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

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(Article begins on next page)

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

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25

26 **Abstract**

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

42

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

44

45 **Introduction**

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

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

68 Mental fatigue (MF) has been described as a psychobiological state characterized by tiredness,
69 lack of energy, and apathy feelings induced for long periods of demanding cognitive activity (Smith
70 et al., 2018; Van Cutsem et al., 2017). Tasks that require inhibition response, boredom, and sustained
71 attention (e.g. the Stroop Task) (Smith et al., 2018) seems to induce MF. The effects of MF on
72 performance are broadly investigated, showing impairments on endurance, cognitive function, and
73 some studies are emerging with negative effects on RT (Gantois et al., 2021; Van Cutsem et al.,
74 2017). Gantois et al. (2021) observed a reduction in RT volume following 30-min of social network
75 using. However, most studies have been using controlled strategies to induce MF, which barely will
76 be seen in the real world (Ting et al., 2008).

77 Although the Stroop task induces MF, its ecological validity is low. Other activities such as
78 reading, driving, and smartphone use seem to cause mental fatigue and present higher ecological
79 validity. Fortes et al. (L. S. Fortes et al., 2020) revealed that 30-min using social media apps on

80 smartphones led to an MF state in soccer athletes, reducing passing decision-making in professional
81 athletes. Also, studies observed a negative effect of MF caused by social networks in swimmers and
82 RT practitioners (L. S. Fortes et al., 2021; Gantois et al., 2021). However, whether smartphone social
83 media apps affect the inhibitory control following a resistance exercise session remains unclear.

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

93

94 **Methods**

95 *Participants*

96 The sample size was calculated through an equation suggested elsewhere ($n = 8e^2/d^2$; n , e , and
97 d denote the required sample size, coefficient of variation, and magnitude of the treatment,
98 respectively), assuming “ e ” of 7.5 % for inhibitory control performed by trained adults (Fortes et al.,
99 2018) and a conservative “ d ” of 1.0 %, thus resulting in ~ 14 participants. However, considering a
100 possible sample loss, 16 trained male adults (21.4 ± 3.3 years; 1.73 ± 0.09 m; 74.2 ± 11.7 kg)
101 volunteered to participate in this study. They had a RT frequency of 4.1 ± 0.5 sessions/week and a
102 training experience of ~ 3.4 years when the study was conducted. They were non-smokers and free
103 from cardiovascular, visual, auditory, and cognitive disorders. The procedures of this study were
104 approved by the local Institutional Review Board and according to the Declaration of Helsinki.
105 Written informed consent was obtained from each participant before participation.

106

107 *Design and Procedures*

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

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

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

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

120 CMJ and HRV were measured before and after 10 and ~30-min from each experimental
121 condition. All experimental procedures are illustrated in Figure 1. The participants were instructed to
122 abstain from any physical exercise, ingest alcohol 48-h previous experimental sessions, and abstain
123 from caffeine at least 3-h before experimental sessions.

124

125 **Figure 1 here**

126

127 *Mental fatigue protocol*

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

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

138

139 *Resistance exercise sessions*

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

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

150

151 *Measures*

152 *Stroop task.* The Stroop Task (Graf et al., 1995) was adopted to assess IC and selective attention; both
153 are considered components of executive functions (Diamond, 2015). Therefore, three assessments
154 (pre-experiment, 10-min, and 30-min post-experiment) were performed in each experimental
155 condition. The tests were carried out on a full-HD screen (1800 × 1260 pixels) laptop (MacBook Pro,
156 A1502 model, USA). On the test, the participants answered the word color or according to its name,
157 since the color of the words might be different from what is typed (e.g., the word “blue” might show
158 up in “red” color, the word “green” in “blue”, and so on). A stimulus of 30 words with 200 ms of the
159 interval was provided between the response and a new stimulus. Moreover, the stimulus did not fade
160 from the screen until any response was given. Stimuli vary between congruent (word and color have
161 the same meaning), incongruent (word and color have a different meaning), and control (colored
162 rectangle with one of the colors of the test: red, green, blue, and black). The keys D (red), F (green),
163 J (blue), and K (black) were used for answering the questions. The stimulus disappeared when the
164 answer was correct, and then a new one was set. An X showed up on the screen in case of incorrect
165 answers, and a new stimulus subsequently appeared. The accuracy of the correct answers and
166 response time were collected at the end of the test. The evaluator was blind for all the assessments
167 and had previous training for the test. The intraclass correlation coefficient (ICC) determined the test-
168 retest reproducibility for the accuracy [ICC .86, IC_{95%} .59 – .95] and response time [ICC .97, IC_{95%} .93
169 – .99] was acceptable.

