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# Combining HIIT Plus Cognitive Task Increased Mental Fatigue but Not Physical Workload in Tennis Players

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**Abstract:** Mental fatigue can significantly impair physical performance during sports practice. However, previous studies have not analyzed the impact of combining High-Intensity Interval Training (HIIT) with a cognitive task on physical performance. In this line, we developed the present research to investigate the specific aspects of mental and physical fatigue as well as the potential impact of combining HIIT with a cognitive task. Therefore, the objective of this study was to compare mental and physical fatigue indicators between single HIIT and an incongruent Stroop task added to the HIIT protocol. A cross-sectional study was conducted with 32 tennis players (25 men and 7 women, mean age = 21.40). Two HIIT sessions were performed: (1) one with the incongruent Stroop task presented during rests, and (2) another without the Stroop task during rests. Mental fatigue, mental load, and wellness were measured. Additionally, mean and maximum heart rate, mean and peak speed, and heart rate variability through RMSSD were recorded using a heart rate monitor. Mann-Whitney U tests and Wilcoxon tests were performed to explore differences between during-session loads and pre- and post-HIITs. The results showed that mixed HIIT with the incongruent Stroop task caused higher increases in mental fatigue ($p = 0.04$) and the ratio of perceived exertion ($p = 0.001$) from pre- to post-HIIT. However, no significant differences in external (speed) and internal (heart rate) factors were observed between the protocols. This suggests that subjective feelings of physical exertion increased significantly due to mental fatigue. However, it did not decrease the physical workload during HIIT for tennis players. Therefore, incorporating short periods of the incongruent Stroop task during HIIT could be used to develop tolerance to mental fatigue without a decrease in the workload.

**Keywords:** stroop; cognitive fatigue; HRV; physical fatigue

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**Citation:** Díaz-García, J.; Clemente-Suárez, V.J.; Fuentes-García, J.P.; Villafaina, S. Combining HIIT Plus Cognitive Task Increased Mental Fatigue but Not Physical Workload in Tennis Players. *Appl. Sci.* **2023**, *13*, 7046. https://doi.org/10.3390/app13127046

Academic Editors: Samo Rauter and Jongchul Park

Received: 11 May 2023
Revised: 2 June 2023
Accepted: 9 June 2023
Published: 12 June 2023



## 1. Introduction

Sports can be mentally as well as physically tiring [1]. Athletes experience mental fatigue due to cognitive efforts associated with technical-tactical decisions and emotion regulation. In addition, extrinsic variables such as travel or studies can contribute to mental fatigue accumulation [2,3]. Mental fatigue is characterized by subjective feelings of tiredness, exhaustion, aversion to continuing the current activity, or a decrease in perceived commitment during or after a task. The objective changes induced by these feelings are referred to as fatigability, which is associated with impaired cognitive and behavioral performance [4,5].

Previous studies have investigated the impact of physical and mental tasks on the perception of fatigue and fatigability. One consistent finding is the increase in the rate of perceived exertion (RPE) during exercise. It can be explained by alterations in the processing of neural signals underlying the perception of effort [6–9]. Questionnaires and scales, such as the NASA Task Load Index or visual analog scales (VAS), have been used to evaluate subjective feelings of mental fatigue [10,11].

Regarding fatigability, research has examined the effects of mental fatigue on various performance outputs. Aerobic endurance performance has shown significant impairments, including decreased time to exhaustion, self-selected velocity, and increased completion time [11]. However, negative impairments have not been consistently observed in anaerobic tests due to the short duration of the efforts [11–13]. Physiological variables such as heart rate, blood lactate, and cardiac output have generally been unaffected by mental fatigue. Nevertheless, the impact of mental fatigue on heart rate variability (HRV) has not been extensively explored. HRV, specifically the root mean square of successive differences (RMSSD), is considered a biomarker of fatigue and has shown sensitivity to cognitive stimuli [14–18].

