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Effects of smartphone use before resistance exercise on inhibitory control, heart rate variability, and countermovement jump

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Abstract

Background: the effect of MF induced by exposure time to social media smartphone apps on inhibitory control, heart rate variability (HRV), and high-intensity physical effort following a resistance exercise session might indicate whether strength and conditioning professionals should suggest smartphone avoidance before a resistance exercise session. **Aim:** thus, the objective of this study was to analyze the effect of mental fatigue on inhibitory control, HRV, and countermovement jump (CMJ) in trained adults after resistance exercise. **Methods:** sixteen trained males (21.4 ± 3.3 years) volunteered in this study. The participants performed resistance exercises with and without mental fatigue. The Stroop Task, countermovement jump, and heart rate variability were evaluated before and after the resistance exercise. In the mental fatigue condition, the participants used smartphones, whereas the participants watched TV in the control condition. **Results:** no condition x time interaction was found for the Stroop accuracy (p=0.87) and CMJ (p=0.68) as well as SDNN (p=0.15), and pNN50 (p=0.15) in the heart rate variability. For Stroop response time, an interaction was found (p=0.01) with a higher response time for the mental fatigue condition (p=0.01). **Conclusions:** mental fatigue impaired the inhibitory control performance after a resistance exercise session in trained adults.

Keywords: Cognition, fatigue, mental fatigue, social network, performance, psychology.

Introduction

Inhibitory control (IC), heart rate variability (HRV), and countermovement jump (CMJ) are variables that are frequently measured in training monitoring (Halson, 2014). Observing how the athletes respond to every stimulus has been crucial to improving performance (Halson, 2014; Nakamura et al., 2016), and the IC, HRV, and CMJ are reliable variables to determine internal load (L. S. Fortes et al., 2020; Halson, 2014; Nakamura et al., 2016). IC is a key part of the executive function, related to successful task performance(Albuquerque et al., 2019; Diamond, 2015; Gejl et al., 2018). It enables individuals to control their attention, behavior, thoughts, and emotions (Diamond, 2015). Also, IC seems to regulate perceived exertion rating during a physical exercise session(Franco-Alvarenga et al., 2019; S. M. Marcora et al., 2009). HRV and CMJ are more related to physical performance; higher intensity training causes more disturbance in HRV and CMJ, indicating higher fatigue levels and consequently more recovery time (Halson, 2014). The study of Kassiano et al. (2021) found an impairment in HRV and CMJ following more intense exercise following a resistance training (RT) session.

RT is widely applied to improve health and performance, recommended in several medical conditions and sports modalities (Bangsbo, 2015; Westcott, 2012). Interestingly, studies have observed cognitive gains in the old and young populations despite the physical gains possible with RT (Westcott, 2012). In a study by Fortes et al. (L. de S. Fortes et al., 2018), they observed an increase in IC following an RT session in young, healthy individuals. A brain oxygenation improvement (e.g., prefrontal cortex region), the use of lactate as an energy substrate to the brain, increased dopamine neurotransmission concentration, and brain-derived neuro factors (BDNFs) might explain those improvements(Church et al., 2016; Portugal et al., 2013). However, mental fatigue might reduce or even suppress the beneficial effects of an RT session on IC.

Mental fatigue (MF) has been described as a psychobiological state characterized by tiredness, lack of energy, and apathy feelings induced for long periods of demanding cognitive activity (Smith et al., 2018; Van Cutsem et al., 2017). Tasks that require inhibition response, boredom, and sustained attention (e.g. the Stroop Task) (Smith et al., 2018) seems to induce MF. The effects of MF on performance are broadly investigated, showing impairments on endurance, cognitive function, and some studies are emerging with negative effects on RT (Gantois et al., 2021; Van Cutsem et al., 2017). Gantois et al. (2021) observed a reduction in RT volume following 30-min of social network using. However, most studies have been using controlled strategies to induce MF, which barely will be seen in the real world (Ting et al., 2008).

Although the Stroop task induces MF, its ecological validity is low. Other activities such as reading, driving, and smartphone use seem to cause mental fatigue and present higher ecological validity. Fortes et al. (L. S. Fortes et al., 2020) revealed that 30-min using social media apps on smartphones led to an MF state in soccer athletes, reducing passing decision-making in professional athletes. Also, studies observed a negative effect of MF caused by social networks in swimmers and RT practitioners (L. S. Fortes et al., 2021; Gantois et al., 2021). However, whether smartphone social media apps affect the inhibitory control following a resistance exercise session remains unclear.

