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1 **Effects of plyometric training and creatine supplementation on maximal-intensity exercise and**
2 **endurance in female soccer players**

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41 **Abstract**

42 *Objectives:* to investigate the effects of a six-week plyometric training and creatine supplementation
43 intervention on maximal-intensity and endurance performance in female soccer players during in-season
44 training.

45 *Design:* Randomized, double-blind, placebo-controlled trial

46 *Methods:* Young (age 22.9 ± 2.5 y) female players with similar training load and competitive background
47 were assigned to a plyometric training group receiving placebo (PLACEBO, n = 10), a plyometric training
48 group receiving creatine supplementation (CREATINE, n = 10) or a control group receiving placebo
49 without following a plyometric program (CONTROL, n = 10). Athletes were evaluated for jumping,
50 maximal and repeated sprinting, endurance and change-of-direction speed performance before and after
51 six weeks of training.

52 *Results:* After intervention the CONTROL group did not change, whereas both plyometric training groups
53 improved jumps (ES = 0.25-0.49), sprint (ES = 0.35-0.41), repeated sprinting (ES = 0.48-0.55), endurance
54 (ES = 0.32-0.34) and change-of-direction speed performance (ES = 0.46-0.55). However, the CREATINE
55 group improved more in the jumps and repeated sprinting performance tests than the CONTROL and the
56 PLACEBO groups.

57 *Conclusions:* Adaptations to plyometric training may be enhanced with creatine supplementation.

58

59 **Key words:** muscle strength; sports; women; strength training; ergogenic aids.

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67 1. Introduction

68 Soccer players must perform numerous single maximal-intensity exercises, including jumping,
69 kicking, accelerating and decelerating¹, actions that might precede most of the goals scored in competitive
70 leagues², and correlate with competition success³. Repeating these maximal-intensity actions across a 90-
71 min game is also important⁴ and might be associated with endurance⁵, but also with intramuscular creatine
72 phosphate⁶, a critical energy source for maximal-intensity actions. Therefore, investigating the methods by
73 which single and repeated maximal-intensity actions (alongside endurance) can be enhanced in female
74 soccer players is important for this population. Plyometric training in female players may improve their
75 maximal-intensity exercise and endurance⁷. However, further investigation in this population is required⁸,
76 especially in regard to factors that might be mediating the effects of plyometric training on maximal-
77 intensity exercise and endurance performances adaptations, such as dietary supplements⁹.

78 Previous research involving male¹⁰ as well as female soccer players¹¹ has demonstrated that acute
79 creatine intake (i.e., one week) can enhance maximal-intensity exercise (e.g., jump, sprint, agility).
80 Despite these meaningful results, recently it has been shown that acute creatine supplementation had no
81 positive effects on fatigue and repeated sprint ability in a match simulation protocol¹², suggesting that
82 longer-term use might be more beneficial to performance¹³. Among the few longitudinal studies conducted
83 with regard to soccer, during a seven-week functional overreaching pre-season, creatine supplementation
84 prevented deterioration of male soccer players' maximal-intensity performance¹⁴. In female players,
85 creatine showed a positive effect on strength during a 13-week off-season¹⁵. However, to our knowledge,
86 it remains unknown whether creatine supplementation and plyometric training can elicit similar
87 improvements in female players when compared to plyometric training alone.

88 Therefore, the objective of this study was to investigate the effects of a six-week plyometric
89 training and creatine supplementation intervention on maximal-intensity and endurance performance in
90 female soccer players.

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92

93 2. Methods

94 After written informed consent, 33 amateur female players (three goalkeepers, nine defenders, ten
95 midfielders and eleven forwards) participated in this study. Participants had no regular strength or
96 plyometric training during the three months prior to the intervention and had never before taken creatine
97 supplements. The sample size was determined according to changes in vertical jump performance in a
98 group of soccer players submitted to a control ($\Delta = 0.5$ cm; $SD = 1.1$) or to a short-term plyometric
99 training ($\Delta = 2.6$ cm; $SD = 1.6$)¹⁶ comparable with that performed in this study. Eight participants per
100 group would yield a power of 95% and $\alpha = 0.01$, with a detectable ES of 0.2.