Many sports, including team or racket sports, involve a combination of aerobic and anaerobic efforts. Previous studies have demonstrated that mental fatigue can negatively affect physical sports such as soccer or basketball, where the aerobic and anaerobic systems are utilized. High-intensity interval training (HIIT) is a well-known training method in these sports, combining short anaerobic efforts with brief periods of aerobic recovery. HIIT has shown benefits for physical conditioning and mental health [19–23].

Recent studies have examined the effects of combining HIIT with a cognitive task, particularly the incongruent condition of the Stroop color and word test (SCWT), which induces mental fatigue [24–26]. The SCWT involves selective attention, interference inhibition, and processing speed. A previous study found a significant reduction in accuracy in tennis serves after HIIT combined with a cognitive task [24]. However, the impact of HIIT combined with a cognitive task on RMSSD and subjective mental fatigue has not been extensively explored. Furthermore, most studies have induced mental fatigue before physical load with cognitive activities longer than 30 min. However, mental fatigue and fatigability in sports typically occur during matches or competitions such as tennis, where tennis players often experience challenging environmental conditions [1,27] and physical demands that require high-intensity interval efforts.

Therefore, and taking into account previous research in the field that suggested that shorter tasks could induce mental fatigue in sports [1], the present study aims to investigate the effect of inducing mental fatigue on HIIT in a sample of tennis practitioners. We hypothesize that mental fatigue will negatively influence the behavioral outcomes (mean and maximum heart rate and speed), perception of effort and mental fatigue, muscle soreness, stress level, mood state, and RMSSD of tennis practitioners during HIIT.

## 2. Materials and Methods

### 2.1. Participants

A total of 32 tennis practitioners (25 men and 7 women) were recruited in this cross-sectional study. Participants had a mean age with a standard deviation of 21.40 $\pm$ 1.52 years, a total of 3.26 (9.78) hours per week of tennis training, and a mean experience of 0.84 (0.80) years practicing tennis. Participants were randomly assigned to the A or B groups (16 participants in each group: the A group had 2 women and 15 men, and the B group had 5 women and 12 men). Any participant who suffered from any physical condition or mental disorder in the previous four months.

The G*Power software 3.1.9.4 (Kiel University, Kiel, Germany) estimated that, with the sample size recruited and considering the VAS for mental fatigue as one of the primary outcomes, this study had a power of 0.68 to detect a $p$-value < 0.05, taking into account the mean difference and standard deviation ($-9.37 \pm 23.96$) of the HIIT and HIIT plus cognitive task sessions.

The university ethics committee approved all the procedures, and participants voluntarily gave written informed consent. This research fulfilled the Helsinki Declarations (revised in Brazil, 2013) on human research.

### 2.2. Procedures

All the participants had to perform two HIIT training sessions: (A) combining HIIT with a cognitive task and (B) a HIIT session without a cognitive task.

(A) HIIT plus cognitive task: Participants had to conduct a sequence of 30 s of push-ups, 30 s of squats, and 30 s of lateral displacements four times. After each of the exercises, participants had 30 s of rest. During the 30 s of rest, participants had to conduct an incongruent Stroop Task. Therefore, participants performed 6 min of exercise plus 6 min of cognitive tasks. The Stroop task was conducted on their mobile phones, using a validated mobile application for this purpose (UMH-MEMTRAIN, Elche, Spain), in a seated position. A researcher was watching to ensure that all the participants did the Stroop task;

(B) HIIT without cognitive tasks. a sequence of 30 s of push-ups, 30 s of squats, and 30 s of lateral displacements four times. After each exercise, 30 s of passive rest (seated position) were conducted. Thus, participants carried out a 6-minute workout. Participants were not allowed to perform an active recovery to simulate the resting condition of the HIIT plus cognitive task session.

Figure 1 shows more details about the procedures and the timeline of the experimental design. On the first day, group A conducted HIIT plus cognitive task sessions, whereas group B conducted HIIT without cognitive task sessions. After 48 h, the order was inverted, and group A conducted the HIIT without cognitive task session, and group B conducted the HIIT plus cognitive task session. All the procedures were carried out at the same time (between 11:00 a.m. and 12:00 a.m.). Participants were not allowed to intake drugs or substances that alter the autonomic nervous system or conduct physical exercise 24 h before and after the first day of protocol.

