Creatine supplementation and sprint performance in soccer players

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ABSTRACT

MUJIKA, I., S. PADILLA, J. IBAÑEZ, M. IZQUIERDO, and E. GOROSTIAGA. Creatine supplementation and sprint performance in soccer players. *Med. Sci. Sports Exerc.,* Vol. 32, No. 2, pp. 518–525, 2000. **Purpose:** This investigation examined the effects of creatine (Cr) supplementation on intermittent high-intensity exercise activities specific to competitive soccer. **Methods:** On two occasions 7 d apart, 17 highly trained male soccer players performed a counter-movement jump test (CMJT), a repeated sprint test (RST) consisting of six maximal 15-m runs with a 30-s recovery, an intermittent endurance test (IET) consisting of forty 15-s bouts of high-intensity running interspersed by 10-s bouts of low-intensity running, and a recovery CMJT consisting of three jumps. After the initial testing session, players were evenly and randomly included in a CREATINE (5 g of Cr, four times per day for 6 d) or a PLACEBO group (same dosage of maltodextrins) using a double-blind research design. **Results:** The CREATINE group's average 5-m and 15-m times during the RST were consistently faster after the intervention (0.95 $\pm$ 0.03 vs 0.97 $\pm$ 0.02 s, $P < 0.05$ and 2.29 $\pm$ 0.08 vs 2.32 $\pm$ 0.07 s, $P = 0.07$, respectively). Neither group showed significant changes in the CMJT or the IET. The CREATINE group's recovery CMJT performance relative to the resting CMJT remained unchanged postsupplementation, whereas it tended to decrease in the PLACEBO group. **Conclusion:** In conclusion, acute Cr supplementation favorably affected repeated sprint performance and limited the decay in jumping ability after the IET in highly trained soccer players. Intermittent endurance performance was not affected by Cr. **Key Words:** HIGH-ENERGY PHOSPHATES, ERGOGENIC AIDS, ENERGY METABOLISM, AMMONIA

Recent investigations have focused on the possible ergogenic value of supplementing the athletes' diet with approximately 20 $g \cdot d^{-1}$ of creatine (Cr) monohydrate for 5 to 7 d. It has often been shown that this type of acute Cr supplementation can result in increased total muscle Cr (5,15,21,24,25,27,29,30,39,49) and phosphocreatine (PCr) (15,21,29,30,52) concentrations. Studies have also shown that this elevated intramuscular PCr can enhance the rate of ATP and PCr resynthesis after high-intensity efforts, causing a delayed onset of muscular fatigue and an increased performance during repeated bouts of high-intensity exercise (1,5,15,18,26,27,35).

In a recent review of the literature, it was suggested that highly trained athletes who participate in sports in which performance relies on repeated efforts could benefit from Cr ingestion by means of an increased ability to perform intermittent high-intensity exercise bouts either during training or competition (38). This would be the case in competitive soccer. Indeed, it has been reported that, among professional players, high-intensity running accounts for about 8–18% of the total playing time during a soccer match, whereas 70–80% of the playing time is spent walking or running at a low intensity (8,45,53,54). In addition to the intermittent high-intensity running pattern, players also perform 10–19 tackles and 9–13 headings, most of which involve jumping for aerial possession of the ball (8,19,54). Moreover, a relationship has been reported between the quality of the soccer play and the amount of high-intensity exercise performed during a match (19).

This investigation was thus designed to determine whether acute oral Cr supplementation could enhance performance and recovery in highly trained soccer players performing sport-specific exercise tasks, and to analyze the influence of this intervention on the main metabolic pathways supplying the necessary energy for the completion of those tasks.

METHODS

Subjects

Nineteen highly trained male soccer players (three goalkeepers, five defenders, eight midfield players, and three forwards) agreed to participate in this investigation. A written consent was obtained from the subjects after they were thoroughly informed of the purpose and potential risks of participating in the study. All experimental procedures were approved by the Ethics Committee of the Universidad del País Vasco. All subjects were members of the same team and were competing at a national level at the time of the

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study. None of the participating players was vegetarian or ate unusually large quantities of meat. Because of illness and injury, only 17 of the initial 19 subjects completed the study. Physical characteristics of the subjects are presented in Table 1.