101 Exclusion criteria included (a) potential medical problems that compromised participation or
102 performance in the study, (b) any lower-extremity surgery in the past two years, (c) previous use creatine
103 consumption. Based on these criteria, three participants were excluded (one defender and two midfielders
104 were identified with recent history of ankle or knee injury). The participants included in the study
105 (between 19 and 28 y of age) were randomly assigned to either a plyometric training group receiving
106 placebo (PLACEBO, $n = 10$), a plyometric training group receiving creatine supplementation
107 (CREATINE, $n = 10$) or a control group receiving placebo without following a plyometric program
108 (CONTROL, $n = 10$). No vegetarians were registered in the study. At baseline, no differences were
109 observed in any descriptive (or dependent) variable between groups (Table 1). The study was conducted in
110 accordance with the Declaration of Helsinki and was approved by the ethics committee of the responsible
111 department.

112
113 *****Table 1 near here*****
114

115 Participants were accustomed to the testing procedures, as athletes incorporate them as a regular
116 aspect of their training schedule. Measurements were taken one week before and after intervention,
117 completed in three non-consecutive days and were always administered in the same order, at the same

118 time of the day and by the same investigators, who were blinded to each participant's group assignment.
119 Ten minutes of standard warm-up was performed before testing.

120 On day one, height, body mass, squat jump, countermovement jump, 20-m sprint test and running
121 anaerobic sprint test (RAST) measurements were completed. On day two, 20-cm and 40-cm drop jump
122 reactive strength indexes, peak jump power and peak jump power load testing were completed. On day
123 three, unilateral 20-cm drop jump reactive strength indexes (right and left leg), change-of-direction speed
124 test (i.e., *Illinois* test) and 20-m multi stage shuttle run tests were completed. Three maximal trials were
125 allowed for all performance tests, excepting the single shuttle run test, peak jump power test and RAST
126 measurements. At least two minutes of rest were permitted between each maximal trial to reduce the
127 effects of fatigue.

128 Anthropometric measurements employed a stadiometer (Bodymeter 206, SECA, Hamburg,
129 Germany) and an electrical scale (BF 100_Body Complete, BEURER, Ulm, Germany). Test protocols for
130 the jumps, 20-m sprints, change-of-direction speed¹⁷ and shuttle run tests¹⁸ were performed as previously
131 described. Briefly, for the jumps, players executed maximal effort jumps on a mobile contact mat
132 (Ergojump; Globus, Codogne, Italy) with arms akimbo. Take-off and landing were standardized to full
133 knee and ankle extension on the same spot. The participants were instructed to maximize jump height. In
134 addition, for the 20 and 40 cm drop jump reactive strength index, players were instructed to minimize
135 ground contact time after dropping down from a 20 and 40 cm drop box, respectively. For the 20-m
136 sprints, participants had a standing start with the toe of the preferred foot forward and just behind the
137 starting line. For the change of direction speed test, the timing system and procedures were same as for the
138 20-m sprint test, except that players started supine and completed a circuit with several changes of
139 directions. For the shuttle run endurance test, players ran back and forth between two lines, spaced 20-m
140 apart, in time with the "beep" sounds from an electronic audio recording. Each successful run of the 20-m
141 distance was a completion of a shuttle. The beep sounded at a progressively increasing pace with every
142 minute of the test, and the player had to increase speed accordingly until volitional fatigue. For unilateral

143 jumps, instead of using both legs during jumping and landing, participants used their left and right legs
144 alternatively.

145 Peak jump power measurements employed the same equipment and movement patterns as
146 countermovement jump measurements; however, instead of adopting arms akimbo, participants put weight
147 bars on their shoulders. To estimate power (W), a previously established testing protocol¹⁹ and equation²⁰
148 $[W = 65.1 \times \text{jump height (cm)} \times 25.8 \times \text{body mass (kg)} - 1413.1]$ was used. Briefly, unloaded peak jump
149 power was determined with a broomstick, while, in the following attempts, loads were increased by 5 kg
150 and tests were stopped when reductions in power output were greater than 50 W compared to previous
151 jump load measurements. Though the number of attempts were not predetermined, >90% of athletes
152 completed between four and six attempts, reducing the probability that fatigue affected test outcomes.

