Short-term Creatine Supplementation Improves Maximum Quadriceps Contraction in Women

Kenneth W. Kambis and Sarah K. Pizzedaz

Creatine monohydrate (CrH₂O) supplementation has been demonstrated to increase skeletal muscle power output in men. However, its effect upon women is not as clearly defined. This study investigated the effect of oral creatine supplementation upon muscle function, thigh circumference, and body weight in women. Twenty-two consenting college-age women were assigned to 1 of 2 groups matched for dietary and exercise habits, phase of menstrual cycle, and fat-free mass (FFM). After familiarization with testing procedures, pretrial measures of muscle function (5 repetitions 60 deg · s⁻¹ and 50 repetitions 180 deg · s⁻¹) were conducted during maximal voluntary concentric contraction of the preferred quadriceps muscle using an isokinetic dynamometer. Subjects then ingested 0.5 g · kg⁻¹ FFM of either CrH₂O or placebo (one fourth dosage 4 times daily) in a double-blind design for 5 days. Resistance exercise was prohibited. After the ingestion phase was completed, all measures were repeated at the same time of day as during pretrials. Statistical analysis revealed time to peak torque in quadriceps extension decreased from pre-test values of 255 ± 11 ms (mean ± SEM) to post-test values of 223 ± 3 ms; average power in extension increased from 103 ± 7 W pre-test to 112 ± 7 W post-test; and, during flexion, average power increased from 59 ± 5 W pre-test to 65 ± 5 W post-test in the creatine group as compared to controls (p ≤ .05). FFM, percent body fat, mid-quadriceps circumference, skinfold thickness of the measured thigh, and total body weight did not change for both groups between trials. We conclude that CrH₂O improves muscle performance in women without significant gains in muscle volume or body weight.

Key Words: muscle function, strength, power, fat-free mass

The Role of Creatine in Energy Production

Adenosine triphosphate (ATP) supplies cells with energy for their metabolic processes. Creatine phosphate plays a role in this energy transfer by transporting the third phosphate molecule from the mitochondrial ATP to the ADP in the cytoplasm for phosphorylation. The energy released when creatine phosphate is split into its component parts drives the phosphorylation of ADP. By supplementing the amount
of creatine already present in the cell, ATP production may be extended for a few seconds beyond its normal 3 to 6 s of availability. Such an extension of ATP production could theoretically provide energy needed to continue to accelerate during a sprint or generate increased muscle force during other activities (1, 4, 9, 17, 18, 35, 37).

Hultman et al. (14) reported that a rapid way to increase muscle creatine was to ingest 0.3 g CrH₂O · kg⁻¹ body mass for 6 days. Such ingestion of creatine supplements has been shown to increase muscle power (1, 2, 4, 6, 9, 11, 13, 18, 21, 23, 29, 37). This increase in function is often associated with an increase in total body weight. It is speculated that the increased intracellular creatine causes an influx of water into the cell because creatine is osmotically active and preferentially stored in type II muscle fibers (1, 4, 6, 24). More recent studies indicate that the increase in body mass may be a result of body water retention or muscle fiber size (20, 33, 34). Although many studies have included women in their research (19, 22, 24–26, 29), the literature reveals an under representation of research exclusively utilizing women subjects in the study of creatine supplementation (7, 13, 28, 29, 32, 37). Because a considerable majority of those seeking to enhance performance through creatine supplementation were male, researchers may have tended to focus on this group.

There is also inconsistency in determining creatine dosage. Most studies found increases in muscle performance with doses of approximately 20 g each day for 5 days without any deleterious side effects (2, 4, 10, 14, 18, 20, 21, 23, 27, 28, 32, 37). The purpose of this study was to investigate the effect of oral creatine supplementation on maximal concentric contractions of the quadriceps muscle in women using dosages controlled for differences in body composition. We hypothesized that creatine monohydrate supplementation of 0.5 g · kg⁻¹ fat-free mass (FFM) for 5 days would improve quadriceps contractile function in women.

**Methods**

Twenty-two fully informed healthy volunteer female subjects from the student population of The College of William and Mary were selected for this study. None of the subjects had used creatine previously. Subject demographics (Table 1) are: age, 20.3 ± 0.2 (mean ± SEM) years; height, 163.1 ± 1.3 cm; weight, 61.3 ± 0.5 kg; percent fat, 22.1 ± 0.9; and, fat-free mass, 47.6 ± 1.1 kg.

The study was approved by the Protection of Human Subjects Committee of The College of William and Mary. The 22 women reported to the Human Perfor-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SEM</th>
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</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>20.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Percent fat</td>
<td>22.1</td>
<td>0.9</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>47.6</td>
<td>1.1</td>
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mance Laboratory for familiarization with all equipment and measurements. The familiarization phase consisted of the same testing protocol as the pre- and post-tests with the exception that each subject was asked to complete a Food Frequency Questionnaire (8), exercise log, and record the first day of her last menstrual cycle. All of our subjects exhibited improvement from the familiarization trial to the pretrial tests, underscoring the importance of familiarization trials.

Based on each subject’s dietary habits, exercise habits, menstrual cycle phase, and FFM, we assigned participants to one of two groups of 11 subjects each. The groups were matched relative to meat intake, exercise history (either predominantly endurance or resistance), menstrual cycle phase (luteal or follicular), and FFM (Table 2). Using a double-blind protocol, one group was given a placebo and the other group given creatine.

