Caffeine does not change the anaerobic performance and rate of muscle fatigue in young men and women

Abstract

Aim: The aim of the study was to investigate the effects of caffeine intake on anaerobic performance and rate of muscle fatigue in young men and women.

Methods: Fourteen recreationally active college students volunteered to the study (7 male, 29.1 ± 2.8 y and 7 female, 22.5 ± 2.9 y) (73.06 ± 13.08 Kg, 173.00 ± 6.90 cm, 24.08 ± 3.01 Kg/m^2). The participants performed the Wingate Test (WT) to evaluate the anaerobic performance in two conditions: caffeine (CAF), ingesting $6mgKg^{-1}$ of caffeine, and placebo (PL), in random order. The variables analyzed during the WT were the Relative Peak Power ($W\text{-}Kg^{-1}$) (RPP), Relative Mean Power (WKg^{-1}) (RMP), Fatigue Index (%) (Fl) and Peak Power Instant (s) (PPI). EMG signals were analyzed using the Normalized Median Frequency (NMF) to determine the rate of muscle fatigue of the superficial muscles of the Quadriceps Femoris (QF), Rectus Femoris (RF), Vastus Medialis (VM) and Vastus Lateralis (VL). Data analysis was performed using the Student's t test and the two-way AN OVA for repeated measures, followed by the Sheffe post-hoc to compare the results.

Results: Caffeine intake had no effect on anaerobic performance parameters (RPP, RMP, Fl and PPI) when compared with placebo ($p > 0.05$). The rate of muscle fatigue did not change with caffeine intake in the muscles studied ($p > 0.05$).

Conclusions: Although caffeine may influence endurance and power in short-term, intense exercise; we did not observe such effects in the variables measured in this study.

Keywords: *1,3,7-trimethylxanthine, EMG, athletic performance, fatigue, muscle.*

Introduction

Caffeine (1,3,7-trimethylxanthine) is a is a central nervous system and metabolic stimulant from the group of the xanthines that can be found in coffee, tea, chocolate, some energy drinks and some medications [1-3]. The substance was in the list of forbidden substances by the World Anti-Doping Agency (WADA) until the end of 2003, but since its ban was removed, WADA maintains a monitoring program for the use of the drug [1]. The effects of caffeine on metabolism have been well described in the literature, with different protocols showing an increase in lactate concentration, epinephrine, norepinephrine, glycerol and glucose [4-9].

Regarding the effects of the drug in open-loop exercises, the substance is able to delay the fatigue and increase time to exhaustion [3,5,8,10-12]. However, in closed-loop exercises, especially those of high intensity and short duration, the results seem to be quite controversial [1,13].

Caffeine acts as an antagonist to adenosine receptors, mainly those of the Aj and A_{2A} types, by influencing the action of neurotransmitters such as dopamine, serotonin and GABA (y-aminobutyric acid). Such actions result in increased alertness and decreased sleepiness, and it is these two effects that are responsible for its widespread use around the world [11, 14, 15]. Caffeine increases the excitability of neurons at spinal and supraspinal level, therefore increasing its ability to recruit motor units and the incidence of "self-sustained firing" [3, 16,17]. Moreover, in dynamic exercises, caffeine might minimize the deleterious effects of neuromuscular fatigue and improve performance, since the processes involved in the onset of fatigue includes motivational factors, increase in perceived exertion and decrease of muscle contraction strength, caused by changes in the neural drive [18,19].

On supramaximal exercise, the effects of caffeine in performance are not so well understood, with different studies showing conflicting results, while some studies have observed an increase in power [4,9], others found no effect [2,6]. Moreover, studies examining the effects of caffeine intake in women are scarce, making it difficult to extrapolate the results to this population. The different protocols used and a lack of normalization of variables makes it difficult to determine the real effects of caffeine on supramaximal exercises. Therefore, the aim of this study was to investigate the effects of caffeine intake on anaerobic performance and rate of fatigue of the superficial muscles of the Quadriceps Femoris (QF) during supramaximal exercise in young men and women. We hypothesize that caffeine will not be able to improve performance and attenuate the rate of fatigue in both genders.