153 Participants performed six 35-m maximal sprints with 10 s of rest for the RAST, as previously
154 described and validated elsewhere²¹. The start for each sprint (10-s interval) occurred with a sound from
155 the measurement equipment. Sprint times were measured using single beam infrared photoelectric cells
156 (Globus Italy, Codogne, Italy) leveled ~0.7 m above the floor (i.e., hip level). The starting position was
157 standardized to a split position with the toe of each preferred foot forward and behind the starting line.
158 Mean RAST times were used for analyses.

159 All groups participated in the same soccer training program, such that similar training loads were
160 measured by session rating of perceived exertion (RPE), as previously described⁷ (Table 1). Briefly, each
161 player's session RPE was collected ~30 min after each soccer training session and match to ensure that the
162 perceived effort reflected the entire session rather than the most recent exercise intensity. Total training
163 load was calculated as RPE \times training session duration (i.e., minutes).

164 Experiments were completed during competition (i.e., mid portion of the in-season), which was
165 similar between groups (Table 1). Participants in the plyometric training groups performed plyometric
166 drills immediately after warm-up and as a substitute for some soccer drills (i.e., technical-tactical) within
167 the usual 120-minute practice twice per week for six weeks. Plyometric intervention was determined
168 based on previous research regarding soccer players¹⁶. A detailed description of the training program can

169 be found in a previous study¹⁸. Briefly, plyometric training included unilateral and bilateral horizontal and
170 vertical jumps with both cyclic and acyclic arm swings. Participants were motivated to achieve maximal
171 effort in every jump, instructed to aim toward maximal vertical heights and horizontal distances for
172 acyclic jumps and minimum ground contact times for cyclic jumps, in order to maximize reactive strength.

173 Before the training period, participants were accustomed to all exercises completed in the
174 plyometric program, and all training sessions were supervised with a coach to player ratio of 1:3, with
175 particular attention paid to technique. Plyometric training sessions were separated by a minimum of 48
176 hours (including games). Each plyometric training group completed the same number of total jumps, with
177 the same progressive overload, used the same surface and time of day for training and the same rest
178 intervals between jumps (i.e., 15 s for acyclic jumps) and sets (i.e., 60 s).

179 The CREATINE group participants received 20 g/d of creatine monohydrate (Gnc Pro
180 Performance, USA), divided into four equal doses, over the course of one week, followed by single daily
181 doses of 5 g for the next five weeks¹⁴. Participants in the PLACEBO and CONTROL groups were given
182 the same dosages of glucose. During the loading phase, supplements were presented in four packages, and
183 participants were instructed to ingest the packet contents at breakfast, lunch, dinner and before bedtime.
184 During the maintenance phase, each participant consumed the supplement as a single dose during her
185 lunch. To mask the taste and texture of the supplements provided to them, participants were asked to
186 dissolve the supplements in juice that contained a small amount of carbohydrates to reduce creatine
187 muscle uptake. Compliance to supplementation was monitored weekly via personal communication. Only
188 one athlete in the CREATINE group reported mild gastrointestinal distress, but this participant completed
189 the study. The supplement packages were coded, so that neither the investigators nor the participants were
190 aware of the contents until completion of the analyses. The supplements were distributed by a staff
191 member who was not an investigator in this study. Participants' feedback on group assignments post study
192 demonstrated the effectiveness of the double blinded protocol (in which 30% of participants guessed their
193 group assignments).

194 One week immediately before and after intervention, each participant's energy, macronutrient and
195 creatine intakes were determined through a 24-hour food recall questionnaire conducted in three different
196 days of the week, as previously described²².

