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Caffeine, Taurine, High- and Moderate-Intensity Exercise on Advanced Cognition of Older Adults

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Abstract

Introduction: *The exercise was pointed as a low valuable to improvement the cognition, but, caffeine and taurine has been used to this objective, however, the blood lactate, molecule produced in high-intensity exercise, have a central role in this phenomenon.* ***Objective****: To verify the acute effects of caffeine, taurine, high, and moderate-intensity exercise on cognition of healthy older adults, and mechanisms related.* ***Methodology:*** *Seventy-five older adults were randomly divided into 5 groups (n=15 each), CAF (subjected to 5mg/kg^{-1}), TAU (subjected to 20mg/ kg^{-1}), HIIT (subjected to Hight-intensity exercise session), MICT (subjected to moderate-intensity exercise session) and CG had no supplementation or underwent the exercises. The*

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cognition was evaluated by the inhibitory control across the Go/no-Go (GNG), Reaction Time (TR) and Flanker (FLK), performed immediately before, and after 60 minutes of their experimental situation. Electroencephalographic data, and blood lactate were assessed to try explaining the outcomes. The statistics was performed by Kruskal-Wallis with Dunn's posterior test with significance of 5%. ***Results:*** *Caffeine and taurine supplementations did not improve the speed of response in the RT, GNG, the congruent and incongruous FLK ($p>0.05$) in this experimental situation. However, the exercises provided acute improved response time for GNG ($p<0.05$), TR ($p<0.05$), congruent ($p<0.0001$) and incongruous FLK ($p<0.001$ both) with advantage to high-intensity exercise with highest correlation with the blood-lactate levels. Only the high-intensity exercise increased the Alpha, Beta waves and the SMR Rhythm power output.* ***Conclusion:*** *Contrasting with part of the literature, caffeine and taurine do not improve inhibitory control of the young adults, but the high-intensity, but not the moderate-intensity exercises session did acute improvement of the cognition performance and the on Alpha, Beta band and SMR rhythm power output suggesting a possible mechanism under the EF enhancement due to sprint interval short exercise.*

Keywords: Executive Functions, Inhibitory Control, Intense Exercise, Motricity. Sit.

PROBLEM AND AIM

EFs, also known as cognitive planning, refer to highly hierarchical mental processes that are part of brain functioning that enables mental planning, the concatenation of ideas and the reduction of time between thought and action, thus being one of the most important functions of the human mind. When one needs to pay attention to some cognitive or motor task, or when we are not in intuitive activities it would be more difficult to perform these tasks without the FE (Diamond, 2013; Lima et al., 2017). However, the EF requires greater effort than performing tasks in an automated way, so that maintaining attention or focus on a task requires a greater effort than automating actions (Diamond, 2013).

It is a consensus that there are three main nuclei of Efs, and that this nucleus are advanced compounds of cognition; (i) inhibitory control

(Ghacibeh et al., 2007) linked to perception and motricity, (ii) interference control such as selective attention and working memory (Wambach et al., 2011) and (iii) cognitive flexibility closely linked to creativity (Diamond, 2013; Lima et al., 2017) and are fundamental skills for physical, mental, school success, skills for day-to-day tasks, cognitive activity, social interactions and adequate psychological development (Collins, Roberts, Dias, Everitt, & Robbins, 1998).

Different possibilities have been described to positively influence EFs, such as nutrients, so that caffeine and taurine stand out for a central and peripheral activity (McLellan, Caldwell, & Lieberman, 2016; Santos et al., 2014), mental training in the biofeedback modality (Calomeni et al., 2017) and physical exercises of various natures, types, volume and intensities (Alves et al., 2012; Lima et al., 2017; Liu-Ambrose et al., 2010; Nouchi et al., 2014; Vestberg et al., 2012). However, lack about the acute effect of short-exhaustive exercise need be investigated because, one session of acute exercise may be present in several professions as Police, Fireman, or, to several sports as soccer, basketball players, or martial arts that before on he may be forced to make a quick decision and defects in executive functions, especially in reaction time, can cause errors or mistakes leading to an inadequate outcome of motor action due to a depression in the speed of mental processing.

