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ORIGINAL ARTICLE

Acute effect of intermittent high-intensity exercise on inhibitory control performance in female futsal athletes

Efeito agudo do exercício intermitente de alta intensidade no desempenho do controle inibitório em atletas de futsal feminino

Efecto agudo del ejercicio intermitente de alta intensidad sobre el rendimiento del control inhibitorio en atletas de futbol sala femenina

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Keywords:
Team sport;
Endurance;
Executive functions;
Female athletes.

ABSTRACT
The aim of the study was to verify the acute effect of high-intensity intermittent exercise on inhibitory control performance in female futsal athletes. Fourteen adult female futsal athletes were randomly subjected to a high-intensity intermittent (HIE) exercise condition and a sedentary condition. Before and after the sessions, tests were applied to evaluate inhibitory control performance (Stroop test, Testinpacs®). A time effect was observed only in the HIE condition ($p<0.05$). The delta [post-pre] of the response time of the incongruous phase of the Stroop test showed a significant difference between the experimental conditions ($p<0.05$). Conclusion: The HIE improved acute inhibitory control performance in female futsal athletes.

Palavras-chave:
Esporte coletivo;
Endurance;
Funções executivas;
Atletas femininas.

RESUMO
O objetivo do estudo foi verificar o efeito agudo do exercício intermitente de alta intensidade no desempenho do controle inibitório em atletas de futsal feminino. Quatorze atletas adultas de futsal foram submetidas aleatoriamente a uma condição de exercício intermitente de alta intensidade (EIAI) e uma condição sedentária. Antes e após as sessões, avaliou-se o desempenho do controle inibitório (Teste de *Stroop*, *Testinpacs®*). Observou-se um efeito do tempo apenas na condição EIAI ($p<0,05$). O delta [pós-pré] do tempo de resposta da fase incongruente do teste de *Stroop* apresentou diferença significativa entre as condições experimentais ($p<0,05$). Conclui-se que o EIAI aprimorou o desempenho do controle inibitório agudo em atletas de futsal feminino.

Palabras-clave:
Deporte de equipo;
Resistencia;
Funciones ejecutivas;
Atletas femeninas.

RESUMEN
El objetivo del estudio fue verificar el efecto agudo del ejercicio intermitente de alta intensidad sobre el desempeño del control inhibitorio en atletas de futsal femenino. Catorce atletas de fútbol sala adultos fueron sometidos aleatoriamente a una condición de ejercicio intermitente de alta intensidad (EIAI) y una condición sedentaria. Antes y después de las sesiones se evaluó el desempeño del control inhibitorio (Test de *Stroop*). Se observó un efecto del tiempo solo en la condición AIIE ($p<0.05$). El delta [post-pre] del tiempo de respuesta de la fase incongruente de la prueba de *Stroop* mostró una diferencia significativa entre las condiciones experimentales ($p<0,05$). Se concluye que el EIAI mejoró el desempeño del control inhibitorio agudo en atletas de futsal femenino.

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INTRODUCTION

Futsal is a sport with intermittent characteristics that require high physiological demands (Naser et al., 2017) and good performance in technical and tactical components (Barbero-Alvarez et al., 2008). Due to the various attack and defense movements, athletes tend to exhibit increased cognitive abilities during matches (Ferreira and Gomes, 2009).

Inhibitory control (IC) is one of the core executive function related to successful task performance; it enables individuals to control their attention, behavior, thoughts, and emotions and also regulates the rating of perceived exertion during a physical exercise session (Diamond, 2013). As part of IC, decision-making can be observed as the intellectual process that results in a particular action from several different options in each match situation, for example, progress toward the opponent's goal or keeping possession of the ball (Kaya, 2014). This decision refers to a tactical action and requires that a player use cognition at each point in the game to process the perceived information and generate an execution decision (Petiot et al., 2017).

The ability of athletes to make decisions is based on their capacity to integrate information related to the current situation with previously acquired knowledge. These adjustments are essential, particularly in sports in which game speed and time constraints often outweigh the ability of athletes to process information (Roca et al., 2011). Thus, decision-making in sports is important in instantaneous actions during matches (Roca et al., 2018), since the ability to produce creative solutions is essential for performance (Vestberg et al., 2012).