197 Statistical analyses employed the STATISTICA statistical package (Version 8.0; StatSoft, Inc,
198 Tulsa). All values are reported as the means \pm standard deviations. Relative changes (%) in performance
199 and Cohen's d-effect sizes (ES) are expressed with 90% confidence limits. Normality and
200 homoscedasticity assumptions made for all data before and after intervention were checked using the
201 Shapiro-Wilk and Levene tests, respectively. To determine the effects of the intervention on performance
202 adaptations, groups were compared using mixed-design factorial ANOVA. When a significant F value
203 occurred for interaction between groups or for main effects of group or time, Tukey post hoc procedures
204 were performed. In addition, a between-groups one-way analysis of variance compared changes between
205 groups (i.e., the differences between scores before and after the intervention). The α level was set at $p <$
206 0.05 for statistical significance. In addition to this null hypothesis testing, data were also assessed for
207 practical meaningfulness using a magnitude-based inference approach. Threshold values for assessing
208 magnitudes of ES were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively²³.
209 Magnitudes of differences in training effects between groups were evaluated non-clinically²³: if the
210 confidence interval overlapped thresholds for substantial positive and negative values, the effect was
211 deemed unclear (i.e., trivial). The effect was otherwise clear and reported as the magnitude of the
212 observed value with a qualitative probability, as above (i.e., small, moderate, large, and very large).

213

214 **3. Results**

215 The reliability of assessments was determined using the typical error of measurement expressed as
216 a percentage of the mean (i.e., coefficient of variation) and ranged from 0.8 to 5.8%.

217 The energy, carbohydrate, lipids, protein and creatine intakes did not differ before, during and
218 after the intervention for the CONTROL (2678 ± 427 kcal·day⁻¹; 377 ± 89.8 g·day⁻¹; 91.1 ± 23.8 ; $88.1 \pm$
219 25.4 ; 1.2 ± 0.5 g·day⁻¹, respectively), PLACEBO (2819 ± 242 kcal·day⁻¹; 420 ± 61.2 g·day⁻¹; 86.1 ± 10.9

220 $\text{g}\cdot\text{day}^{-1}$; $91.4 \pm 15.3 \text{ g}\cdot\text{day}^{-1}$; $1.2 \pm 0.4 \text{ g}\cdot\text{day}^{-1}$, respectively) or CREATINE group ($2635 \pm 325 \text{ kcal}\cdot\text{day}^{-1}$;
221 $383 \pm 66.4 \text{ g}\cdot\text{day}^{-1}$; $84.2 \pm 15.9 \text{ g}\cdot\text{day}^{-1}$; $86.3 \pm 10.9 \text{ g}\cdot\text{day}^{-1}$; $1.3 \pm 0.4 \text{ g}\cdot\text{day}^{-1}$, respectively). Similarly,
222 body mass and body mass index were not different before, during and after the intervention for the
223 CONTROL ($60.1 \pm 7.5 \text{ kg}$; $23.3 \pm 2.2 \text{ kg}\cdot\text{m}^{-2}$, respectively) or PLACEBO ($56.8 \pm 5.4 \text{ kg}$; $21.2 \pm 1.4 \text{ kg}\cdot\text{m}^{-2}$,
224 2 , respectively) groups. However, regarding the basal value of body mass ($60.4 \pm 8.0 \text{ kg}$) and body mass
225 index ($23.2 \pm 3.1 \text{ kg}\cdot\text{m}^{-2}$) of the CREATINE group, an increase ($p < 0.05$; 1.4%) was observed during the
226 experimental period.

227 Both plyometric training groups (CREATINE and PLACEBO) increased ($p < 0.05$) jump and
228 power performance (ES = 0.23-0.49), however, only the CREATINE group showed a greater increase
229 compared with the CONTROL group (Table 2). In addition, the CREATINE group had small greater
230 meaningful training effects on peak jump power load, squat jump and 40-cm drop jump reactive strength
231 index compared to PLACEBO group (Table 2).

232
233 *****Table 2 around here*****
234
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236

237 Regarding RAST, change of direction speed, 20-m sprint and shuttle run endurance, both
238 plyometric training groups increased ($p < 0.05$) performance in these test (ES = 0.32-0.55), however, the
239 CREATINE group had small greater meaningful training effects on the RAST compared to PLACEBO
240 group and CONTROL group (Table 3).

241
242
243
244 *****Table 3 around here*****
245

246

247 **4. Discussion**

248 Our results suggest that replacement of some soccer drills with specific plyometric training, with
249 no additional training time during (in-season) competition, is an effective training strategy for increasing
250 maximal-intensity and endurance performance in female soccer players. Furthermore, our results
251 demonstrated that creatine supplementation during plyometric training may boost further adaptations
252 related to maximal-intensity exercise and repeated sprint ability.