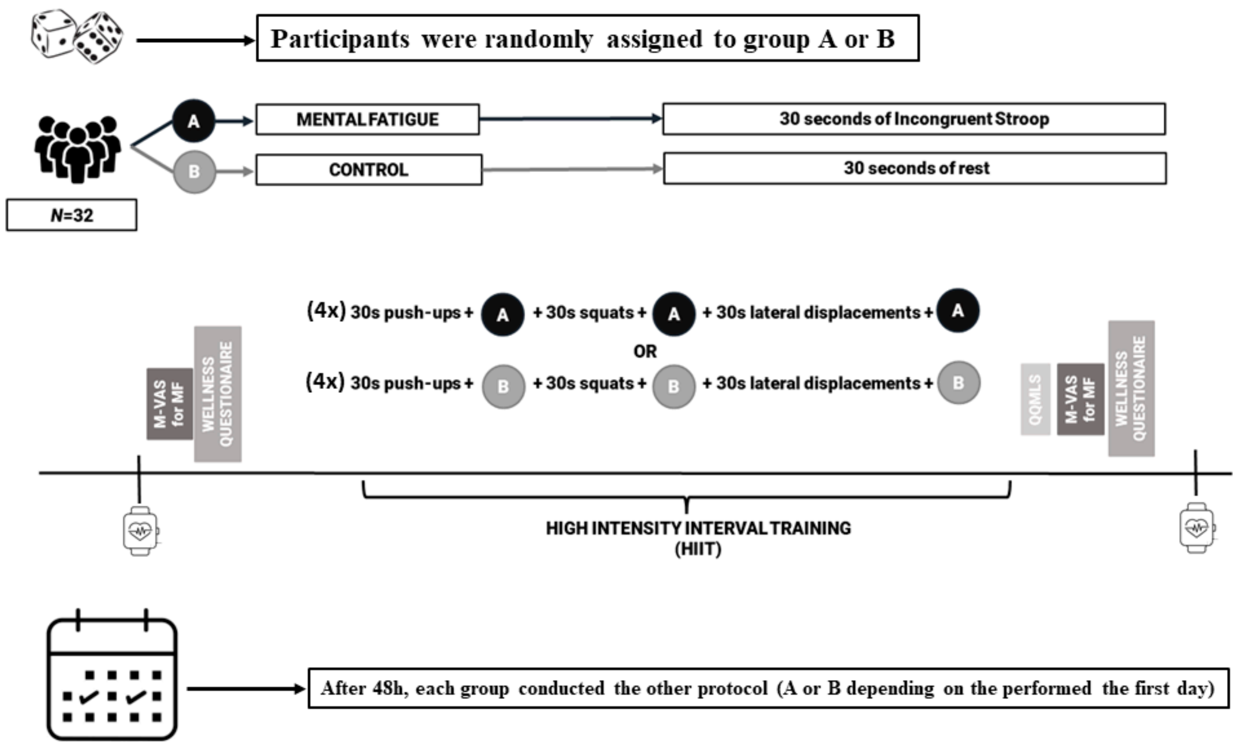


**Figure 1.** Timeline of experimental protocols. Notes: VAS—Visual Analogue Scale; QQMLS—Questionnaire to Quantify the Mental Load in Sports; HIIT—High Intensity Interval Training.