From a practical standpoint, acutely, RT increases IC and reduces HRV and CMJ. However, when individuals are mentally fatigued, the effects of RT on IC, HRV, and CMJ are still unclear. Moreover, it is crucial to understand any alterations on those variables following exercise bouts once they are essential for training monitoring. It might indicate whether strength and conditioning professionals should suggest smartphone avoidance before an RT session. Thus, the study aims to analyze how MF induced by social media smartphone apps affects IC, HRV, and CMJ performance in trained adults following an RT session. Also, we developed the following hypothesis: the use of social media on smartphone apps leads to an impairment on IC, but HRV and CMJ remain similar following an RT session in mentally fatigued trained adults.

Methods

Participants

The sample size was calculated through an equation suggested elsewhere ($n = 8e^2/d^2$; n, e, and d denote the required sample size, coefficient of variation, and magnitude of the treatment, respectively), assuming "e" of 7.5 % for inhibitory control performed by trained adults (Fortes et al., 2018) and a conservative "d" of 1.0 %, thus resulting in ~ 14 participants. However, considering a possible sample loss, 16 trained male adults (21.4 ± 3.3 years; 1.73 ± 0.09 m; 74.2 ± 11.7 kg) volunteered to participate in this study. They had a RT frequency of 4.1 ± 0.5 sessions/week and a training experience of ~ 3.4 years when the study was conducted. They were non-smokers and free from cardiovascular, visual, auditory, and cognitive disorders. The procedures of this study were approved by the local Institutional Review Board and according to the Declaration of Helsinki. Written informed consent was obtained from each participant before participation.

Design and Procedures

This is a randomized and cross-over investigation with two experimental conditions run in a one-week washout interval in trained male adults.

Participants performed two experimental conditions (mental fatigue [MF] vs. control [CON]) following the two baseline visits to analyze reproducibility of HRV, CMJ, Stroop task, and 15 repetition maximum (15RM) in half-back squat and bench press. The participants performed the same resistance exercise configurations after both experimental conditions in a randomized order (Figure

1). Simple randomization was carried out for both MF and CON conditions. The random number table was generated on the www.randomizer.org site.

A Stroop Task trial was performed before and after MF (smartphones app use) and CON (watching an Olympic Games documentary) conditions along with a visual analog scale (VAS) to assess the rating of mental fatigue as an intervention check. Then, the participants warmed up in half back-squat and bench press.

CMJ and HRV were measured before and after10 and ~30-min from each experimental condition. All experimental procedures are illustrated in Figure 1. The participants were instructed to abstain from any physical exercise, ingest alcohol 48-h previous experimental sessions, and abstain from caffeine at least 3-h before experimental sessions.

Figure 1 here

Mental fatigue protocol

MF was induced by 30-min of continuous activity in social networks (e.g., Facebook®, Instagram®, Twitter®) through smartphone apps. Participants were strongly encouraged to stay in constant activity on the smartphone (reading texts, writing messages, and posting information on social networks). A blinded research member instructed participants to maintain only their activities on social media for 30 min. The participants were asked to avoid using smartphones 2-h before the experimental condition to minimize residual effect during the control session.

The control condition consisted of watching coaching videos about Olympic Games for 30-min on an 84-inch tv screen (smartphones were not allowed in the room). All participants remained in the same room while using their smartphones or watching the video. The participants were not allowed to speak amongst themselves.

Resistance exercise sessions

In both experimental conditions (MF and CON), the participants underwent 4 sets of 10 repetitions at 15RM with 3-minute interval rest between sets and exercises (half back-squat and bench press). The number of repetitions in each set was maintained the same; the subjects performed an equal number of repetitions in the two experimental conditions (i.e., 80 total repetitions). After the last repetition in each set, the Reserve Repetition Scale was presented for the participant. They were asked to demonstrate the how many repetitions they could perform at concentric muscular failure, as proposed by Zourdos et al. (2016).

Participants were instructed to exhale during the concentric phase and inhale in the eccentric phase during each repetition in both exercises. The aim was to maintain a ratio of 1:2 for the concentric and eccentric actions, respectively.

Measures

Stroop task. The Stroop Task (Graf et al., 1995) was adopted to assess IC and selective attention; both are considered components of executive functions (Diamond, 2015). Therefore, three assessments (pre-experiment, 10-min, and 30-min post-experiment) were performed in each experimental condition. The tests were carried out on a full-HD screen (1800 × 1260 pixels) laptop (MacBook Pro, A1502 model, USA). On the test, the participants answered the word color or according to its name, since the color of the words might be different from what is typed (e.g., the word “blue” might show up in “red” color, the word “green” in “blue”, and so on). A stimulus of 30 words with 200 ms of the interval was provided between the response and a new stimulus. Moreover, the stimulus did not fade from the screen until any response was given. Stimuli vary between congruent (word and color have the same meaning), incongruent (word and color have a different meaning), and control (colored rectangle with one of the colors of the test: red, green, blue, and black). The keys D (red), F (green), J (blue), and K (black) were used for answering the questions. The stimulus disappeared when the answer was correct, and then a new one was set. An X showed up on the screen in case of incorrect answers, and a new stimulus subsequently appeared. The accuracy of the correct answers and response time were collected at the end of the test. The evaluator was blind for all the assessments and had previous training for the test. The intraclass correlation coefficient (I_{CC}) determined the test-retest reproducibility for the accuracy [I_{CC} .86, $IC_{95\%}$ .59 – .95] and response time [I_{CC} .97, $IC_{95\%}$ .93 – .99] was acceptable.