Materials and methods

Experimental Approach to the Problem

All participants performed the Wingate test to evaluate the anaerobic performance under the caffeine (CAF) or placebo (PL) conditions. The interval between tests was 72 h. The participants were instructed not to ingest any substance or food containing caffeine during the period of the experiment, as well as any alcoholic beverage, and to not perform vigorous physical activity in the 24 h prior to the tests in order to avoid any interference in the results. Each participant was tested at the same time of the day to minimize the effects of diurnal biological variation. The participants underwent a pilot study in order to familiarize with the test protocol and equipment used.

Participants

Participants consisted of fourteen (7 men, 29.1 ± 2.8 y and 7 women, 22.5 ± 2.9 y) recreationally active (Table 1), college students who volunteered for the study. All procedures were approved by the Ethics in Research committee of the Faculty of Medicine of UNICAMP and informed consent was obtained from each participant prior to any testing.

Body weight was measured using a digital platform scale (Urano*, model PS 180, 0.1 kg precision) and stature was determined using a wooden stadiometer with 0.1 cm precision, according to the procedures described by Gordon et al. (20). All individuals were measured and weighted barefooted, wearing a bathing suit. Body Mass Index (BMI) was calculated by dividing body weight (kg) by height (m^2).

Procedures

Evaluation of Anaerobic Performance

Anaerobic performance was evaluated with the Wingate test (21,22). Anaerobic performance indexes were determined by a computer program (WINGATE TEST*, CEFISE, BRASIL) that allowed for the determination of the power generated at each second of the test, as well as relative peak power (W-kg!) (RPP), relative mean power (ฬ-kg ') (RMP), fatigue index (%) (FI) and peak power instant (PPI).

The protocol consisted of a four minute warm-up on a mechanic cycloergometer (MONARK* 324E, SWEDEN) with a 50 ฬ load and a pedaling rate of 70 rpm, and at the beginning of each minute the participants performed a 6 s sprint (23). After warm-up, there was an interval of two minutes to measure body weight, adjust the height of the cycloergometer s saddle and to adjust effort intensity. Each participant then performed the Wingate test, with no previous rotation, with a resistance load of 0.075 kg-kg^{1} of body weight. At test conclusion the participants continued to pedal at zero load for three minutes of active recovery to minimize possible side effects caused by the physical effort.

Prior to the beginning of the study a familiarization protocol was used to reduce the learning effects and establish the reproducibility of the test. All participants were tested in a situation identical to the experimental protocol, in two different sessions, with an interval of 48 h. The intra-class correlation coefficients found were 0.98, 0.95 and 0.90 for RPP, RMP and FI (%).

Each participant's cycloergometer saddle height and distance, headset height and distance, and handgrip position were standardized to minimize interference in the recruitment of the evaluated muscles. For all tests, the temperature and relative humidity were controlled and kept between 21 and 24°c and 40 and 60%, respectively.

Electromyographic Signal (EMG) Analyses

EMG signals were collected during the WT in the CAF or PL conditions, following the protocol as established by ISEK (24). Before the beginning of each WT, EMG bipolar active electrodes (model TSD 150™ BIOPAC Systems*, USA), with fixed inter-electrode distance of two centimeters, were placed on the superficial muscles of the right Quadriceps Femoris (QF): Vastus Lateralis (VL), Vastus Medialis (VM) and Rectus Femoris (RF). After skin abrasion and cleaning with alcohol, the electrodes were positioned on each muscle according to the standardization proposed by the SENIAM Project (25). Electromyographic activity was recorded by a 16-channel electromyograph (model MP150™ Biopac System*, USA), with a sampling frequency of 2000 Hz. The common-mode rejection ratio (CMRR) was 95 dB, and the signal input limits were established in ± 5 mV. The reference (ground) electrode was placed on the lateral epicondyle of the right elbow.