253 Considering that neither group changed dietary intake during the experimental period, the increase
254 in body mass (1.4%) and body mass index in the CREATINE group could be attributed to the acute effect
255 of creatine supplementation, as similar increases in body mass have been shown after seven days of
256 supplementation in female soccer players (0.8%)¹⁰. Alternatively, creatine supplementation has been
257 shown to increase the cross-sectional areas of both type I and type II muscle fibers as well as several
258 myogenic regulatory factors during long-term training²⁴, although this effect may be more elusive in
259 female players after short-term training interventions¹⁵.

260 Our results indicated that both plyometric training groups improved sprint performances, change-
261 of-direction speeds and endurance at the end of the interventions; on the other hand, no changes were
262 observed in the CONTROL group. These results are similar to those previously reported in female soccer
263 players⁷. The improvements observed after plyometric training in unidirectional (i.e., sprint)²⁵ or maximal-
264 intensity change-of-direction maneuvers²⁶ may have been mediated by rapid (i.e., < 6-weeks)
265 neuromuscular adaptations of targeted muscle groups²⁷, which occur during even the most competitive
266 periods of the athletes' calendar (i.e., in-season)⁷. The observed improvements in endurance might have
267 occurred by means of cardiovascular (i.e., VO₂max)²⁸, neuromuscular-mediated changes in the athletes'
268 running economies²⁹ or neuromuscular power improvements that affect the athletes' change-of-direction
269 endurance results³⁰.

270 Although both plyometric training groups increased their sprint performances, change-of-direction
271 speeds and endurance, only the CREATINE group showed a meaningful increase in peak jump power

272 load (Table 2). More so, the CREATINE group showed a greater increase in 40-cm drop jump reactive
273 strength index, peak jump power load and squat jump performance compared with the CONTROL and
274 PLACEBO groups (Table 2). The greater enhancement in muscular capabilities observed with regard to
275 loads (i.e., peak jump power loads) and in concentric-only maximal-intensity performances (i.e., squat
276 jumps) in the CREATINE group may be indicative of greater force-related adaptations¹⁹. Alternatively,
277 compared to the PLACEBO group, the greater improvements in jump performance observed in the
278 CREATINE group might have been caused by smaller decays in drills-intensity during training sessions¹⁰
279 and reduced time required for recovery after training¹³. This is partially supported by the greater jump
280 heights, jump lengths and reactive strength indexes values (used as biofeedback in some training sessions)
281 observed (although not reported in this manuscript) in the CREATINE group during plyometric training
282 sessions.

283 RAST mean sprint times improved for both PLACEBO and CREATINE groups after plyometric
284 training (Table 3). However, compared to the PLACEBO group, the CREATINE group showed greater
285 improvement in RAST mean sprint times (Table 3). To the author's knowledge, the results reported herein
286 are novel, in that our experiments involved female soccer players, making comparisons with previous
287 studies difficult. However, creatine supplementation have shown to increase repeated sprint abilities of
288 male soccer players¹⁰, possible by means of increasing phosphocreatine re-synthesis rates during
289 recoveries between RAST sprints⁶; this adaptation might help explain the greater RAST improvements
290 observed in the CREATINE group compared to the PLACEBO group. As sprints¹ and their repetition⁴
291 during games are key aspects of soccer competition, and might be related with goals scored² and success³,
292 the greater power during repeated sprints²¹ achieved by the CREATINE group might allow female players
293 to achieve an important competitive advantage.

294

295 **5. Conclusions**

296 For female soccer players, replacement of some low-intensity technical-tactical soccer drills
297 during the in-season period with maximal-intensity exercise plyometric drills, in a short-term (i.e., 6

298 weeks) plyometric training intervention, induced higher maximal-intensity exercise and endurance
299 performance improvements compared to soccer training alone, and the improvements induced by
300 plyometric training were enhanced by creatine supplementation. In practical terms, creatine
301 supplementation may be seen as an ergogenic aid while applying plyometric training in adult female
302 soccer players, at least when the target is improving specific physical performance.

303

304 **Practical Implications**

305 · Replacing some low-intensity technical-tactical soccer drills with plyometric drills might induce higher
306 maximal-intensity and endurance performance improvements in participating female soccer players,
307 compared to soccer-training alone.