Performance Testing

The experimental procedures started 3 d after the last match of the competitive season. Subjects did performance tests twice, 7 d apart. Because all subjects were members of the same team, they performed similar training programs during the experimental period. All subjects were familiar with the experimental procedures. Both testing sessions started by weighing the subjects (Seca 708, Hamburg, Germany) and were carried out after 1 d of complete rest, at the same time of the day, and under the same experimental conditions. Only one player was tested at a time, and each player was instructed and verbally encouraged to give a maximal effort for each performance test. Performance testing (Fig. 1) was initiated after a standardized 10-min warm-up that included low-intensity forward, sideways, and backward running, several acceleration runs, jumping at a progressively increased intensity, and stretching exercises.

Counter-movement jump test (CMJT). The resting CMJT consisted of three maximal vertical jumps performed on an Ergojump contact platform (Newtest OY, Oulu, Finland), which were initiated from a standing position, allowed a preparatory counter-movement, and were interspersed with approximately 30 s of rest. Subjects were required to keep their hands on their waist throughout the jump. Flight times were measured by means of a digital timer connected to the platform; these times were used to calculate the height of the jump (14). The best of the three jumps was retained for each player.

Repeated sprint test (RST). Three minutes after completion of the CMJT, subjects performed six maximal 15-m sprints that were interspersed by 30 s of recovery. Each sprint was initiated from an individually chosen standing position. Upon initiation of each run, subjects passed through a photocell gate (Newtest OY, Oulu, Finland) placed 0.4 m above the ground, which started a digital timer. Additional photocell gates were placed at 5 m and 15 m, which recorded elapsed and final times, respectively.

Intermittent endurance test (IET). Eight minutes after the RST, the field players but not the 3 goalkeepers took a previously described IET (6,7). Briefly, this test lasts 16.5 min, during which players alternate between forty 15-s bouts of high-intensity exercise and thirty-nine 10-s low-intensity exercise bouts. During the high-intensity periods, players follow an outlined circuit around the penalty area of a soccer field, running 40 m forward, 8.25 m backwards, 95.25 m forward and through a slalom, 8.25 m sideways while facing away from the center of the circuit, and 8.25 m sideways while facing the center of the circuit. During the low-intensity periods, players jog to the center of the circuit and back to the position they reached during the previous high-intensity period. The test result is the distance covered during the 40 periods of high-intensity running.

TABLE 1. Physical characteristics of the participating subjects (N = 17).

Age (yr)	20.3 ± 1.4
Height (cm)	179.9 ± 5.5
Mass (kg)	74.8 ± 5.5
Body fat (%)	7.9 ± 1.6

Values are mean ± SD.
Body fat was estimated from seven skinfold measurements as described by Jackson and Pollock (32).

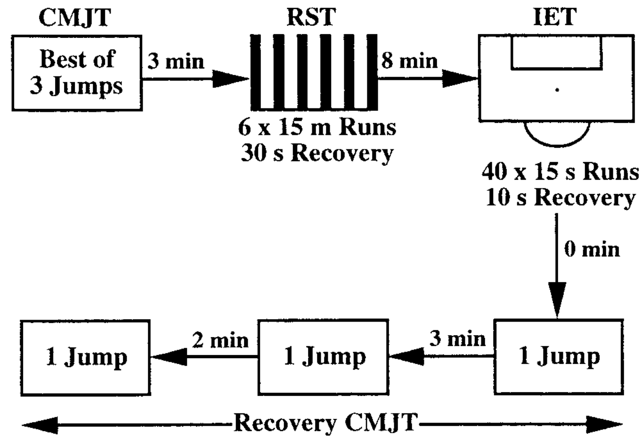

Figure 1—Schematic design of the performance testing protocol. CMJT, counter-movement jump test; RST, repeated sprint test; IET, intermittent endurance test.