Table 1. *Mean values ± standard deviation of the anthropometric characteristics of men, women and all participants*

Variables	Men (ท = 7)	Women (ท = 7)	All (ท = 14)
Body Mass (kg)	82.44 ± 10.13	63.68 ± 7.93	73.06 ± 13.08
Height (cm)	179.00 ± 1.00	168.00 ±3.10	173.00 ±6.90
BMI (kg-nr^2)	25.69 ± 2.6	22.47 ± 2.62	24.08 ±3.01

For signal acquisition and processing the Ac-qKnowledge 3.8.1™ (BIOPAC Systems*, USA) software and mathematical simulation environment MatLab 7.0 (Mathworks*, South Natick, MA, USA) were used. Raw EMG signals were digitally band-pass filtered at 20Hz-500Hz. EMG signals of the VL, VM, RF and integrated QF ([VL + VM + RF] /3) muscles were analyzed by Fast Fourier Transform (FFT) for each 5 ร period during the 30 ร test and normalized by its initial median frequency (MF) (5 ร). Muscle fatigue index was determined according to Ng et al. (26) via linear regression using the slope of the curve from the normalized median frequency (NMF) and exercise duration.

Caffeine Intake

Participants ingested pure caffeine (CAF) (6mg-kg ') or maltodextrin (PL), each prepared and packaged separately in gelatin capsules, at the beginning of the 60 min [27] rest period prior to the WT. Caffeine ingestion was the same for men and women, since previous studies [28,29] have shown that gender and menstrual cycle have no effect in caffeine pharmacokinetics. The study was of a randomized, counterbalanced, double-blind design.

Table 2. *Mean values ± standard deviation of relative peak power (RPP), relative mean power (RMP), fatigue index (FI) and peak power instant (PPI)for men, women and all participants in the CAF and PL conditions*

		RPP (W-kg-^{1})	RMP (W-kg-^{1})	FI (%)	PPI (ร)
Men	CAF	10.03 ± 1.04	7.35 ± 0.62	53.49 ± 9.79	4.14 ±0.37
(ท=7)	PL	9.99 ± 0.96	7.23 ± 0.49	52.3 ± 8.91	4.28 ± 0.75
Women	CAF	7.80 ±	5.63 ±	54.14 ±	5.00 ±

		0.95	0.68	13.92	1.15
(ɳ=7)	PL	7.66 ± 1.00	5.65 ±0.61	48.03 ± 9.63	4.42 ± 0.97
All	CAF	8.91 ± 1.50	6.49 ± 1.09	53.81 ± 11.56	4.57 ± 0.93
(ɳ=14)	PL	8.82 ± 1.53	6.44 ± 0.97	50.16 ±9.18	4.35 ± 0.84

Table 3. *Mean values ± standard deviation of the rate of fatigue of the vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF) and integrated quadriceps femoris (QF)for men, women and all participants in the CAF and PL conditions, in arbitrary units*

Rate of Muscle Fatigue					
		VL	VM	RF	QF
Men	CAF	-3.86 ± 1.29	-2.73 ± 2.10	-2.74 ± 1.72	-3.12 ± 0.95
(ɳ=7)	PL	-3.40 ±2.14	-3.26 ± 1.69	-3.03 ± 1.64	-3.23 ± 1.38
Women	CAF	-4.87 ± 1.73	-3.92 ± 0.87	-3.99 ± 1.49	-4.31 ± 0.94
(ɳ=7)	PL	-4.47 ± 1.0	-3.18 ± 1.01	-3.93 ±0.61	-3.86 ±0.37
All	CAF	-4.36 ± 1.55	-3.33 ± 1.66	-3.37 ± 1.67	-3.71 ± 1.10
(ɳ=14)	PL	-3.93 ± 1.70	-3.22 ± 1.34	-3.48 ± 1.28	-3.54 ± 1.02