308 · Maximal-intensity and endurance performance improvements induced by plyometric drills might be
309 enhanced by creatine supplementation, particularly in task where a shift in force production might result in
310 more powerful movements (i.e., loads at peak power or SJ) or where increases in intramuscular creatine
311 content are relevant (i.e., RAST).

312 · Creatine supplementation, when combined with plyometric training, show no detrimental effect on
313 endurance performance of female soccer players during a short-term in-season competitive period.

314

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318

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Table 1. Descriptive data of the control group (CONTROL, n = 10), plyometric training group receiving placebo (PLACEBO, n = 10) and plyometric training group receiving creatine supplementation (CREATINE, n = 10).

	CONTROL	PLACEBO	CREATINE
Age (y)	22.5 ± 2.1	22.9 ± 1.7	23.1 ± 3.4
Body mass (kg)	60.1 ± 7.5	56.8 ± 5.4	60.4 ± 8.0
Height (m)	1.61 ± 0.06	1.64 ± 0.09	1.62 ± 0.04
Body mass index (kg.m⁻²)	23.3 ± 2.2	21.2 ± 1.4	23.2 ± 3.1
Session rating of perceived exertion^a	468 ± 332	396 ± 234	424 ± 229
Soccer experience (y)	7.9 ± 3.7	7.5 ± 4.2	8.3 ± 4.7
Competition games during experimental period	4.0 ± 1.6	4.2 ± 1.3	4.0 ± 1.5
Weekly participation in other sport or training modality (h)	1.3 ± 1.1	1.2 ± 1.0	1.4 ± 1.0

Notes: ^aSoccer training load was determined by multiplying the minutes of soccer training by the rating of perceived exertion after each soccer training session.

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Table 2. Training effects (with 90% confidence limits) for the jump performance variables for the control group (CONTROL, n = 10), plyometric training group receiving placebo (PLACEBO, n = 10) and plyometric training group receiving creatine supplementation (CREATINE, n = 10).

	Baseline Mean \pm SD	Change (%)	Effect sizes
Peak jump power (W)			
CONTROL	1979 \pm 211	1.7 (-2.4, 6.0)	0.13 (-0.19, 0.45)
PLACEBO	1940 \pm 338	5.0 (3.6, 6.4) ^a	0.25 (0.18, 0.32)
CREATINE	1969 \pm 250	7.0 (4.8, 9.3) ^{b, c}	0.49 (0.33, 0.64)
Peak jump power load (kg)			
CONTROL	14.1 \pm 6.9	-8.5 (-25.8, 12.8)	-0.09 (-0.31, 0.13)
PLACEBO	14.7 \pm 9.2	11.5 (-4.0, 29.6)	0.18 (-0.07, 0.42)
CREATINE	14.5 \pm 8.8	20.4 (7.1, 35.4) ^a	0.34 (0.12, 0.55) ^d
Squat jump (cm)			
CONTROL	23.5 \pm 4.1	-0.7 (-4.1, 2.9)	-0.04 (-0.22, 0.15)
PLACEBO	25.0 \pm 4.5	5.1 (2.8, 7.5) ^a	0.27 (0.15, 0.39)
CREATINE	24.9 \pm 4.4	8.3 (5.1, 11.5) ^{b, c}	0.47 (0.29, 0.65) ^d
Countermovement jump (cm)			
CONTROL	25.9 \pm 4.1	0.5 (-3.5, 4.8)	0.03 (-0.22, 0.29)
PLACEBO	28.7 \pm 5.1	4.4 (2.7, 6.1) ^a	0.23 (0.14, 0.32)
CREATINE	27.3 \pm 5.2	6.5 (3.9, 9.2) ^{b, c}	0.30 (0.18, 0.41)
20 cm reactive strength index (mm.ms⁻¹)			
CONTROL	1.40 \pm 0.6	1.1 (-5.7, 8.3)	0.03 (-0.15, 0.21)
PLACEBO	1.36 \pm 0.4	8.0 (5.6, 10.4) ^a	0.25 (0.18, 0.33)
CREATINE	1.33 \pm 0.3	10.7 (7.5, 14.0) ^{b, c}	0.42 (0.3, 0.54)
40 cm reactive strength index (mm.ms⁻¹)			
CONTROL	1.20 \pm 0.4	4.1 (-5.5, 14.7)	0.14 (-0.2, 0.49)
PLACEBO	1.30 \pm 0.3	10.1 (6.5, 14.0) ^a	0.39 (0.25, 0.53)
CREATINE	1.20 \pm 0.3	13.6 (7.8, 19.7) ^b	0.48 (0.29, 0.68) ^d
Right leg unilateral 20 cm reactive strength index (mm.ms⁻¹)			
CONTROL	0.63 \pm 0.3	4.9 (-8.1, 19.7)	0.08 (-0.14, 0.3)
PLACEBO	0.52 \pm 0.2	19.1 (11.5, 27.2) ^b	0.44 (0.28, 0.61)
CREATINE	0.65 \pm 0.3	16.2 (10.0, 22.7) ^b	0.40 (0.25, 0.54)
Left leg unilateral 20 cm reactive strength index (mm.ms⁻¹)			
CONTROL	0.43 \pm 0.1	1.8 (-8.8, 13.6)	0.06 (-0.31, 0.43)
PLACEBO	0.42 \pm 0.1	16.1 (11.8, 20.5) ^a	0.47 (0.35, 0.59)
CREATINE	0.43 \pm 0.2	17.9 (12.7, 23.4) ^{b, c}	0.46 (0.34, 0.59)

