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The Effect of Creatine on Treadmill Running With High-Intensity Intervals

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ABSTRACT

To determine whether creatine monohydrate supplementation would improve performance during a submaximal treadmill run interspersed with high-intensity intervals, 15 college soccer players (8 women, 7 men) received either creatine or a maltodextrin placebo at 0.3 g·kg body mass per day for 6 days. The speed of the treadmill was constant at 160.8 m·min, and every 2 minutes the grade was elevated to 15%. Each hill segment was 1 minute long. At the end of the 20-minute protocol, the treadmill was again elevated to 15% and held there until volitional exhaustion occurred. There was a significant treatment effect of creatine supplementation on body mass ($p < 0.05$) in the men; however, no significant differences were observed in the women ($p > 0.05$). There were no treatment effects ($p > 0.05$) on time to exhaustion, ratings of perceived exertion, or blood lactate concentration. There was a tendency for blood lactate levels to be lower after short-term creatine supplementation in the women, but this was not statistically significant. Based on these results, it appears that creatine supplementation does not improve performance in submaximal running interspersed with high-intensity intervals.

Key Words: creatine phosphate, adenosine triphosphate, ergogenic aids, supplementation

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Introduction

The energy for short duration, high-intensity exercise is derived primarily from the adenosine triphosphate-phosphocreatine (ATP-PCr) energy system. Creatine, via the creatine kinase reaction, plays a crucial role in the maintenance of the ATP-PCr metabolic pathway. Whereas the capacity for ATP resynthesis, and subsequent energy production is markedly reduced when phosphocreatine stores are depleted, the availability of PCr for muscle contraction has long been considered a limiting factor for short-term supramaximal exercise performance (16). Several short-term supplementation studies have shown that oral ingestion of creatine monohydrate can increase both intramuscular creatine as well as phosphocreatine concentrations with concurrent increases in body mass (21) and enhanced performance (21). Pearson et al. (21) reported significant strength gains in the bench press, squat, and power clean following creatine supplementation of 5 g·day during a 10-week strength training program. Gotshalk et al. (9) demonstrated increases in body mass as well as several indices of muscle performance in older men. Other studies have found that creatine supplementation may also improve performance in resistance training (27), cycling (16, 24, 26), and running (4).

To date, there is very little research on creatine loading and possible effects on endurance activities that involve anaerobic bursts of power. This is somewhat surprising when one considers that even endurance events such as distance running, cycling, soccer, and swimming require intermediate and finishing spurts that are primarily anaerobic in nature. Englehardt et al. (7) studied 12 regional class triathletes after 5 days of creatine monohydrate loading with each athlete ingesting 6 g·day. Subjects completed 60 total minutes of aerobic exercise on a cycle ergometer divided by an anaerobic interval exercise bout performed at the 30-minute (halfway) point. Creatine supplementation significantly improved interval power performance during the high intensity exercise while endurance performance at 3 $mmol \cdot L^{-1}$ lactate was not influenced. It was concluded that creatine appears to have a positive effect on short-term, high-intensity exercise incorporated with aerobic endurance exercise.

More recently, Rico-Sanz and Marco (22) studied highly trained cyclists who ingested 20 g·day of creatine or placebo over a 5-day period. Subjects were then asked to complete a protocol that consisted of alternating 3-minute intervals of 30 and 90% maximal power output to the point of exhaustion. Both oxygen consumption and time to exhaustion increased following creatine loading but not with the placebo condition. Based on these findings, it seems plausible that creatine supplementation may enhance the performance capacity of muscle in activities with metabolic demands that favor aerobic pathways while alternating between aerobic and anaerobic metabolism (22).

As shown by Balsom et al. (1), however, creatine supplementation may actually be detrimental to an endurance athlete's performance. Prior to and following 6 days of creatine supplementation of 20 g·day ($n = 9$) or placebo ($n = 9$), 18 well-trained men completed a treadmill run to exhaustion at 120% of $\dot{V}O_2$max and a 6-km run on a forest track with an undulating terrain. After comparing pre- with posttest scores, the creatine group took significantly longer to complete the terrain run following supplementation. It was suggested that this increase in running time was due to the increase in body mass that the creatine group also experienced.