In this same context, the physical exercise has acute and chronic effects on cognition. Was reported that the chronic exercise may be very important to keep the cognition and the mental processing healthy condition (de Greeff et al., 2018; Lima et al., 2017; Macpherson et al., 2017), however, the short, or very short term exhaustive exercise may lead to decreasing in the mental processing due, perhaps the central fatigue, and can be considered immediate and potent, allowing to affirm that EFE improve after an exercise session (Jäger et al., 2014; Wen et al., 2018). In another hand, Diamond (2013) stated that exercise is one of the most inefficient way to improve executive functions, a statement questioned here in this paper when comparing the effect of caffeine and taurine with exercise, which allows comparing the hypothesis that exercise is a powerful way to improve the inhibition control.

Several evidences associate exercise with functional and structural improvements of the entire brain with different exercise approaches and for different populations, from normal children or with ADHD to healthy elderly, or in pathological conditions such as Alzheimer's or dementia (El-Sayed et al., 2002; Flöel et al., 2010; Furtado da Silva et al., 2017; Jäger et al., 2014; Liu-Ambrose et al., 2010; Liu et al., 2017; Nouchi et al., 2014). The present study aimed to verify the acute effects of caffeine, or taurine intake, and short-exhaustive exercise session on advanced cognition compounds of healthy young adults and to provide explanations about the electrophysiological mechanisms related.

METHODS

Study type and participants

The Pre-sent study was of the almost experimental type, because it had experimental groups chosen at random, through direct invitation of the researchers and did not have a control group, however, their control was themselves. This study was conducted at a Higher Education Institution in Rio Branco, Acre, Brazil. Sixty volunteers with 25.55±3.22 years and 76.44±15.39 kg of body mass, of both sexes, all residents of Rio Branco, Acre, Brazil.

Caffeine and Taurine

Caffeine (1-3-7-trimethylxanthene) and taurine (amino sulfonic acid) were acquired at the Valfarma handling pharmacy located at Avenida Carlo Gomes, 1987, Porto Velho, CNPJ: 05.552.589/0001-54, and the reports of analysis and traceability of the products were presented, as well as meeting the physical and chemical characteristics of each raw material. The material were analyzed by High-Performance Liquid Cromatrograph (Shimatzu) and before in Mass Spectrometer (Mald Tof/Tof) to determination of their composition confirming the caffeine, and taurine both with more than 90% of purity.

Design, instruments and study procedures

The volunteers were instructed to wear light clothing, not to perform vigorous physical exercises, or to consume large amounts of caffeine or products containing caffeine, such as chocolate, soda, Guarani at least 24 hours before the tests. The tests were performed at three separate distinct times for 15 days between them to avoid any interference that one experimental situation could have on the other.

The initial group of 60 volunteers was randomly divided into four groups. The first group, hereinafter referred to as CON (*n*=15), did not consume caffeine, nor taurine and did not exercise, CAF (*n*=15), consumed caffeine at $6mg^{\cdot}kg^{-1}$, TAU (*n*=15) consumed Taurine at $40mg^{\cdot}Kg^{-1}$ and the third group, called EXE (*n*=15) was submitted to an acute and standardized situation of exhausting exercise of short duration until exhaustion (see the Run Shuttle session).

The executive function tests in the CON groups were performed before and after 60 minutes in a passive resting situation. For the CAF and TAU groups, supplementation was performed before and after 60 minutes, since the literate you state that your maximum concentrations happen between 40 and 60 minutes remaining for up to 240 minutes (Haskell, Kennedy, Wesnes, Milne, & Scholey, 2007; Outlaw et al., 2014). The group submitted to exhaustive exercise performed the tests immediately after the exercise.