^{a, b}: denote significant difference pre to post training ($p < 0.05$ and $p < 0.01$, respectively). ^c: denote significant difference with the CONTROL post training ($p < 0.05$); ^d: denote significant greater effect compared to PLACEBO and CONTROL groups.

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Table 3. Training effects (with 90% confidence limits) for the running anaerobic sprint test (RAST), change of direction speed, 20-m sprint and endurance performance for the control group (CONTROL, n = 10), plyometric training group receiving placebo (PLACEBO, n = 10) and plyometric training group receiving creatine supplementation (CREATINE, n = 10).

	Baseline Mean \pm SD	Performance change (%)	Effect sizes
RAST mean sprint time (s)			
CONTROL	7.35 \pm 0.5	-0.6 (-3.2, 2.0)	-0.1 (-0.51, 0.31)
PLACEBO	7.08 \pm 0.6	-4.2 (-6.1, -2.3) ^a	-0.48 (-0.70, -0.26)
CREATINE	7.48 \pm 1.0	-5.3 (-7.6, -3.0) ^{b,c}	-0.55 (-0.80, -0.31) ^d
20-m sprint (s)			
CONTROL	3.99 \pm 0.2	-0.2 (-2.3, 2.0)	-0.05 (-0.58, 0.49)
PLACEBO	3.87 \pm 0.3	-3.2 (-4.4, -2.1) ^{a,c}	-0.41 (-0.56, -0.27)
CREATINE	3.98 \pm 0.4	-3.3 (-4.6, -2.0) ^{b,c}	-0.35 (-0.48, -0.21)
Change of direction speed test time (s)			
CONTROL	19.4 \pm 0.8	-0.5 (-2.2, 1.2)	-0.14 (-0.64, 0.35)
PLACEBO	18.8 \pm 1.2	-2.8 (-4.1, -1.6) ^a	-0.46 (-0.67, -0.26)
CREATINE	19.3 \pm 1.1	-2.9 (-3.9, -1.8) ^b	-0.55 (-0.75, -0.34)
20-m multi stage shuttle run test (min)			
CONTROL	7.4 \pm 1.9	2.0 (-1.3, 5.4)	0.06 (-0.04, 0.17)
PLACEBO	7.8 \pm 1.5	6.4 (3.2, 9.6) ^a	0.32 (0.16, 0.47)
CREATINE	8.0 \pm 1.6	7.2 (2.6, 12.1) ^b	0.34 (0.12, 0.56)

^{a, b}: denote significant difference pre to post training ($p < 0.05$ and $p < 0.01$, respectively). ^c: denote significant difference with the CONTROL post training ($p < 0.05$). ^d: denote significant greater effect compared to PLACEBO and CONTROL groups.