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Original Investigation

Effects of acute boxing exercises on attention and psychophysiological states

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Purpose: The objective of this investigation was to determine the effects of acute boxing exercises on attention, heart rate (HR), and mood states among regional boxing secondary school students.
Methods: Fourteen students (8 males and 6 females, age = 16.10 ± .30 years, height = 166.92 ± 3.66 cm, body mass = 60.90 ± 7.80 kg) specialized in competing in boxing participated in the present study. They were randomly assigned to one of the following three sessions in a crossover design: (i) a tag boxing game condition, (ii) a footwork drills condition, and (iii) a control condition (CC). Cognitive performance, namely concentration performance (CP) and fluctuation rate (FR), HR, and rating of perceived exertion (RPE) were assessed pre and immediately post each condition using d2 test, a wrist monitor recorder, and Borg CR-10 scale, respectively. Mood state was quantified using Brunel Mood Scale (BRUMS) questionnaire only immediately after each condition.
Results: The findings revealed that while overall CP did not differ between tag boxing games and footwork drills (P= .24), the consistency of attention was superior following tag boxing, as indicated by a significantly lower FR (P= .02). FR was also lower in tag boxing compared to the CC (P< .001). No significant difference in HR was found between the two exercise conditions (P= 1.00). Regarding psychological measures, higher RPE and fatigue subscale values were reported after footwork drills than after tag boxing games (P= .03 and .04, respectively) and CC (P< .001). Conversely, higher vigor subscale values were reported following tag boxing games compared to footwork drills (P= .03) and CC (P< .001).
Conclusions: Acute boxing exercises, notably tag boxing games, demonstrate a significant benefit for the persistence and consistency of attention control, despite showing no difference in overall concentration performance. This suggests that boxing practitioners may implement tag boxing games prior to any tasks requiring sustained and stable visual attention.

Keywords: Boxing, exercise, foot work, cognition, mood

Introduction

Recent studies in the field of exercise-cognition suggest that acute exercise is beneficial for people's cognition and, more specifically, attention.[1] The most apparent benefits are seen for the elderly, where physical activity slows the rate of cognitive decline associated with ageing[2] Improved cognitive skills including attention and adequate cognitive functioning allow for better psychosocial adjustment, facilitating adaptation to the environment and contributing to greater success in multiple physical, academic, and social tasks.[3]

Studies have shown that physical activity has protective qualities, as well as anxiolytic effects, regardless of demographics. Similarly, there is a growing body of scholarly evidence demonstrating that physical activity can reduce depressive symptoms and improve mood, sleep, and quality of life. However, most studies assess the effects of acute exercise bouts on cognitive functions focusing on simple physical activities such as walking or running,[4,5] cycling,[6,7] or certain singled-out aspects of sports and decontextualized sports-related skills.[8] Less is known about the effects of participating in sports, with only a few studies reporting positive preliminary findings.[8,9] In the school context, in-depth studies elucidating the effects of practicing different sports disciplines on physical and cognitive performance and academic success in terms of time, dosage, and specificity of each sport are warranted. Among the popular specialties, boxing requires high levels of attention, decision-making, and complex motor control within a dynamic environment.[10] Also, it is characterized by high-intensity performance with short intervals between rounds. These characteristics may have an impact on academic success, which requires sustained attention and ability to reconcile between theory and practice.

Boxing and martial arts share some commonalities in training in terms of awareness of body/stance, footwork, shadow boxing, and various striking techniques. As it relates to mental health, **attention serves as the foundational cognitive function in boxing, preceding and enabling effective reaction time and decision-making.[11]** Specifically, visual selective attention is critical for punch anticipation. Studies have shown that elite boxers exhibit superior target detection (≈200ms faster) than novices when identifying attack cues, a skill directly reflecting their ability to quickly focus on relevant visual information.[12]

This capacity for rapid, selective processing of visual stimuli, while not a direct neuroimaging technique, is precisely what is assessed by behavioral tests such as the d2 Test, which measures sustained selective attention and processing speed under time pressure.

