

Acute Creatine Supplementation and Performance During a Field Test Simulating Match Play in Elite Female Soccer Players

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This study investigated the effects of acute creatine (Cr) supplementation on the performance of elite female soccer players undertaking an exercise protocol simulating match play. On two occasions, 7 days apart, 12 players performed 5 × 11-min exercise testing blocks interspersed with 1 min of rest. Each block consisted of 11 all-out 20-m running sprints, 2 agility runs, and 1 precision ball-kicking drill, separated by recovery 20-m walks, jogs, and runs. After the initial testing session, subjects were assigned to either a CREATINE (5 g of Cr, 4 times per day for 6 days) or a PLACEBO group (same dosage of a glucose polymer) using a double-blind research design. Body mass (BM) increased (61.7 ± 8.9 to 62.5 ± 8.9 kg, $p < .01$) in the CREATINE group; however, no change was observed in the PLACEBO group (63.4 ± 2.9 kg to 63.7 ± 2.5 kg). No overall change in 20-m sprint times and agility run times were observed, although the CREATINE group achieved faster post-supplementation times in sprints 11, 13, 14, 16, 21, 23, 25, 32, and 39 ($p < .05$), and agility runs 3, 5, and 8 ($p < .05$). The accuracy of shooting was unaffected in both groups. In conclusion, acute Cr supplementation improved performance of some repeated sprint and agility tasks simulating soccer match play, despite an increase in BM.

Key Words: high-energy phosphates, ergogenic aids, repeated sprints, agility, body mass, lactate

Introduction

It is now well established that acute supplementation with creatine (Cr) increases muscle Cr and phosphocreatine (PCr) concentrations (4, 8, 12, 14, 16, 18, 19, 33). Numerous studies have demonstrated that acute Cr supplementation is associated with an enhanced ability to perform repeated high-intensity exercise bouts inter-

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persed by short recovery periods (1, 2, 4, 8, 10, 11, 15, 17, 21, 26, 27, 32), although a smaller number of studies have shown no performance benefit (5, 9, 12). Many of these studies have been undertaken in a laboratory setting and have involved essentially untrained subjects. Some researchers have reported beneficial effects of Cr loading on field-based performance measures with highly trained athletes (1, 17, 21, 26, 27, 32, 34). However, a major concern of most of these studies is that performance protocols do not precisely mimic the activity patterns of actual competition.

Although the literature supporting beneficial performance outcomes from Cr supplementation in repeated high-intensity exercise situations with short recovery periods is robust, it is not clear whether these benefits apply equally across all sporting situations. Variables include the duration of the exercise efforts, the duration of the recovery periods, whether the exercise is weight-bearing, and the gender and caliber of the athletes. Indeed, there are few studies involving repeated brief sprints (1, 26), and none of these involve elite female athletes. Therefore, this study was undertaken to investigate the effects of an acute Cr supplementation regimen on the performance of elite female soccer players undertaking an exercise protocol that simulated the activity patterns of match play.

Methods

Subjects

Fourteen elite female soccer players (1 goal keeper, 3 defenders, 6 midfield players, and 4 forwards) from the 22 member squad of the Australian Institute of Sport Soccer program were eligible and willing to participate in this study. All subjects were current members of the Australian National Soccer Team. A written consent was obtained from subjects after they were thoroughly informed of the purpose and risks of participating in the study. One of the participating subjects followed a lacto-ovo-vegetarian diet. All experimental procedures were approved by the Australian Institute of Sport Ethics Committee. Because of illness and injury, only 12 of the initial 14 players completed the study. Physical characteristics of the subjects are presented in Table 1. Subjects were instructed to refrain from taking Cr supplements 8 weeks before the commencement of the study.

Table 1 Subjects' Physical Characteristics (*N* = 12)

Variable	Value
Age (years)	22.1 ± 5.4
Height (cm)	166.0 ± 7.2
Body mass (kg)	62.6 ± 6.4
Body fat (mm)	97.3 ± 27.9

Note. Values are mean ± SD. Body fat was estimated from seven skinfold measurements as described by Telford et al. (30).

