The Effect of Creatine Supplementation on Two 700-m Maximal Running Bouts

Kent A. Terrillion, Fred W. Kolkhorst, Forrest A. Dolgener, and Sue J. Joslyn

We investigated the effect of creatine supplementation on maximal running performance in a simulated track competition. Twelve competitive male runners were assigned to either a placebo or creatine supplementation group. Both groups completed two maximal 700-m running bouts 60 min apart on an outdoor track. A second identical trial was performed 7 days later, and for 5 days prior to the second trial, subjects ingested 20 g · day⁻¹ of either creatine monohydrate or a placebo. Subjects in the placebo group ran 110.2 ± 3.5 s and 110.4 ± 3.0 s for the first trial and 108.5 ± 2.9 s and 108.0 ± 1.7 s for the second trial, while the creatine group ran 109.9 ± 3.2 s and 110.4 ± 3.6 s for the first trial and 109.7 ± 3.3 s and 107.8 ± 2.2 s for the second trial. There were no significant differences between groups by trial or Trial × Time for running time, postexercise blood lactate concentration, or body weight (p > .05). We concluded that creatine supplementation does not enhance performance of single or twice-repeated maximal running bouts lasting 90–120 s.

Key Words: creatine monohydrate, creatine phosphate, fatigue, postexercise blood lactate, performance

Creatine phosphate (CP) is highly effective for maintaining adenosine triphosphate (ATP) concentrations for short periods of time. Studies have found that ATP concentrations in human fast-twitch muscle fibers decreased only 32–43% from resting levels after electrical stimulation to fatigue, while CP concentrations decreased 93% (4, 21). Because the supply of CP is limited, CP depletion has been implicated as a primary cause of fatigue in high-intensity exercise. This was illustrated by the parallel decline in force output and CP concentrations during electrical stimulation of rat (11) and human (4, 21) skeletal muscle.

If CP depletion in skeletal muscle leads to fatigue during high-intensity exercise, then increasing preexercise CP concentrations may delay the onset of fatigue and improve force maintenance. Increasing the creatine pool in skeletal muscle through supplementation has been reported to improve performance in certain exercise protocols but not others. Following supplementation, work output was increased in studies involving repeated bouts of cycle ergometry.

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(1, 3, 6), maximal knee extensions (13), and 4 × 300 m and 4 × 1,000 m running bouts (15).

However, most investigations that have included a single bout of maximal exercise have failed to demonstrate a benefit. Creatine supplementation did not improve performance in a 60-m running sprint (18), maximal cycling lasting 15 s (8), 25-m to 100-m swimming sprints (7), exhaustive treadmill running lasting 3–4 min (2), or a 24-min terrain run (2). In a recent report, though, competitive oarsmen performing a 1,000-m simulated rowing competition significantly decreased their rowing time from 211.0 s to 208.7 s (19). Consistent with other reports showing benefits of creatine supplementation (1, 3, 6, 13, 15), there was a diminished decline in power during the latter part of the exercise bout (19).

Despite the inconclusive evidence on creatine supplementation and performance, athletes in track and field as well as other sports are using creatine supplementation as an ergogenic aid (17). Moreover, creatine is not currently banned by either the International Olympic Committee or the NCAA. Whether creatine supplementation actually enhances athletic performance in competition has still not been established.

The purpose of this study was to investigate the effect of creatine supplementation on performance in a simulated track competition. Track athletes often compete in several trials and/or multiple events during a day of competition. We attempted to simulate a typical track situation by having trained runners perform two maximal running bouts at a distance that would take between 90 and 120 s to complete.

**Methods**

Twelve well-trained and competitive male runners provided written informed consent prior to beginning the study (age = 21.0 ± 2.4 years, weight = 70.2 ± 8.6 kg, percentage body fat = 6.0 ± 2.4%). All subjects had just completed a collegiate track season and/or were currently training for road races. This study utilized a placebo-controlled matched-pair design. As a group, subjects completed a maximal 600-m timed run on an outdoor track and then were matched in pairs based on their performance. Each subject in a pair was assigned to either a creatine supplementation or placebo group so there were 6 subjects in each group.