Numerous activities including soccer, cross-country running, or mountain biking require high-intensity bouts of speed and power during competition without any complete rest or recovery periods. The purpose of this investigation was to examine the effects of creatine monohydrate supplementation on endurance activity interspersed with intermittent, high-intensity intervals.

Methods

Experimental Approach to the Problem

Testing was completed during the respective off-seasons of the athletes in late fall and early winter. Subjects reported to the human performance lab in a 3-hour fasted state for pre- and posttesting. Following measurement of body mass (Tanita electronic scale, model BWB-800A, Tanita Corporation, Tokyo, Japan), each subject completed a treadmill running protocol as follows: The treadmill was set at 0% grade and a constant speed of 160.8 m·min. After completion of the second minute, the grade of the treadmill was increased to 15% at which it remained for 20 seconds before returning to 0%. The entire process of elevating, maintaining, and returning the treadmill grade to 0% required approximately 65 seconds. Once the treadmill was back to 0% grade, running continued for 2 minutes before the elevation process was repeated. This procedure continued for 20 minutes whereupon the treadmill grade was raised to 15% and held constant until the subject could no longer maintain the required speed. Once volitional exhaustion occurred, the subject immediately stepped off the treadmill and recovered in an upright seated position for 5 minutes.

Blood lactate samples were obtained via the finger prick method while running and analyzed using a YSI Sport 1500 lactate analyzer for the women (Yellow Springs Instruments, Yellow Springs, OH) and the Accusport lactate analyzer (Accusport, Mannheim, Germany) for the men immediately prior to the start of exercise, at the 6-, 12-, and 18-minute marks, upon exhaustion, and 5 minutes post exercise. Ratings of perceived exertion (RPE) were measured at the completion of each hill segment using the Borg scale (6–20) of perceived exertion (3).

The day following the initial pretest protocol, each subject was randomly placed into an experimental or placebo group utilizing a randomized block design. The experimental group (Cr) ingested 0.3 g·kg of body mass of creatine in powder form for 6 consecutive days following the pretest protocol. This supplementation procedure was employed based on the work of Hultman et al. (15), who reported gains in PCr stores in men using this dosage. The control group (Pl) ingested an equivalent amount of maltodextrin.

Subjects were instructed to ingest the powder with 250 ml of fruit juice after breakfast, lunch, and dinner and before bedtime (10). In an attempt to ensure compliance with the supplementation protocol, the subjects were also instructed to return the empty powder bags to the lab at the posttest session. Participants were asked to maintain their normal activity levels and dietary habits throughout the course of the study.

Subjects

Fifteen college soccer players (8 women, 7 men) volunteered to participate in this study, which was conducted in accordance with and approval by the institutional review board for human subjects at 2 universities located in the upper Midwest. All participants signed an informed consent that described the inherent risks associated with the parameters of the study.

Statistical Analyses

A double-blind, repeated-measures, cross-over design was employed for the study with a minimum 4-week washout period between creatine-placebo testing periods. Data analysis was performed using SYSTAT 9.0S (SPSS Inc., Chicago, IL). A $2 \times 2 \times 2$ (creatine vs. placebo, pretest vs. posttest, man vs. woman) repeated-measures analysis of variance (ANOVA) was used to determine possible differences in body mass and time to exhaustion. The data for RPE and blood lactate concentrations were analyzed with a $2 \times 2 \times 2 \times 7$; RPE and $2 \times 2 \times 2 \times 6$ blood lactate repeated-measures ANOVA. A significance level of $p \leq 0.05$ was chosen, and all values are expressed as means $\pm$ *SD* of the mean ($X \pm SD$).

Results

There was a statistically significant ($p < 0.05$) treatment effect of creatine as body mass increased in the men soccer players; however, this effect was not observed in the women soccer players in whom body

Table 1. Body mass (kg) at pre- and posttreatment (creatine and placebo) for male and female soccer players (mean ± *SE*) (*n* = 15).