15RM. Initially, the load related to the 15RM was determined after the 15RM test. The exercises performed were bench press and half back-squat. The participants performed the 15RM test in 2 distinct sessions with a recovery time of 48 hours. Two attempts were made with intervals of 10 minutes between sets. Accordingly, a warm-up (2 sets of 6-8 repetitions with 100%-body mass for half back-squat and 2 sets of 6-8 repetitions with 70%-body mass for bench press, adopting rest intervals of 150-second between sets) was performed before the 15RM test. It was adopted a 5-min interval between the warm-up breakup and the beginning of the 15RM test. Verbal encouragement was given throughout the 15RM test. The I_{CC} determined the test-retest reproducibility for the 15RM [bench press: I_{CC} .97, $IC_{95\%}$ .96 – .98, half back-squat: I_{CC} .98, $IC_{95\%}$ .96 – .99] were acceptable.

Countermovement jump (CMJ). An electronic contact jump mat (Hidrofit®, Jump System, Belo Horizonte, Brazil) was used to analyze the CMJ height. Each participant performed three attempts with a 30-s interval among trials. The best result was retained for analysis. The participants performed the CMJ with hands on the waist, and no restrictions were placed on the knee angle during the eccentric phase of the jump. Also, participants were instructed to maintain the legs in a straight position during the flight and land at the point of take-off. All participants were familiar with the test before the beginning of the investigation. In the present study, the intraclass correlation coefficient was .98 ($IC_{95\%}$ = .96 to .99) for CMJ, indicating good reproducibility of the test.

Heart rate variability (HRV). The R-R intervals recordings were assessed during 10-min in the seated position using a portable heart rate monitor with Bluetooth (H10, Polar Electro Oy®, Finland) with sampling at 1,000 Hz and downloaded via a validated smartphone app (Elite HRV app®) (Perrota et al., 2018). The participants remained in the sitting position for ten minutes before initiating the resting HRV (Task Force, 1996) in an air-conditioned room (24°C). Data were analyzed in the last five minutes after excluding the first five minutes allowed for heart rate stabilization. All the evaluations were performed under the same conditions. The analyzed variables were the standard deviation of all NN intervals (SDNN) and the success percentage of R-R interval differences greater than 50 ms (pNN50). These variables are most commonly adopted in scientific studies with physical exercise (Chen et al., 2011; Figueiredo et al., 2015). The SDNN value was presented in milliseconds (ms). The I_{CC} determined the test-retest reproducibility for the HRV [SDNN: I_{CC} .96, $IC_{95\%}$ .94 – .98, pNN50: I_{CC} .98, $IC_{95\%}$ .95 – .99] were acceptable.

Visual analog scale (VAS). Subjective ratings of MF were assessed using the 100 mm VAS's as previously adopted (Franco-Alvarenga et al., 2019; Smith et al., 2019). This scale has two extremities anchored at one "none at all" and "maximal" at the other. No other descriptor was presented in the VAS. The participants were required to answer "How mentally fatigued you feel now?" having 0 (zero) as "none at all" and 100 as "maximal" mental fatigue. Participants were oriented to perform a vertical line throughout the 100 mm scale according to their current perceived status. To quantify the values, we measured the millimeter distance from the "none at all" extremity across the end of the line indicated by the individual.

Internal training load. The internal load was quantified by-product between RPE-session and volume-load (Foster et al., 2001). The participants answered the following question 30 min after the end of the resistance exercise session in each of the experimental conditions (CON and MF): "How was your training?". The participant was asked to demonstrate the intensity perception of the session from the 10-point Borg scale (0 = rest to 10 = maximum effort) according to the method developed by Foster et al. (Foster et al., 2001). The session values product demonstrated by the RPE scale and the volume-load (kg) was calculated, thus expressing the internal load of the training session. The participants were familiarized with the RPE-session method for 30 days before beginning the investigation.