Executive Function Assessment

To measure changes in the inhibition, control the participants completed the Reaction Time, Go/no-Go and Flanker tests, the latter, in its congruent and incongruous version, were applied. Initially, before data collection, the subjects went through two consecutive sessions of habituation with 50 tests each and, without then, another 50 experiments were carried out, the latter 50 counting as results. The same procedure was performed for the Pre- and for the Post--Test. All three tests were performed on computers, inside a computer laboratory of the UNINORTE University Center, with controlled temperature, lightning, and sound to avoid interference.

The Go/no-Go test required a binary decision on each stimulus. According to the type of stimulus, the subject should react (Go) or not (no-Go). Therefore, this test is considered a measure of inhibition response and is generally used to evaluate the ability to inhibit the "overbearing" response. Specifically, the test required participants to respond quickly, as quickly as possible and accurately to a circle of 5.5 cm in diameter with a massive green color that occurred in between 40 and 60% of the trials and not respond to a non-target circle of 5.5 cm with a different color pattern and that diameter that occurred between 40 and 60% of the trials randomly and with different stimulus times so that there was no Pre-diction of when the circle would appear.

As for the T-test of R and simple choice, the volunteer should react to a stimulus as soon as possible. This stimulus was the appearance of a 5.5 cm ball, black in color on the computer screen, with different stimulus times so that there was no Pre-diction of when the circle would appear.

Finally, the Flanker has two versions, the congruent in which the test presents equal stimuli and the incongruous, in which the test presents different stimuli to which the volunteer must identify the stimulus before making the decision. The stimulus is a screen with black arrows of varying size and quantity in which the subject should Press the arrow of the computer keyboard according to the side that the center arrow of the screen appeared. If the center arrow was pointing left the left arrow of the keyboard should be pressed, and otherwise, if the center arrow was pointed to the right, the right arrow of the keyboard should be pressed. In the congruent version, all arrows would point to the same side, however, in the incongruous, the arrows would appear in different directions, forcing the subject to first identify the arrow to the right side.

Acquisition of electroencephalographic signals

In order to verify the amplitude of the Alpha and SMR bands, EEG-Neurofeedback Procomp+ (Touch technology-Canada) was used. This equipment has its own grounding, condition that minimizes the interference of electrical signals or electromagnetic noise which if not controlled would impair the reliability of signal capture. For the present study, the distribution occurred at scalp point CZ and at auricular points A1 and A2, as recommended in the international 10-20 system (Klem et al., 1958) when the objective is the verification of the standard modulator of cortex (da Silva et al., 2016). So, the Alpha wave Bata wave and SMR rhythm were assessed before and after the interventions, however, after the EF tests. The data acquiring have 3 minutes of recording separated at one minute of resting. In addition, the data was acquired in a calm place, with sound and light controlled and, with no details that would distract the volunteer. All acquisition data were performed with opened eyes.

Shuttle Run

The Shuttle Run was used with the objective of providing a standard exercise, of short duration until exhaustion as described in previous studies (Léger, Mercier, Gadoury, & Lambert, 2017; Ramsbottom, Brewer, & Williams, 1988.

The stress tests were carried out at night, in the parking lot of the aforementioned educational institution, in a flat place and with mild temperature. All subjects answered a small questionnaire to identify data, such as name and age.

To perform the test, a flat site with at least 25 meters, a laptop, sound box, 4 cones, crepe tape, stopwatch, scoreboard with number of turns and annotation sheets were required. The test was applied to groups of 5 people, who ran together, at a rhythm based on audio recorded especially for this purpose. They traveled a space of 20 meters, delimited between 2 parallel lines. The audio at specific intervals for each stage, and each beep the evaluated should cross with one of the feet one of the 2 parallel lines, that is, coming out of one of the lines ran towards the other, crossed the line with at least one of the feet and, upon hearing another "beep", came back in the opposite direction.

In audio, the end of a stage is signaled with 2 consecutive beeps and with a voice warning the completed stage number. The duration of the test depends on the cardiorespiratory fitness of each person, being progressive and maximum, less intense at the beginning and becoming more intense at the end, making a possible total of 21 minutes (stages).