	Men (*n* = 7)		Women (*n* = 8)	
	Pretest	Posttest	Pretest	Posttest
Placebo	78.3 ± 8.4	78.3 ± 8.6	63.1 ± 5.6	63.2 ± 5.7
Creatine	78.2 ± 9.0	79.4 ± 8.5*	63.5 ± 5.5	63.9 ± 5.5

* Significant ($p < 0.05$) difference from pretest measurement.

Table 2. Mean time to exhaustion (minutes) at pre- and posttreatment (creatine and placebo) for male and female soccer players (mean ± SE) (*n* = 15).

	Men (*n* = 7)		Women (*n* = 8)	
	Pretest	Posttest	Pretest	Posttest
Placebo	21.04 ± 2.30	20.89 ± 2.78	20.46 ± 2.44	20.86 ± 2.35
Creatine	20.57 ± 2.19	21.48 ± 2.11	21.58 ± 1.28	21.52 ± 1.03

mass showed little change (Table 1). Creatine supplementation appeared to have little effect on time to exhaustion, which did not differ significantly from pre- to posttest in either the men or women with both the placebo and creatine treatments (Table 2).

Ratings of perceived exertion and blood lactate concentrations at the various time points did not differ significantly between the creatine and placebo conditions in either the men or women. Not surprisingly, there was a significant main effect of time for RPE (Figures 1 and 2) and blood lactate concentrations (Figures 3 and 4) because both showed significant incremental increases throughout the exercise protocol.

Discussion

The results of this study indicate that short-term (1 week) oral creatine supplementation has little effect on the performance of submaximal exercise interspersed with high-intensity intervals. Although the men did increase body mass significantly while ingesting creatine, this effect was not observed in the women. Many studies have shown an increase in body mass in men following creatine supplementation (1, 15, 20). Balsom et al. (1) reported a mean increase in body weight of 1 kg with supplementation of 20 g·day for 6 days. Mujika et al. (20) also reported a mean increase in body mass with male subjects following a similar regimen. The finding of no change in body mass in the women soccer players is consistent with previous research (17, 23) on female athletes following a similar supplementation protocol (0.3 g·kg of body mass for 6 days). The diet and activity logs for each subject revealed similar patterns between trials and subjects, which supports the contention that any body mass changes were due to the creatine supplementation.

It is possible that women, with greater endogenous total creatine concentrations than men, do not respond to creatine supplementation as readily as men do. In a sex comparison of muscle composition, Forsberg et al.