Performance Testing

Subjects participated in two performance testing sessions 7 days apart, immediately before and after the experimental period. The investigation was conducted during the final phase of their training program leading up to their participation in the Sydney 2000 Olympic Games, 8 weeks before the first match. Testing took place in an indoor soccer arena with a synthetic grass surface, and testing time and conditions were replicated for each subject on both occasions.

A standardized testing protocol was designed to mimic the physical demands of a soccer match as closely as possible. Although the duration of a soccer match is 90 min plus injury overtime, discussions with players and coaches indicated that it would be difficult to gain the compliance of players to complete two full-length match simulations at 100% game intensity on an indoor synthetic soccer surface during their Olympic preparation. However, it was agreed that a 60-min match simulation would be a suitable compromise, allowing a genuine effort from players while eliciting a reasonable physiological response. We noted that this protocol was considerably greater in duration than the test protocols used to simulate soccer performance in other studies of creatine supplementation (26). All participating subjects were familiar with the testing procedures and completed one familiarization trial before the study. Furthermore, the performance tests included in the study were modeled on the players' routine physiology testing protocols. The study testing was built into the players' training schedule so that training was controlled for the week prior to each performance session, and a standardized diet providing 7 g carbohydrate per kilogram body mass (BM) was provided to each subject for the 24-hour period before each test. Food diaries were kept by each subject to assess compliance with the standardized nutritional procedures. All participating subjects were weighed on Precision Health Scales UC 300 (A & D Company, Ltd., Tokyo, Japan) in the early morning after an overnight fast on the day after each testing session.

Subjects completed a standardized warm-up before initiating the performance testing protocol illustrated in Figure 1. The protocol consisted of five 12-min exercise testing blocks (1 min of exercise and 1 min recovery) based on activity patterns previously observed in female soccer matches. Each of these exercise testing blocks consisted of 11 all-out 20-m running sprints, two agility runs, and one precision ball-kicking drill (described below), separated by several standardized recovery 20-m walks, jogs, and runs (Figure 1). A compact disc was developed to ensure consistency of instructions and timing of performance and non-performance tasks. Total time for each performance trial was 60 min ($5 \times 11 \text{ min} + 1 \text{ min recovery}$). During both performance sessions, 2 subjects at a time were tested on parallel testing settings, and each player was verbally encouraged to provide a maximal effort for

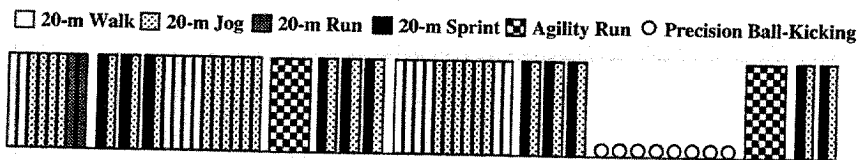


Figure 1 — Schematic representation of a performance testing block. Each block was repeated five times, with 1-min recovery intervals between blocks.

the duration of the test.

Repeated Sprints. Each 20-m sprint was initiated from an individually selected standing position 20-cm behind a photocell gate (Swift Performance, Lismore, Australia), which started a digital timer. Sprint time was recorded by the system's control panel when the subject passed through a second set of photocell gates placed at the 20-m position.

Agility Runs. Each agility run was initiated from an individually selected standing position 20 cm behind a photocell gate (Swift Performance, Lismore, Australia), which started a digital timer. Agility time was recorded by the system's control panel once the subject completed the agility circuit and passed through the set of photocell gates placed at the start-finish position. The agility run was performed on a 4.5-m square circuit (Figure 2).