Then, the number of arrivals is compared with the reference table for determining the speed achieved. Immediately after the determination of the speed, this data is used in one for the calculation of vo_2 max (procedure not performed). These procedures were previously described(Léger et al., 2017; Ramsbottom et al., 1988) and validity determined by different authors found high or very high correlation*(r calculated up* to 0.96 in correlation test with spirometer) (Paliczka, Nichols, Boreham, V.J., & A.K., 1987; Ramsbottom et al., 1988).

Statistical Analysis

To verify the normality of the data, the Kolmogorov-Smirnov statistical test was performed. For data processing, variance analysis ANOVA THREE WAY with significance of 5% was used. All tests were performed with a significance of 5% in the Graph Pad Prism 5.0 program.

Research Ethics

This research complied with all mandatory requirements in accordance with law no. 466/2012 of the National Health Council of Brazil and was approved by the Ethics Council duly consolidated under the number of CAAE: 44907715.2.0000.5653 on 07/27/2015. All volunteers signed the free and informed consent form, were informed of the risks and benefits of the research, as well as all phases of the research, where they could decline their participation at the time they wished without entailing any penalty on the volunteer or any of the researchers and that their participations would not be remunerated.

RESULTS

Single both of exhaustive exercise provoke acute enhancement in inhibitory control, but not CAF and TAU

The data are shown in Figure 1 show that in all tests the Pre-test had similar results with no difference between the groups($p>0.05$). Caffeine and taurine were not able to modify the inhibition control of young adults in any of the tests ($p>0.05$). However, the high intensity exhaustive exercise performed until exhaustion increase the reaction to the Go/no-Go of the Pre- to the Post-test (Fig. 1A) ($p<0.05$) and the moment Post- the EXE test also showed a difference for the results of the other groups (Fig. 1A) ($p<0.05$). The reaction time also showed a difference from Pre- to Post-test only in EXE (Fig. 1B) ($p<0.05$) with a similar result for the comparison of EXE results with that of the other groups (Fig. 1B) ($p<0.05$). As for the Flanker, there was a clear difference between the EXE Pre- (Fig. 1C) ($p<0.0001$) and, compared to the results of the other groups, there was a similar result (Fig. 1C) ($p<0.0001$) in its congruent version and, in its incongruous version, an equal effect of EXE was noted for both the Post- compared to the Pre- (Fig. 1D) ($p<0.0001$) as to the comparison between the EXE results and the other groups (Fig. 1D) ($p<0.0001$).