170

171 *15RM.* Initially, the load related to the 15RM was determined after the 15RM test. The exercises
172 performed were bench press and half back-squat. The participants performed the 15RM test in 2
173 distinct sessions with a recovery time of 48 hours. Two attempts were made with intervals of 10
174 minutes between sets. Accordingly, a warm-up (2 sets of 6-8 repetitions with 100%-body mass for
175 half back-squat and 2 sets of 6-8 repetitions with 70%-body mass for bench press, adopting rest
176 intervals of 150-second between sets) was performed before the 15RM test. It was adopted a 5-min
177 interval between the warm-up breakup and the beginning of the 15RM test. Verbal encouragement
178 was given throughout the 15RM test. The ICC determined the test-retest reproducibility for the 15RM
179 [bench press: ICC .97, IC_{95%} .96 – .98, half back-squat: ICC .98, IC_{95%} .96 – .99] were acceptable.

180

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

189
190 *Heart rate variability (HRV)*. The R-R intervals recordings were assessed during 10-min in the seated
191 position using a portable heart rate monitor with Bluetooth (H10, Polar Electro Oy®, Finland) with
192 sampling at 1,000 Hz and downloaded via a validated smartphone app (Elite HRV app®) (Perrota et
193 al., 2018). The participants remained in the sitting position for ten minutes before initiating the resting
194 HRV (Task Force, 1996) in an air-conditioned room (24°C). Data were analyzed in the last five
195 minutes after excluding the first five minutes allowed for heart rate stabilization. All the evaluations
196 were performed under the same conditions. The analyzed variables were the standard deviation of all
197 NN intervals (SDNN) and the success percentage of R-R interval differences greater than 50 ms
198 (pNN50). These variables are most commonly adopted in scientific studies with physical exercise
199 (Chen et al., 2011; Figueiredo et al., 2015). The SDNN value was presented in milliseconds (ms).
200 The ICC determined the test-retest reproducibility for the HRV [SDNN: ICC .96, IC_{95%} .94 – .98,
201 pNN50: ICC .98, IC_{95%} .95 – .99] were acceptable.

202
203 *Visual analog scale (VAS)*. Subjective ratings of MF were assessed using the 100 mm VAS's as
204 previously adopted (Franco-Alvarenga et al., 2019; Smith et al., 2019). This scale has two extremities
205 anchored at one “none at all” and “maximal” at the other. No other descriptor was presented in the
206 VAS. The participants were required to answer “How mentally fatigued you feel now?” having 0
207 (zero) as “none at all” and 100 as “maximal” mental fatigue. Participants were oriented to perform a
208 vertical line throughout the 100 mm scale according to their current perceived status. To quantify the
209 values, we measured the millimeter distance from the “none at all” extremity across the end of the
210 line indicated by the individual.

211
212 *Internal training load*. The internal load was quantified by-product between RPE-session and
213 volume-load (Foster et al., 2001). The participants answered the following question 30 min after the
214 end of the resistance exercise session in each of the experimental conditions (CON and MF): “How
215 was your training?”. The participant was asked to demonstrate the intensity perception of the session

216 from the 10-point Borg scale (0 = rest to 10 = maximum effort) according to the method developed
217 by Foster et al. (Foster et al., 2001). The session values product demonstrated by the RPE scale and
218 the volume-load (kg) was calculated, thus expressing the internal load of the training session. The
219 participants were familiarized with the RPE-session method for 30 days before beginning the
220 investigation.