Executive function has gained considerable relevance in scientific literature due to the decision-making capacity of athletes in different types of sports modalities (Hagyard et al., 2021). In this way, improvement in the executive function of the athletes, such as IC, is important for increase sport performance (Martin et al., 2016). Thereby, findings on the effects of different intensities of physical exercise on IC are inconsistent. Athletes should avoid cognitive activities immediately prior to official matches (Costa et al., 2023) Induced mental fatigue negatively influences physical, technical and tactical performance in football-specific tests (Thompson et al., 2019). The literature has presented the influence of aerobic exercise on brain function, improving inhibitory control (Browne et al., 2016; Ekkekakis, 2009; Hillman et al., 2008). Regarding the direct effects of physical exercise, increased cerebral blood flow in the brain may be related to cognitive functioning (Verburgh et al., 2014a). Some authors maintain that IC can improve at low and moderate intensities and decrease only at high intensities (Ando et al., 2011; Mekari et al., 2015), while others indicate no change in IC at low and moderate intensities, and effects only at high intensities (Wang et al., 2013).

Therefore, as futsal is characterized as an intermittent high-intensity modality and, over a season, the athletes are submitted to several matches with high intensity and high ability of athletes to make decisions (Barbero-Alvarez et al., 2008; Ferreira and Gomes, 2009; Naser et al., 2017). Once fatigued by prolonged use of social media on a smartphone, it might impair decision-making performance in amateur boxers (Fortes et al., 2023), in male soccer athletes (Fortes et al., 2019). Previous studies have shown that an activity of high cognitive demand before an exercise session results in mental fatigue and can compromise physical performance (Martin et al., 2018; McMorris et al., 2018; Thompson et al., 2019) and would provide information to suggest changes in usual players behaviors associated with cognitive demands before matches (Lopes et al., 2023). Thus, the aim of the present study was to verify the acute effect of intermittent high-intensity exercise, compared with a condition sedentary, on inhibitory control performance in female futsal athletes. It was hypothesized that high-intensity intermittent exercise could optimize psychophysiological responses in young futsal players.

METHOD

It was a controlled and randomized investigation with two experimental conditions with a 48-h washout interval, performed with female futsal athletes. The participants visited the research place on three occasions. On the first visit, all the information about the study was clarified, and the tests were conducted to ensure familiarization (IC and aerobic performance). Then, the participants were submitted to (1) a high-intensity exercise condition (HIE) and (2) control condition (CON). Simple randomization was conducted for the two experimental conditions (HIE and CON). The random number table was generated on the www.randomizer.org site.

One Stroop Task trial was performed for approximately 15 minutes before and after the HIE or CON. All experimental procedures are illustrated in Figure 1. The participants were instructed to abstain from any physical exercise, ingest alcohol 48 hours before experimental sessions, and abstain from caffeine at least 3 hours before experimental sessions. This study complies with the principles of the Declaration of Helsinki and was approved by the ethics committee of the local university, protocol number 1.706.413.

PARTICIPANTS

Fourteen female futsal athletes (20.1 ± 3.1 years; 58.6 ± 5.2 kg; 160.0 ± 5.0 cm; and 22.8 ± 1.9 kg/m^2) participated in the study. The athletes were from the adult professional category and were part of the national female league's vice-champion team. All the athletes had previously competed in national and regional competitions. The athletes train 15 to 17 hours per week (5 to 8 training sessions per week, including small-sided games, technical and tactical training, and strength training in the classroom), with one official match per week.