Precision Ball-Kicking. Players were required to kick a rolling ball into a 0.8- × 2.3-m target constructed in the center of a goal. Four balls were rolled from the players' left-hand side, followed by four balls from the players' right-hand side. Balls were rolled at 6-s intervals from purpose-built ramps to ensure a constant ball speed. Players were instructed to kick the ball with their dominant kicking foot when it reached a 1.0- × 1.0-m square marked on the playing surface 7.0 m away from the target. Between each ball strike, subjects returned to a baseline position 5.5 m behind the strike zone before approaching the next ball.

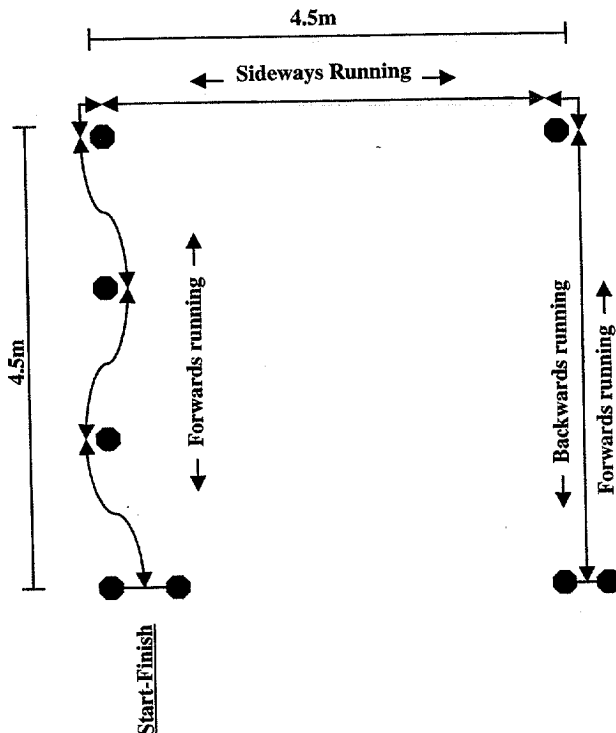


Figure 2 — Diagram of Agility Run Circuit.

Physiological Measurements

Heart Rate. Heart rate was measured at 5-s intervals throughout each testing session using a heart rate monitor (Sport Tester PE 3000, Polar Electro Oy, Kempele, Finland). Mean heart rate for each exercise testing block was computed.

Blood Variables. Fingertip blood samples (25 μ L) were collected immediately after completion of each 11-min exercise testing block. Blood lactate concentration and pH were analyzed by a Blood and Oximetry Analyzer (ABL 725, Radiometer Medical A/S, Copenhagen, Denmark).

Rating of Perceived Exertion (RPE). Immediately after completion of each 11-min exercise testing block, players were asked to provide a rating of their perceived effort using the Borg scale.

Creatine or Placebo Supplementation

At the completion of the initial performance testing, subjects were assigned to either a Cr monohydrate supplement group (CREATINE, $n = 6$) or a placebo group (PLACEBO, $n = 6$). Groups were matched for physical and performance characteristics. Using a double-blind research procedure, the experimental group ingested four doses of 5 g of micronized Cr monohydrate (Aussie Bodies Pty Ltd., Mt. Waverley, Australia) per day for 6 days. The placebo group ingested an identical dosage of a glucose polymer. The creatine monohydrate or glucose polymer was mixed with a flavored drinking powder to disguise the taste and texture differences and was individually packaged for each player for each of the treatment days. All subjects reported consuming each of their daily supplements when completing a questionnaire at the completion of the study.

Statistical Analysis

All reported values correspond to the 12 players who completed the study and are expressed as mean \pm *SD*, except in figures, in which values are mean \pm *SE*. Both groups presented similar physical characteristics, mean performance, and physiological values at baseline, as shown by a student's *t* test for unpaired samples. A one-way ANOVA for repeated measures was used to compare pre- versus post-supplementation values within each group with Scheffe's post hoc tests being applied when a significant difference or interaction was noted. The level of statistical significance was set at $p < .05$.