221

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

232

233 *Statistical analysis*

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

249

250 **Results**

251 *Mental Fatigue*

252 VAS. The results showed a condition ($F_{(2, 14)} = 124.43$; $p = 0.01$; $h^2 = 0.90$; large ES) and time effect
253 ($F_{(2, 14)} = 87.79$; $p = 0.01$; $h^2 = 0.86$; large ES), and a condition x time interaction (Figure 2; $F_{(4, 12)} =$
254 96.77 ; $p = 0.01$; $h^2 = 0.87$; large ES) for subjective rating of mental fatigue. The MF condition
255 demonstrated higher subjective rating of mental fatigue than control one ($p = 0.01$). Only the MF
256 condition showed an increase in subjective rating of mental fatigue ($p = 0.01$), as indicated in Figure
257 2.

258

259 *Internal training load*

260 The MF condition demonstrated higher internal training load than control (Figure 2; $F_{(2, 14)} =$
261 10.21 ; $p = 0.01$; $h^2 = 0.42$; low ES).

262

263 *Figure 2 here*

264

265 *Inhibitory Control Performance*

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

269 There was observed a condition ($F_{(2, 14)} = 31.66$; $p = 0.01$; $h^2 = 0.70$; moderate ES) and time
270 ($F_{(2, 14)} = 19.86$; $p = 0.01$; $h^2 = 0.59$; moderate ES) effects and a condition x time interaction (Figure
271 3, $F_{(4, 12)} = 30.57$; $p = 0.01$; $h^2 = 0.69$; moderate ES) for response time. The MF condition demonstrated
272 higher response time than control at 10-min ($p = 0.01$) and 30-min ($p = 0.01$) after resistance exercise
273 session. The control condition showed improved response time at 10-min ($p = 0.01$) and 30-min ($p =$
274 0.01) after resistance exercise session than pre-experiment. The MF condition was impaired for
275 response time at 10-min ($p = 0.01$) and 30-min ($p = 0.01$) after resistance exercise session compared
276 to pre-experiment, as shown in Figure 3.

277

278 *Figure 3 here*

279

280 *CMJ performance*

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

286

287 **Figure 4 here**

288

289 ***HRV indicators***

290 The results revealed no condition effect for SDNN ($F_{(2, 14)} = 0.31$; $p = 0.58$; $h^2 = 0.02$; trivial
291 ES) and pNN50 ($F_{(2, 14)} = 2.86$; $p = 0.11$; $h^2 = 0.17$; trivial ES). The results presented time effect for
292 SDNN ($F_{(2, 14)} = 51.47$; $p = 0.01$; $h^2 = 0.79$; moderate ES) and pNN50 ($F_{(2, 14)} = 39.86$; $p = 0.01$; $h^2 =$
293 0.74 ; moderate ES). It was revealed no condition x time interaction for SDNN ($F_{(4, 12)} = 0.08$; $p =$
294 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
295 a decreased SDNN and pNN50 in 10-min post-experiment compared to pre-experiment for all
296 experimental conditions ($p = 0.01$), with no difference between them. Also, it was revealed an
297 increased SDNN and pNN50 in 30-min post-experiment compared to 10-min post-experiment for
298 both experimental conditions ($p = 0.01$), although the values remained smaller compared to pre-
299 experiment in all conditions ($p = 0.01$), with no difference between them.

300

301 ***Repetitions in reserve***

302 The results showed a condition ($F_{(2, 14)} = 414.87$; $p = 0.01$; $h^2 = 0.97$; large ES) and time ($F_{(2,$
303 $14)} = 25.08$; $p = 0.01$; $h^2 = 0.64$; moderate ES) effects for perceived repetition in reserve; despite that,
304 it was revealed no condition x time interaction for perceived repetition in reserve (Figure 5, $F_{(4, 12)} =$
305 1.17 ; $p = 0.32$; $h^2 = 0.07$). The MF condition demonstrated lower perceived repetition in reserve than
306 control one after all sets (back squat and bench press) in resistance exercise sessions ($p = 0.01$). The
307 self-reported perceived repetition in reserve was reduced in both experimental conditions during the
308 resistance exercise sessions ($p = 0.01$), as shown in Figure 5.