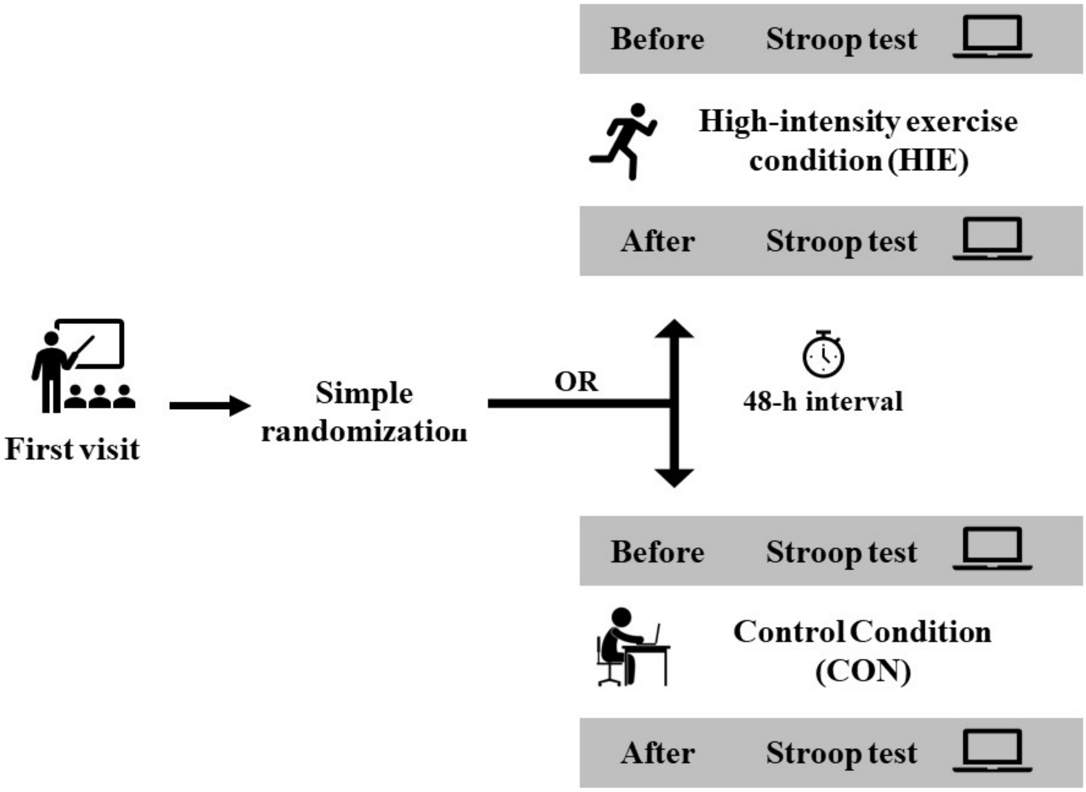

Figure 1. Experimental design. HIE = High-intensity exercise; CON = Control condition.

INHIBITORY CONTROL (IC)

Inhibitory control performance was assessed by the Stroop computerized test (Testinpacs®) with the help of a 14-inch notebook. The test was applied 15 minutes before and after each condition (HIE and CON). The instrument contains three stages, the first two congruent and the last incongruent:

- *Step 1*: Rectangles in green, blue, black, and red were individually displayed in the center of the monitor. In the lower corners of the monitor, responses that matched or did not match the color of the rectangle were displayed until the participant responded to the attempt by pressing the ← or → key.
- *Step 2*: Both the stimuli and the responses were displayed in the condition of words, always in white color. When the stimulus and the response coincided, this was calculated as a hit.
- *Step 3*: The word of one of the four colors was displayed in an incompatible color. The respondent was instructed to press the key corresponding to the color of the word and inhibit the response based on the identity of the word.

At all stages, the stimuli were presented automatically and randomly, with 12 trials per stage. The response time (RT) in milliseconds (ms) and the number of errors (number) committed in each step were recorded.

EXERCISE CONDITION

The Yo-Yo intermittent recovery test level 1 was used during the first exercise condition (Krustrup et al., 2003). Initially, the cognitive task was conducted and then the exercise. The Yo-Yo is characterized as a progressive exercise in which the running speed increases sequentially according to sound signals. For the accomplishment of the exercise, two markers are placed with a distance of 20m apart and a rest area of 5m on the initial side. VO_{2max}. values were obtained using the equation: distance covered (m) × 0.0084 + 36.4.