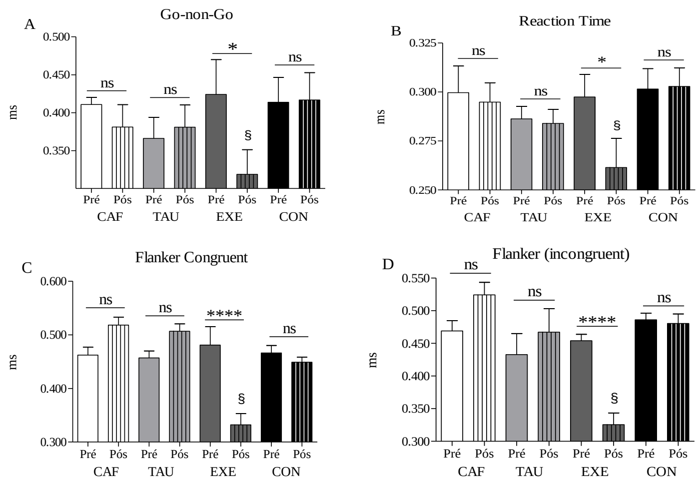

Figure 1: Inhibitory Control. Sixty subjects were divided and three groups, Control (CON, *n*=15) Caffeine (CAF, *n*=15), Taurine (TAU, *n*=15) and Exercise (EXE, *n*=15) and submitted to four tests to determine the inhibitory control (A) Go/no-Go, (B) Reaction Time, (C) Congruent Flanker and (D) Flanker Incongruent immediately before the experimental situations and 60 minutes after supplementation with caffeine ($6mg \cdot kg^{-1}$) and Taurine ($40mg \cdot Kg^{-1}$) and immediately after the exhaustive exercise(Run Shuttle). The ANOVA THREE WAY and Dunn's subsequent test with 5% significance was used to determine the possible differences between the Pre and The Post- Test intragroup differences and intergroup differences. **Note:** (ns= not significant) (1A and 1B *= p<0.05 for EXE Post- vs Pre- and §= p<0.05 EXE Post- vs CAF Post-, TAU Post- CON Post-) 1C and 1D ****= p<0.001 for EXE Post- vs. Pre- and §= p<0.001 EXE Post- CAF Powder, TAU Post- CON Post-); (Pre = baseline data; Post = comparison data).

Single both of exhaustive exercise provoke acute enhancement in Alpha, Beta and SMR EEG bands, but not CAF and TAU

For all electrophysiological parameters, Alpha wave (Fig 2A), Beta wave (Fig. 2B), and SMR rhythm (Fig. 2C) all exhibited no difference in absolute power output to CAF, TAU and CON groups (p>0.05).

To the Alpha Band the CAF reached in Pre- 3.99±7.01mV and in Post-moment 4.48±12.35mV (p>0.05), the TAU reached in Pre- 4.02±1.03mV and in Post-moment 4.56±1.65mV (p> 0.05), the CON reached in Pre- 3.56±2.66mV and in Post-moment 4.18±3.22mV (p>0.05) (Fig. 2B), however, the EXE reached in Pre- 4.07±7.01mV and in post-moment 12.48±12.35) with difference (p= 0.0001).

To the Beta Band the CAF reached in Pre- 3.49±2.39mV and in Post-moment 4.87±7.50mV (p>0.05), the TAU reached in Pre- 4.51±3.66mV and in Post-moment 4.21±3.12mV (p> 0.05), the CON reached in Pre- 5.11±6.21mV and in Post-moment 6.03±5.98mV (p>0.05) (Fig. 2B), however, the EXE reached in Pre- 4.81±2.49mV and in psot-moment 8.87±7.50) with difference (p= 0.0001).

To the SMR Rhythm CAF reached in Pre- 5.98±3.11mV and in Post-moment 7.26±4.18mV (p>0.05), the TAU reached in Pre- 7.12±5.78mV and in Post-moment 6.32±4.23mV (p> 0.05), the CON reached in Pre- 8.51±7.36mV and in post-moment 8.11±6.25mV (p>0.05) (Fig. 2B), however, the EXE reached in Pre- 6.98±3.41mV and in post-moment 12.26±5.68) with difference (p= 0.0001).

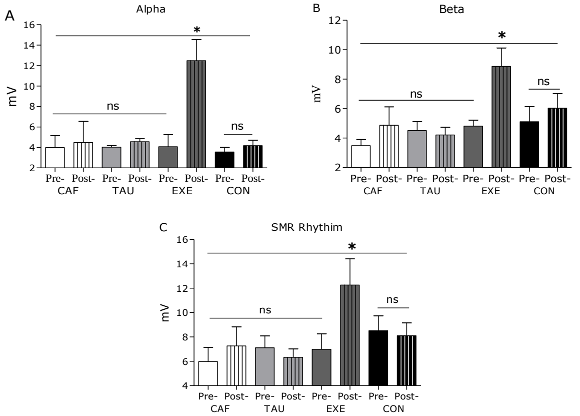

Figure 2: Cortical waves. Sixty-eight subjects between 18 and 28 years old of both sexes, were selected and divided into control group composed by 32 (n=32) subjects, and the experimental group with 36 (n=36) subjects. They are submitted to four minutes of data collection of Alpha, SMR and Beta cortical waves. Alpha (A), SMR (B) and Beta (C). The ANOVA THREE WAY and Dunn's subsequent test with 5% significance was used to determine the possible differences between the Pre- and The Post- Test intragroup differences and intergroup differences. **Note:** (A, B and C * = p <0.0001 Post- *vs*- Pre); (Pre = baseline data; Post = comparison data).

