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

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Abstract

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

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

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

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

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

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

1. Introduction

Soccer players must perform numerous single maximal-intensity exercises, including jumping, kicking, accelerating and decelerating[1], actions that might precede most of the goals scored in competitive leagues[2], and correlate with competition success[3]. Repeating these maximal-intensity actions across a 90-min game is also important[4] and might be associated with endurance[5], but also with intramuscular creatine phosphate[6], a critical energy source for maximal-intensity actions. Therefore, investigating the methods by which single and repeated maximal-intensity actions (alongside endurance) can be enhanced in female soccer players is important for this population. Plyometric training in female players may improve their maximal-intensity exercise and endurance[7]. However, further investigation in this population is required[8], especially in regard to factors that might be mediating the effects of plyometric training on maximal-intensity exercise and endurance performances adaptations, such as dietary supplements[9].

Previous research involving male[10] as well as female soccer players[11] has demonstrated that acute creatine intake (i.e., one week) can enhance maximal-intensity exercise (e.g., jump, sprint, agility). Despite these meaningful results, recently it has been shown that acute creatine supplementation had no positive effects on fatigue and repeated sprint ability in a match simulation protocol[12], suggesting that longer-term use might be more beneficial to performance[13]. Among the few longitudinal studies conducted with regard to soccer, during a seven-week functional overreaching pre-season, creatine supplementation prevented deterioration of male soccer players' maximal-intensity performance[14]. In female players, creatine showed a positive effect on strength during a 13-week off-season[15]. However, to our knowledge, it remains unknown whether creatine supplementation and plyometric training can elicit similar improvements in female players when compared to plyometric training alone.

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

2. Methods

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

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

*****Table 1 near here*****

Participants were accustomed to the testing procedures, as athletes incorporate them as a regular aspect of their training schedule. Measurements were taken one week before and after intervention, completed in three non-consecutive days and were always administered in the same order, at the same time of the day and by the same investigators, who were blinded to each participant's group assignment. Ten minutes of standard warm-up was performed before testing.

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

Anthropometric measurements employed a stadiometer (Bodymeter 206, SECA, Hamburg, Germany) and an electrical scale (BF 100_Body Complete, BEURER, Ulm, Germany). Test protocols for the jumps, 20-m sprints, change-of-direction speed[17] and shuttle run tests[18] were performed as previously described. Briefly, for the jumps, players executed maximal effort jumps on a mobile contact mat (Ergojump; Globus, Codogne, Italy) with arms akimbo. Take-off and landing were standardized to full knee and ankle extension on the same spot. The participants were instructed to maximize jump height. In addition, for the 20 and 40 cm drop jump reactive strength index, players were instructed to minimize ground contact time after dropping down from a 20 and 40 cm drop box, respectively. For the 20-m sprints, participants had a standing start with the toe of the preferred foot forward and just behind the starting line. For the change of direction speed test, the timing system and procedures were same as for the 20-m sprint test, except that players started supine and completed a circuit with several changes of directions. For the shuttle run endurance test, players ran back and forth between two lines, spaced 20-m apart, in time with the "beep" sounds from an electronic audio recording. Each successful run of the 20-m distance was a completion of a shuttle. The beep sounded at a progressively increasing pace with every minute of the test, and the player had to increase speed accordingly until volitional fatigue. For unilateral jumps, instead of using both legs during jumping and landing, participants used their left and right legs alternatively.

Peak jump power measurements employed the same equipment and movement patterns as countermovement jump measurements; however, instead of adopting arms akimbo, participants put weight bars on their shoulders. To estimate power (W), a previously established testing protocol[19] and equation[20] [W = 65.1 × jump height (cm) × 25.8 × body mass (kg) - 1413.1] was used. Briefly, unloaded peak jump power was determined with a broomstick, while, in the following attempts, loads were increased by 5 kg and tests were stopped when reductions in power output were greater than 50 W compared to previous jump load measurements. Though the number of attempts were not predetermined, >90% of athletes completed between four and six attempts, reducing the probability that fatigue affected test outcomes.