Results

Side Effects

The only identified side effect associated with the supplementation was one case of mild gastrointestinal distress, reported by one of the subjects included in the CREATINE group. This, however, did not prevent her from completing the study.

Body Mass

BM increased significantly from 61.7 ± 8.9 to 62.5 ± 8.9 kg ($p < .01$) in the CREATINE group following the supplementation period. All 6 players included in this

group showed an increased BM, ranging between 0.3 and 1.5 kg. No significant change in BM was observed in the PLACEBO group (63.4 ± 2.9 kg before supplementation and 63.7 ± 2.5 kg after supplementation).

Performance

Sprints. Performance times attained by each group before and after the experimental period are illustrated in Figure 3. The CREATINE group achieved consistently faster post-supplementation times between sprints 10 and 47, the improvement reaching statistical significance in 9 of 55 sprints (sprints 11, 13, 14, 16, 21, 23, 25, 32, and 39). The average time for all 55 sprints decreased from 3.75 ± 0.19 to 3.69 ± 0.18 s, but this change did not reach the statistical significance level. On the other hand, only 2 of 55 sprints (sprints 46 and 54) were significantly faster after treatment in the PLACEBO group. Average sprint times for this group pre- and post-supplementation were, respectively, 3.66 ± 0.18 and 3.65 ± 0.18 s.

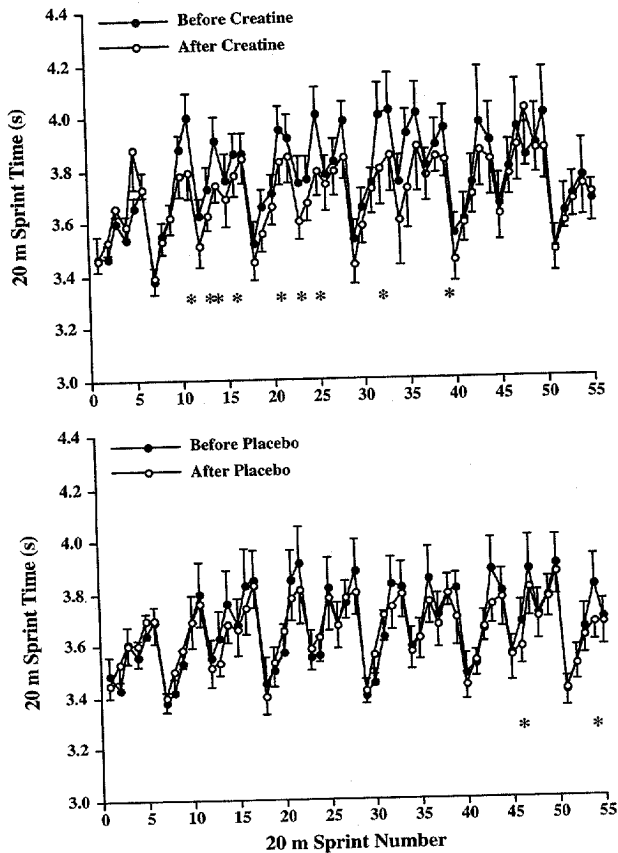


Figure 3— Performance times during each of the 55 sprints performed by the subjects, before and after creatine or placebo supplementation. *Denotes a significant difference between pre- and post-supplementation. Values are mean \pm SE.