309

310 **Figure 5 here**

311

312 **Discussion**

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

317 The findings of the present investigation indicated that the use of social media smartphone
318 apps (Whatsapp[®], Instagram[®], or Facebook[®]) for 30-min increases the subjective rating of mental
319 fatigue, corroborating the literature findings (L. S. Fortes et al., 2019). MF caused by social networks
320 presented similar effects to previous studies involving controlled tasks (i.e., Stroop task) (Ting et al.,

321 2008), driving a car (Ting et al., 2008) and reading (Thompson et al., 2020). It seems the adenosine
322 concentration in the anterior cingulate cortex (Martin et al., 2018), inhibition of dopamine
323 neurotransmission receptor in the brain (Smith et al., 2018), reduction of brain glycoses (Martin et
324 al., 2018), and attenuation of brain oxygenation (Russell et al., 2019) are involved with the
325 mechanisms that explain the mental fatigue. It would explain the reduction in IC following an MF
326 state induced by social networks.

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

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

345 According to HRV indicators (SDNN and pNN50), attenuation after a resistance exercise
346 session compared to the pre-experiment was observed in both conditions, without a difference
347 between MF and control. Our findings support the literature since other studies have reduced HRV
348 after resistance exercise (Chen et al., 2011; Figueiredo et al., 2015). The main brain areas activated
349 in high cognitive demanding are the prefrontal cortex and anterior cingulate cortex (Martin et al.,
350 2018), whereas the main brain areas activated to control the autonomic nervous system are the left
351 insular cortex, stem, and cerebellum (Fontes et al., 2015; Montenegro et al., 2014). Thus, once the
352 MF and HRV activate different brain regions, it is reasonable to assume that the MF does not
353 influence HRV indicators (L. S. Fortes et al., 2019; Penna et al., 2018). It would explain why HRV
354 remains unaltered following MF induction.

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

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

378 **Conclusion**

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

386 The results allow the conclusion that the MF impairs the IC performance after a resistance
387 exercise session in trained adults, but the CMJ performance and HRV indicators were not changed.
388 It seems that the mental fatigue induced by social media smartphone apps might be detrimental to
389 cognitive performance. This study strongly suggests that smartphone social media induces mental

390 fatigue might impair cognitive function after a resistance exercise session in male adults. This, it is
391 crucial to control the time expended on smartphones before RT sessions in male adults.