Beyond mere speed, attentional control modulates perceptual sensitivity and inhibitory control, crucial for defending against feints and avoiding attentional lapses. Functional magnetic resonance imaging (fMRI) studies reveal that expert boxers activate specific prefrontal-parietal networks to suppress distractors,[13] highlighting the neural basis for filtering irrelevant information. This ability to maintain focus despite competing stimuli is paramount, as evidenced by findings that a significant proportion (e.g., 72%) of landed punches exploit an opponent's attentional lapses.[14] The d2 test, by requiring participants to identify specific targets while simultaneously ignoring visually similar distractors, provides a practical behavioral measure of this inhibitory control and resistance to interference. Furthermore, the temporal dynamics of sustained attention are paramount, particularly in prolonged bouts. Electroencephalogram (EEG) studies demonstrate that fluctuations in alpha power, indicative of focus lapses, reliably predict defensive failures in later rounds.[15] This underscores the necessity of maintaining vigilance throughout a match. The d2's design, requiring continuous performance over several minutes, directly assesses an individual's capacity for sustained attention and vigilance, reflecting their ability to maintain focus and avoid cognitive fatigue under pressure. Thus, while advanced neuroimaging techniques like fMRI and EEG elucidate the underlying neural mechanisms of attention in boxing, behavioral measures like the d2 Test offer a practical and ecologically valid means to quantify the functional outcomes of these complex cognitive processes. It serves as a diagnostically revealing metric, reflecting an athlete's capacity for focused processing, inhibitory control, and sustained vigilance, all of which are highly trainable and directly influence performance and tactical adaptability.[16]

Although the long-term mental and cognition benefits of boxing exercises are well established,[10] knowledge concerning their acute effects on mood and cognition is scarce. The aim of the present study was to test the acute effects of acute specific aerobic boxing exercises on attention, heart rate (HR), and mood states among boxing students. We hypothesized that both exercises sessions would improve both mood state and attention compared with the control condition (CC).

Methods

Participants

Fourteen secondary school students (8 males and 6 females, age = 16.10 ± .30 years, height = 166.92 ± 3.66 cm, body mass = 60.90 ± 7.80 kg) specialized in boxing participated in the present study. They were assigned to each one of the following three conditions in a randomized order: (i) a tag boxing game condition, (ii) a footwork drills condition, and (iii) a CC. Participants were included if they met the following criteria (s): (a) competing in regional boxing championships; (b) having boxing experience between 3 and 5 years; (c) attending physical education class twice a week and training in boxing three times a week; and (d) not receiving any supplement (e.g., coffee or vitamins). We excluded any participants who did not meet any of these criteria. The investigation was conducted in accordance with the guidelines of the Declaration of Helsinki. All participants were informed about the objective of the study and provided written assent, with corresponding written consent obtained from their parents or legal guardians, in order to be included in this investigation.

Procedure

The investigation was designed as a randomized counterbalanced crossover trial. It was conducted in four sessions separated by a washout period of 72 hours controlled by a specialized teacher of boxing during the school course. During the first session, participants familiarized with exercises conducted for each condition as well as with the cognitive test and psychological questionnaires.

During the second and third sessions (tag boxing games and footwork drills sessions), all participants filled in the Rating of Perceived Exertion (RPE) questionnaire and completed a cognitive performance test (d2 test) before 15 min and immediately after each condition, in addition to the Brunel Mood Scale (BRUMS). HR was also assessed before and immediately each condition. Of note, all test assessments were conducted by evaluators who were blinded to the participants' group allocation.

Both tag boxing games and footwork drills sessions started with a 10-min warm-up, which consisted of 5 min of moderate-intensity running, followed by 5 min dynamic stretching exercises and 3 repetitions of accelerated punching during 5 s. Then, at the end of each session, participants performed 5-min cooling down, followed by shadow boxing at low-intensity.