Statistical Analyses

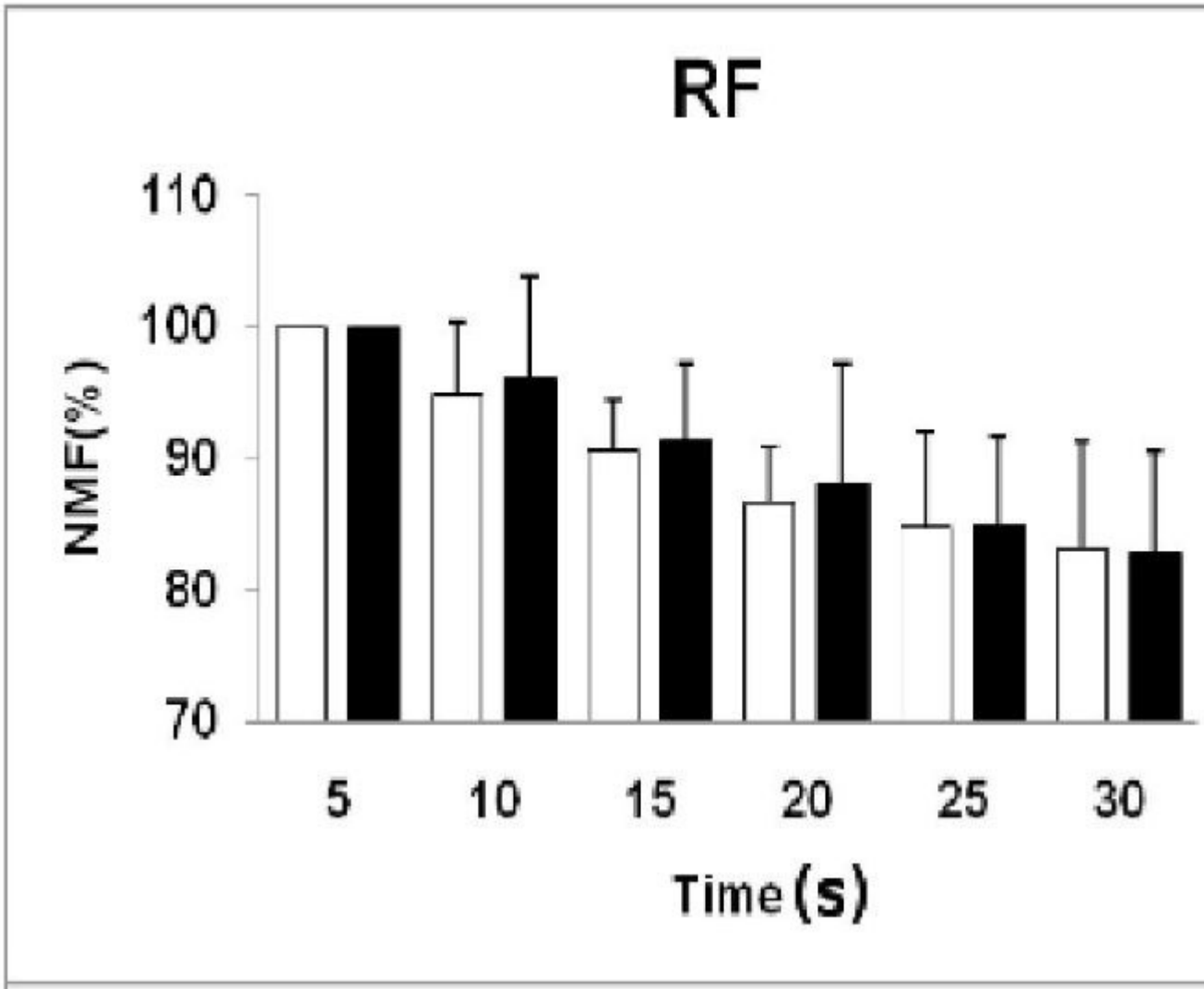
Normality and homogeneity of data was confirmed with Shapiro-Wilk's test and Levene's test, respectively, and the results were expressed in mean values and standard deviation. Comparisons of anaerobic performance data and the rate of muscle fatigue of the QF muscles between the CAF and PL conditions were performed using a paired Student's t test. To check for eventual differences in the behavior of the NMF of the QF muscles in the CAF and PL conditions, for each 5 ร period during the 30 ร of the WT, we used a two-way ANOVA, followed by the Scheffe's test when F values were statistically significant. The significance level adopted for all analysis was 5%. Data analysis was conducted using the Statistica™ 6.0* (STATSOFT INC., TULSA, OK, USA) statistical package. For greater precision in the data analysis, the statistical power of the sample was calculated based on the peak power (พ), using the values presented by Greer et al. [2] as a parameter for comparison. The statistical Power found for our sample was of 100%.

Results

Table 2 lists the values of the anaerobic performance variables for both genders and the combined gender group in the CAF and PL conditions. No statistically significant difference ($p > 0.05$) was found for either gender or the combined gender group in the CAF and PL conditions.