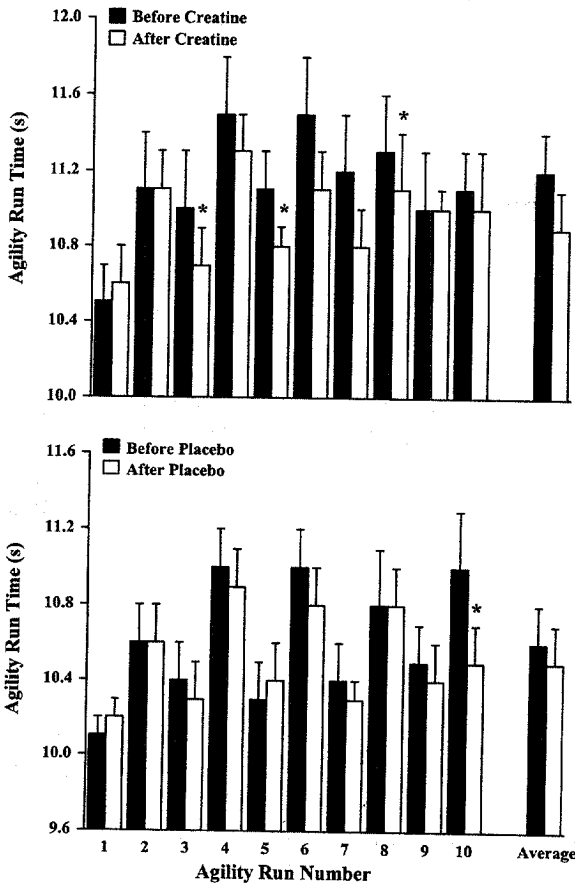


Figure 4 — Performance times during each of the 10 agility runs performed by the subjects, before and after creatine or placebo supplementation. *Denotes a significant difference between pre- and post-supplementation. Values are mean \pm SE.

Agility Runs. As shown in Figure 4, the CREATINE group achieved significantly faster times post-supplementation in the first agility run of exercise testing blocks 2 and 3, and the second run of block 4 (i.e., agility runs 3, 5, and 8). The first run of block 4 (i.e., agility run 7) also tended to be faster ($p = .07$). The change in the average time for the 10 agility runs did not reach the level of statistical significance (from 11.2 ± 0.6 to 10.9 ± 0.4 s). However, the average time for the 6 agility runs in blocks 2–4 was significantly lower after creatine supplementation (from 11.3 ± 0.6 to 10.96 ± 0.5 s, $p = .02$). In the PLACEBO group, only the second run of exercise testing block 5 (i.e., agility run 10) was significantly faster after supplementation. Average times pre- and post-supplementation were, respectively, 10.6 ± 0.4 and 10.5 ± 0.4 s.

Precision Ball-Kicking. The accuracy of shooting was unaffected by the supplementation period in both groups. Before supplementation, CREATINE successfully scored 4.5 ± 2.7 , 5.0 ± 2.3 , 5.0 ± 1.7 , 3.8 ± 1.5 , and 5.2 ± 1.8 in exercise testing

blocks 1 to 5, respectively (average, 4.6 ± 1.5). After supplementation, values were 4.8 ± 1.0 , 4.8 ± 2.5 , 5.0 ± 1.4 , 4.6 ± 1.8 , and 4.6 ± 1.5 (average, 4.8 ± 1.2). Pre- and post-supplementation scores for PLACEBO were, respectively, 5.5 ± 2.3 , 5.5 ± 1.4 , 5.8 ± 0.8 , 6.0 ± 1.3 , and 6.0 ± 1.3 (average, 5.8 ± 0.6), and 4.7 ± 1.2 , 5.7 ± 1.4 , 5.3 ± 1.5 , 6.7 ± 1.0 , and 6.2 ± 0.8 (average, 5.7 ± 0.6).

Physiological Measurements

Heart Rate. As can be seen in Table 2, average heart rate values during each of the 5 exercise testing blocks were significantly lower after CREATINE. Mean heart rate for the 5 exercise testing blocks was also significantly reduced. In the PLACEBO group, on the other hand, heart rate was only significantly lower during the 5th exercise testing block, but the mean value for the 5 exercise testing blocks remained unchanged after the experimental period.

Blood Lactate. Blood lactate concentration following exercise testing blocks 1 and 2 decreased significantly in CREATINE after supplementation, and the mean value for the 5 exercise testing blocks also tended to be lower ($p = .09$). No significant changes in blood lactate values were observed in the PLACEBO group (Table 2).