### 2.3. Instruments and Outcomes

In the present study, different outcomes were assessed:

(1) Before and after the session, the wellness questionnaire recommended by Hooper and Mackinnon [28] was used to assess general fatigue, muscle soreness, stress level, and mood state. Each dimension (general fatigue, muscle soreness, stress level, and mood state) was measured by a Likert scale (1 to 5), where one represents the worst (always tired, very sore, highly stressed, or highly annoyed depending on the dimension) and five the best state (very fresh, feeling great, very relaxed, or very positive mood depending on the dimension). Therefore, lower scores represented higher soreness, stress level, general fatigue, or mood state. This questionnaire has been previously used in the field of sports [29–31];

(2) Before and after the session, the subjective perception of mental fatigue was measured using a 0 to 100 VAS scale. This scale allowed us to assess the perceived mental fatigue, where 0 indicated "not mental fatigue" and 100 "extreme mental fatigue". The VAS for mental fatigue has been employed in previous studies to assess mental fatigue in sports [32,33];

(3) During the session, the Polar Team software version 1.9 (Polar Electro, Kempele, Finland), using H10 polar sensors, assessed the mean heart rate, maximum heart rate, mean speed, and maximum speed. Heart rate variables refer to internal physical load, while speed variables refer to external physical load. Additionally, this software reported the root mean square of successive differences between normal heartbeats (RMSSD). A higher RMSSD has been related to higher parasympathetic modulation [34]. Therefore, the RMSSD was registered at rest (5 min before and 5 min after each session). Participants were required to sit quietly during this period without talking to anyone;

(4) After each session, the Questionnaire to Quantify the Mental Load in Sports (QQMLS) [35] was administered. This instrument has four items: physical effort (how demanding would you quantify the physical effort of this session?), cognitive effort (how demanding would you quantify the cognitive effort of this session?), emotional effort (how demanding would you quantify the effort made to manage your emotions during this session?), and affective (how demanding would you quantify the effort made in this session to manage emotional relationships with the rest of the participants?). However, due to the individual character of the session, the affective question was not included in our procedure. Therefore, we selected the physical, cognitive, and emotional demand dimensions. All these questions were evaluated using a Likert scale with responses ranging from 0 to 10, where 0 means nothing and 10 is the maximum required value for each item. This questionnaire showed an internal consistency of Cronbach's $\alpha$ (0.73).

### 2.4. Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21.0 (SPSS Inc., Chicago, IL, USA). Shapiro–Wilk, skewness, and kurtosis were analyzed to study the normality of the data (see Supplementary Tables S1 and S2). In this regard, non-parametric or parametric statistical tests were employed when appropriate. To analyze the differences in mental and physical efforts between HIIT sessions, Wilcoxon signed rank or paired sample *t*-tests were performed between HIIT sessions with and without cognitive load for physical, cognitive, and emotional efforts, mean and maximum HR, and mean and maximum speed (see results in Table 1). Secondly, we checked for possible differences in wellness, VAS, and RMSSD from pre- to post-sessions. Therefore, to quantify the change from pre- to post-HIIT sessions on wellness, VAS and RMSSD Wilcoxon signed rank tests were performed for each session separately. Indeed, *p*-values were corrected using the Bonferroni adjustment for multiple comparisons in order to avoid Type I error. To quantify if the change from pre- to post-session between sessions was different, the $\Delta$ = post-session value—pre-session value was calculated for each variable. Finally, a comparison using

Wilcoxon signed rank or paired sample *t*-tests was performed between the Δ of the same variables between the two sessions (see results of Table 2). Statistical significance was set at $p < 0.05$.

**Table 1.** Analysis of physical and mental load indicators during training sessions. Comparison between different protocols.

| Variables | HIIT without Cognitive Load | HIIT with Cognitive Load | *p* |
|---|---|---|---|
| Questionnaire to quantify the mental load in sports | | | |
| Physical effort (a.u.) | 3.78 ± 2.39 | 6.00 ±1.90 | 0.001 * |
| Cognitive effort (a.u.) | 4.56 ± 2.17 | 5.43 ± 1.88 | 0.015 * |
| Emotional effort (a.u.) | 6.38 ± 1.95 | 6.84 ± 2.14 | 0.164 |
| Behavioral data | | | |
| Mean HR (bpm) | 160.70 ± 13.06 | 159.86 ± 11.67 | 0.64 † |
| Maximum HR (bpm) | 176.90 ± 11.31 | 176.88 ± 9.19 | 0.99 † |
| Mean speed (Km/h) | 9.86 ± 1.68 | 9.94 ± 1.72 | 0.65 |
| Maximum speed (Km/h) | 14.42 ± 1.69 | 14.60 ± 1.64 | 0.42 † |

*: $p < 0.05$; †: Due to distribution requirements, the *p*-value was obtained from a paired sample *t*-test. *p*-values reported in the table were adjusted for Bonferroni corrections for multiple comparisons. HR—Heart Rate; HIIT—High-intensity interval training; a.u.—arbitrary units; bpm—beats per minute.