During the session of tag boxing games, which is a drill or sparring with light contact, each participant tried to tag/touch a specific body part of their partner with an open hand, without being tagged themselves. Specifically, participants had to tag the partner’s shoulders, thigh, and belly without hurting them for 15 s followed by 15 s of active recovery in the space of 4/4 meters. More in detail, during the first round, each participant tried to tap/touch their partner on the shoulder or thigh without being touched/tagged in order to earn a higher number of points during 15 s interrupted by 15 s of dynamic recovery, which consisted of movements in all directions in guard position at moderate intensity. During the second round, participants had to tap the right or the left shoulder of their partner and the last one attempted to touch back with the opposite hand on the reverse shoulder during the first half round. Then, in the second half round (1 min), participants tried to touch back the same shoulder with the same hand after an attack by their partner. In the third round, boxers tried to touch back with the same hand the belly of their partner at the same time when the last one had to tap their shoulder. Of note, participants switched their role every 15 s.

In the footwork drills session, participants performed some basic and advanced footwork drills (e.g., unilateral foot transfer, lateral shuffle, crossover step, in-out footwork pattern, river dance footwork, unipedal hopping, hop scotch, centipede, 10-step, 16-step, Ali shuffle, and single double rotations) in the rhythm scale at a high intensity lasting 15 s followed by 15 s of active recovery (running at moderate intensity). Of note, both training sessions consisted of 3 rounds of 2 min each interrupted by 1 min of passive recovery. In total, each session lasted approximately 24 min and was performed in the gym.

During the control session, participants read a book for approximately 24 min and completed cognitive and psychophysiological tests as in the other experimental conditions.

Attention assessment

Concentrated visual attention was assessed used the d2 test,[17] which consisted of scanning the letter d with two dashes from a grid of 14 lines, each one containing 47 characters (the letter d or p, with one-to-four dashes above and below each letter) and lasting 20 s.

Two outcomes were extracted from the d2 test, namely the concentration performance (CP) and the fluctuation rate (FR). CP was computed by reporting the number of correctly crossed-out d2-symbols minus the number of incorrectly crossed-out symbols. FR was computed as the difference between the worst and the best performance in each of the 14 lines (Max–Min).

Heart rate

HR was assessed before and immediately after each condition using a wrist monitor recorder (Polar Electro, Finland) and a wireless chest HR transmitter. Resting HR was assessed following 10 min supine rest before each condition and measured in beats per minute (bpm).

Rating of Perceived Exertion (RPE)

Perceived effort was evaluated before and immediately after each session using the RPE scale. RPE ranges between 0 "no perceived effort" (i.e., rest) and 10 "maximal perceived effort" [i.e., "the most stressful exercise ever performed"[18]] arbitrary unit (a.u.). Of note, high reproducibility (.86-.92) was reported for controlled aerobic exercises.[19]

Mood

Mood state was assessed using BRUMS[20] and consisted of answering to the following question "How do you feel right now?" immediately after each session. It comprised a total of 24 items, from six subscales, namely, fatigue, anger, vigor, confusion, depression, and tension. The items were graded on a 5-point Likert scale (from 1 = not at all, to 5 a.u. = extremely). Overall, this questionnaire has moderate to good reproducibility **(~.70-.88).**[20]

Statistical analysis

An *a priori* power analysis was conducted using G*Power (version 3.1.9.7) to determine the minimum required sample size for detecting a statistically significant effect given the study design. The analysis assumed a large effect size (ES), an alpha level of .05, a statistical power (1 − β) of .80, a correlation among repeated measures of .75, three conditions, and two time points (pre- and post-intervention). Under these parameters, the computed required total sample size was 12 participants.

Descriptive statistical analyses were conducted by calculating the means and standard deviations for each of the parameters under study. The normality of data distribution was verified by carrying out the Shapiro–Wilk test, which was preferred over other statistical tests, given the small sample size utilized in the present investigation. One- and two-way analysis of variance (ANOVA) or their non-parametric versions, based on the normality of data, were conducted to identify differences, if any, (a) between the pre- and post-tests (effect of time) and (b) among the various conditions (effect of intervention). Moreover, post-hoc Bonferroni test was applied for multiple comparisons. An ES based on the partial eta squared[21] was computed to quantitatively evaluate the main and interaction effects. The magnitude of the ES was interpreted using the following rule of thumb: namely, it was deemed small if < .06 and large if > .14. All statistical analyses were performed by means of the commercial software "Statistical Package for Social Sciences" (SPSS version 24.0, IBM, Armonk, NY, USA). Only those results with *P* -values < .05 were considered statistically significant.