Recovery CMJT. After completion of the IET, subjects were instructed to run to another Ergojump contact platform situated by the penalty area where the IET had been completed and immediately perform a maximal counter-movement jump, followed by two more jumps, 3 min and 5 min into recovery, respectively.

Blood Ammonia

A 20-μL capillary blood sample was taken from an ear lobe 3 min after completion of the RST. Samples were immediately assayed for ammonia concentration using a reflectometrical method (Ammonia Checker II, Kyoto Daiichi, Kagaku Co., Ltd., Japan; Menarini Diagnostics, Italy).

Blood Lactate

Ear lobe blood samples (25 μL) were also taken 3.5 min after completion of the RST and 3.5 min after the IET. Whole-blood lactate concentrations were measured enzymatically using a YSI 2300 STAT Plus (Yellow Springs Instruments, Yellow Springs, OH).

Urinary Creatinine

Twelve-hour overnight urine samples were collected in containers each day of performance testing. After collection, all samples were measured for urinary volume, and mixed samples were immediately analyzed for urinary creatinine concentration by spectrophotometry using a Synchron CX7 apparatus (Beckman Instruments Inc., Brea, CA).

Creatine or Placebo Supplementation

After the initial baseline control session, players were assigned to either a Cr monohydrate supplementation group (CREATINE, $N = 8$) or a placebo group (PLACEBO, $N = 9$). Groups were matched for physical characteristics, playing positions, and level of performance on the different tests. A double-blind research procedure was followed to administer the Cr and placebo treatments. The CREATINE group ingested four 5-g doses of Cr monohydrate (CREATINA ENERVIT) per day for 6 d, whereas the PLACEBO group ingested the same dosage of maltodextrins. The supplementation was initiated 1 d after the control session and ended 1 d before the second performance testing session.

Statistical Analysis

Values are expressed as mean ± SD unless otherwise stated. All reported values are from the 17 subjects who completed the study. A student's *t*-test for unpaired samples indicated that there were no baseline differences between groups. Presupplementation versus postsupplementation comparisons within groups were performed using a one-way ANOVA for repeated measures. The level of statistical significance was defined as $P < 0.05$.

RESULTS

Side Effects

None of the participating subjects complained about gastrointestinal distress, muscular problems, or any other supplementation-associated side effects.

Body Mass

The CREATINE group significantly increased body mass from 73.8 ± 5.7 to 74.4 ± 6.0 kg ($P < 0.05$) during the supplementation period. Six of the eight players included in this group increased their body mass between 0.4 and 1.4 kg, whereas one subject maintained and one subject decreased body mass by 0.6 kg. The body mass of the PLACEBO group, on the other hand, remained unchanged throughout the experimental period (75.7 ± 5.4 and 75.9 ± 5.8 kg before and after the supplementation, respectively).

Performance

CMJT. Neither group showed significant changes in the CMJT after the supplementation period. The CREATINE group jumped 47.4 ± 6.0 and 46.8 ± 6.0 cm before and after the intervention, respectively. Two of the subjects included in this group improved, one maintained, and five decreased the height of their counter-movement jump. Values for the PLACEBO group were 47.1 ± 4.5 and 47.1 ± 4.8 cm, respectively, with five of the subjects improving and four decreasing their performance in this test.