**Table 2.** Analysis of subjective and physiological indicators of mental fatigue. Comparison between different protocols.

| | HIIT without Cognitive Load | | | HIIT with Cognitive Load | | | |
|---|---|---|---|---|---|---|---|
| Variables | Pre (1) | Post (2) | Pre-Post Change | Pre (3) | Post (4) | Pre-Post Change | Pre-Post Change Inter-Protocols |
| Hooper and Mackinnon wellness questionnaire | | | | | | | |
| General Fatigue (a.u.) | 3.97 ± 0.89 | 2.81 ± 0.78 | <0.001 * | 4.06 ± 0.98 | 2.97 ± 0.78 | <0.001 * | 0.87 |
| Muscle soreness (a.u.) | 3.72 ± 1.08 | 3.50 ± 0.98 | 0.132 | 3.84 ± 1.11 | 3.47± 1.07 | 0.105 | 0.67 |
| Stress level (a.u.) | 3.84 ± 1.11 | 3.56 ± 1.08 | 0.197 | 3.97 ± 1.06 | 3.69 ± 0.85 | 0.150 | 0.95 |
| Mood state (a.u.) | 4.25 ± 0.80 | 3.94 ± 0.88 | 0.039 * | 4.25 ± 0.76 | 4.25 ± 0.91 | 1.00 | 0.15 |
| VAS for MF (a.u.) | 23.44 ± 17.20 | 29.69 ± 19.67 | 0.014 * | 25.78 ± 17.97 | 41.40 ± 21.48 | 0.001 * | 0.04 * |
| Physiological indicator of fatigue | | | | | | | |
| RMSSD (ms) | 47.94 ± 12.68 | 30.66 ± 7.24 | <0.001 *,† | 51.18 ± 10.84 | 32.72 ± 8.08 | <0.001 *,† | 0.53 † |

*: $p < 0.05$; †: Due to distribution requirements, the *p*-value was obtained from a paired sample *t*-test. *p*-values reported in the table were adjusted to Bonferroni corrections for multiple comparisons. HIIT—High-intensity interval training; VAS—Visual analogue scale; RMSSD—Root mean square of successive differences between normal heartbeats; MF—Mental fatigue.; a.u.—arbitrary units; ms—miliseconds.

## 3. Results

Table 1 shows the comparison between HIIT with and without cognitive load in the perception of physical, cognitive, and emotional efforts and behavioral data (speed and heart rate). The physical effort was significantly higher during the HIIT with cognitive load than during the HIIT without cognitive load ($p = 0.001$), although no significant differences in external physical load (heart rate and speed) were observed between sessions. Cognitive efforts were also significantly higher during the HIIT with cognitive load ($p = 0.015$).

Table 2 shows the comparison between pre- and post-training on physical, cognitive, and emotional efforts (obtained from the Hooper and Mackinnon wellness questionnaire and the VAS for mental fatigue) and the RMSSD for HIIT with and without cognitive load. A significant increase in the subjective feelings of general fatigue ($p < 0.001$) and a significant decrease in RMSSD ($p < 0.001$) were observed in both protocols without differences between them. Additionally, a significant increase in subjective feelings of mental fatigue was observed in HIIT without cognitive load ($p = 0.014$) and HIIT with cognitive load ($p = 0.001$), with a significant higher increase in the HIIT with cognitive load than in the HIIT without cognitive load ($p = 0.04$). Meanwhile, only HIIT without cognitive load caused poorer levels of mood state reported from pre- to post ($p = 0.039$). No significant differences from pre- to post- nor inter-protocol were observed for muscle soreness or stress level.