Repetitions in reserve. After the last repetition in each set (half back squat and bench press), subjects were shown a 1–10 RPE scale and were verbally asked to provide an RPE value. Before testing, investigators verbally explained the details of the RPE scale by using the following script: “This RPE scale will measure repetitions in reserve. For instance, a 10 RPE represents ‘max effort’ or no more repetitions could be performed” (Zourdos et al., 2016). A 9.5 RPE means you could not do another repetition but could add more weight. A 9 RPE means you could do one more repetition. An 8.5 RPE means you could do between 1 and 2 more repetitions. An 8 RPE means you could do 2 more repetitions. A 7.5 RPE means you could do between 2 and 3 more repetitions. A 7 RPE means you could do 3 more repetitions, a 5–6 RPE means you could do 4–6 more repetitions, a 3–4 RPE indicates that the set was of little effort, while an RPE of 1–2 indicates that the set was of little to no effort

Statistical analysis

The Shapiro-Wilk test was used to evaluate the distribution of data. The Levene test was used for homoscedasticity. Measures of central tendency (mean) and dispersion (standard deviation) were used to describe the research variables. Repeated-measures analysis of variance (ANOVA) compared the internal training load (RPE-session method) between the experimental treatments. A factorial ANOVA of repeated measurements, with a mixed design 2x3, was used to analyze the treatment (MF vs. CON) × time interaction (pre-experiment vs. 10-min vs. 30-min post-experiment) for CMJ, HRV, and Stroop task. The two-way ANOVA of repeated measurements was used to analyze the treatment (MF vs. CON) × time interaction (pre-smartphone or TV vs. post-smartphone or TV) for the VAS scale. A Bonferroni post-hoc test was used to identify possible statistical differences. In addition, the effect size (ES) at pre-experiment versus post-experiment [utilizing eta square (h^2)] was used to reveal differences from a practical point of view. The following criteria were used according to the Cohen (Cohen, 1992) guidelines for highly trained participants: $h^2 < 0.2$ = trivial ES, $0.2 \leq h^2 < 0.5$ = low ES, $0.5 \leq h^2 < 0.8$ = moderate ES, and $h^2 \geq 0.8$ = large ES. All data were processed in Statistical Package for Social Sciences Version 21.0 (IBM Corp., Armonk, NY, USA) using a significance level of 5%.

Results

Mental Fatigue

VAS. The results showed a condition ($F_{(2, 14)}$ = 124.43; p = 0.01; h^2 = 0.90; large ES) and time effect ($F_{(2, 14)}$ = 87.79; p = 0.01; h^2 = 0.86; large ES), and a condition x time interaction (Figure 2; $F_{(4, 12)}$ = 96.77; p = 0.01; h^2 = 0.87; large ES) for subjective rating of mental fatigue. The MF condition demonstrated higher subjective rating of mental fatigue than control one (p = 0.01). Only the MF condition showed an increase in subjective rating of mental fatigue (p = 0.01), as indicated in Figure 2.

Internal training load

The MF condition demonstrated higher internal training load than control (Figure 2; $F_{(2, 14)}$ = 10.21; p = 0.01; h^2 = 0.42; low ES).

Figure 2 here

Inhibitory Control Performance

Stroop task. The findings presented similar condition ($F_{(2, 14)}$ = 0.44; p = 0.51; h^2 = 0.03; trivial ES) and time effects ($F_{(2, 14)}$ = 0.46; p = 0.62; h^2 = 0.03; trivial ES) for accuracy. In addition, it was not found condition x time interaction for accuracy ($F_{(4, 12)}$ = 0.08; p = 0.87; h^2 = 0.05; trivial ES).

There was observed a condition ($F_{(2, 14)}$ = 31.66; p = 0.01; h^2 = 0.70; moderate ES) and time ($F_{(2, 14)}$ = 19.86; p = 0.01; h^2 = 0.59; moderate ES) effects and a condition x time interaction (Figure 3, $F_{(4, 12)}$ = 30.57; p = 0.01; h^2 = 0.69; moderate ES) for response time. The MF condition demonstrated higher response time than control at 10-min (p = 0.01) and 30-min (p = 0.01) after resistance exercise session. The control condition showed improved response time at 10-min (p = 0.01) and 30-min (p = 0.01) after resistance exercise session than pre-experiment. The MF condition was impaired for response time at 10-min (p = 0.01) and 30-min (p = 0.01) after resistance exercise session compared to pre-experiment, as shown in Figure 3.

Figure 3 here

CMJ performance

There is no condition effect for CMJ ($F_{(2, 14)}$ = 0.48; p = 0.83; h^2 = 0.003; trivial ES) in contrast with the time effect observed ($F_{(2, 14)}$ = 58.44; p = 0.01; h^2 = 0.81; large ES). It was not revealed condition x time interaction for CMJ ($F_{(4, 12)}$ = 0.39; p = 0.68; h^2 = 0.03; low ES). It was identified a decreased CMJ in post-experiment (10-min and 30-min) (p = 0.01), with no difference between MF and control conditions, as shown in Figure 4.