DISCUSSION

The Pre-sent study aimed to investigate the effect of caffeine, taurine, and intense exercise on the inhibiting control of healthy adults. The data here showed no effect of caffeine and taurine, while the proposed exercise was able to improve the inhibitory control in all tests. Although the mechanisms by which the behavior described here were not investigated, according to the literature, the substances used here are consider as a central nervous system stimulant, it due to the use in a stimulant drinks, because, previously was identified activation of the central nervous system (Graham, 2001; McLellan et al., 2016; Nehlig, Daval, & Debry, 1992). Otherwise it seems that the physical component Pre-sent in exercise has some influence on the inhibition control as previously demonstrated (Chang et al., 2015; Guiney, Lucas, Cotter, & Machado, 2015; Loprinzi & Kane, 2015) and that the data from this investigation corroborate.

By the use of the specific mechanisms of the caffeine seems that of the main means that this compound is associated with improvement of cognitive performance and an antagonism the receptors of adenosine A1 and A2a (Lorist & Tops, 2003; Wells et al., 2013) inside the brain, relieving symptoms of central fatigue (Davis et al., 2003). The blockade of adenosine receptors promoted by caffeine is seems to propitiate an excitation of the ethical skeletal muscle leading to better coupling and contraction, increased muscle strength, working capacity and power (Tallis, Duncan, & James, 2015), however, these data are still controversial, where other authors have not evidenced increased strength and potency, which may otherwise be associated with an effect of habituation of the intake of this compound in different beverages and foods (Wilk, Krzysztofik, Filip, Zajac, & Del Coso, 2019).

The intake of taurine can benefit the cardiac and skeletal muscles, modulating the calcium channels, favoring cardiac contraction and helping in the distribution of blood (Huxtable, 2017). A greater cerebral blood flow resulting from the response to this substance intake may influence brain activation, which is considered the most likely mechanism related to the possible effect of this compound on cognition, and motive activities such as those proposed here (Huxtable, 2017). However, neither caffeine nor taurine had an effect on the inhibitory control; therefore, the present discussion will be primarily focused on the effect of exercise observed here in the inhibiting control of young adults, to which it is the central issue of this study. The data here displayed about the effect of caffeine and taurine disagree with many part of the literature that treat this theme (Addicott et al., 2009; Alhaider et al., 2010; Lorist & Tops, 2003; Meeusen et al., 2013; Mosca et al., 2014; Nehlig et al., 1992). Indeed, here we challenged the affirmation of Diamond (2013) who postulated that exercise is the most inefficient way to improve executive functions.

Different actions can improve EF in an acute or chronic way, in people with different ages and physical and mental conditions (Furtado da Silva et al., 2017; Lima et al., 2017; Verburgh et al., 2014; Wen et al., 2018).

Regarding the improvements observed (Jo et al., 2018) described that an aerobic exercise session can reduce the interference between cognition and learning, that is, it is able to facilitate the acquisition of the transit of information to perform motor procedures. What has been somewhat confirmed here, because if the inhibition control is part of the superior cognitive functions and they seem to have been positively influenced by exercise it is reasonable to think that this improvement can play an important role on the cognition and motricity of the group that was part of the research here.

Another study demonstrated that cognitive performance maybe related to exercise intensity and this fact probably has implications for the sports, educational and occupational environment (Rattray & Smee, 2016) important for future work, as well as simplification for the discussion of the Pre-sent study. The data shown here corroborate these authors, although the experimental situation used here was intense and exhaustive exercise differently from previous studies that used resistance or aerobic exercises with moderate to intense intensity as a priority.