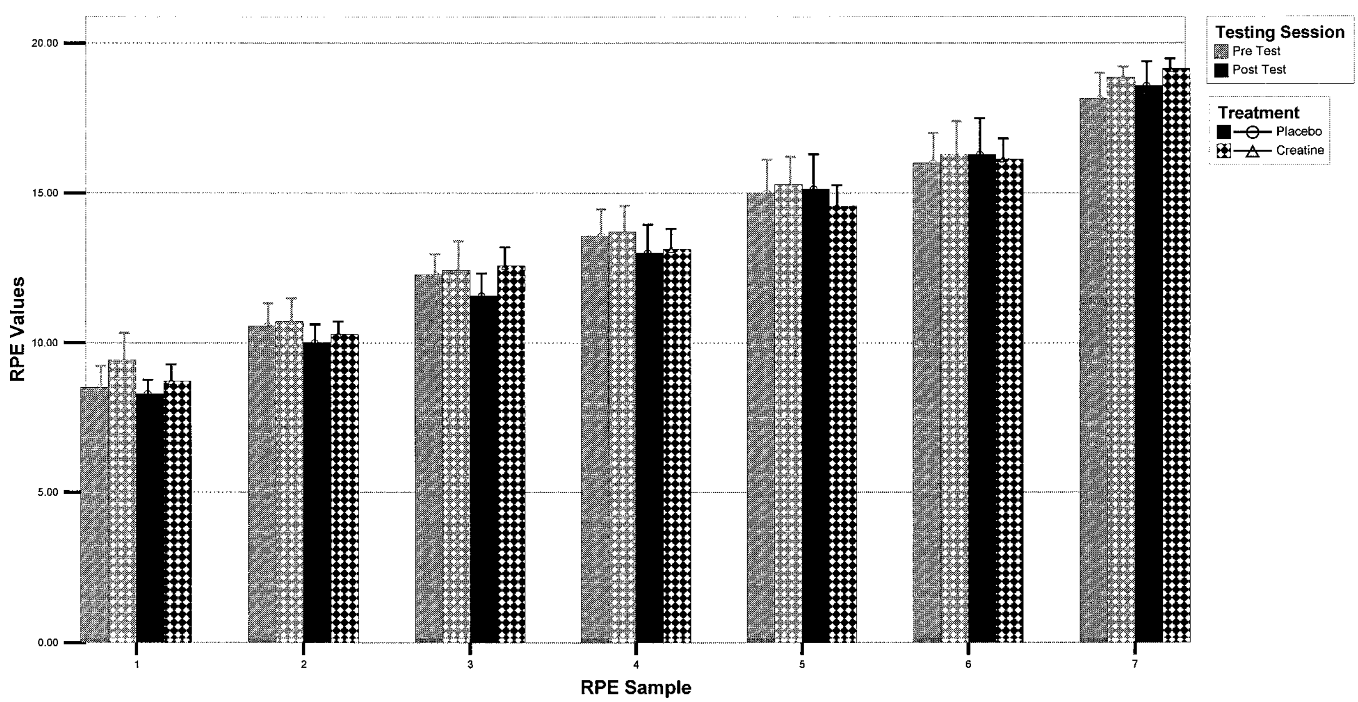

Figure 1. Ratings of perceived exertion (RPE) at pre- and posttreatment (creatine or placebo) for male soccer players (mean ± *SE*).