## 4. Discussion

The present study aimed to evaluate the effects of including induced mental fatigue during a HIIT training session on physical load, fatigue, and mental fatigue. The main findings of the present study suggested that physical efforts were not significantly different between the mentally fatiguing and the control HIIT conditions. Therefore, mental fatigue did not impair physical performance during the HIIT. Despite this, the presence of induced mental fatigue caused higher increases in subjective feelings of physical and mental fatigue in comparison with conventional HIIT.

The absence of significant differences in physical efforts between the mentally fatiguing and control conditions warrants a thorough discussion to provide potential explanations for these findings. One possible reason for the non-significant results could be the design of the HIIT protocol used in the study. It was shown that variations in the intensity, duration, and recovery intervals of HIIT can influence its impact on physical performance [36]. Additionally, the duration of the mental fatigue induction may have played a role in the lack of significant differences, although the markers of mental fatigue indicate that this duration significantly increased the feelings of mental fatigue between the HIIT with incongruent Stroop and the conventional Stroop. In this line of reasoning, the duration of the cognitive task can affect subsequent physical performance [37,38]. Furthermore, individual variations in response to the cognitive task could have contributed to the non-significant findings. Other authors highlighted the existence of interindividual differences in susceptibility to mental fatigue and its impact on physical performance [39,40]. By considering these factors, it becomes evident that the interaction between mental fatigue and physical efforts is complex and multifaceted. Future studies should further investigate the optimal design of HIIT protocols, the duration of mental fatigue inductions, and individual differences to better understand the underlying mechanisms and provide practical recommendations for coaches and practitioners.

We hypothesized that mental fatigue would negatively influence the physical performance (behavioral outcomes) of tennis practitioners during HIIT. On the contrary, the results of the present study showed that the physical efforts quantified with mean and maximum HR and mean and maximum speed were not significantly different between the mentally fatiguing and the control HIIT conditions. Therefore, this hypothesis should be rejected. Despite previous authors reporting impairments in physical efforts during specific anaerobic-aerobic tests [19–21], it is also certain that most of these authors suggested that these impairments were caused by an increase in the values of RPE [41]. Higher values of RPE would cause a significant decrease in physical performance as a reduction in the time to exhaustion [42] or in the performance in aerobic performance competitions [12]. Although the physiological mechanisms involved in this phenomenon are unclear, the accumulation of adenosine in the brain appears to be a candidate [43–45]. However, it has also been suggested that there are brain mechanisms mediated by motivation that could counterattack this negative effect of increased RPE on physical performance [1]. In the present study, a significant increase in general fatigue (analogous to RPE) was also observed in the presence of mental fatigue without significative changes in objective (i.e., heart rate and speed variables) indicators of physical performance. Therefore, the presence of induced mental fatigue increased subjective feelings of fatigue during HIIT without changing physical performance. Future studies should test the effect of motivation as a moderator in the relationship between mental fatigue, RPE, and physical performance. In this regard, studies should be performed analyzing the electroencephalogram (EEG) signal before, during, and after mental fatiguing tasks and exercises. The EEG signal should be complemented with performance and subjective perception to explore all spheres. The results would elucidate the physiological reason behind the findings.

Our results also showed a significant reduction in the mood state after the HIIT without cognitive tasks. In contrast, the values of mood state stayed stable after the HIIT with the Stroop task. We hypothesized that this reduction in the mood state could be related to motivation and boredom. The repetitive nature and the general fatigue induced by a HIIT session could make that participant's perceived mood state worse. On the contrary, the appearance of a novel task (such as the incongruous Stroop) could have reduced the effects of boredom on mood states. Nevertheless, differences between sessions were not found. Thus, future studies should explore the role of Stroop or other cognitive tasks during physical exercise practice as a way to maintain motivation and decrease boredom during practice.