Blood pH. Increased blood pH values following exercise testing block 1 were observed after CREATINE. Blood pH also tended to be higher following exercise testing block 2 ($p = .08$), but it remained unchanged after subsequent blocks, and the mean value for all 5 exercise testing blocks did not change significantly. Post-exercise blood pH did not change in the PLACEBO group after the supplementation period (Table 2).

Rating of Perceived Exertion. As shown in Table 2, the experimental period had no effect on post-exercise RPE, neither in the CREATINE group nor in the PLACEBO group.

Discussion

The major findings of this investigation were that, in elite female soccer players, acute Cr supplementation (a) improved performance of some of the repeated sprint and agility tasks simulating soccer match play, despite an increase in BM; (b) was accompanied by a significant reduction of exercise heart rate; and (c) reduced blood lactate concentration and increased blood pH during the early stages of the exercise protocol. Similar changes were observed less often in the placebo group. This is the first study to report such a benefit in elite female athletes performing a sports-specific activity.

The Cr protocol used in the study has been repeatedly shown to increase total Cr and PCr content of the muscle (4, 8, 12, 14, 16, 18, 19, 33). Although direct measurements of muscle Cr were not undertaken in this study, the reported compliance of subjects to a proven Cr loading protocol provides indirect support of the success of our supplementation protocol.

The enhancement of certain repeated running sprint efforts (3–4 s) and longer agility run efforts (~11 s) are supported by the findings of previous studies (2, 4, 8, 15, 17, 21, 26, 27). However, other groups have failed to find improvements in the performance of repeated high-intensity exercise bouts following creatine supplementation (5, 9, 12). This apparent contradiction in the literature has recently been

Table 2 Physiological Measurements Following Each Performance Testing Block

Variable	Heart rate (bpm)		Blood lactate (mmol · L ⁻¹)		Blood pH		Rating of perceived exertion	
	Before	After	Before	After	Before	After	Before	After
CREATINE								
Block 1	174.5 ± 13.7	167.2 ± 14.4**	13.0 ± 3.2	9.7 ± 2.2**	7.236 ± 0.052	7.278 ± 0.041*	15.0 ± 2.8	13.5 ± 1.2
Block 2	179.2 ± 10.8	173.3 ± 11.7**	10.9 ± 3.1	9.3 ± 3.0*	7.292 ± 0.040	7.313 ± 0.029	15.8 ± 2.5	15.3 ± 1.0
Block 3	178.0 ± 11.5	173.5 ± 9.9*	10.2 ± 3.3	9.9 ± 2.5	7.299 ± 0.042	7.283 ± 0.057	16.3 ± 2.6	16.8 ± 2.3
Block 4	176.6 ± 12.2	171.4 ± 10.5*	10.0 ± 2.4	9.6 ± 2.9	7.304 ± 0.027	7.301 ± 0.056	16.6 ± 2.3	17.4 ± 2.1
Block 5	176.2 ± 11.2	169.6 ± 11.8**	9.6 ± 3.4	9.4 ± 3.1	7.305 ± 0.038	7.299 ± 0.051	17.2 ± 1.9	17.6 ± 2.3
Mean ± SD	176.5 ± 12.5	170.9 ± 12.4**	10.8 ± 3.0	9.2 ± 2.7	7.295 ± 0.037	7.314 ± 0.030	16.1 ± 2.3	15.0 ± 3.5
PLACEBO								
Block 1	166.7 ± 9.3	160.3 ± 10.5	10.2 ± 2.0	9.0 ± 2.7	7.286 ± 0.035	7.299 ± 0.052	14.2 ± 1.8	13.5 ± 0.8
Block 2	172.2 ± 9.6	167.2 ± 9.8	10.8 ± 0.8	9.4 ± 2.9	7.289 ± 0.032	7.303 ± 0.048	15.3 ± 1.0	15.0 ± 1.1
Block 3	172.2 ± 9.9	168.2 ± 9.4	10.0 ± 2.3	9.6 ± 3.0	7.304 ± 0.041	7.317 ± 0.052	16.7 ± 1.5	16.0 ± 1.7
Block 4	172.2 ± 9.7	168.2 ± 8.6	10.4 ± 2.0	9.3 ± 3.2	7.310 ± 0.045	7.317 ± 0.056	17.2 ± 1.8	17.0 ± 2.1
Block 5	170.0 ± 9.5	165.7 ± 9.3	9.5 ± 0.8	8.9 ± 2.9	7.316 ± 0.039	7.309 ± 0.047	18.3 ± 2.3	18.0 ± 2.1
Mean ± SD	170.5 ± 9.5	165.7 ± 9.3	10.3 ± 1.3	8.9 ± 2.6	7.301 ± 0.035	7.309 ± 0.050	16.3 ± 1.5	15.9 ± 1.4