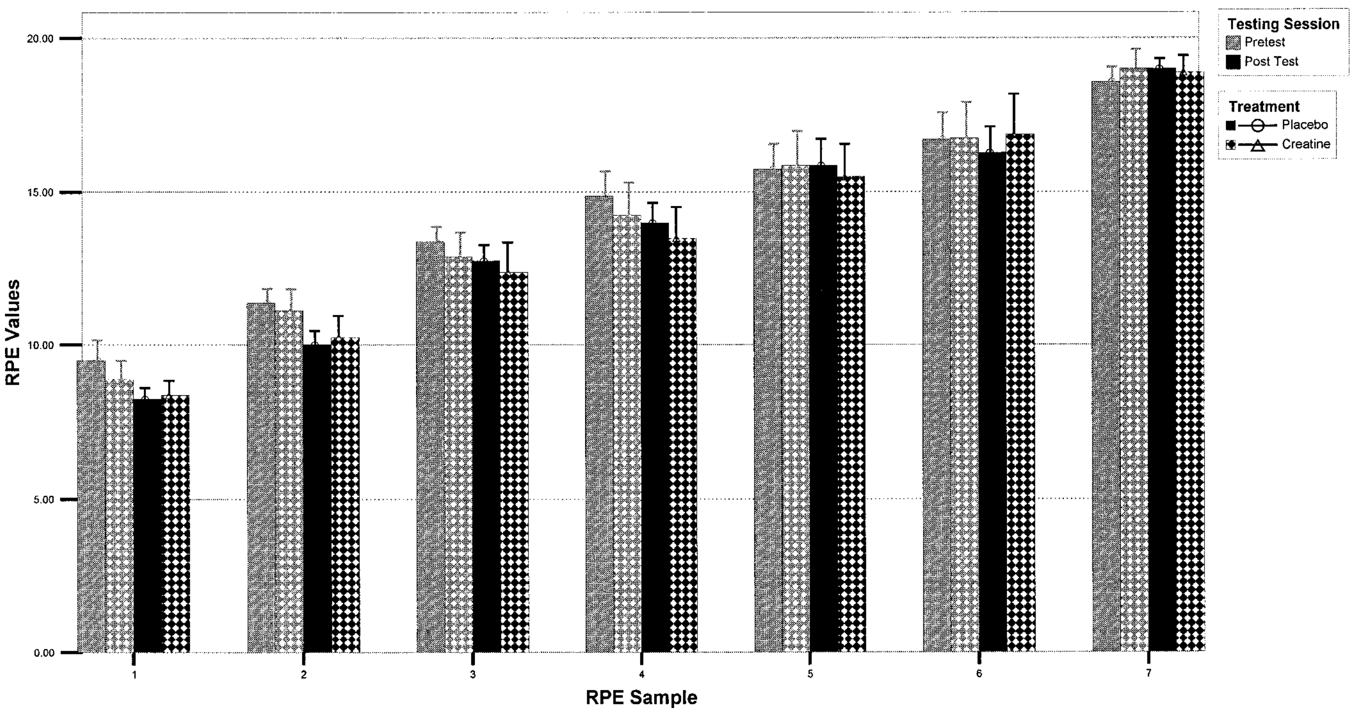

Figure 2. Ratings of perceived exertion (RPE) at pre- and posttreatment (creatine or placebo) for female soccer players (mean ± *SE*).

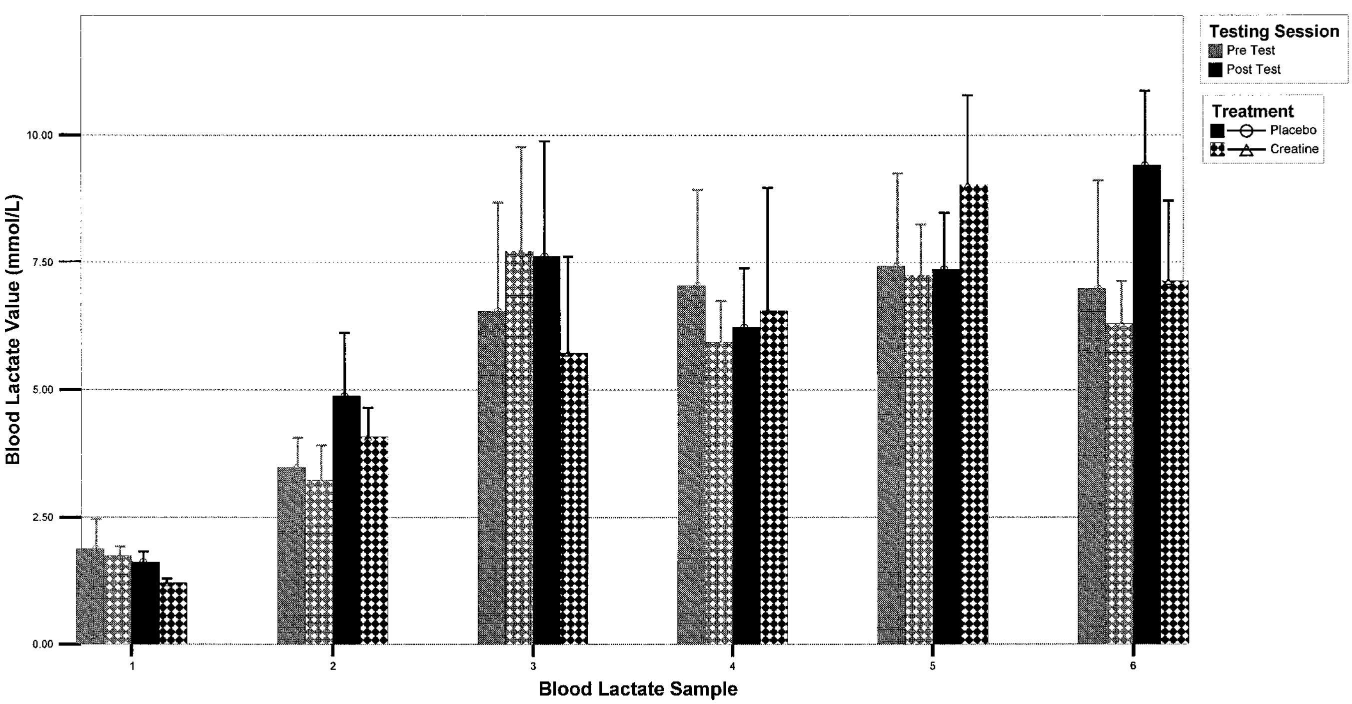

Figure 3. Blood lactate levels ($mmol{\cdot}L^{-1}$) at pre- and posttreatment (creatine or placebo) for male soccer players (mean ± *SE*).