Figure 4 here

HRV indicators

The results revealed no condition effect for SDNN ($F_{(2, 14)} = 0.31$; $p = 0.58$; $h^2 = 0.02$; trivial ES) and pNN50 ($F_{(2, 14)} = 2.86$; $p = 0.11$; $h^2 = 0.17$; trivial ES). The results presented time effect for SDNN ($F_{(2, 14)} = 51.47$; $p = 0.01$; $h^2 = 0.79$; moderate ES) and pNN50 ($F_{(2, 14)} = 39.86$; $p = 0.01$; $h^2 = 0.74$; moderate ES). It was revealed no condition x time interaction for SDNN ($F_{(4, 12)} = 0.08$; $p = 0.91$; $h^2 = 0.008$; trivial ES) and pNN50 ($F_{(4, 12)} = 2.06$; $p = 0.15$; $h^2 = 0.13$; trivial ES). It was observed a decreased SDNN and pNN50 in 10-min post-experiment compared to pre-experiment for all experimental conditions ($p = 0.01$), with no difference between them. Also, it was revealed an increased SDNN and pNN50 in 30-min post-experiment compared to 10-min post-experiment for both experimental conditions ($p = 0.01$), although the values remained smaller compared to pre-experiment in all conditions ($p = 0.01$), with no difference between them.

Repetitions in reserve

The results showed a condition ($F_{(2, 14)} = 414.87$; $p = 0.01$; $h^2 = 0.97$; large ES) and time ($F_{(2, 14)} = 25.08$; $p = 0.01$; $h^2 = 0.64$; moderate ES) effects for perceived repetition in reserve; despite that, it was revealed no condition x time interaction for perceived repetition in reserve (Figure 5, $F_{(4, 12)} = 1.17$; $p = 0.32$; $h^2 = 0.07$). The MF condition demonstrated lower perceived repetition in reserve than control one after all sets (back squat and bench press) in resistance exercise sessions ($p = 0.01$). The self-reported perceived repetition in reserve was reduced in both experimental conditions during the resistance exercise sessions (p = 0.01), as shown in Figure 5.

Figure 5 here

Discussion

The objective of this study was to analyze the effect of MF induced by social media smartphone apps on IC, HRV, and CMJ performance in trained adults after a resistance exercise session. The main findings showed that mental fatigue impairs IC response time following RT sessions, and HRV and CMJ remain unaltered. Thus, the hypotheses corroborated with the results.

The findings of the present investigation indicated that the use of social media smartphone apps (Whatsapp®, Instagram®, or Facebook®) for 30-min increases the subjective rating of mental fatigue, corroborating the literature findings (L. S. Fortes et al., 2019). MF caused by social networks presented similar effects to previous studies involving controlled tasks (i.e., Stroop task) (Ting et al., 2008), driving a car (Ting et al., 2008) and reading (Thompson et al., 2020). It seems the adenosine concentration in the anterior cingulate cortex (Martin et al., 2018), inhibition of dopamine neurotransmission receptor in the brain (Smith et al., 2018), reduction of brain glycoses (Martin et al., 2018), and attenuation of brain oxygenation (Russell et al., 2019) are involved with the mechanisms that explain the mental fatigue. It would explain the reduction in IC following an MF state induced by social networks.

Literature has pointed out that mental fatigue might reduce human cognitive performance (Coutinho et al., 2018; L. S. Fortes et al., 2019), mainly IC (Gantois et al., 2020). In this study, the accuracy in the Stroop task was similar between experimental conditions as well as previous studies found no change in Stroop task accuracy following this condition (L. S. Fortes et al., 2019; Gantois et al., 2020). Regarding the response time, the present study showed impaired performance in the MF than in the control condition after a resistance exercise session (10 and 30-min). On the one hand, the response time of IC reduced in the control condition after the resistance exercise session, different from the MF condition with increased response time. The results for the control condition corroborate other studies (Best et al., 2015; L. de S. Fortes et al., 2018; Iuliano et al., 2015).

About the CMJ performance, the results showed a reduction following ten and 30-min of resistance exercise. Studies also revealed an impaired CMJ performance in the time-course until 30-min after resistance exercise (Costa et al., 2021). The results indicate that MF does not affect CMJ performance in trained adults. Also, findings from other studies showed no effect of mental fatigue on high intensity and short duration physical tasks (Pageaux et al., 2013). Pageux et al. (2013) showed that the muscular function of knee extensors was similar between MF and CON conditions. In the present study, the results for CMJ were similar in the post-experiment between MF and control conditions, corroborating the scientific literature. It seems that mental fatigue presents no detrimental effect on high intensity and short time physical performance.

