

Original Research

Physical fatigue exacerbates the negative effects of mental fatigue on soccer performance in practitioners

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Abstract: Soccer is mentally as well as physically fatiguing. Negative effects of isolated mental fatigue on soccer performance have been reported, however, it does not appear isolated in soccer. This study compared the effects of baseline, mental fatigue and combined mental and physical fatigue on soccer performance. Voluntarily, 18 male soccer practitioners (23.61 ± 4.12 y) participated in six randomized and crossover sessions— two non-induced fatigue baseline (30 min. documentary), 2 isolated mental fatigue (30 min. Incongruent Stroop) and 2 combined physical and mental fatigue (30 min. Incongruent Stroop while cycling at 80-85% of the theoretical Maximum Heart Rate). The Visual Analogue Scale pre- and post- fatiguing protocol for mental fatigue, and the Questionnaire to Quantify Mental Load in Sports Team for mental load post-fatiguing protocol were collected. The Loughborough shooting and passing test were performed post- fatiguing protocols. Results revealed the combined protocol as the most mentally loading and fatiguing, showing significant differences when compared with isolated mental fatigue and baseline ($p < .001$). Isolated mental fatigue was significantly more mentally loading ($p < .001$) and fatiguing ($p < .001$) than baseline. Significant impairments on soccer performance were observed after isolated mental fatigue and combined protocols in comparison with baseline ($p < .001$). However, these impairments were significantly higher after combined than isolated mental fatigue ($p < .043$). In conclusion, the presence of physical fatigue combined with mental fatigue exacerbates the negative effects that isolated mental fatigue causes on soccer performance.

Keywords: cognitive fatigue; mental exertion; physical exertion; Incongruent Stroop Task; Visual Analogue Scale; Loughborough soccer test

1. Introduction

Soccer is physically (Nedelec et al., 2012) as well as mentally demanding (Abbott et al., 2020; Thompson et al., 2020).



On one hand, soccer requires prolonged low-intensity physical efforts interspersed with repeated short bouts of high-intensity activity (Smith et al., 2018). On the other hand, soccer mental demands are caused by the extremely challenging perceptual-cognitive demands of soccer (Smith et al., 2018). Specifically, these authors indicated that soccer players must remain alert for extended period, constantly scanning their dynamic performance and selecting only to relevant information. Indeed, players must integrate this information with tactical strategies and opposition and teammate tendencies.

Despite this, soccer has been mainly analyzed from a physical viewpoint (Nedelec et al., 2012). However, mental fatigue appears as a widely investigated topic in soccer since the starts of 2020's as observed in the systematic review of Kunrath et al. (2020). Mental fatigue is a psychobiological state caused by specific-sport mental demands (Van Cutsem et al., 2017). It may course with subjective, behavioral and/or physiological symptoms (Van Cutsem et al., 2022), although the perceptions of mental fatigue depends of each athlete specifically and coaches sometimes has the capacity to identify it among their own players (Russell, Jenkins, Rynne, Halson, & Kelly, 2019).

Previous studies have confirmed negative effects of mental fatigue on soccer performance, as summarized the review of Smith et al. (2018). Indeed, it has been observed negative effects of mental fatigue on physical (Filipas, Borghi, La Torre, & Smith, 2021; Trecroci, Boccolini, Duca, Formenti, & Alberti, 2020), technical (Badin, Conte, & Coutts, 2011; Smith, Fransen, Deprez, Lenoir, & Coutts, 2017) and tactical (Coutinho et al., 2018; Smith et al., 2016). components of soccer performance.

The most extended explanation to the negative effects caused by mental fatigue in soccer is that mental fatigue increases the ratio of perceived effort of the players when compared to the same effort in non-mentally fatiguing conditions (Van Cutsem et al., 2017). It means that mentally fatiguing players feel their-self as more physically tired than in non-mentally fatiguing conditions. Consequently, players technical and tactical decisions are negatively influenced by this increased feeling of physical fatigue, as explained by Coutinho et al. (2018).

However, all these studies that checked the effects of mental fatigue on soccer performance have investigated the isolated effect of mental fatigue on performance. Otherwise, as we previously explained, soccer players simultaneously suffer mental and physical fatigue at the same time. Therefore, test the isolated effect of physical or mental fatigue does not represent the reality of the soccer players during competitions. Consequently, the present study aimed to check if the presence of physical fatigue would exacerbate the negative effects of mental fatigue on soccer passing and shooting performance. To the best of our knowledge, no previous studies have checked this information, therefore, the topic of the study is innovative.