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396

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398 The author(s) declared no potential conflicts of interest concerning this article's research,
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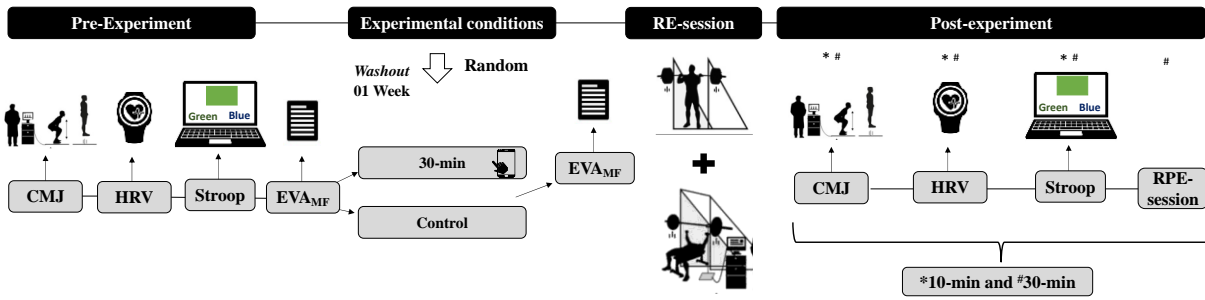
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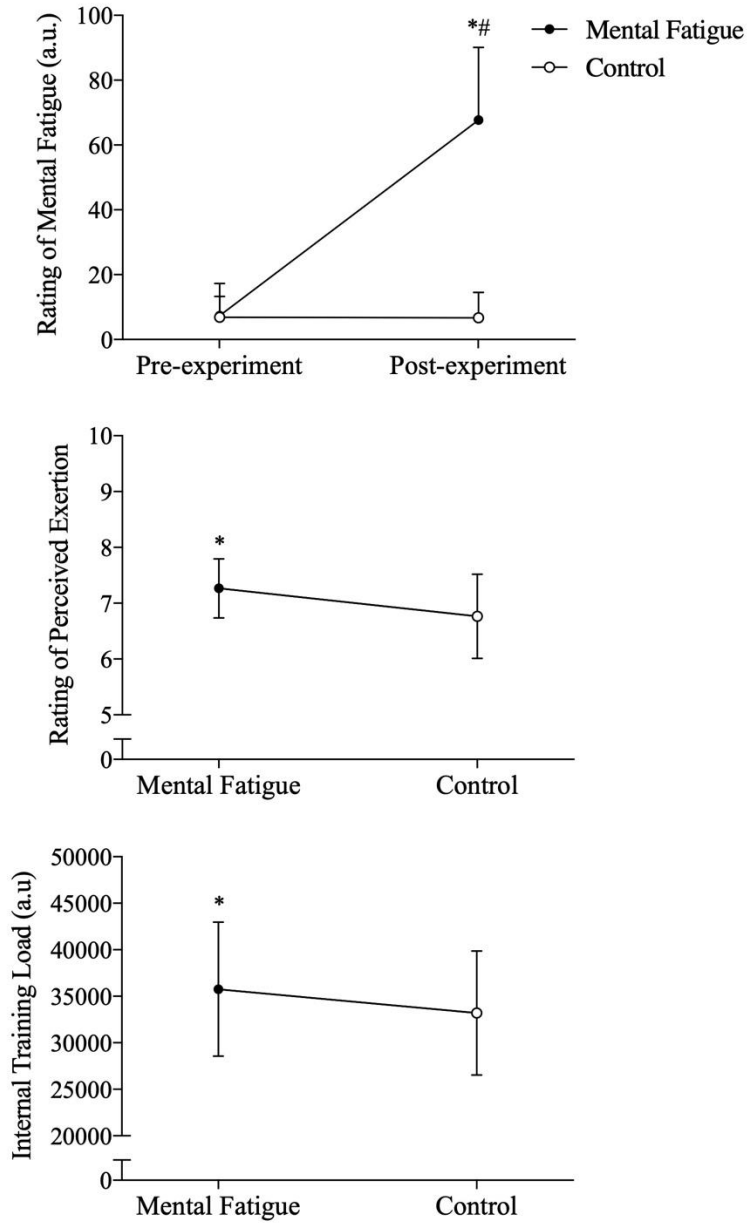
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543 Figure 1

544 *Experimental design of study*

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

547



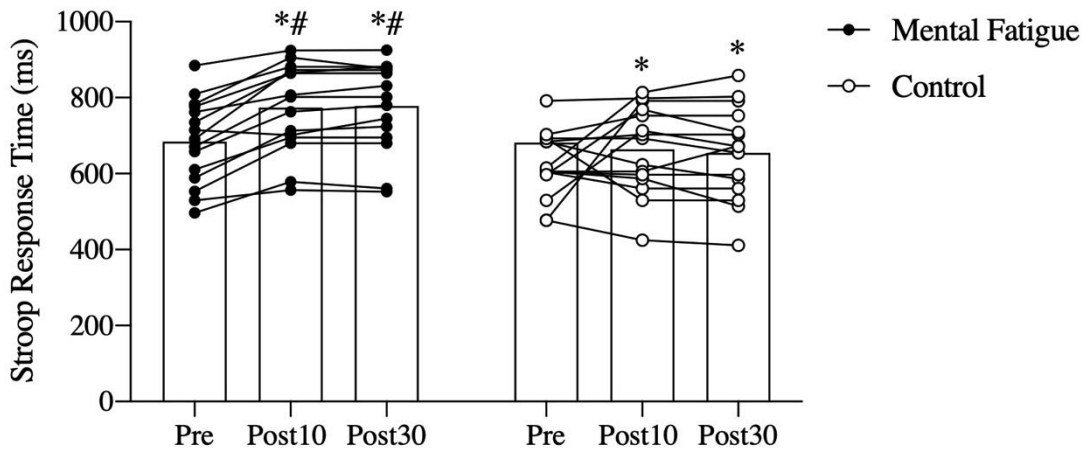
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549 Figure 2