Participants performed six 35-m maximal sprints with 10 s of rest for the RAST, as previously described and validated elsewhere[21]. The start for each sprint (10-s interval) occurred with a sound from the measurement equipment. Sprint times were measured using single beam infrared photoelectric cells (Globus Italy, Codogne, Italy) leveled ~0.7 m above the floor (i.e., hip level). The starting position was standardized to a split position with the toe of each preferred foot forward and behind the starting line. Mean RAST times were used for analyses.

All groups participated in the same soccer training program, such that similar training loads were measured by session rating of perceived exertion (RPE), as previously described[7] (Table 1). Briefly, each player's session RPE was collected ~30 min after each soccer training session and match to ensure that the perceived effort reflected the entire session rather than the most recent exercise intensity. Total training load was calculated as RPE × training session duration (i.e., minutes).

Experiments were completed during competition (i.e., mid portion of the in-season), which was similar between groups (Table 1). Participants in the plyometric training groups performed plyometric drills immediately after warm-up and as a substitute for some soccer drills (i.e., technical-tactical) within the usual 120-minute practice twice per week for six weeks. Plyometric intervention was determined based on previous research regarding soccer players[16]. A detailed description of the training program can be found in a previous study[18]. Briefly, plyometric training included unilateral and bilateral horizontal and vertical jumps with both cyclic and acyclic arm swings. Participants were motivated to achieve maximal effort in every jump, instructed to aim toward maximal vertical heights and horizontal distances for acyclic jumps and minimum ground contact times for cyclic jumps, in order to maximize reactive strength.

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

The CREATINE group participants received 20 g/d of creatine monohydrate (Gnc Pro Performance, USA), divided into four equal doses, over the course of one week, followed by single daily doses of 5 g for the next five weeks[14]. Participants in the PLACEBO and CONTROL groups were given the same dosages of glucose. During the loading phase, supplements were presented in four packages, and participants were instructed to ingest the packet contents at breakfast, lunch, dinner and before bedtime. During the maintenance phase, each participant consumed the supplement as a single dose during her lunch. To mask the taste and texture of the supplements provided to them, participants were asked to dissolve the supplements in juice that contained a small amount of carbohydrates to reduce creatine muscle uptake. Compliance to supplementation was monitored weekly via personal communication. Only one athlete in the CREATINE group reported mild gastrointestinal distress, but this participant completed the study. The supplement packages were coded, so that neither the investigators nor the participants were aware of the contents until completion of the analyses. The supplements were distributed by a staff member who was not an investigator in this study. Participants' feedback on group assignments post study demonstrated the effectiveness of the double blinded protocol (in which 30% of participants guessed their group assignments).

One week immediately before and after intervention, each participant's energy, macronutrient and creatine intakes were determined through a 24-hour food recall questionnaire conducted in three different days of the week, as previously described[22].

Statistical analyses employed the STATISTICA statistical package (Version 8.0; StatSoft, Inc, Tulsa). All values are reported as the means ± standard deviations. Relative changes (%) in performance and Cohen´s d-effect sizes (ES) are expressed with 90% confidence limits. Normality and homoscedasticity assumptions made for all data before and after intervention were checked using the Shapiro-Wilk and Levene tests, respectively. To determine the effects of the intervention on performance adaptations, groups were compared using mixed-design factorial ANOVA. When a significant F value occurred for interaction between groups or for main effects of group or time, Tukey post hoc procedures were performed. In addition, a between-groups one-way analysis of variance compared changes between groups (i.e., the differences between scores before and after the intervention). The α level was set at $p < 0.05$ for statistical significance. In addition to this null hypothesis testing, data were also assessed for practical meaningfulness using a magnitude-based inference approach. Threshold values for assessing magnitudes of ES were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively[23]. Magnitudes of differences in training effects between groups were evaluated non-clinically[23]: if the confidence interval overlapped thresholds for substantial positive and negative values, the effect was deemed unclear (i.e., trivial). The effect was otherwise clear and reported as the magnitude of the observed value with a qualitative probability, as above (i.e., small, moderate, large, and very large).