Results

For the CP, significant effects both for time ($F_{(1,39)}$ = 357.14; *P*< .001; ES= .90 [large]) and intervention ($F_{(1,39)}$ = 10.69; *P*< .001; ES= .35 [large]) could be reported. A significant time × intervention interaction effect was also found ($F_{(1,39)}$ = 79.93; *P*< .001; ES=.76 [large]). The post-hoc test showed that the post-CP value was lower in the CC than in the footwork and tag boxing game conditions (*P*= .002 and *P*< .001, respectively), whereas no significant difference between the footwork and tag boxing game conditions (*P*= .24) could be computed (Table 1).

Table 1. Values of concentration performance, fluctuation rate, HR and RPE broken down according to the condition.

Variable		Footwork drills (Mean ± SD)	Tag boxing games (Mean ± SD)	CC (Mean ± SD)	Statistical Significance (Time × Intervention)
Concentration performance (NH)	Before	167.07 ± 28.80	169.07 ± 29.76	162.35 ± 31.84	*P*< .001
	After	237.00 ± 31.07	262.07 ± 32.78	167.0714 ± 35.04	
Fluctuation rate (NH)	Before	8.21 ± 1.71	8.14 ± 1.65	7.92 ± 1.49	*P*< .001
	After	5.21 ± 1.36	2.92 ± 1.59	8.07 ± 1.43	
HR (bpm)	Before	78.92 ± 7.64	81.07 ± 8.36	80.35 ± 7.95	*P*< .001
	After	132.14 ± 11.88	125.35 ± 10.08	81.42 ± 8.18	
RPE (a.u.)	Before	1.35 ± .49	1.64 ± .49	1.14 ± .66	*P*< .001
	After	6.57 ± 1.39	5.14 ± 1.09	1.64 ± .63	

Abbreviations: a.u.: arbitrary unit, bpm: beats per minute, CC: control condition, HR: heart rate, NH: net hits, RPE: Rating of Perceived Effort

The FR differed between interventions ($F_{(1,39)}$ = 11.58; *P*< .001; ES= .37 [large]). A significant effect of time ($F_{(1,39)}$ = 152.01; *P*< .001; ES = .77 [large]) was found, with higher values post-session compared with pre-session (Table 1). A significant time × intervention interaction effect ($F_{(1,39)}$ = 44.92; *P*< .001; ES= .69 [large]) was also observed. Post hoc comparisons revealed that the FR value was lower in the tag boxing game condition than in the footwork condition (*P*= .02) and the CC *(P*< .001) and in the footwork condition than in the CC (*P*= .01).

For the HR, significant effects both for time ($F_{(1,39)}$ = 507.84; *P*< .001; ES= .92 [large]) and intervention ($F_{(1,39)}$ = 42.29; *P*< .001; ES= .68 [large]) were observed. A significant time × intervention interaction effect ($F_{(1,39)}$ = 121.94; *P*< .001; ES= .86 [large]) was also reported. Post-hoc comparisons revealed that the post-HR value was higher in the footwork (*P*< .001) and the tag boxing game (*P*< .001) conditions than in the CC. Post-HR value did not differ between the footwork and the tag boxing game conditions (*P*= 1.00).