RST. Group performance values attained in the RST are illustrated in Figure 2. The CREATINE group showed consistently faster posttreatment 5-m and 15-m performance times over the six sprints. The improvements were statistically significant at the 5-m distance of sprint 1 and at the 15-m distance of sprint 2 and were slightly above the level of statistical significance at the 5-m distance of sprint 2 ($P = 0.07$) and at the 15-m distance of sprints 1 and 3 ($P = 0.07$ and $P = 0.06$, respectively). Improvements were also observed in the sum of times (5.81 ± 0.14 vs 5.68 ± 0.17 s, $P < 0.05$ and 13.88 ± 0.41 vs 13.74 ± 0.47 s, $P = 0.05$ for 5-m and 15-m distances, respectively) and the average times (0.97 ± 0.02 vs 0.95 ± 0.03 s, $P < 0.05$ and 2.32 ± 0.07 vs 2.29 ± 0.08 s, $P = 0.07$, for 5-m and 15-m distances, respectively) of the six sprints, with all but one of the subjects achieving faster times. The PLACEBO group ran consistently faster postsupplementation in the first three sprints (Fig. 2). However, statistical significance was only reached at the 15-m distance of sprint 3, whereas the 5-m times of sprints 1 and 3 tended to be faster ($P = 0.08$). Neither the sum of times (5.79 ± 0.14 vs 5.72 ± 0.16 s for a 5-m distance, and 13.79 ± 0.27 vs 13.74 ± 0.32 s for a 15-m distance) nor the average times (0.97 ± 0.02 vs 0.96 ± 0.03 s for a 5-m distance, and 2.30 ± 0.04 vs 2.29 ± 0.05 s for a 15-m distance) changed significantly in this group.

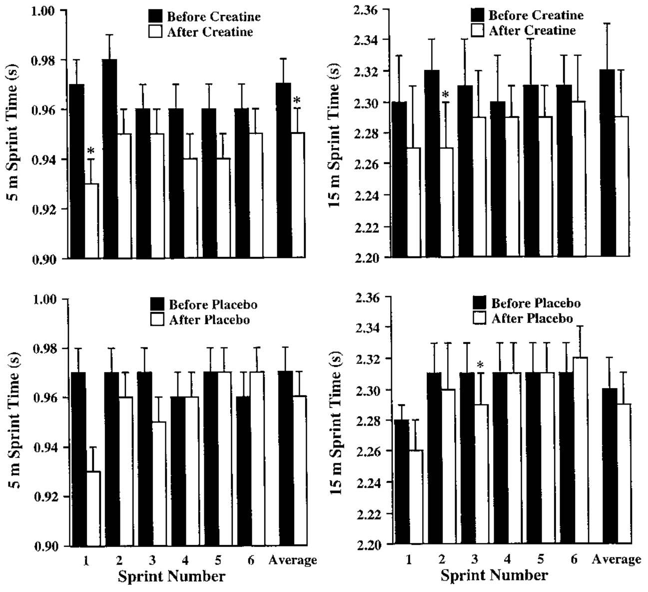

Figure 2—Five-meter and 15-m performance times during the repeated sprint test before and after the creatine or placebo supplementation period. * Denotes a significant difference between presupplementation and postsupplementation. Values are mean ± SE.

IET. Presupplementation and postsupplementation IET performance values were statistically unchanged in the CREATINE (1747 ± 61 vs 1751 ± 61 m, respectively) and the PLACEBO (1743 ± 49 vs 1760 ± 47 m, $P = 0.09$) groups.

Recovery CMJT. Even though both groups decreased performance in this test after the supplementation (average heights of the three jumps preintervention and postintervention were 47.1 ± 4.4 vs 45.0 ± 5.5 cm, $P < 0.05$ for CREATINE and 45.7 ± 3.7 vs 42.4 ± 2.9 cm, $P < 0.05$ for PLACEBO, respectively), the CREATINE group's post-IET jumping performance relative to the resting CMJT