3. Results

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

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

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

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

*****Table 2 around here*****

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

*****Table 3 around here*****

4. Discussion

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

Considering that neither group changed dietary intake during the experimental period, the increase in body mass (1.4%) and body mass index in the CREATINE group could be attributed to the acute effect of creatine supplementation, as similar increases in body mass have been shown after seven days of supplementation in female soccer players (0.8%)[10]. Alternatively, creatine supplementation has been shown to increase the cross-sectional areas of both type I and type II muscle fibers as well as several myogenic regulatory factors during long-term training[24], although this effect may be more elusive in female players after short-term training interventions[15].

Our results indicated that both plyometric training groups improved sprint performances, change-of-direction speeds and endurance at the end of the interventions; on the other hand, no changes were observed in the CONTROL group. These results are similar to those previously reported in female soccer players[7]. The improvements observed after plyometric training in unidirectional (i.e., sprint)[25] or maximal-intensity change-of-direction maneuvers[26] may have been mediated by rapid (i.e., < 6-weeks) neuromuscular adaptations of targeted muscle groups[27], which occur during even the most competitive periods of the athletes' calendar (i.e., in-season)[7]. The observed improvements in endurance might have occurred by means of cardiovascular (i.e., VO2max)[28], neuromuscular-mediated changes in the athletes' running economies[29] or neuromuscular power improvements that affect the athletes' change-of-direction endurance results[30].

Although both plyometric training groups increased their sprint performances, change-of-direction speeds and endurance, only the CREATINE group showed a meaningful increase in peak jump power load (Table 2). More so, the CREATINE group showed a greater increase in 40-cm drop jump reactive strength index, peak jump power load and squat jump performance compared with the CONTROL and PLACEBO groups (Table 2). The greater enhancement in muscular capabilities observed with regard to loads (i.e., peak jump power loads) and in concentric-only maximal-intensity performances (i.e., squat jumps) in the CREATINE group may be indicative of greater force-related adaptations[19]. Alternatively, compared to the PLACEBO group, the greater improvements in jump performance observed in the CREATINE group might have been caused by smaller decays in drills-intensity during training sessions[10] and reduced time required for recovery after training[13]. This is partially supported by the greater jump heights, jump lengths and reactive strength indexes values (used as biofeedback in some training sessions) observed (although not reported in this manuscript) in the CREATINE group during plyometric training sessions.

RAST mean sprint times improved for both PLACEBO and CREATINE groups after plyometric training (Table 3). However, compared to the PLACEBO group, the CREATINE group showed greater improvement in RAST mean sprint times (Table 3). To the author's knowledge, the results reported herein are novel, in that our experiments involved female soccer players, making comparisons with previous studies difficult. However, creatine supplementation have shown to increase repeated sprint abilities of male soccer players[10], possible by means of increasing phosphocreatine re-synthesis rates during recoveries between RAST sprints[6]; this adaptation might help explain the greater RAST improvements observed in the CREATINE group compared to the PLACEBO group. As sprints[1] and their repetition[4] during games are key aspects of soccer competition, and might be related with goals scored[2] and success[3], the greater power during repeated sprints[21] achieved by the CREATINE group might allow female players to achieve an important competitive advantage.

5. Conclusions

For female soccer players, replacement of some low-intensity technical-tactical soccer drills during the in-season period with maximal-intensity exercise plyometric drills, in a short-term (i.e., 6 weeks) plyometric training intervention, induced higher maximal-intensity exercise and endurance performance improvements compared to soccer training alone, and the improvements induced by plyometric training were enhanced by creatine supplementation. In practical terms, creatine supplementation may be seen as an ergogenic aid while applying plyometric training in adult female soccer players, at least when the target is improving specific physical performance.

Practical Implications

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

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

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

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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: [a]Soccer training load was determined by multiplying the minutes of soccer training by the rating of perceived exertion after each soccer training session.