Note. Values are mean ± SD. *, **denote a significant difference between pre- and post-supplementation ($p < .05$ and $p < .01$, respectively).

addressed by Tarnopolsky and MacLennan (29) who explain that differences in the experimental design and the choice of the performance outcome will affect the apparent efficacy of acute creatine supplementation trials. In particular, issues affecting the statistical power of the study are important to avoid a type II statistical error, or the failure to detect small but real changes in performance (29).

In the present study, we aimed to incorporate as many factors as possible to reduce the variability of performance outcomes. First, we recruited elite female soccer players who were match fit, injury-free, and motivated to perform well in the tests. Unfortunately, these restrictions limited the possible sample size from the squad of 22 players to 14 players. In the end, only 12 players were able to complete the study requirements. Although we were aware of the effect of a small sample size on statistical power, pilot testing in which additional players were recruited from the next tier of nationally represented soccer teams, showed a substantial increase in variability of performance outcomes in these players and a detrimental effect on statistical power (G. Cox, unpublished observations). Therefore we decided to work with small numbers of elite players and concentrate on strategies to enhance the reliability of their performances. These strategies included involving subjects in the design of the match simulation protocol, undertaking pre-trial familiarization over this protocol, standardizing training during the study, providing control diets for the 24 hours prior to each testing day, and scheduling tests to occur at identical times of the day for each subject. Although formal test-retest studies of the reliability of the performance tasks were not undertaken, comparison of the pre-supplementation and post-supplementation performances of the placebo group reveals that differences were small.

One of the suggested mechanisms to explain improvements in repeated bouts of high-intensity exercise following acute creatine supplementation is an enhanced resynthesis of PCr during the recovery period between maximal efforts (16). Significant performance benefits were only evident in exercise testing blocks 2, 3, and 4 of our study. It is likely that lack of performance improvement in the last exercise testing block is due to an increased reliance on aerobic metabolism during the latter phases of our exercise protocol (6, 13). Although not statistically significant, the observed mean improvement of ~ 0.06 s across 20-m sprints and 0.3 s in the agility runs in the CREATINE group represent improvements of 1.6% and 2.7%, respectively. This would translate into distances of ~ 30 cm and ~ 70 cm, which would be meaningful for the outcome of the game—for example, to allow a player to outrun her opponent and gain possession of a ball. Effects on sprint performance were achieved without effect on the skill precision of ball shooting.

