered at high intensities of MAS or V(max) define the calibre of the athlete; if a long-distance runner can sustain a pace close to his/her aerobic maximum over the competition distance, this is a good indicator of success. Likewise, if a footballer or rugby player has a total volume at high intensity, even when each repetition involves no more than 30 metres, this too is a good indication of success in his/her discipline. This proposal should not, therefore, be ignored.

To illustrate Billat's recommendation better, in Table 3 we have taken three male examples who obtained the same V(max), 15 km•h^{-1}, in our study.

The three subjects have the same field V(max) (15 km•h^{-1}), but differ in T-Lim. Subject 2 kept running for 90 seconds longer (27%) than subject 17, but 105 seconds less than subject 3 (-25%). Subject 3 kept running for 195 seconds more than subject 17 (60%). Given this variability, Billat suggests that the run be designed according to T-Lim. As can be observed in Table 3, each subject has a personal training distance. Any other training design, such as 10 repetitions of 400 metres, would only have running speed and not endurance capacity in mind. Billat's approach, therefore, should be taken into account because it means that the workload is individualised more specifically, particularly for high-intensity runs (near VO_2max). It also provides the fitness coach with another work methodology, bringing diversity to aerobic training.

Table 3. Example of repetition design based on T-Lim for 3 male subjects with the same V(max).

Subject	V(max) (km•h^{-1})	TLim (s)	DLim (m)	Repetition (m)	(60% TLim) (s)
2	15	416	1733.3	1040	250
3	15	521	2170.8	1302	313
17	15	326	1358.3	815	196

s: seconds. m: metres.

Other authors have come up with alternatives based on Billat's proposition. Millet *et al.* used the total duration of T-Lim to design variable continuous runs[10]. Esfarjani *et al.* also designed 2 modalities based on T-Lim, with intensities between 100 and 130% MAS. After 10 weeks of training, they observed improvements in MAS, the threshold speed, run performance (3,000 metres) and T-Lim[14]. Smith *et al.* compared the effects of training on 2 groups using 2 different approaches: one group did repetitions based on 60% T-Lim, while the other worked with 70%. The latter group registered greater improvements[12]. Heubert *et al*. used different percentages of T-Lim to design exercise repetitions (25%, 50% and 75%), ranging intensity from 90 to 115% MAS[13].

The different proposals cited above demonstrate that T-Lim is a valid criterion to establish individual volumes of work near VO_2max, meaning that trainers should not rule out this idea for aerobic training, while also measuring endurance capacity using other variables related to aerobic power (VO_2max and MAS).

On the basis of the results obtained, it can be concluded that, for the sample analysed, there is no difference in T-Lim between the sexes and the correlation between V(max) and T-Lim is low. Great variability in terms of T-Lim was also observed between subjects with the same V(max). This shows that T-Lim is an important indicator when it comes to individualising training volumes in sessions. This study should be replicated with sportspeople to see if the same difference exists between men and women.

Practical applications

T-Lim can be used to measure individual aerobic endurance capacity and fractionate workloads to bring diversity to aerobic training near VO_2max. Although the indirect method may constitute a constraint, it is the one used by the vast majority of trainers and fitness coaches to prescribe training workloads; hence its usefulness.

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