According to HRV indicators (SDNN and pNN50), attenuation after a resistance exercise session compared to the pre-experiment was observed in both conditions, without a difference between MF and control. Our findings support the literature since other studies have reduced HRV after resistance exercise (Chen et al., 2011; Figueiredo et al., 2015). The main brain areas activated in high cognitive demanding are the prefrontal cortex and anterior cingulate cortex (Martin et al., 2018), whereas the main brain areas activated to control the autonomic nervous system are the left insular cortex, stem, and cerebellum (Fontes et al., 2015; Montenegro et al., 2014). Thus, once the MF and HRV activate different brain regions, it is reasonable to assume that the MF does not influence HRV indicators (L. S. Fortes et al., 2019; Penna et al., 2018). It would explain why HRV remains unaltered following MF induction.

Concerning the internal training load, the findings revealed higher values for MF than the control condition. The internal training load is a product between perceived exertion and volume (Foster et al., 2001). It is important to highlight that the volume load was the same in both experimental conditions. As mentioned above, it has been suggested that highly demanding cognitive tasks may increase adenosine concentration in the anterior cingulate cortex, leading to a higher perceived exertion when compared with non-fatigued subjects (S. M. Marcora et al., 2009; Pageaux et al., 2013). It is essential for training volume maintenance as high perceived exertion is related to the subject disengagement from a whole-body endurance task. A higher internal training load was accompanied by a lower perceived repetition in reserve for all sets in the resistance exercise session (half back squat and bench press). The perceived repetition in reserve is a measure that indicates the account of repetitions remaining at concentric muscular failure and show a negative linear correlation with the rating of perceived exertion (Zourdos et al., 2016). Notably, perceived repetition in reserve was lower in the mental fatigue condition from the first set of the back-squat exercise and remained lower in all other sets when compared to the control condition. The psychobiological model theory proposed by Marcora (S. Marcora, 2010) seems to explain the lower perceived repetition in reserve and greater internal training load in MF condition because a reduction in the engagement of exercise impairs motivation in the mental fatigue state.

Although the present study presents important findings, some limitations should be mentioned. It was not measured from the theta wave at electroencephalogram (EEG) as a mental fatigue indicator. The lactate or other metabolic measure was not used as well. It was not measured the velocity and power in each repetition in a resistance exercise session. In this sense, it is recommended that future investigations include EEG’s measures to demonstrate mental fatigue, metabolic stress measures, and velocity and power for each repetition.

Conclusion

From the practical standpoint, the present study's findings demonstrated that the use of smartphone apps (Whatsapp®, Instagram® or Facebook®) should be used with caution before the resistance exercise session. Besides, it is important to determine before the resistance exercise session if the subject is under a mental fatigue state (which makes it necessary to measure the Stroop task at baseline). The mental fatigue might determine the magnitude of internal training load and IC response, once a mentally fatigued individual might have the IC impaired after a resistance exercise session.

The results allow the conclusion that the MF impairs the IC performance after a resistance exercise session in trained adults, but the CMJ performance and HRV indicators were not changed. It seems that the mental fatigue induced by social media smartphone apps might be detrimental to cognitive performance. This study strongly suggests that smartphone social media induces mental fatigue might impair cognitive function after a resistance exercise session in male adults. This, it is crucial to control the time expended on smartphones before RT sessions in male adults.

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Declaration of Conflicting Interests

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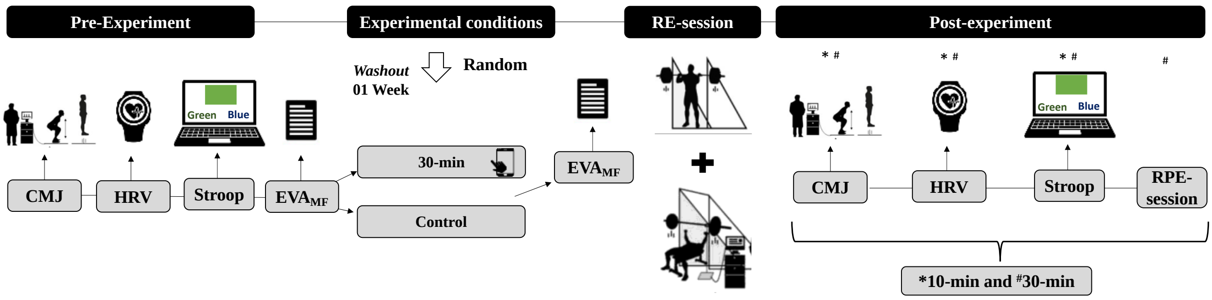

Figure 1

Experimental design of study

Note. CMJ = countermovement jump; EVA_{MF} = Mental Fatigue Visual Analogue Scale; HRV = heart rate variability; RPE = rated perception exertion; RE = resistance exercise.