(8) reported a 10% greater concentration of total muscle creatine in women (145 ± 10 $mmol{\cdot}kg^{-1}$ dry muscle mass), compared with men (132 ± 10 $mmol{\cdot}kg^{-1}$ dry muscle mass). It is possible that the women, or a subgroup of them, had higher levels of creatine in the muscle prior to supplementation, resulting in nonresponders. Because no muscle biopsies were taken in the current study, it is not possible to confirm that there was an increase in skeletal muscle total creatine concentration as a result of the creatine loading.

Another confounding variable that was not accounted for in the current study was the phase of the menstrual cycle that supplementation occurred. Weight gain or loss, because of water retention or loss,

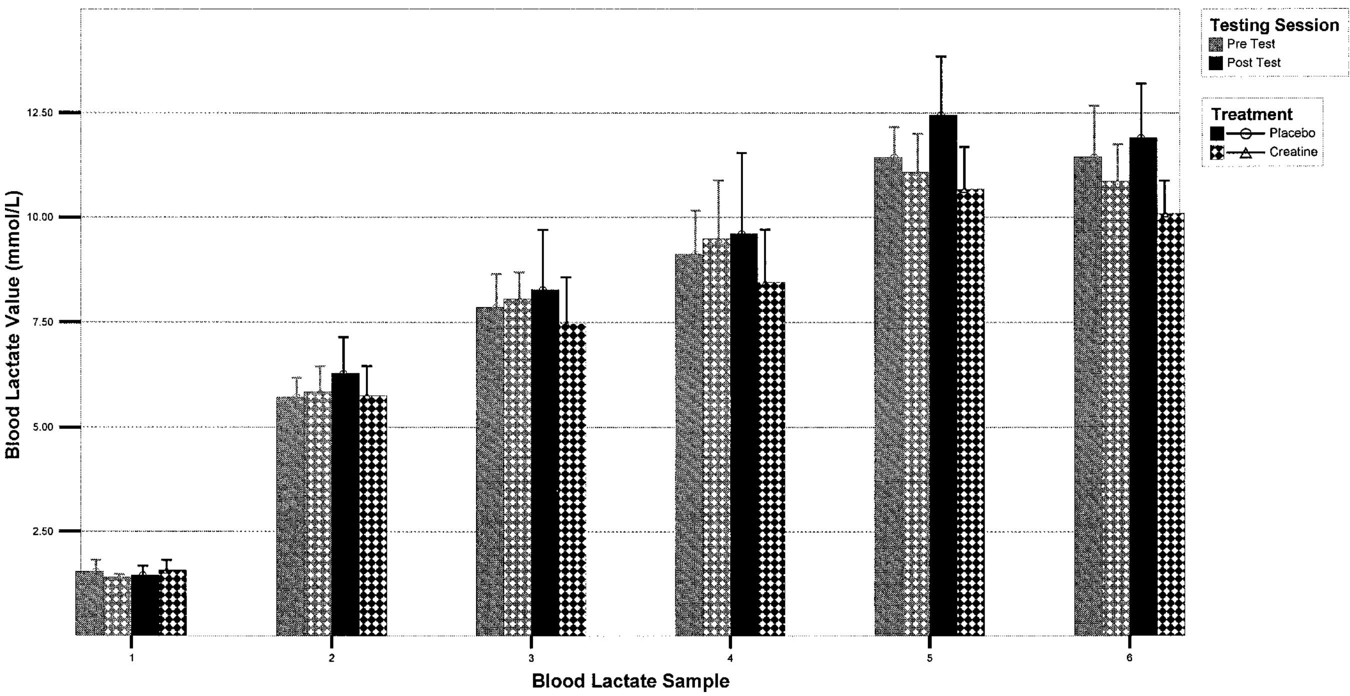

Figure 4. Blood lactate levels (mmol·L^{-1}) at pre- and posttreatment (creatine or placebo) for female soccer players (mean ± *SE*).

is common during the phases of the menstrual cycle (5). Any weight gain caused by the uptake of the creatine may be masked by the variability of each subject throughout the menstrual cycle. Thus, the variability of water retention during the menstrual cycle may mask the retention required for creatine storage. To date, there is no research regarding how the menstrual cycle may affect acute creatine loading. According to Hultman et al. (15), urinary volume is decreased during short-term supplementation, a finding that suggests that water retention may explain the rapid increase in body mass.