Concerning the RPE, significant effects both for intervention ($F_{(1,39)}$ = 55.57; *P*< .001; ES= .74 [large]) and time ($F_{(1,39)}$ = 340.68; *P*< .001; ES= .89 [large]) were found. A significant time × intervention interaction effect ($F_{(1,42)}$ = 140.23; *P*< .001; ES= .87 [large]) was also observed. Moreover, post-hoc comparisons revealed that the post-RPE value was higher in the footwork

condition than in the tag boxing game condition (P= .03) and the CC (P< .001) and in the tag boxing game condition than in the CC (P< .001) (Table 1).
Regarding the BRUMS scale, analyses revealed a significant effect of condition in the fatigue subscale ($F_{(1,39)}$ = 10.98.67; P< .001; ES= .36 [large]), with higher fatigue value in the footwork than in the tag boxing game condition (P= .04) and the CC (P< .001). In addition, vigor differed between conditions ($F_{(1,39)}$ = 20.91; P< .001; ES= .51 [large]). All remaining sub-scales did not significantly differ between conditions (P > .05).

Discussion

To the best of the authors' knowledge, this is the first investigation that aimed to compare the effects of two non-contact boxing exercises on cognition (attention), HR, and psychological states (mood). In line with our hypothesis, the results of this study indicated that both footwork exercise and tag boxing games significantly increased concentration performance, HR, and decreased FR. However, the beneficial effect was much more pronounced after tag boxing games for FR, which may be explained by the positive improvement in mood subscales, namely the increase of vigor, and the less increase in fatigue and RPE following tag boxing games when compared with footwork exercises.
Few investigations studied the effect of acute non-contact boxing on cognitive function. Different exercises were tested, including pad work, punching bag, skipping, and footwork drills.[10,22] For instance, Slimani et al.[22] examined the effect of 30-min non-contact boxing exercise sessions (1:1 work:rest ratio) on attention, as measured by the d2 test. The authors reported that the CP increased by 26.1% immediately after a non-contact boxing session. In contrast, Jordan et al.[23] and Stiller et al.[24] reported a negative effect of acute boxing sparring on information processing speed, as assessed using the Symbol Digit Modalities Test. The contradiction between the studies' findings may depend on many factors, such as the type of boxing exercises.
The significantly greater improvement in FR within the d2 test following the tag boxing game intervention, compared to footwork drills, can be attributed to the heightened cognitive engagement inherent in its game-based design. The FR metric is a particularly sensitive indicator of consistency in attentional performance, and its enhancement suggests superior development of cognitive control and stability. The interactive, unpredictable nature of the tag game—requiring constant vigilance, rapid decision-making, and adaptive responses to an opponent's feints and movements—directly challenges the neural networks responsible for sustained and focused attention. This aligns with contemporary literature; for instance, Bouzouraa et al.[25] demonstrated that rondo possession games, which share similar cognitive demands of anticipation and problem-solving under pressure, significantly improved creative thinking and executive functions in young athletes. This principle is further reinforced by the exercise-cognition literature, which indicates that acute physical activity that incorporates cognitive engagement (e.g., open-skill exercises) produces larger benefits for executive function and attention than closed-skill activities, likely due to the increased neurocognitive demands placed on the prefrontal cortex.[26] The interactive "tag" element likely imposed higher cognitive demands—requiring rapid perception-action coupling, strategic evasion, and adaptive planning—thereby fostering a more robust transfer to the functional reaching task, which itself requires quick, goal-directed movements in a dynamic context.
The positive improvement of attention after non-contact boxing exercises is possibly due to the nature and volume of exercises. Specifically, short intervals with moderate period of intermittent/interval exercises have been found to alter physiological parameters, such as HR, and molecules like cortisol, catecholamines (noradrenaline, dopamine), brain-derived neurotrophic factor (BDNF), and blood flow. This in turn may increase attention when engaging in cognitive tasks.[27-31] In addition, intermittent/interval exercises have been found to increase brain Hydrogen Peroxide and Tumor Necrosis Factor-alpha levels and activate the signaling of peroxisome proliferator-activated.[32,33]
Some studies indicated that a single session of exercise performed at moderate intensity can improve the execution of cognitive tasks, resulting into enhanced processing speed, selective attention, and short-term memory.[34-37] Aerobic physical activity promotes an increase in Vascular Endothelial Growth Factor (VEGF) and BDNF concentrations, which may improve cognitive processes, increase parasympathetic tonus, and decrease sympathetic activation. This condition can decrease peripheral vascular resistance and lead to increased cerebral blood flow in the prefrontal cortex, positively impacting cognitive ability.[38]
From a psychological point of view, it has been reported that a single session of tag boxing games leads to a greater significant increase in vigor and a lower increase in fatigue.[39,40] This finding is similar to the results reported by Martinez et al.[41] and Slimani et al.[22], who described that acute specific intermittent boxing exercises and high intensity interval training (HIIT) increased positive affect. In addition, acute combat sports exercises, including punching bag workouts, Brazilian jiu-jitsu training session, and mixed martial arts training session can reduce perceived stress, tension, anxiety, anger, fatigue and increase, self-efficacy, and mental toughness.[42-45]
The observed mood profile improvements, characterized by higher vigor and lower fatigue following the tag boxing game intervention, are further supported by contemporary evidence highlighting the psychological benefits of game-based exercise modalities. This finding aligns with the principle that activities designed to be inherently engaging and enjoyable can significantly enhance affective responses. The structure of the tag game, which incorporates elements of play, competition, and social interaction, likely promotes a more positive psychological state compared to the monotony of repetitive drills. This is corroborated by research in team sports; for instance, a recent study by Farhani et al.[46] on soccer players demonstrated that small-sided games were highly effective in maintaining a positive mood balance, a outcome directly linked to their enjoyable and stimulating nature. This concept is reinforced by earlier work indicating that exercise sessions perceived as enjoyable lead to more positive affective states and greater intrinsic motivation, which are critical for long-term adherence and psychological well-being.[47] Therefore, the superior mood outcomes associated with the tag boxing game not only underscore its immediate psychological benefits but also suggest its potential as a more sustainable and engaging training method.

