



Evaluation of Central Fatigue by the Critical Flicker Fusion Threshold in Cyclists

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Abstract

Central fatigue related in sport stimuli was studied by Critical Flicker Fusion Threshold (CFFT) to know the influence of exercise on the central nervous system (CNS), but there is a lack of knowledge about the central or peripheral fatigue in endurance events. This study aimed to analyze changes in CFFT before and after the incremental cycle ergometer test as a means to assess the fatigue of the CNS. CFFT ascending and descending, the subjective criterion and sensory sensitivity were analysed in 8 professional male cyclists (72.1 ± 5.59 kg, 180.3 ± 6.43 cm, 17.4 ± 0.7 years) before and after a maximum incremental cycle ergometer test (start 50w increases 50w each 5 min). In this incremental test, the induced fatigue was probably more a peripheral phenomenon than one due to central nervous system fatigue, because sensory sensitivity did not significantly decrease. In conclusion, an incremental cycle ergometer test increased the cortical arousal and does not affect negatively the CNS of professional cyclists.

Keywords Cortical arousal · Central nervous system · Fatigue · Flicker fusion threshold · Cycle ergometer

Introducción

One of the causes of decreased human performance [1–3] and specifically athletes performance is fatigue of central nervous system (CNS) [4]. The influence of physical effort in fatigue of CNS is an area little studied. One of the methods frequently used to measure fatigue of CNS and cognitive function is critical flicker fusion threshold (CFFT). The utility of CFFT in sport has been focused in the relationship of arousal level with CNS [5]. Increase in CFFT suggests an increase in cortical arousal and sensory sensitivity. By contrast, a decrease of CFFT suggests a reduction in the efficiency of the system to process information [6]. Another author also relationship CFFT whit fatigue of CNS, so that if the values fall below the baseline means that there is fatigue of CNS [7, 8].

CFFT was affected by non-sensory and sensory factors. The results obtained in a CFFT test must be interpreted considering two different parameters. The parameter relationship whit sensory factor was subjective criterion (CS), which reflects the response criterion. This response can be conservative or liberal. The parameter relationship whit non-sensory factor was sensory sensitivity (SS). In methods we will explain the form to calculate these parameters [9].

Several authors studied the CFFT in different sport stimuli. There was analyzed incremental VO₂max test [9], 30 min maximum trial [10], 70% of VO₂max cycling trial [11], incremental cycling test [12]; 120' cycling trial [13], 270 km ultraendurance run relay event [14]; exercise to exhaustion [15] or RSA speed test [16]. Only in exhaustion exercise and speed test presented a decreased in CFFT, showing a fatigue of CNS. In other stimuli only appear increased the cortical arousal.

These results showed that efforts performed at maximal speed and with greater involvement of force appear to further affect the CNS. These exercises due to its high intensity could strain the CNS [17] and cause a decrease in performance of the athletes. The knowledge in this line is actually limited, for this reason we developed the present research with the aim of to study modifications in CFFT as measured of cortical arousal and fatigue of CNS in an incremental cycloergometer test in professional cyclists.

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Methods

We analyzed 8 professional trained cyclists (72.1 ± 5.59 Kg., 180.3 ± 6.43 cm, 17.4 ± 0.7 years, $14.1 \pm 2.69\%$ fat, 22.2 ± 1.65 Kg. Muscle mass, 22.2 ± 1.65 Kg/m²; VO₂max [ml/Kg/min.] 83.24 ± 4.06 , VO₂max [l]: 5.95 ± 0.53). Participants were informed of the characteristics of the study and the test that took place and the potential risks derived from those who are exposed, also, they all signed a consent form in accordance with the declaration of Helsinki.