These findings of improved performance in certain sprints and agility tests are important considering they were achieved during very short periods of weight-bearing exercise, and despite a significantly increased BM following Cr supplementation. Acute increases in BM have been previously reported as a side-effect of Cr loading (2–4, 11, 14, 16, 21, 24–26). Consistent with these earlier studies, BM of subjects in the CREATINE group in this study increased by 0.8 kg or 1.3% of total BM. The increased BM of Cr-loaded subjects meant an increased work output during the performance testing protocol. Previously, the studies that most frequently demonstrate benefits from acute Cr supplementation were those involving non-weight bearing activities such as laboratory cycling (2, 7, 10, 11), weight lifting (11, 21, 35), ergometer rowing/kayaking (24, 28), swimming (17, 27), and protocols of isolated muscle contractions (15, 23). It has been speculated that in weight-bearing

activities such as running or uphill cycling, benefits from Cr supplementation might be compromised or negated by the additional energy cost of activity with an increased BM (for review, see 20). This effect was not seen in our study; in fact, our Cr-loaded subjects achieved this greater work with a lower heart rate. This finding of a reduced heart rate during repeated-sprint exercise following Cr supplementation has not been observed in other studies.

The lower lactate concentrations and better acid-base balance observed in the first performance block of the protocol used in our study are in agreement with the work of Balsom and co-workers (2, 4), but contrast the results of other studies in which the lactate response to single or repeated sprints has not been altered (7, 8, 15, 25–27). These findings may be specific to the protocol used in our study and in fact were not evident in subsequent exercise testing blocks. It is possible that the early preservation of acid-base balance and lower lactate concentrations was associated with the subsequent performance benefits in the 2–4 exercise testing blocks. Cr supplementation may have allowed greater ATP generation from resynthesis of PCr with a lower contribution from the glycolytic pathway in the first exercise testing block. In subsequent blocks, a greater amount of work was produced and faster sprint times were achieved until the growing glycolytic contribution reached its maximum capacity. The lack of differences in performance during the final exercise testing block indicates a growing dependence on aerobic metabolism. This interpretation of our observations, however, must remain speculative until further investigations are undertaken.

Our study represents an advance on previous studies that have reported performance enhancements in well-trained team sport players following acute Cr supplementation. Others have reported that various Cr supplementation protocols were associated with enhanced performance of repeated cycling sprints by college football players (21), repeated running sprints during an intermittent exercise protocol by semi-professional soccer players (26), and repeated running sprints in handball players (1). Although such findings can be applied to the activity patterns that are characteristic of the competitive performance of these athletes, we believe the present study is the first to measure performance in a protocol that is closely based on the characteristics of the match play of real life sport. Despite our attempt to simulate a soccer match, the performance trials in this study were only 60 min in duration, which may not truly reflect the influence of acute creatine supplementation in a full-length soccer game. However, we were interested in gaining the involvement and full compliance of internationally competitive athletes, during a period of important competition preparation. The consensus of discussions between sports scientists, coaches, and players was that a 60-min protocol based on the activity patterns observed in women's soccer would provide a balance between the real physiological characteristics of soccer and the player's agreement to participate at full match intensity. We note that our protocol is considerably greater in duration to the protocols used in previous simulated match play studies (26).

The heart rates achieved by subjects in our protocol mirror the heart rates observed during actual matches played by this team (D. Tumilty, unpublished observations). However, lactate concentrations in the study tended to be higher than those observed during competition, although it has not been possible to achieve blood collection during highly competitive matches at such predictable intervals. The subjective perception of our subjects was that the test protocol was equal or more strenuous than a typical match. Most importantly, this study addresses the lack

of information about the effect of Cr supplementation on repeated sprint performance in female subjects. To date, the only data available on repeated sprint performance of highly trained female athletes involves swimmers (17, 22, 32).

In summary, this is the first study in elite female athletes to show that acute Cr supplementation enhances some sprint performance tasks during a protocol mimicking the activity patterns of a soccer match. Despite small subject numbers, increases in performance of certain brief repeated efforts (3–4 s) and longer agility runs (~11 s) during the sports specific protocol were statistically significant and meaningful to the contests seen in a soccer match. These data suggest that Cr supplementation is a worthwhile strategy for elite female soccer players, although further studies mimicking typical exercise loads experienced during competition are needed to clarify the potential performance gain.

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