Previous studies have reported that an acute session of aerobic exercise can improve EF, including inhibitory control, in different populations (Byun et al., 2014; Hyodo et al., 2012; Tsukamoto et al., 2017; Yanagisawa et al., 2010). In addition, it has been previously demonstrated that the improvement of inhibitory control induced by aerobic exercise is related to the improvement of neural activity (Hyodo et al., 20102; Yanagisawa et al., 2010).. Also along the same lines, Byun et al., á (2014) demonstrated that the increase in cerebral neural activity induced by aerobic exercise is related to increased neural arousal, a fact that was expected for caffeine and seems not to have happened. Based on these findings, previous studies have proposed that the potential mechanism underlying the improvement of the inhibition control is associate do with increased cerebral neuronal activation and stimulation (Silva et al., 2020; Souza et al., 2019). This may be a mechanism linked to the behaviors observed here for the inhibitory control (Byun et al., 2014; Hyodo et al., 2012; Yanagisawa et al., 2010).

This increase in neural excitability can be mediated by a number of different mechanisms such as increased cerebral blood flow (Guiney et al., 2015), neurogenesis, synaptic plasticity, cell proliferation, acute increase in brain-derived neurotrophic factor (Tsai et al., 2014),and associated neural efficiency, which may be partially dependent on cardiorespiratory fitness (Tsai, Pan, Chen, Wang, & Chou, 2016). However, due to what was observed for exercise, differently to what was observed for caffeine and taurine, probably the increase in blood flow (Tsai et al., 2016) refers, should be the main mechanism that provided the aforementioned improvement in the inhibition control of young adults, conclusion made when observing that the exercise proposed here and the subsequent data collection was immediately after exercise.

Crush and Loprinzi (2017), in an extensive investigation that sought to determine the effect of exposure time of moderate intensity exercise, recovery time and different combinations of these two factors noted that all training regimens benefited from planning capacity, memory, inhibitory control and also described that there is an effect dose exercise response and recovery on EF, which in fact corroborate the data of the present study.

To train to explain the behavior here observed to the EF, the electrophysiological data were acquired. Here, the CAF and TAU did not affect the Alpha wave, Beta wave, and the Sensory Motor Rhythm. Here, all parameters were modified by exercise, however, the caffeine and taurine did not affect the brain electrophysiological pattern, which can help us to explain why these substances did not improved the EF. Another studies displayed improvement in EF in response to exercise (de Greeff et al., 2018; Souza et al., 2019; Tsai et al., 2016), although, Diamond (2013) postulated that the exercise is not the best way to improve the EF.

In another hand, studies has been shown that the caffeine is able to improve the EF (Lorist & Tops, 2003; McLellan et al., 2016; Mitchell et al., 2011; Scholey & Kennedy, 2004). About the taurine, although several physiological and nutritional functions were identified (Huxtable, 2017; Stavsky & Maitra, 2019), in regards the EF no data were available until this moment, however, one study display that the taurine can affect the brain wave patterns similarly to the alcohol (Neuwirth et al., 2019).

Together, the data demonstrated here give theoretical support to the findings observed here in such a way that the exhaustive exercise with short duration promotes immediate positive effects on the inhibition control of young adults, probably mediated to the improvement on the Alpha, Beta and SMR power output. Thus, there is consistent evidence that short-term exhaustive exercise can improve the inhibiting control and decision-making of healthy young adults that may be associated with cognition and brain health.

CONCLUSIONS

In spite of a series of previous evidence on the contrary, caffeine and/or taurine per se did not improve advanced cognitive functions of the young subjects of this present study, as the promoted by the intense and exhaustive session of exercise programmed to them. The effects of exercise on inhibitory control, as seen in this present study, is not new evidence but brings some interesting details in which it refers to the intensity of the employed exercises. On the other hand, the study also demonstrated a visible relationship of the exercise nature with the cortical Alpha, Beta and SMR bands, evidence that can be an important start point to a more detailed explanation about the electrophysiological mechanisms underserving our propulsive mind. To progress on this direction, it is suggested a strong dose of research centering on this modality of exercise about advanced cognition compounds as well as to other human executive functions.

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