Body composition was analyzed with Inbody 230 (Biospace, Seoul, Korea). Incremental cycling test was developed in a cicloergometer (Lode Excalibur, Lode BV, Groningen, Holland), previously adapted to each cyclist. Incremental test started at intensity of 50w for 10 min, after increase the intensity 50w each 5 min until exhaustion. All incremental test was performed between 90 and 105 rpm. In the last minute of each series we analysed lactate concentration, heat rate and Rating of Perceived Exertion (RPE). With lactate values we calculated the anaerobic threshold with previous methodologies [18–22], associating power, heart rate and RPE in this physiological moment. We also analysed the maximal heart rate and RPE at maximal power at the end of the test.

Heart rate was measured through the pulsometer Polar S810. [Polar Electro Ibérica. Barcelona). RPE was measured with 6–20 RPE scale. Blood lactate concentration was analyzed with Dr. Lange Miniphotometer plus LP 20. v 1.4.

The CFFT measurements were carried out before and immediately after the incremental test. Participants were seated in front of a viewing chamber (Lafayette Instrument Flicker Fusion Control Unit Model 12,021), which was constructed to control extraneous factors that might distort CFFT values. Two light-emitting diodes (58 cd/m²) were presented simultaneously in the viewing chamber, one for the left eye and one for the right eye. The stimuli were separated by 2.75 cm (center to center) with a stimulus-to-eye distance of 15 cm and a viewing angle of 1.9°. The inside of the viewing chamber is painted flat black to minimize reflection. The flicker frequency increment (1 Hz/s) changed in two ways: either it increased from 0 to 100 Hz until the participant perceived fusion, or it decreased from 100 to 0 Hz until flicker was detected. After a fovea binocular fixation, participants were required to respond by pressing a button upon identifying the visual flicker (descending frequency) and the fusion (ascending frequency) thresholds. Prior to the experiment they performed as many practice trials as needed to become familiarization with the exigencies of the CFF test. Then, three ascending and three descending trials were performed alternatively [9, 23, 24]. Subjects carried out the test three times with an interval of 5 s.

In each one of the test, time was quantified as the amount of time that a subject took for detecting the changes in the lights

from the beginning of the test until the moment to pressing a button, to be able to determine the CFFT:

- CFFa - (Critical Flicker Fusion ascending), value obtained in the ascending test.
- CFFd - (Critical Flicker Fusion descending), value obtained in the descending test.
- SC (Subjective Criterion), difference among the stocking of the values obtained in the ascending test and the stocking of the values obtained in the descending test
- SS - (Sensorial Sensibility), median of the sum of the values obtained in the ascending test and descending test.

The data collected in this study were analyzed with the SPSS 17.0 statistical program. First, the normality of the sample was checked with the Shapiro-Wilks test. Friedman test was performed, to see if there were any significant differences and to subsequently carry out the Wilcoxon test. The level of significance was set at $p < 0.05$ for all the comparisons.

Results

Results showed how CFFa increased significantly ($p < 0.05$). However, CFFd increased not significant as we can see in Table 1. CS values presented a not significant increase as well as SS. (42.1%).

Description of physiological variables of the test measured are shown in Table 2. Cyclists reached a maximum rated of perceived exertion at a maximal power of 350 w.

Discussion

The present research aims to study modifications in CFFT as measured of cortical arousal and fatigue of CNS in an incremental cicloergometer test in professional cyclists. The results showed how after the incremental cicloergometer test SS values increased not significantly 6.6%. This increase showed how this type of stimuli increases the cortical arousal

Table 1 Incremental test physiological data

	Average \pm SD
Maximal Power (W)	350.0 \pm 26.73
Maximal Heart Rate (bpm)	184.6 \pm 10.98
Maximal RPE	19.5 \pm 0.76
Power in Anaerobic Threshold (W)	148.3 \pm 22.01
Heart Rate in Anaerobic Threshold (bpm)	145.7 \pm 14.19
RPE in Anaerobic Threshold	12.3 \pm 2.31