Greenhaff et al. (12) have suggested that an increase in PCr concentration may improve the buffering capacity of the muscle. Anaerobic glycolysis increases lactic acid accumulation, with increased hydrogen ion concentration, a possible contributor to muscle fatigue. ATP resynthesis from ADP and PCr consumes a hydrogen ion in the process, so utilization of PCr would contribute to the buffering of H^+. It has been estimated that creatine supplementation may increase the buffering capacity by 7% (12). Balsom et al. (2) observed lower postexercise blood and muscle lactate levels following supplementation and suggested that an increase in the total creatine pool and phosphocreatine resynthesis rate inhibit glycolysis. Blood lactate levels, if lowered, may be indicative of less reliance on anaerobic glycolysis for ATP production. In the current study, blood lactate concentration increased over the course of the testing session (Figures 3 and 4). However, no significant differences in blood lactate concentration were observed between the Cr and Pl groups. Nevertheless, a tendency for lower blood lactate levels appeared evident after creatine supplementation, compared with the placebo in the female group.

A possible limitation of the current study was the length of the hill segment because of the treadmill's slow rate of climb. If the hill segment was shorter, a decrease in blood lactate concentration may have been observed because of the greater reliance on the phosphagen system for ATP production. Creatine supplementation has been reported to enhance recovery in high-intensity bouts of activity (16, 24, 26) that stress the phosphagen system. Therefore, a protocol with shorter, more intense hill segments may have demonstrated an ergogenic effect when compared with the current protocol.

When comparing time to exhaustion among several studies, the most important factor is the study design. This will obviously influence how each energy system will function and thus determine the results of each study. The protocol used in the current investigation is unlike most of the running studies that have been published. The literature is abundant with running and sprinting protocols that involve passive recovery periods. The current study did not use a passive recovery period during the test protocol but rather a 2-minute low-intensity portion to allow for partial recovery of PCr stores separated each high-intensity hill segment. In the current investigation, no significant differences were observed between the creatine or placebo groups in running time to exhaustion (Table 2).

Sprinting and running studies involving maximal effort have been conducted with mixed results. Terrillion et al. (25) studied track athletes during 2 maximal 700-m runs. No change in running time was observed. The 2 runs, however, were separated by 60 minutes of rest, most likely allowing for complete recovery regardless of supplementation. In contrast, Harris et al. (14) found improved 300-m and 1,000-m run times with creatine supplementation. Each sprint was separated by 4-minute and 3-minute rest periods, respectively. The difference in recovery times may be the greatest contrasting factor between these two studies. In a study by Balsom et al. (1), subjects ran at 120% of $\dot{V}O_2$max and experienced no changes in time to exhaustion when compared before or after creatine supplementation. A study by Bosco et al. (4) implemented an all-out running test at 20 km·hour at a 5% grade. The creatine group demonstrated a significant improvement in maximal running time from 59.1 ± 5.1 seconds to 66.9 ± 8.9 seconds after creatine supplementation. Bosco et al. (4) concluded that creatine supplementation will increase performance in exhaustive running tests.

No significant differences were observed for RPE in the current study (Figures 1 and 2). RPE increased over time for each of the test conditions. In the current study, because there were no significant differences in time to exhaustion or blood lactate values, it is reasonable to assume that RPE would remain unchanged as well.

Practical Applications

The data obtained from this investigation indicated that soccer athletes ingesting creatine monohydrate did not experience enhanced performance during a submaximal treadmill run interspersed with high-intensity intervals. The efficacy of creatine is most prevalent during anaerobic work efforts of 30 seconds or less or during repeated and more prolonged work efforts in which recovery between work bouts may be improved from the increased ATP and PCr resynthesis observed with creatine supplementation (10, 12). Activities such as sprinting (100–400 m) and sprint cycling would be obvious choices as would activities such as tennis and weight training. In addition, sports such as soccer, mountain biking, and distance running may not benefit from creatine supplementation because phosphocreatine metabolism may not be the limiting factor in performing these activities.

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