One week later, each matched pair of subjects completed an initial trial on an outdoor track, consisting of two 700-m maximal running bouts separated by 60 min. All subjects used a standardized warm-up prior to each 700-m run and were given verbal encouragement during their runs. An identical trial was repeated 7 days later. For the 5 days preceding the second trial, each subject ingested either 5 g of creatine monohydrate plus 1 g of sucrose or 6 g of sucrose four times a day. The creatine and placebo were administered in a double-blind fashion. Although diet was not controlled during the study, subjects were encouraged to maintain their normal dietary intakes and physical activity patterns.

Following the finish of each 700-m run, subjects walked into a nearby locker room, located approximately 40 m from the finish, and were seated. Five minutes after subjects finished a 700-m run, blood was sampled from a finger stick and collected in a 25-μl heparinized capillary tube. Blood lactate concentration was
measured in duplicate using a YSI Model 23L Lactate Analyzer (Yellow Springs Instrument Co. Inc., Yellow Springs, OH) and averaged.

**Statistical Analysis**

A two-factor (trial and treatment) MANOVA with repeated measures was performed to compare run time, postexercise blood lactate concentration, and body weight between groups and trials. Significance was established at .05.

**Results**

There were no statistical differences in performance times between the creatine and placebo groups by trial or trial by time (Table 1). Mean time differences between the first 700-m run and the second 700-m run for the creatine group were $0.5 \pm 1.3$ s and $-1.9 \pm 1.6$ s for Trial 1 and Trial 2, respectively, and $0.3 \pm 1.2$ s and $-0.4 \pm 1.9$ s for Trial 1 and Trial 2, respectively, for the placebo group.

Changes in body weight, measured prior to warm-up for the first 700-m run of each trial, were nonsignificant. Body weights for the first and second trials were $70.8 \pm 9.1$ kg and $71.4 \pm 9.3$ kg, respectively, for the creatine group, and $69.7 \pm 9.0$ kg and $69.5 \pm 8.7$ kg, respectively, for the control group. Likewise, there were no significant differences in postexercise blood lactate concentration for trial or trial by time (Table 2).

**Discussion**

The main finding of this study was that performance of two repeated 700-m maximal running bouts did not improve after creatine supplementation. Drawing on previous studies, we judged that the level of creatine supplementation used in this study likely increased subjects’ average total muscle creatine pool. Although there was a wide variation in responses in published studies, ingestion of 20 g · day$^{-1}$ of creatine for 5–6 days produced an average 14–17% increase in the total muscle creatine pool (3, 12, 14). More than 89% of the increase, though, was due to an elevation of free creatine concentrations. Furthermore, the response was greater

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Results of 700-m Maximal Runs (s)</th>
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<tbody>
<tr>
<td></td>
<td>Trial 1</td>
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<tr>
<td></td>
<td>Bout 1</td>
</tr>
<tr>
<td></td>
<td>$M$</td>
</tr>
<tr>
<td>Creatine</td>
<td>109.9</td>
</tr>
<tr>
<td>Placebo</td>
<td>110.2</td>
</tr>
</tbody>
</table>

*Note.* There was no performance difference between groups by trial or Trial × Time ($p > .05$).
Table 2 Postexercise Blood Lactate Concentrations (mM) Measured 5 Min After Each 700-m Maximal Run

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
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<th>Trial 2</th>
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<tbody>
<tr>
<td></td>
<td>Bout 1</td>
<td>Bout 2</td>
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<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Creatine</td>
<td>10.8</td>
<td>0.7</td>
<td>10.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Placebo</td>
<td>9.3</td>
<td>1.9</td>
<td>9.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Creatine</td>
<td>9.9</td>
<td>0.8</td>
<td>10.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Placebo</td>
<td>10.4</td>
<td>0.3</td>
<td>10.7</td>
<td>0.7</td>
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</tbody>
</table>

Note. There was no difference in blood lactate concentrations between groups by trial or Trial x Time (p > .05).

when supplementation was coupled with high-intensity exercise (14). Regardless, the likely increase in the muscle creatine pool in our subjects had no effect on running performance.