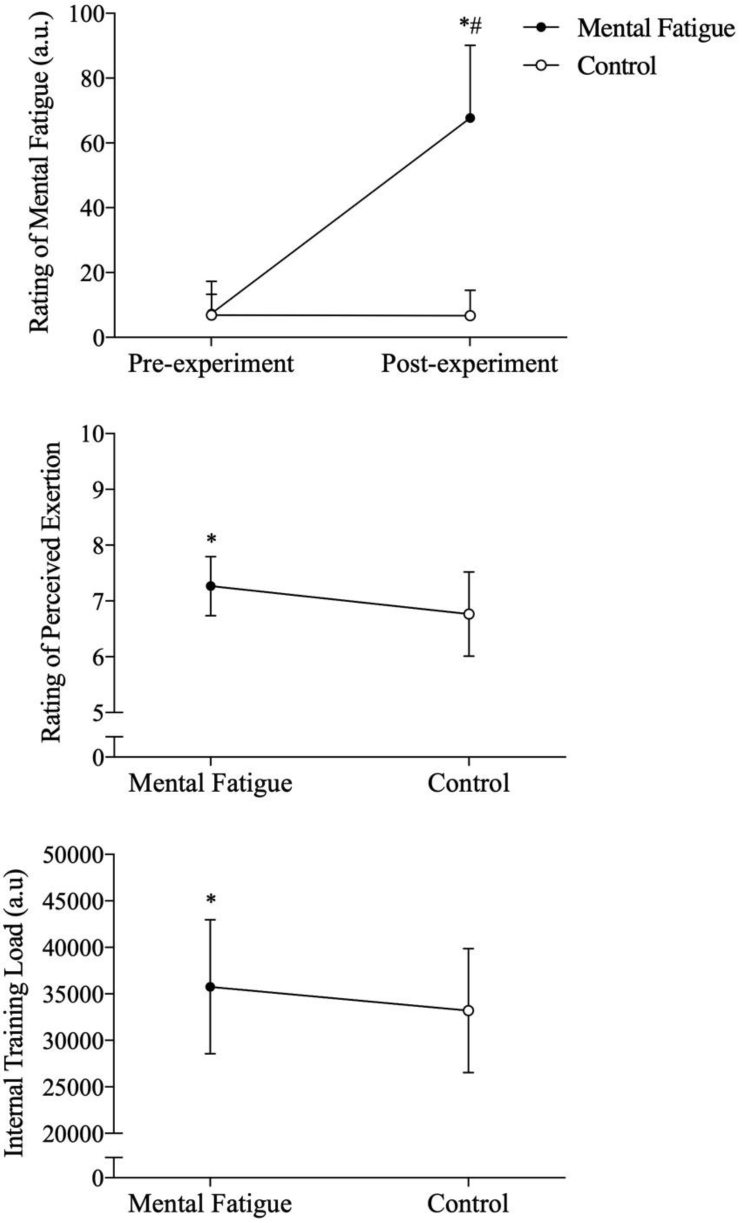

Figure 2

VAS mental fatigue and rating of perceived effort according to the experimental conditions.

Note. * = main single condition and time effect ($p < 0.05$); # = interaction effect (time x condition) ($p < 0.05$).

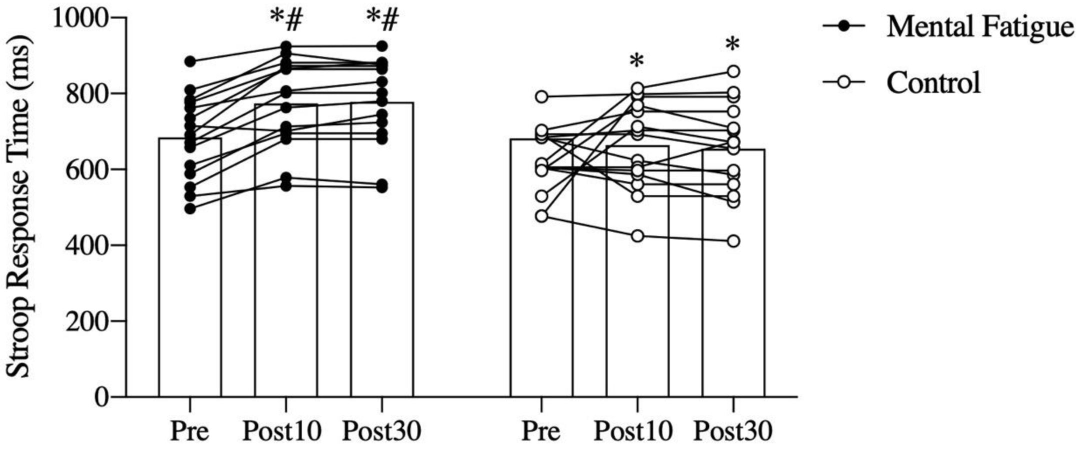

Figure 3

Average (Figure A) and individual (Figure B) Stroop task response time performance in the pre- and post-experiment according experimental conditions.