The HRV provides information about the balance between the parasympathetic and sympathetic nervous systems [34]. Therefore, the HRV could reflect the interaction between brain and heart [46]. Thus, previous studies have used the HRV to prevent athletes from overtraining [47,48]. Our results showed that the RMSSD had been reduced after the HIIT sessions. Similar results have been previously reported after exercise [49–51]. This could be due to increased sympathetic modulation due to the extra cardiac output required while exercising [52,53]. In addition, previous studies have found that RMSSD could be sensitive enough to decrease during cognitive processing [54] or emotional stimuli [55]. However, our results did not show statistically significant differences between the two types of HIIT (with or without cognitive tasks). This could mean that although mental fatigue was perceived in the HIIT with cognitive load session, it was not enough to increase the fatigability of the autonomic nervous system. Thus, future studies should examine different types of cognitive tasks to explore if the autonomic modulation could change.

Regarding the efforts reported during both protocols, the higher mental load and mental fatigue reported during the HIIT with cognitive load can be explained by the cognitive effort performed during the Stroop. Despite the fact that a single HIIT implies cognitive load, caused by self-pacing, attention, or the efforts to remember the execution of the HIIT [56,57], the introduction of cognitively demanding tasks may increase the cognitive effort caused during a HIIT. This could confirm previous studies investigating Stroop's incongruent efficacy to induce cognitive load and fatigue in sports [2,57–59]. Sustained attention might cause the cognitive effort, response inhibition, cognitive flexibility, and working memory demand that Stroop implies [1]. Therefore, conducting the incongruent Stroop task during the recovery periods of HIIT could induce mental fatigue in tennis players.

Although it is difficult to generalize all this information based on two isolated training sessions, the results suggest important pre-indices and practical applications. In this regard, single HIITs produce significant increases in mental fatigue; therefore, coaches should not perform HIITs during competitions because of the perceived physical and mental fatigue after this training [59]. Indeed, adding an external (i.e., Stroop) cognitive demanding task could significantly enhance the increase caused by HIIT trainings on mental fatigue. Furthermore, the results of this investigation are relevant since they could confirm that subjective perceptions of mental fatigue can be induced using shorter cognitive stimuli during exercise practice. This information could be important for coaches in managing mental fatigue due to the use of a cognitive task in HIIT during season periods where resistance to mental fatigue has to be worked [60,61].

### *4.1. Limitations of the Study*

This study has several limitations that should be acknowledged and discussed in more depth. Firstly, the study was conducted with tennis practitioners, which may limit the generalizability of the findings to other sports or health conditions. The specific demands and skills required in tennis may influence the interaction between mental fatigue and physical performance differently compared to other sports. Future studies should aim to replicate the study with participants from various sports to examine the applicability of the results across different athletic populations.

Secondly, due to limitations with the Polar Team software, only the RMSSD metric of heart rate variability (HRV) was reported in this study. HRV offers valuable insights into autonomic modulation, and exploring a wider range of HRV metrics (such as time domain, frequency domain, and non-linear metrics) would provide a more comprehensive understanding of the impact of HIIT with a cognitive task on autonomic regulation. Therefore, future studies should strive to include a broader set of HRV metrics to gain a more detailed assessment of the autonomic responses.

Another limitation is the lack of cognitive performance data during the incongruent Stroop task. Monitoring cognitive performance would have provided valuable information regarding the impact of mental fatigue on cognitive functioning, the level of engagement of participants with the task, the temporal evolution of cognitive performance during the training session, and potential differences between groups (e.g., the Stroop task performed in the first session versus the second session). Incorporating cognitive performance measures in future studies would enhance our understanding of the cognitive effects of mental fatigue during HIIT sessions.

Furthermore, the relatively small sample size of 32 tennis players is another potential limitation. It is important to consider whether this sample adequately represents the larger population of tennis players and if it limits the generalizability of the findings. A larger sample size would increase the statistical power and improve the robustness of the results, allowing for more reliable conclusions to be drawn. Future studies should aim to include larger and more diverse samples to strengthen the validity and generalizability of the findings.