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

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

552



553

554 Figure 3

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

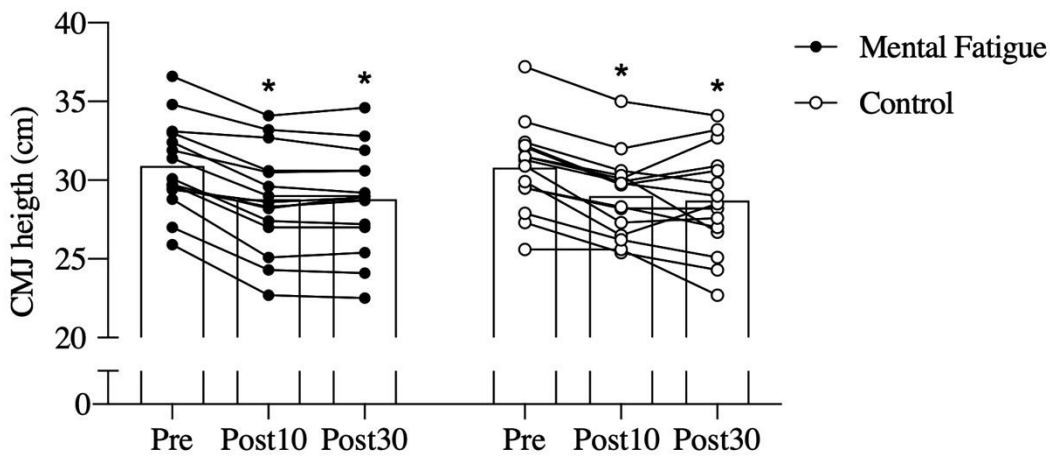
557 Note. * = single main time effect compared to pre-experiment values ($p < .05$); # = interaction effect (time x condition) ($p < .05$).

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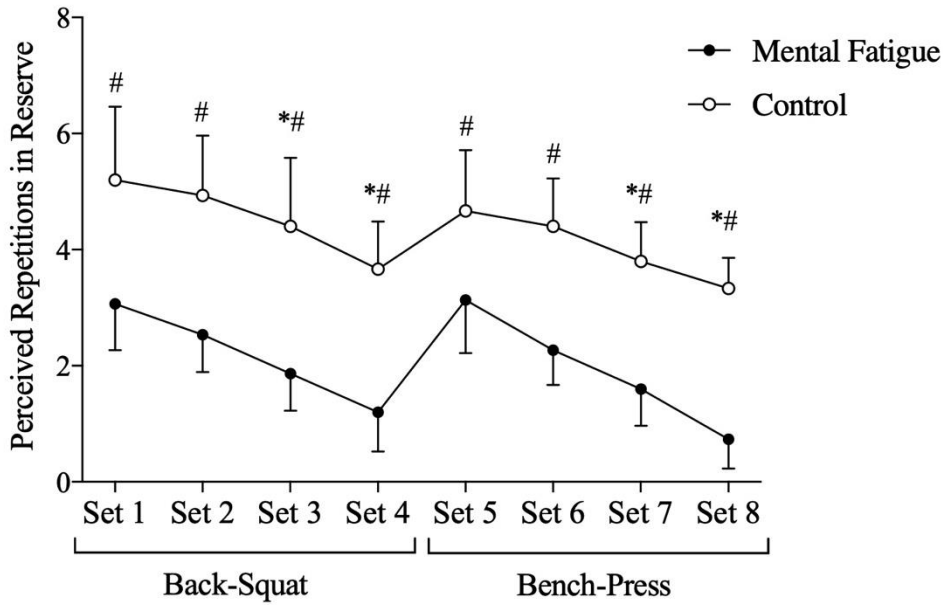
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563 Figure 4

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

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

567



568

569 Figure 5

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

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

573