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 ± SD	Change (%)	Effect sizes
Peak jump power (W)			
CONTROL	1979 ± 211	1.7 (-2.4, 6.0)	0.13 (-0.19, 0.45)
PLACEBO	1940 ± 338	5.0 (3.6, 6.4) [a]	0.25 (0.18, 0.32)
CREATINE	1969 ± 250	7.0 (4.8, 9.3) [b, c]	0.49 (0.33, 0.64)
Peak jump power load (kg)			
CONTROL	14.1 ± 6.9	-8.5 (-25.8, 12,8)	-0.09 (-0.31, 0.13)
PLACEBO	14.7 ± 9.2	11.5 (-4.0, 29.6)	0.18 (-0.07, 0.42)
CREATINE	14.5 ± 8.8	20.4 (7.1, 35.4) [a]	0.34 (0.12, 0.55) [d]
Squat jump (cm)			
CONTROL	23.5 ± 4.1	-0.7 (-4.1, 2.9)	-0.04 (-0.22, 0.15)
PLACEBO	25.0 ± 4.5	5.1 (2.8, 7.5) [a]	0.27 (0.15, 0.39)
CREATINE	24.9 ± 4.4	8.3 (5.1, 11.5) [b, c]	0.47 (0.29, 0.65) [d]
Countermovement jump (cm)			
CONTROL	25.9 ± 4.1	0.5 (-3.5, 4.8)	0.03 (-0.22, 0.29)
PLACEBO	28.7 ± 5.1	4.4 (2.7, 6.1) [a]	0.23 (0.14, 0.32)
CREATINE	27.3 ± 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 ± 0.6	1.1 (-5.7, 8.3)	0.03 (-0.15, 0.21)
PLACEBO	1.36 ± 0.4	8.0 (5.6, 10.4) [a]	0.25 (0.18, 0.33)
CREATINE	1.33 ± 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 ± 0.4	4.1 (-5.5, 14.7)	0.14 (-0.2, 0.49)
PLACEBO	1.30 ± 0.3	10.1 (6.5, 14.0) [a]	0.39 (0.25, 0.53)
CREATINE	1.20 ± 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 ± 0.3	4.9 (-8.1, 19.7)	0.08 (-0.14, 0.3)
PLACEBO	0.52 ± 0.2	19.1 (11.5, 27.2) [b]	0.44 (0.28, 0.61)
CREATINE	0.65 ± 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 ± 0.1	1.8 (-8.8, 13.6)	0.06 (-0.31, 0.43)
PLACEBO	0.42 ± 0.1	16.1 (11.8, 20.5) [a]	0.47 (0.35, 0.59)
CREATINE	0.43 ± 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.

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 ± SD	Performance change (%)	Effect sizes
RAST mean sprint time (s)			
CONTROL	7.35 ± 0.5	-0.6 (-3.2, 2.0)	-0.1 (-0.51, 0.31)
PLACEBO	7.08 ± 0.6	-4.2 (-6.1, -2.3) [a]	-0.48 (-0.70, -0.26)
CREATINE	7.48 ± 1.0	-5.3 (-7.6, -3.0) [b, c]	-0.55 (-0.80, -0.31) [d]
20-m sprint (s)			
CONTROL	3.99 ± 0.2	-0.2 (-2.3, 2.0)	-0.05 (-0.58, 0.49)
PLACEBO	3.87 ± 0.3	-3.2 (-4.4, -2.1) [a, c]	-0.41 (-0.56, -0.27)
CREATINE	3.98 ± 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 ± 0.8	-0.5 (-2.2, 1.2)	-0.14 (-0.64, 0.35)
PLACEBO	18.8 ± 1.2	-2.8 (-4.1, -1.6) [a]	-0.46 (-0.67, -0.26)
CREATINE	19.3 ± 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 ± 1.9	2.0 (-1.3, 5.4)	0.06 (-0.04, 0.17)
PLACEBO	7.8 ± 1.5	6.4 (3.2, 9.6) [a]	0.32 (0.16, 0.47)
CREATINE	8.0 ± 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.