No statistically significant difference ($p > 0.05$) was in the fatigue rate of the VL, VM , RF and integrated QF muscles for either gender or the combined gender group in the CAF and PL conditions ($p > 0.05$) (Table 3).

Figure 1 presents the means ± SD values of the normalized median frequency (NMF) (%), in each period of 5 ร during the 30 ร period of the WT of the VL, VM, RF and integrated QF muscles for all participants in the CAF and PL conditions. No significant difference was found for NMF between the CAF and PL conditions in all muscles studied ($p > 0.05$). There were significant differences in NMF only in relation to time, in both conditions ($p > 0.05$).


RF
110
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NMF(%)
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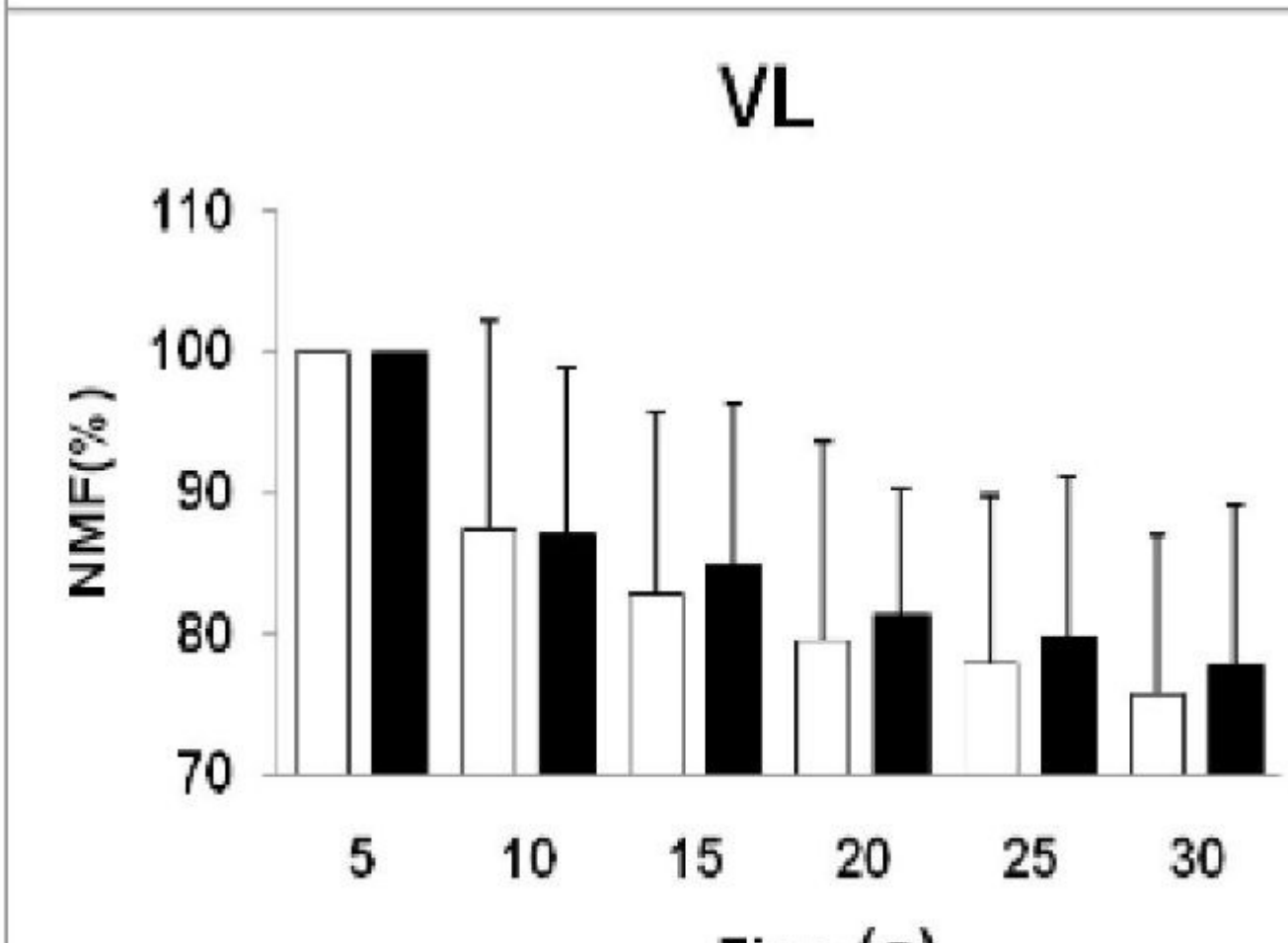
Time (s)