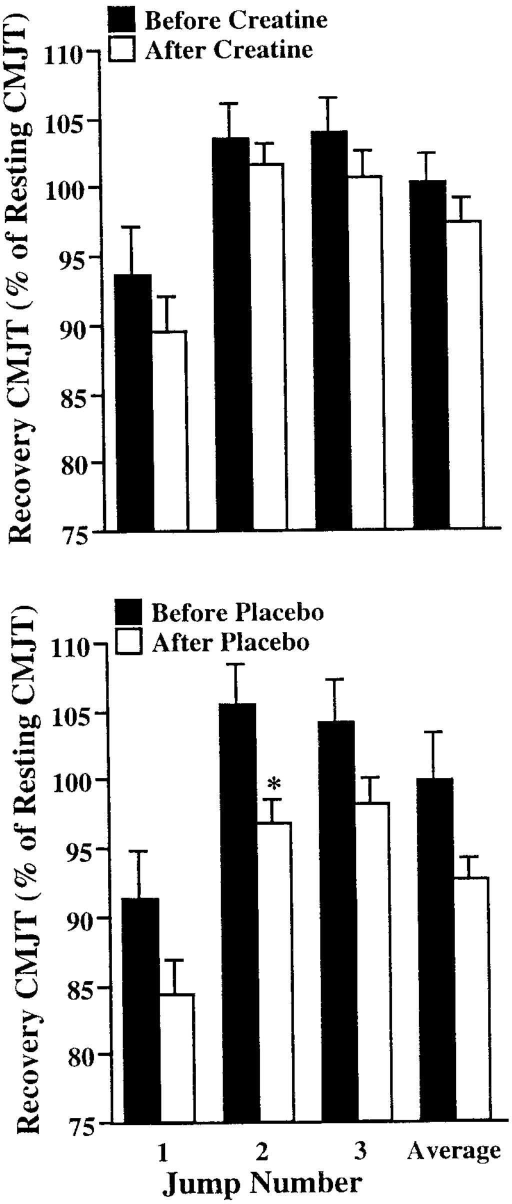

Figure 3—Recovery counter-movement jump test (CMJT) performance, expressed as a percentage of the performance attained in the resting CMJT, before and after the creatine or placebo supplementation period. * Denotes a significant difference between presupplementation and postsupplementation. Values are mean ± SE.

remained statistically unchanged postsupplementation (Fig. 3), whereas the PLACEBO group showed a tendency toward worsened performance ($P = 0.07$ and $P < 0.05$ for jumps 1 and 2; $P = 0.07$ for the average of the three jumps).

Blood Ammonia

Blood ammonia concentration values measured after the RST are shown in Figure 4. These values decreased postsupplementation in both the CREATINE (from 119.5 ± 44.8 to 81.1 ± 17.6 μmol·L^{-1}, $P < 0.05$) and PLACEBO (from 103.1 ± 27.9 to 66.0 ± 17.0 μmol·L^{-1}, $P < 0.01$) groups.

Blood Lactate

No significant difference was observed when comparing post-RST and post-IET blood lactate concentrations before and after the Cr or placebo supplementation period (Fig. 5).

Urinary Creatinine

Urinary creatinine excretion tended to increase postsupplementation in the CREATINE group (215.1 ± 69.9 vs 262.8 ± 60.4 mg·dL^{-1}, $P = 0.09$), whereas it remained unchanged in the PLACEBO group (165.2 ± 45.2 vs 176.8 ± 52.9 mg·dL^{-1}). Urinary volume did not change with the treatment in either group: 46.4 ± 9.0 mL·h^{-1} presupplementation and 39.3 ± 13.4 mL·h^{-1} postsupplementation in the CREATINE group and 67.7 ± 23.4 presupplementation and 55.0 ± 18.4 mL·h^{-1} postsupplementation in the PLACEBO group.

DISCUSSION

The results of this investigation indicate that highly trained soccer players can benefit from an acute "Cr loading" strategy (20 g·d^{-1} for 6 d) because this intervention resulted in an improved repeated sprint performance and limited the decay in jumping ability after an exhausting intermittent endurance exercise. Additionally, the present results show that Cr supplementation reduces postexercise blood ammonia concentration but does not alter blood lactate concentration.