2. Materials and Methods

Subjects — A priori power analysis using G*Power software 3.1.9.2 was performed to address the number of participants required in the study to meet a true effect allocating 95% power at $p < .05$, and a medium effect size ($d=50$) based on previous studies (Díaz-García et al., 2023). The minimum required sample size was 16 participants. A total of 18 male soccer practitioners (23.61 ± 4.12 y; 177.31 ± 14.91 cm; 74.32 ± 16.33 Kg.), players in non-

professional leagues, with a training frequency of two days per week and playing one match per week participated in the study voluntarily. All of them have more than 8 years of experience in soccer. Added to all of them, exclusion criteria was also to present physical or mental injuries that impair their participation in the tests of the study. The study protocol was approved by our institutional research ethics committee (approval number: 93/2020). The research was undertaken in compliance with the Declaration of Helsinki and international principles governing research on humans.

Experimental design— The study was a randomized counterbalance experiment where players performed seven different sessions. The first session for all the players was a familiarization session to ensure that players understood tests and questionnaires. The other six experimental sessions were performed in a randomized order: two baseline sessions – where, soccer tests were performed after 30 min. documentary watching; two isolated mental fatigue sessions – where soccer tests were performed after 30 min. incongruent Stroop, and other two combined physical and mental fatigue sessions – where soccer tests were performed after perform 30 min. incongruent Stroop while cycling (80-85% of theoretical maximum heart rate (i.e., $220 - \text{age}$)). Then, all the players performed all the conditions, although, in a counterbalanced order. The inclusion of a documentary protocol was done to compare the effects of the experimental protocol with a non-fatiguing condition and it has been widely used in the topic. The rest of the protocols have been previously used as well (Rubio-Morales et al., 2022). Cycling is not specific of soccer, but it allows players to perform a physically fatiguing protocol while players perform a Stroop at the same time. The medium values between the two sessions of

each protocol were obtained to decrease the variability that may be not explained by the effects of protocols. All sessions were preceded by a 10 min usual soccer warm-up designed by the researchers including running and mobility.

Methodology— All the instruments were recorded using its English version. Specifically, instruments used were:

Visual Analogue Scale. The Visual Analogue Scale-100 was used to ask participant about their subjective perception of mental fatigue: "How mentally fatigued do you feel on a line from 0 to 100?". They must indicate their perceived level of mental fatigue in a line from 0 (minimum) to 100 (maximum), where 0 is the minimum value and 100 is the maximum. There are no previous validation studies for this scale to quantify mental fatigue in soccer, although it is the most used instrument for this purpose (Kunrath et al., 2020) and it has been demonstrated that it is the most sensitive method to detect mental fatigue in athletes (Smith, Chai, Nguyen, Marcora, & Coutts, 2019).

Questionnaire to Quantify Mental Load in Sport Teams: The Questionnaire to Quantify Mental Load in Sport Teams (QQMLST) was used to record the mental load perceived by the players. This instrument is composed by three items: physical (How demanding would you quantify the physical effort of this session?; e.g., a higher number of sprints should be more physically effortful than a small number of sprints), cognitive (How demanding would you quantify the cognitive effort of this session?; e.g., 5 vs 5 situations should be more cognitively demanding than 4x2 situations for attacking players) and emotional (How demanding would you quantify the effort made to manage your emotions during this session?; e.g., higher temporal pressures due to an

adverse results should be more emotionally effortful than other less temporal pressure situations) All responses were recorded on a Likert-type scale from 1 to 10, where 1 was the minimum value and 10 the maximum value. This instrument has been previously validated for the purpose described in team sports (Díaz-García, González-Ponce, Ponce-Bordón, López-Gajardo, & García-Calvo, 2021).

Loughborough passing and shooting test. The Loughborough Soccer Passing Test (LSPT) and the Loughborough Soccer Shooting Test (LSST) were validated to assess the soccer-specific technical performance (Ali et al., 2007). In the LSPS participants were encouraged to make 16 passes against 4x standard gymnasium benches positions in a rectangle with the participant in the center of the rectangle in a delimited area for passes marked by cones. Each bench was marked in its center with a colored piece of cardboard (0.6 x 0.3 m) serving as a target area. The passes were performed in a randomized order, where one researcher indicated to participant the colour where each pass should be done. Participants were instructed to complete the 16 passes as fast as possible, while minimizing errors. Outcomes includes original time (time invested to complete the 16 passes), penalty time (5 s added for missing the bench or passing to a wrong bench, 3 s added for missing the target area, 3 added for handling the ball, 2 s added for passing the ball from outside of the passing area, 2 s added if the ball touched any cone, 1 s added for every second over 43 s and 1 s discounted for each pass in the middle of the target) and performance time (original time added to penalty time). In the LSST participants began 20 m away from the goal line. They were required to sprint and touch one cone (in the left or in the right) positions 6 m behind them. Then, participants

returned to the starting position, passed the ball against a bench before controlling, turning and shooting. Each trial was made up of 10 shots (5 with each foot, in a randomized order), separated by 1 min of rest. Points per shoot (depending of the part of the goal where the ball passed, encouraging to shoot toward the corners of the goal) was calculated as the mean of the points accumulated and time to complete each shot were calculated. Shot sequence time was also recorded. These tests has been previously used in the topic of mental fatigue and its effects on soccer technical performance (Smith et al., 2016).