Our results appear to conflict with results from a recent report on competitive oarsmen who significantly improved performance by approximately 1% (from 211.0 s to 208.7 s) in a 1,000-m simulated rowing competition following supplementation (19). Moreover, the rowing exercise was about 100 s longer than the running bouts in our study. In other studies, anaerobic ATP contribution for 120 s of high-intensity cycling was only 34% (10), and the CP contribution relative to glycolysis was approximately 25% during 102 s of electrical stimulation in an occluded leg (21). Nevertheless, the small contribution of CP to the total ATP production in the longer rowing bouts (19) was still an important energy source, as a 1% performance improvement in an athletic event is highly significant. However, the discrepancy of supplementation effectiveness between the simulated rowing competition and the maximal running bouts in our study may be due to the difference in exercise modes. Although subjects' rowing cadence averaged 30 strokes·min⁻¹, the rest-to-work ratio of the working muscles was about 2:1 (19). As the rest-to-work ratio of running is closer to 1:1, the resting phase during rowing exercise is approximately twice that of running. An accelerated rate of CP resynthesis is frequently suggested as the primary mechanism to explain performance enhancement following creatine supplementation (1, 12, 13, 19). Thus, the longer resting phase in rowing exercise compared to running may have allowed greater CP resynthesis following creatine supplementation and improved performance. Consequently, the potential of creatine supplementation to benefit high-intensity athletic events may be greatest in events such as football, basketball, and wrestling, which have a higher rest-to-work ratio than running.

Greenhaff and associates (13) also suggested that an increased CP concentration may improve the buffering capacity of muscle. High-intensity exercise results in a large production of lactic acid, and factors related or parallel to the decrease in intramuscular pH are considered the primary cause of fatigue for maximal exercise
lasting 30–180 s. Transfer of the high-energy phosphate from CP to adenosine diphosphate (ADP) requires H⁺ to resynthesize ATP, but, more importantly, CP is a strong acid and its breakdown to free creatine alkalinizes muscle.

\[ \text{CP}^{2-} + \text{ADP}^{3-} + \text{H}^+ \rightarrow \text{Creatine}^0 + \text{ATP}^4^- \]

Creatine supplementation at the rate of 20 g · day⁻¹ has been estimated to increase buffering capacity by 7% (13).

If creatine supplementation were to increase muscle buffering capacity and work output, an increase in blood lactate concentration should occur. This expectation is supported by studies in which bicarbonate supplementation increased work output as well as postexercise blood lactate concentrations (9, 16). Although we did not measure muscle or blood pH, creatine supplementation had no effect on postexercise blood lactate concentrations or, presumably, glycolysis in our subjects. Balsom and associates, however, observed lower postexercise blood (1) and muscle (3) lactate levels following supplementation and suggested that an increased total muscle creatine pool and CP resynthesis rate inhibit glycolysis. If so, the increased contribution of CP to ATP resynthesis would have to not only supplement ATP for the decreased glycolytic rate but contribute additional ATP for the increased work output.

Although others have reported creatine supplementation to enhance performance, any increase that likely occurred in our subjects' muscle creatine levels and the buffering capacity was so small as to be ineffective. Our data suggest that supplementation had no effect on maximal running performance, which may be due in part to the relatively shorter resting phase of the working muscles during running as compared to other athletic events. Moreover, while the design of the present study utilized a repeated exercise bout, CP resynthesis would have been completed well before the start of the second running bout regardless of supplementation (20). Based on our results, we concluded that high-dose creatine supplementation does not offer any physiological benefit to maximal running performance lasting 90 to 120 s.

References


*Manuscript received: November 15, 1996
Accepted for publication: January 29, 1997*