The Cr supplementation protocol used in the present study has been repeatedly shown to be a useful strategy to Cr load human skeletal muscle (5,15,21,24,25,27,29,30,39,49,52). Several authors have also shown that this intervention is often accompanied by increases in body mass of approximately 0.4–2.1 kg (1,2,5,20,24,25,37,51). In the present investigation, a 0.6-kg average increase in body mass was observed in the

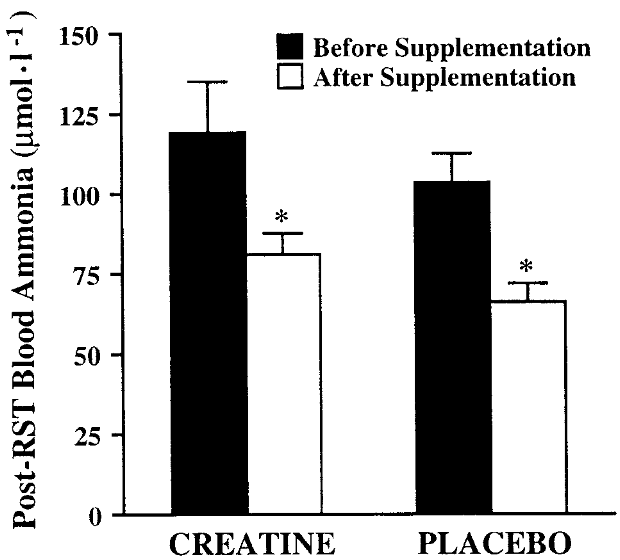

Figure 4—Post-repeated sprint test (RST) blood ammonia concentrations before and after the creatine or placebo supplementation period. * Denotes a significant difference between presupplementation and postsupplementation. Values are mean ± SE.

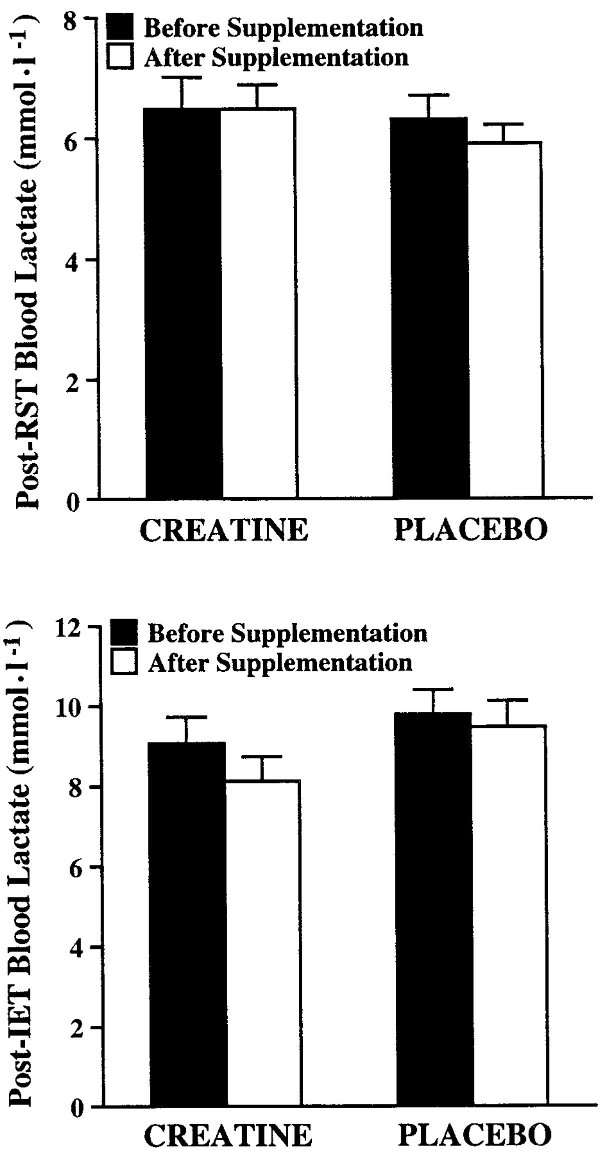

Figure 5—Post–repeated sprint test (RST) and post-intermittent endurance test (IET) blood lactate concentrations before and after the creatine or placebo supplementation period. Values are mean ± SE.