Athletes move from one marker to the next and back; when they reach the starting point, they rest for 10 seconds. The race's running speed is controlled by the audio. The speed was regularly increased every stage of the exercise, requiring the individual to reach the marker before the buzzer. The test was stopped when the athlete was unable to reach two consecutive markers. Shortly after the end of the exercise, the rating of perceived effort (RPE) (Foster et al., 2001) was reported by the athletes to measure the intensity at the end of the exercise.

SEDENTARY BEHAVIOR CONDITION

Participants initially performed the Stroop Task Test. Soon after, they were asked to remain in sedentary behavior for thirty minutes with connection to the internet and social networks. The test was performed 15 minutes after each session.

STATISTICAL ANALYSIS

The data are presented in descriptive statistics (mean, standard deviation, and 95% confidence interval [CI]). The Shapiro-Wilk test confirmed the data's normality. ANCOVA was used to compare IC performance (HIE vs. CON and before vs. after), considering resting values as a covariate. To compare the deltas between two conditions, the T Test was applied. The $p<0.05$ significance level was chosen. The effect size (ES) of the variances was calculated by the eta-squared (η^2), considering no effect (< 0.04), minimum effect (0.05-0.25), moderate effect (0.26-0.64) and strong effect (> 0.64) (Ferguson, 2009).

RESULTS

The athletes covered 637.14 ± 143.76 m and had an estimated VO_{2max}. of 41.75 ± 1.20 $mL \cdot min^{-1} \cdot kg^{-1}$. The RPE immediately post-exercise was 7.3 ± 1.5 arbitrary units, indicating a "very difficult" descriptor. The values before and after, as well as the delta, are shown in Table 1. The ANCOVA revealed a statistically significant difference between conditions (F = 4.267, 0.049, η^2= 0.146, and power: 0.51).

Figure 2 shows the comparisons of the delta [post-pre] pairs of the RT, the incongruous phase of the Stroop test, demonstrating significant differences between conditions ($T_{(13)}$ = 2.605, p = 0.021 mean difference: 101.0; 95% confidence interval: 17.25 to 184.7).

DISCUSSION

The main finding of this study was that high-intensity intermittent acute exercise improves IC performance compared to the sedentary behavior condition in female futsal athletes. These findings corroborate the literature, as acute exercise has a beneficial effect on cognitive function, specifically executive function (Chu et al., 2015). Furthermore, there is a mutable relationship between inhibitory control and exercise that is necessary because executive functions are responsible for the information and behavioral processes that occur in complicated environments with frequent alterations that are unrelated to team sports (Albaladejo-García et al., 2023).

Our findings may be related to the athlete's experience with intermittent high-intensity activity, which has been linked to changes in functional brain connectivity (Raichlen et al., 2016). Raichlen et al. (2016) observed differences in functional connectivity (at rest) between experienced athletes and non-athletes; the authors assume this difference is due to previous cognitive demands associated with sport practice. It is also stated that changes in connection activity in sensorimotor networks at rest can increase athletic performance by allowing for more efficient execution of cognitive and motor demands during very intense activities (Albaladejo-García et al., 2023; Raichlen et al., 2016). Parallel to this, athletes outperform the general population in cognitive tasks, and this may be due to extensive participation in sports as well as the complexity of the stimuli to which an athlete is subjected, which may result in specific adaptations in response (Albaladejo-García et al., 2023).

Additionally, other mechanisms have been proposed to explain the positive effects of physical exercise on executive functions. Biochemical research shows that acute exercise induces increases in plasma catecholamine concentrations. The circulating adrenaline and noradrenaline stimulate the vagal pathway, which in turn induces the synthesis and release of noradrenaline and, indirectly, dopamine in the brain (McMorris et al., 2016). This is most likely because