RPE – Rated of perceived exertion

Table 2 Flicker fusion threshold obtained in the cycling test

	Pre	Post	% Change	Cohen's D	p
UFFa (Hz)	35.1 ± 10.7	39.1 ± 3.6	11.3	0.37	.042
UFFd (Hz)	40.2 ± 6.0	41.2 ± 1.7	2.5	0.17	.092
CS (Hz)	-5.1 ± 11.7	-2.1 ± 4.3	41.2	0.26	.091
SS (Hz)	37.7 ± 6.5	40.2 ± 18	6.6	0.38	.168

CFFa Critical Flicker Fusion ascending; CFFd - Critical Flicker Fusion descending; SC – Subjective Criterion; SS – Sensorial Sensibility

[6]. These data are different than the obtained in a repeated sprints test RSA [16]. Despite being two high-intensity stimuli that develops in a high intensity, incremental test does not seem to adversely affect the CNS. This may be due to the temporal duration of incremental test is higher than each of the sprints repetitions of the RSA test. In the RSA test subjects develop anaerobic alactic power and anaerobic alactic capacity, while in incremental test develop first aerobic and anaerobic threshold and after developing aerobic power, in the end of the test. Possibly, because of these differences in metabolic rules used in each effort, obtain different results in SS values in an incremental and RSA tests. These results suggest that alactic stimuli have a greater effect in CNS and stimuli in which the aerobic metabolism is highly activated only cause an increase in cortical arousal without fatigue of CNS. Also, the data obtain are different than the obtained in triathletes tested after an exercise to exhaustion, since they showed symptoms of CNS fatigue [15]. In this line, also ultraendurance mountain events produce a decrease of SS [25, 26]. We can see that endurance efforts to exhaustion and maximal speed stimuli seem to cause fatigue of CNS. Incremental test developed since aerobic condition, in first stage, until exhaustion, with increment in the workload output. May be because minor duration of incremental test than exhaustion test of Godefroy et al., subjects of present research do not present fatigue of CNS.

The results found in this study were similar than the SS increase after a VO₂max test in adult subjects [9]; in a 30 min maximum trial [10]; in an incremental cycling test [27]; 1RM squat test [28]; an incremental maximum cycling test [29]; in a RSA performed by professional football players [16]; and in a 70% of VO₂max cycling trial [11]. We can see how high intensity effort with duration between 30 s to 30 min do not affect negative CNS. Only sprints stimuli can affect negative CNS. This result showed the influence of different physiological stimuli in cortical arousal, this information joining the knowledge about the effect of different psychological stimuli, like the negative effect of stress perception and the increased sympathetic nervous system associated in cortical arousal and information processing [3, 30–41], allow us a better comprehension of psychophysiology of CNS. In addition, the increase in CS values suggests that the subjective criterion

is conservative, and change observed after incremental test was linked to a cautious strategy [42].

Practical applications

The use of CFFT in sport area could be an effective training tool to avoid overtraining state, since it could report direct information about cortical arousal, information vital for a correct periodization of training, specially in new periodization training models as reverse periodization, where high intensity training has to be distributed in training cycles with caution due to the large psychophysiological requirements of these training [18, 20, 21, 43–45].

Limitation of the study

The main limitation of the present study can be addressed regarding the small sample size evaluated. Due to the difficulty of recruit professional cyclist It was not possible to recruit larger participants for this study. Another possible limitation could be the use of CFFT to analyse cortical arousal. This method, although validated and extensively used in previous research is less accurate when compared to electroencephalogram or positron emission tomography. The accessibility, lower cost and the possibility of the use in specific sport events, make CFFT it more practical and easily usable by sport professionals.

Conclusion

In an incremental test, the induced fatigue was probably more a peripheral phenomenon than one due to central nervous system fatigue, because SS did not significantly decrease. In conclusion, an incremental cycle ergometer test increased the cortical arousal and does not affect negatively the central nervous system of professional cyclists.

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Compliance with Ethical Standards

Conflict of Interest None.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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