CREATINE group, which suggests that a Cr loading was attained in this group of soccer players. Moreover, it has been suggested that the rate of creatinine formation is directly proportional to the muscle Cr concentration (30), and an elevated urinary creatinine excretion was measured after the Cr ingestion period. Some authors have suggested that the increased body mass after Cr supplementation may be attributed to a positive nitrogen balance, which causes an increase in protein synthesis rate (1,4,55). This possibility, however, seems to be more plausible as a result of longer periods of Cr intake simultaneous with resistance training programs (9,18,34,35,42). Based on their observation of a decline in urinary volume occurring at the onset of Cr ingestion, other authors have suggested that these quick increases in body mass are related to body water retention (30). Although no significant decline in the postsupplementation urinary volume was measured in this study, the possibility of a water retention-induced increase in body mass cannot be discarded based on the available body of data. In fact, the above-mentioned authors reported a marked reduction in urinary volume during the initial 2–3 d of Cr intake, and a return to normal levels by the end of the supplementation period (30).

It has been shown that Cr supplementation can improve repeated sprint performance in subjects of various training conditions performing different non–weight-bearing exercise tasks, such as cycling, swimming, or isokinetic knee extensions (1,5,15,26,28,35,43). To the best of the authors' knowledge, however, the present study is the first to show the ergogenic value of Cr for highly trained athletes performing repeated running sprints lasting $<$ 2.5 s. In the first three sprints of the RST, both groups attained faster postsupplementation times. This initial improvement could be attributed to a tapering effect because the investigation took place immediately after the last match of the season and there was a drastic reduction of the training load during the intervention week. However, only the CREATINE group maintained faster sprint times in the remaining three sprints. Considering that ATP production during sprint exercise lasting 6 s or less relies almost exclusively on anaerobic energy sources (22,31,47) and Cr ingestion increases anaerobic capacity and maximum accumulated oxygen deficit (33), and assuming, based on the measured post-RST blood lactate values, that the glycolytic contribution to energy provision was relatively low, the present results suggest an increase in ATP resynthesis rate from PCr in the CREATINE group during the second half of the RST. It should also be pointed out that Cr-supplemented subjects performed a higher amount of work resulting in a similar blood lactate concentration because they ran faster despite their increased body mass. The observed improvement could represent a substantial performance advantage in competitive soccer because each player usually performs ~60–90 sprints per match and travels an average distance of 15–25 m in each of those sprints (45,54). Indeed, the average 0.02-s improvement over 5 m, and 0.03-s over 15 m would translate into distances of 10.3 and 19.3 cm, respectively, which would be more than enough to outrun an opponent and, for example, attain possession of the ball.

These results are in contrast with those previously reported concerning highly trained subjects. Redondo et al. (44) reported no Cr-induced improvements in field hockey and soccer players performing three 60-m races with a 2-min rest between runs. In a recent study, Smart et al. (48) found that highly trained soccer players did not improve performance over thirty 20-m sprints interspersed with 30-s rest periods. The discrepancy between these and the present results could be related to the difference in the amount of repetitions, which could affect the relative contribution of the energy sources to the ATP provision. Indeed, it has been shown that the dependency on aerobic metabolism during repeated sprints increases with the number of repetitions (12,22). More to the point, the oxygen uptake of well-trained subjects measured after fifteen 40-m sprints interspersed with 30-s rest periods increased to 66% of maximum oxygen uptake (3). This increased reliance on aerobic energy sources could minimize the ergogenic potential of an increased PCr availability.

At resting conditions, Cr supplementation did not result in an enhanced counter-movement jump performance in this study. After a similar short-term Cr ingestion procedure, Balsom et al. (5) and Miszko et al. (36) found no vertical jump improvement in physically active males and female softball players, respectively. Longer supplementation periods, on the other hand, have been reported to favorably affect vertical jump in male football players and track athletes (23,50). This difference could be related to the Cr-induced changes in body mass. As discussed above, short-term increases in body mass seem to be most likely caused by an increased body water content, which would be detrimental for performance in events that depend on overcoming the force of gravity, such as vertical jump. On the other hand, if long-term Cr ingestion along with resistance training evokes increments in lean muscle tissue, as previously suggested, this could indeed result in an improved vertical jump performance.