Strengths and limitations

This study offers novel insights into the acute effects of non-contact boxing exercises on attention, physiological arousal, and mood states in a youth athletic cohort. A primary strength is the implementation of a randomized crossover design, which effectively controls for inter-individual variability and enhances the internal validity of the within-subject comparisons. The utilization of well-established, validated instruments, including the d2 Test of Attention and the BRUMS scale, further strengthens the credibility of the measured outcomes.

However, several limitations must be acknowledged. The generalizability of the findings is constrained by the study's small sample size (n=14) and its highly specific composition of regional-level adolescent boxers from a single secondary school. This limits the extrapolation of results to the broader adolescent population, including those of different ages, athletic backgrounds, or skill levels. The unequal gender distribution also precludes any meaningful analysis of gender-specific effects. A further key limitation is that external factors known to influence cognitive performance, such as participants' prior sleep quality, duration, and evening blue light exposure,[48,49] were not controlled for or measured. These variables could act as confounding factors, and future studies should account for them to more precisely isolate the effects of the exercise intervention. Furthermore, while the acute exercise paradigm effectively captures immediate responses, it cannot speak to the long-term or cumulative impacts of chronic boxing training on these variables. Regarding methodological choices, the assessment of mood states was conducted solely following the exercise intervention without a pre-test baseline measure. While this approach is validated in exercise psychology literature to capture the immediate affective signature of exercise and avoid pre-testing biases,[50-52] it does limit our ability to analyze intra-individual change scores from baseline. Finally, the reliance on behavioral and self-report measures, without complementary neurophysiological assessments (e.g., EEG, fMRI), means that the underlying neural mechanisms driving the observed improvements in attention remain speculative.

Conclusions

Acute boxing exercises have positive effects on cognitive function, exactly persistence of attention control. This may be due to the alteration of psychophysiological parameters, notably RPE, mood state, and HR. In view of this data, we can assume that implementing boxing exercises, such as tag boxing games, prior to any tasks that require sustained/maintained visual attention is an appropriate method to increase the level of attention.

Practical applications

Identifying the cognitive and psychophysiological demands and responses elicited by boxing exercises can provide novel insights that may inform the design of more effective training protocols and physical education programs aimed at enhancing attention and cognitive control.

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Informed Consent Statement

All parents signed informed consent.

Ethical Committee approval

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Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

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