Note. * = single main time effect compared to pre-experiment values (p < .05); # = interaction effect (time x condition) (p < .05).

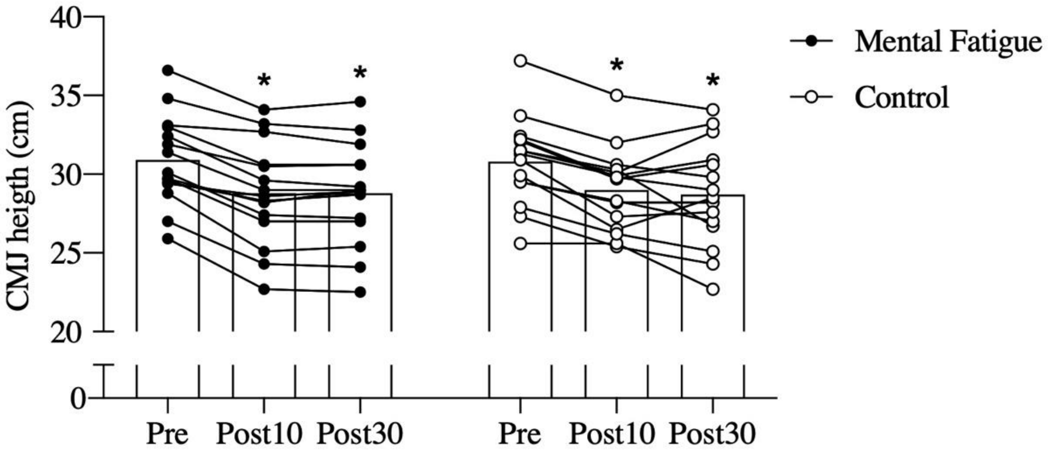

Figure 4

Average (Figure A) and individual (Figure B) CMJ performance in the pre- and post-experiment according experimental conditions.

Note. * = single main time effect compared to pre-experiment values (p < .05).

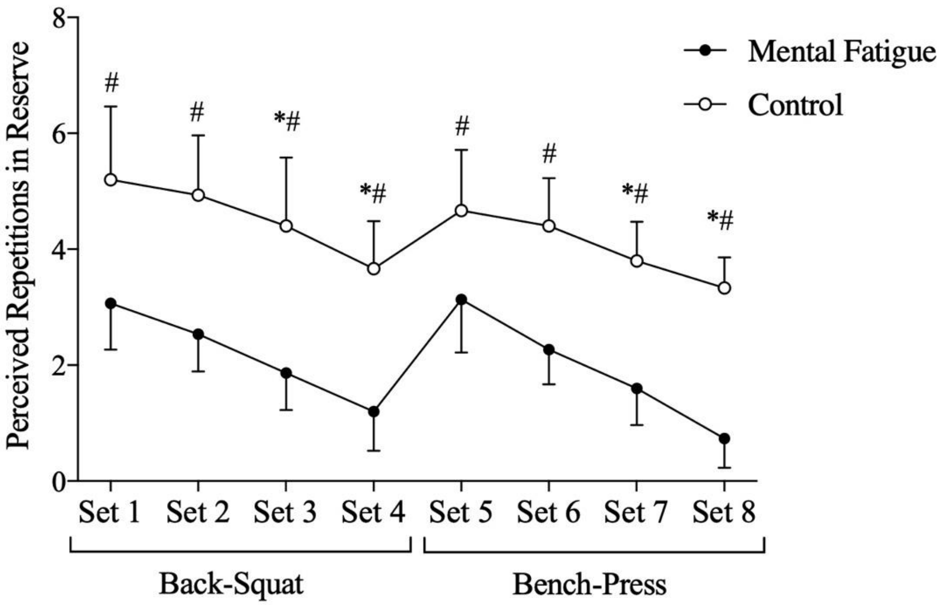

Figure 5

Perceived repetition in reserve during the multi-sets of the back-squat and bench press strength exercises.

Note. Line with circle = Mental fatigue experimental condition; Line with square = Control condition; * = single main time effect compared to Set 1 value ($p < .05$); # = interaction effect (time x condition) ($p < .05$).