There are other indications in the literature that not only does Cr intake not enhance endurance performance in body weight-bearing sports, but it may even have a detrimental effect on it (2,38). In this investigation, the CREATINE group did not show any significant performance change in the IET after the treatment, despite an increased body mass. In line with the data obtained in a recent investigation in which a group of triathletes increased their high-intensity exercise performance included into an endurance exercise task, which was not affected by Cr intake (20), the lack of an ergolitic effect could be related to the intermittent nature of the IET. This endurance test was designed to reflect the intermittent activity profile of soccer and to evaluate the player's endurance capacity in competition (6,7). Therefore, it stresses not only aerobic but also anaerobic energy production pathways, as reflected by the high post-IET blood lactate values and the decreased jumping ability immediately after completion of the test. Thus, it is possible that a body weight-related ergolitic effect could have been counterbalanced by a Cr ingestion-induced increased phosphagen availability.

Both groups of players experienced a decay in their post-IET jumping ability after the supplementation period. Although this finding was somewhat surprising and difficult to explain using the available data, it could be hypothesized that it was the result of a diminished PCr recovery after the IET, in relation with a possible detraining effect caused by the drastic training reduction that took place during the intervention week. Indeed, postexercise PCr resynthesis is an oxygen-dependent process that is limited by the rate of oxidative phosphorylation and the recovery of muscle pH (11,12,13,40,46), and studies on highly trained subjects have shown that 7 d of detraining can lead to a reduced oxidative potential, reduced muscle glycogen content, greater postexercise disturbance in blood acid-base balance, and reduced ability to generate power (16,41). These factors could have thus contributed to the reduced post-IET jumping performance after the supplementation period. The CREATINE group, however, was able to maintain a higher jumping performance level relative to the resting CMJT than the PLACEBO group, which indicates a facilitated PCr recovery because of an increased muscle phosphagen pool. This result could have a great influence on competitive soccer performance, considering that it would facilitate the aerial possession of the ball during the final minutes of a match and that this type of action often determines the final score in competitive soccer.

The observed reduction in post-RST blood ammonia concentration after Cr supplementation is in keeping with previously reported results (10,17,26,37,39,43). This result reflects a lowered AMP deamination during the repeated bouts of sprint running, which suggests that higher ATP turnover rates can be attained after Cr supplementation without a concomitant increase in the rate of adenine nucleotide degradation. However, the interpretation of the above-mentioned observation must remain very prudent because a reduced postexercise blood ammonia concentration was also observed after placebo supplementation.

According to the measured values, Cr supplementation did not alter the blood lactate response to the RST, despite an improved performance in this test. Based on this and previously published similar findings (10,15,26,43), we suggest that the higher ATP resynthesis rates that were presumably attained to allow for the faster sprint running times were achieved without an increased reliance on anaerobic glycolysis. Indeed, it has been estimated that about 150 mmol of additional high energy phosphates would be available after a Cr supplementation procedure similar to the one used in this study (33). Post-IET blood lactate concentrations, which were somewhat higher than those reported by Bangsbo and Lindquist (7) for the same testing protocol, did not change after Cr ingestion. This result is in agreement with a study in which blood lactate values of trained subjects after a 6-km run in undulating terrain were very similar to those measured in the present investigation (2).

To conclude, the present results indicate that acute Cr supplementation (20 $g \cdot d^{-1}$ for 6 d) has an ergogenic potential for highly trained soccer players. Indeed, Cr-supplemented players showed an improved performance during six 15-m sprints, as well as a limited decay in jumping performance after an exhausting soccer-specific intermittent endurance test. These improvements could have a great impact on a player's performance level during actual competitive soccer match-play. According to the measured blood ammonia and blood lactate concentration values, we suggest that the observed ergogenic effects occurred in concomitance with a reduced adenine nucleotide degradation and without an increased reliance on anaerobic glycolysis.

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