### 4.2. Practical Applications

The findings of this study have several practical implications for sports training and performance optimization, as well as for coaches and practitioners managing mental fatigue. Here are some specific examples and recommendations based on the study's results:

- Training Program Design: Coaches can incorporate high-intensity interval training (HIIT) sessions into training programs while considering the potential impact of mental fatigue. It is important to avoid scheduling HIIT sessions close to competitions, as they may induce physical and mental fatigue. By carefully planning the timing of HIIT sessions, coaches can ensure that athletes have adequate recovery time and perform at their best during important events;
- Cognitive Task Integration: Introducing a cognitively demanding task, such as the Stroop task, during recovery periods of HIIT can induce mental fatigue in athletes. This information can be utilized to design training sessions that specifically target mental fatigue resistance. Coaches can incorporate cognitive tasks strategically to challenge athletes' mental resilience and improve their ability to sustain focus and performance under mentally fatiguing conditions;
- Subjective Perception Monitoring: Coaches and practitioners should pay attention to athletes' subjective perceptions of fatigue, both physical and mental, during HIIT sessions. Monitoring the subjective feelings of fatigue can provide valuable insights into athletes' readiness and help adjust training intensity and volume accordingly. Athletes' feedback on their perceived effort, fatigue, and mood state should be taken into account when modifying training programs to optimize performance outcomes;
- Motivational Strategies: Coaches can explore the role of motivation as a moderator in the relationship between mental fatigue and physical performance. Implementing motivational strategies, such as goal setting, positive reinforcement, and creating a supportive training environment, may help counteract the negative effects of increased mental fatigue on physical performance. By fostering motivation, coaches can

potentially enhance athletes' ability to maintain high levels of performance despite experiencing mental fatigue;

- Individualized Approach: It is essential to recognize that athletes may respond differently to mental fatigue. Future studies could explore individual differences in the relationship between mental fatigue, perceived effort, and performance outcomes. Coaches and practitioners can consider tailoring training programs and interventions based on athletes' unique characteristics, such as their psychological profiles and capacity to cope with mental fatigue. This individualized approach can maximize training effectiveness and support athletes' overall well-being.

By implementing these practical applications, coaches and practitioners can optimize training programs, manage mental fatigue, and enhance athletes' performance outcomes. The study's findings provide valuable insights into the complex interaction between mental fatigue and physical performance, opening avenues for further research and the development of evidence-based strategies in sports training and performance.

## 5. Conclusions

The first conclusion of the study is that performing a HIIT training session (with or without incongruous Stroop) significantly increases the perception of general fatigue and subjective mental fatigue and decreases the RMSSD. In addition, this is the first study concluding that short bouts of incongruent Stroop during HIIT training sessions significantly increase the perception of physical effort, mental effort, and mental fatigue when compared with a conventional HIIT session.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13127046/s1, Table S1: Shapiro-Wilk, skewness and kurtosis results of the variables obtained from Hooper and Mackinnon wellness questionnaire, heart rate and speed; Table S2: Shapiro-Wilk, skewness and kurtosis results of the differences between pre and post of the Questionnaire to Quantify the Mental Load in Sports (QQMLS), visual analogue scale for mental fatigue, and RMSSD.

**Author Contributions:** Conceptualization, V.J.C.-S. and J.P.F.-G.; Data curation, J.D.-G., V.J.C.-S., J.P.F.-G. and S.V.; Formal analysis, J.D.-G. and S.V.; Investigation, V.J.C.-S., J.P.F.-G. and S.V.; Methodology, V.J.C.-S. and J.P.F.-G.; Project administration, J.P.F.-G.; Resources, V.J.C.-S. and J.P.F.-G.; Supervision, S.V.; Writing—original draft, J.D.-G. and S.V.; Writing—review & editing, V.J.C.-S., J.P.F.-G. and S.V. All authors have read and agreed to the published version of the manuscript.

**Funding:** This study has been made thanks to the Department of Economy and Infrastructure of the Junta de Extremadura through the European Regional Development Fund. A way to make Europe (GR21094).

**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the University of Extremadura Ethics Committee.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data will be available upon reasonable request to the corresponding author.

**Conflicts of Interest:** The authors declare no conflict of interest.

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