The Visual Analogue Scale was collected pre- and post- fatiguing protocols. The Questionnaire to Quantify Mental Load in Sport Teams was quantified immediately after the fatiguing protocols had finished. The Loughborough shooting and passing test were also recorded after fatiguing protocols.

With regard the Incongruent Stroop to induce mental fatigue. 30 min. of incongruent Stroop task (i.e., the name of the words and the ink colour of the word were different) was used. The words were presented serially, and participants were instructed to read the coloured words. If a fail response happened, participants were advertised and encouraged to repeat it until the response was correct. This task is usually used in studies focused on mental fatigue (Díaz-García et al., 2022). Despite it is not a very ecological tasks, it includes response inhibition or selective attention which are also present in sport game scenarios (Van Cutsem & Marcora, 2021)

Statistical Analysis — Data was presented as Medium \pm Standard Deviation. The Shapiro-Wilk test checked the normality of the data. Due to, data was not normally distributed, the Wilcoxon non-parametric test was used. This test was used to check

possible differences in the two soccer tests between baseline, mental fatigue and combined mental and physical fatigue protocols. Significance was set at $p < .05$. All analysis were performed using the Statistical Package for Social Sciences (SPSS) 25.0 statistical program.

3. Results

The mentally fatiguing and demanding nature of the different protocols was showed in Table 1. The isolated mental fatigue and combined protocols significantly resulted in increased subjective feelings of mental fatigue from pre- to post ($p < .001$). No effects of Documentary on these variables were observed.

The score of the soccer performance tests between protocols was showed in Table 2. Results showed significant

differences between protocols in the LSPT. The players invested significant higher original times in combined when compared with isolated mental fatigue ($p = .043$) and Documentary ($p < .001$). Indeed, the penalty time was also higher in combined than in isolated mental fatigue ($p = .031$) and Baseline ($p < .001$). Players also invested highest time ($p < .001$) and had higher penalties ($p < .001$) in isolated mental fatigue than in Baseline. Similar results were observed in the LSST. The combined protocol showed the worst points per shoot ($p < .001$ in both cases), speed ($p < .001$ in both cases) and sequence times ($p < .001$ in both cases), meanwhile, isolated mental fatigue also impaired the points per shoot ($p < .001$), speed ($p < .001$), and sequence times ($p < .001$) when compared with Documentary.

Table 1. Mental load and fatigue comparing between protocols

Variables	Doc.	Mental fatigue	Combi.
Mental fatigue			
Pre	2.21±.87	2.34±.33	2.28±.94
Post	2.51±.26 ^{b,c}	6.64±.39 ^{a b,d}	8.22±.31 ^{a,c,d}
Mental load:			
Physical	1.12±.21 ^c	1.17±.06 ^d	5.31±1.09 ^{c,d}
Cognitive	2.28±.33 ^{b,c}	7.09±2.19 ^{b,d}	9.02±2.38 ^{c,d}
Emotional	2.02±.29 ^{b,c}	3.10±.91 ^{b,d}	4.91±1.36 ^{c,d}

Doc= Documentary; Combi= Combined; ^a= significant differences from pre- to post- mental fatigue; ^b= significant differences between doc. and mental fatigue; ^c= significant differences between doc. and combi; ^d= significant differences between mental fatigue and combi.

Table 2. Soccer performance comparing between protocols

Variables	Doc.	Mental fatigue	Combi.
LSPT (s.)			
Original	56.31±4.3 ^{b,c}	61.31±4.09 ^{b,d}	63.99±6.14 ^{c,d}
Penalty	17.37±4.33 ^{b,c}	21.32±6.12 ^{b,d}	23.44±5.32 ^{c,d}
Performance	73.68±6.12 ^{b,c}	82.63±9.91 ^{b,d}	87.43±7.12 ^{c,d}
LSST			
Points/shoot	1.07±.32 ^{b,c}	.81±.02 ^{b,d}	.75±.06 ^{c,d}
Speed(km/h)	43.11±6.15 ^{b,c}	38.10±5.33 ^{b,d}	36.94±6.12 ^{c,d}
Sequence(s.)	14.01±4.33 ^{b,c}	15.31±2.99 ^{b,d}	16.22±3.75 ^{c,d}

¹ Notes Doc= Documentary; Combi= Combined; ^a= significant differences from pre- to post- mental fatigue; ^b= significant differences between doc. and mental fatigue; ^c= significant differences between doc. and combi; ^d= significant differences between mental fatigue and combi.