VL
110
100
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NMF(%)
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Figure 1. *Mean values ± standard deviation of the normalized median frequency (NMF) (%), in each period of 5 s during the 30 s period of the WT of the VL, VM, RF and integrated QF muscles for all participants in the CAF and PL conditions*

Discussion

The objective of the present study was to investigate the effect of caffeine intake on the anaerobic performance and the fatigue rate of the superficial muscles of the Quadriceps Femoris in men and women during the 30 ƽ WT. Based on the results of this study, caffeine was not effective in optimizing performance and influencing the process of onset of fatigue.

Regarding the effects of caffeine on the anaerobic performance variables measured, our results corroborates those of Greer et al. [2,7] and Collomp et al. [6], and are in opposition to those of Anselme et al. [4] who found a significant increase in anaerobic power in untrained young participants using a dosage of 250mg of caffeine, and Woolf et al. [9] and Plaskett and Cafarelli [30] who found an increase in peak power during the WT in highly trained young participants (5 mg-kg !)•

The wide variation in results regarding the effects of caffeine on anaerobic exercise may be due the diversity of protocols used to study this effect [1], and to a lack of adequate control of the analyzed variables. The level of training of the participants is another factor that directly influences the results. According to Burke [13], few studies used elite athletes and the probability of finding differences in these athletes is lower, because they show little performance variation between tests. Although the present study used untrained participants, the control of the variables through a familiarization test and the normalization of the data improve the accuracy of the results in order to infer, with less risk of error, that caffeine did not improve anaerobic performance.

One of the hypotheses about the effect of caffeine is that the substance may act both centrally and peripherally. One study [31] has shown that caffeine can increase the release of Ca^{2+} from the sarcoplasmic reticulum, facilitating the excitation-contraction coupling. However, Fredholm et al. [14] dismiss this hypothesis in humans, as the doses required to achieve this effect would be toxic to the body. Nevertheless, the hypothesis that caffeine may act peripherally cannot be completely discarded, since another study [32] using participants with spinal cord injury performing exercise through evoked electric stimulation until exhaustion, showed and increase performance after the ingestion of 6 mg-kg^{1} of caffeine, arguing that another factor, besides increased release of Ca^{2+} from the sarcoplasmic reticulum, might be involved.

In support of this argument, Lynge and Hellsten [33] showed that adenosine receptors are present at peripheral level, especially those of the A_{2A} type in type I fibers. Since caffeine acts as an adenosine receptor antagonist, it could act on the peripheral receptors increasing time to exhaustion [32]. Centrally, caffeine also acts as an antagonist of the inhibitory effects of adenosine over the action of some excitatory neurotransmitters [11, 14]. Therefore, it may act to optimize the recruitment of motor units and attenuate the fatigue by increasing the production of maximal force, at least in isometric contractions [3,17,30,34]. A recent review from Astorino and Roberson [35] discuss a possible

mechanism of caffeine effects in high intensity, short-term exercise; including caffeine action in the brain (central action), which might contribute for an increase in motor unit recruitment. However, such hypothesis was not confirmed in our study, corroborating the findings of Greer et al. [2].

Hypothetically, although such a mechanism could also improve performance during dynamic exercise, our results found that caffeine did not alter the rate of muscle fatigue in supramaximal dynamic exercise. Our results corroborates those of Greer et al. [2], who found no differences in MF after the intake of 5 mg-kg^{1} of caffeine, in dynamic exercise using the WT, in the VL and gastrocnemius.

Conclusions

Based on the results of this study, the ingestion of caffeine (6 mg-kg 0 did not affect the performance in supramaximal dynamic exercise, as well as reduce the rate of fatigue of the superficial muscles of the QF. Although tcaffeine has been shown to influence the performance in some types of exercise, and its antagonistic effects to the adenosine receptors are well documented, we were unable to observe these effects in the present study.

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