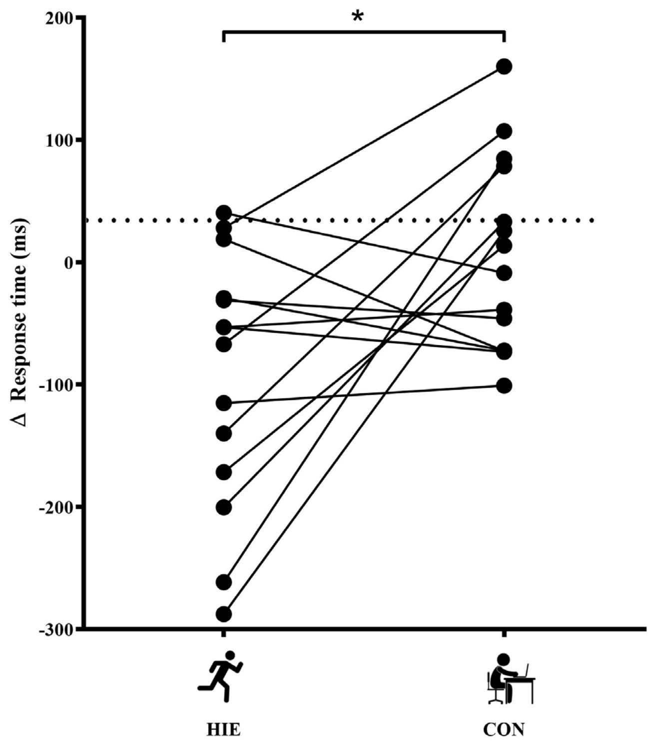

Figure 2. Comparison of Δ between HIE vs. CON conditions of the incongruent phase reaction time in the Stroop test. *Significant difference in relation to exercise condition (p<0.05). HIE = High-intensity exercise condition; CON = Control condition.

Table 1. Response time variation in different experimental conditions.

	Before	After	Δ
HIE Condition (ms)	1621.80 (±125.97)	1527.29 (±107.81)	-94.51 (±105.01)
Control Condition (ms)	1526.35 (±150.86)	1532.79 (±122.39)	6.44 (±79.17)

HIE = High-intensity exercise.

peripherally circulating epinephrine and norepinephrine activate β- adrenoreceptors on the afferent vagus nerve, which runs from the abdomen through the chest, neck, and head and terminates in the nucleus tractus solitarii (NTS) within the blood-brain barrier (McMorris et al., 2015). McMorris et al. (2011) claimed that the increased neurotransmitter concentrations would have a positive effect on speed of processing but possibly induce neural noise in areas of the brain involved in the accuracy of processing working memory tasks (McMorris et al., 2011).

Thus, improved IC may be a signal for success in the sport (Hicheur et al., 2017). Professional soccer players have higher cognitive responses than amateur players, and IC can help with the development of physical talents needed for field performance (Hicheur et al., 2017; Hagyard et al., 2021) and high intensity physical exercise may contribute to increasing cognitive responses (Verburgh et al., 2014; Kao et al., 2017). Cognitive factors appear to play a crucial role in tactical performance in futsal players, as players with better tactical performance had faster reaction times to errors (Albuquerque et al., 2019). Furthermore, cognitive factors play a crucial role in ultramarathon racing, showing superior ability not only to inhibit motor response but also to suppress processing of irrelevant information (Lambourne and Tomporowski, 2010; Cona et al., 2015). This suggests that superior inhibitory control is a psychobiological characteristic of successful endurance athletes who are more likely to persist with strenuous training programs, dietary restrictions, and limitations to their social lives while also being better able to exert control over their thoughts, feelings, and actions during competitions (Martin et al., 2016).

As a limitation of the study, the use of only one measure of executive function requires careful interpretation of the results since IC does not fully explain the cognitive processes associated with exercise. In addition, we highlight the need for future studies using neuroimaging techniques to better understand the responses found in the present study.

With respect to practical applicability, the use of high-intensity exercises could be an important recommendation strategy in the training routine of futsal athletes in order to favor improvement in cognitive function in an acute way, and coaches should evaluate the use of social networks before training and official matches for futsal athletes.

CONCLUSION

Intermittent high-intensity physical exercise appears to promote acute improvement in inhibitory control in female futsal athletes, making it an effective alternative to potentializing cognitive effects given that futsal is a sport that places high demands on the ability to process information.

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CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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