4. Discussion

The main purpose of the present study was to check if the presence of physical fatigue would exacerbate the impairments that mental fatigue on soccer performance. The main findings of the study confirms previous evidence where mental fatigue impairs soccer performance. The present study novelty indicates that this negative effect of mental fatigue on soccer performance seems to exacerbate in presence of combined mental and physical fatigue.

Firstly, the comparison of the mental load and fatigue between protocols showed that the presence of physical fatigue may exacerbate the feelings of mental fatigue when compared with an isolated mental fatigue protocol. This is in line with previous evidence about the effectiveness of Incongruent Stroop to successfully induce mental fatigue (Smith, Chai, Nguyen, Marcora, & Coutts, 2019; Smith et al., 2016). Although it is not a very specific method, it includes response inhibition or attention which are cognitive demands also present in soccer (Van Cutsem & Marcora, 2021). The results are also in concordance with the exacerbation that physical efforts combined with cognitive tasks causes on feelings of mental fatigue (Rubio-Morales et al., 2022). It seems to be caused by the cognitive efforts performed during physical efforts, as self-pacing is (Van Cutsem & Marcora, 2021).

Secondly, the comparison between protocols of soccer performance seems to confirm, on one hand, the negative effects that mental fatigue causes on soccer performance. On the other hand, the results suggest that the combination of physical and mental efforts may cause higher impairments on soccer passing and shooting performance when compared with isolated mental fatigue. To the best of our

knowledge, this is the first study to check this combined effect on soccer performance. Previous studies demonstrated negative effects of isolated mental fatigue on technical and tactical performance which were explained by ratio of perceived effort increases and cognitive performance impairments associated to mental fatigue (Badin et al., 2011; Badin, Smith, Conte, & Coutts, 2016; Filipas et al., 2021; Smith et al., 2016). In the present study, the combination of physical and mental fatigue showed higher increases in the feelings of mental fatigue than the observed in the isolated mental fatigue. Moreover, it may cause a higher increase in the feelings of physical exertion than the caused by the isolated mental fatigue, as was previously showed in Rubio-Morales et al. (2022) as well. Then, and to clarify, previous studies defined the cognitive impairments and the exacerbated feeling of physical fatigue as the causes of the impairments in soccer performance associated to the presence of isolated mental fatigue. Consequently, and because the combination of physical and mental fatigue exacerbates feelings of mental fatigue and associated symptoms (i.e., increased feelings of physical fatigue), it seems logical that alterations in soccer performance may also be exacerbated by this protocol compared to isolated mental fatigue, although future studies should confirm this.

In conclusion, the isolated mental fatigue and the combined physical and mental fatigue results in an increased state of mental fatigue among the players. With regard the comparison between protocols, this combination caused greater values of mental fatigue than the caused by the isolated mental fatigue. The isolated mental fatigue impairs the soccer shooting and passing performance, although, these negative effects on soccer performance were

also exacerbated by the combined protocol. Then, researchers and coaches should consider and treat mental fatigue as a combined aspect together with physical fatigue and not as an isolated variable.

5. Practical Applications

The main purpose of the present study was to check if the presence of physical fatigue would exacerbate the impairments that mental fatigue on soccer performance. The result of the study confirms previous evidence where mental fatigue impairs soccer performance. The present study indicates that this negative effect of mental fatigue on soccer performance is exacerbated in presence of physical fatigue. This suggests several applications for coaches and practitioners. On one hand, it indicates the needed to avoid mentally fatiguing activities previously to matches, as smartphone use or social media are (Fortes et al., 2020). On the other hand, it indicates the needed to not separate mental and physical fatigue during trainings, searching to develop training adaptations versus mental fatigue and its effects. Previous studies suggested that ergogenic aids as caffeine or creatine may be used to counterattack negative effects of mental fatigue on soccer performance. These results also highlight the needed to include measures of mental fatigue during trainings and matches.

6. Strengths, Limitations and future directions

The strengths of this study are the novelty of the topic and the high-ecological design. Otherwise, the information provided should be considered carefully. Specifically, the inclusion of only a post-test of the soccer passing and shooting performance are the main limitations of the study. Future studies

should take into account pre-measures, pure control groups, and other things as the heart rate calculation. In future works, this and other considerations, as the use of a more ecological task to induce mental fatigue and the inclusion of physiological measures of mental fatigue have been take into account.

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

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