Creatine is stored in fat-free mass. By providing individual doses relative to FFM (0.5 g · kg\(^{-1}\) · FFM), we effectively controlled for the range of body composition differences among our subjects. Twenty one-fourth daily doses for each subject of either placebo (white powder corn starch, CPC International, Inc., Englewood Cliffs, NJ) or creatine (Phosphagen, EAS, Inc., Golden, CO) were weighed on an electronic scale (Ohaus, Florham Park, NJ) and placed in covered plastic containers. Attached instructions informed the subjects to consume one cup each, diluted in approximately 250 ml of orange juice, at 8 AM, 12 noon, 4 PM, and 8 PM daily for 5 consecutive days. Subjects were told to avoid caffeine consumption for the duration of the study since Vandenberghe et al. (31) reported that caffeine inhibits the ergogenic effect of creatine.

**Pretrial Procedures**

Each subject’s pre-trial data collection date was determined by her menstrual cycle phase to control for ovarian hormonal fluctuations. Trials were scheduled for the same time of day within 1 hour, 6 days apart, and within the same cycle phase. The

**Table 2  Creatine (n = 11) and Placebo (n = 11) Groups Matched Relative to Meat Intake, Exercise History, Menstrual Cycle Phase, and Fat-Free Mass for Pre-trial and Post-trial**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-trial Mean</th>
<th>Pre-trial SEM</th>
<th>Post-trial Mean</th>
<th>Post-trial SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A: Creatine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.8</td>
<td>3.4</td>
<td>63.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Percent Fat</td>
<td>23.4</td>
<td>1.4</td>
<td>23.4</td>
<td>1.1</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>48.6</td>
<td>2.0</td>
<td>48.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Group B: Placebo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.8</td>
<td>1.9</td>
<td>58.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Percent fat</td>
<td>20.8</td>
<td>1.1</td>
<td>21.0</td>
<td>0.9</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>46.6</td>
<td>1.1</td>
<td>46.5</td>
<td>1.2</td>
</tr>
</tbody>
</table>
control group had 6 follicular phase subjects and 5 luteal phase subjects, and the creatine group had 5 follicular phase subjects and 6 luteal phase subjects. Substantial hormonal fluctuations can occur within a menstrual cycle phase and thus alter fluid balance. Having follicular and luteal phase–matched groups minimized the effect of menstrual cycle phase between groups. Each subject’s height and weight were recorded. Subjects were asked not to weigh themselves during the experiment to prevent counteraction to any weight gain. Subjects were also asked to maintain their normal dietary and exercise habits while refraining from resistance training. Skinfold thickness was measured at the triceps, ileum, and thigh for estimation of percent body fat (15). Using standard procedure, mid-thigh was calculated as half the distance from the greater trochanter to the greater tuberosity of the lateral epicondyle. FFM was calculated as the difference between total body fat, as determined by skinfold thickness, and total body mass. Leg girth was measured at mid-thigh of the preferred leg using a Gulick tape. Prior to strength testing, all subjects completed a 5-min warm-up on a bicycle ergometer (Lode Excalibur, Groningen, Holland) at 40 rpm and 25 W resistance.

Following the warm-up, an isokinetic dynamometer (Biodex model 900-350, Biodex Corp., Shirley, NY) was utilized to conduct isokinetic strength measurements of the preferred quadriceps muscle. Reliability of the Biodex isokinetic dynamometer is between 0.93 and 0.99 for peak torque and average power measurements in extension and flexion (36). Subjects were seated in the appropriate side of the Biodex double chair, and seat adjustments were made to place the knee axis of rotation in the same vertical plane as the powerhead. The calf pad was placed proximal to the malleoli and below the widest portion of the calf musculature. All padded straps were firmly secured to stabilize the subject and minimize upper body musculature involvement. Passive weight of the lower leg was determined prior to setting range of motion limits and speed limits. Subjects then conducted five maximal voluntary concentric contractions (MVC) of the preferred quadriceps and biceps femoris at 60 deg · s⁻¹. After a 5-min rest period, a second measurement consisting of 50 MVC repetitions at 180 deg · s⁻¹ was collected (3, 5, 12, 16, 36). Data was acquired and analyzed (Biodex Advantage Software, Biodex Medical Corporation, Shirley, NY) during each set of MVCs.

During the pretrial, each subject was given her opaque container of either placebo or creatine with accompanying instructions. Beginning in the morning after the pretrial, subjects were asked to dissolve the contents of a single container into one cup of orange juice. Subjects were told to save the empty plastic containers and return them to the investigators during post-trial testing. All subjects recorded daily dietary intake and maintained daily exercise logs. Resistance exercise was prohibited for the duration of the experiment.

**Post-trial Procedures**

Each subject returned to the laboratory 6 days later for their post-trial measurements. The pretrial protocol was followed for all post-trial measures.

**Data Analysis**

Repeated measures ANOVA was used to compare the results from the creatine group to the control group across trials or within groups between trials. Post hoc
comparisons of the treatment means were made with Tukey’s test. Descriptive statistics are presented as means ± SEM. Data were considered significantly different if the level of probability was equal to or less than .05.

Results

All subjects brought 20 empty containers and food and exercise diaries to their post-trial session. Eleven subjects in each group completed the experiment. There were no complaints of side effects resulting from ingestion of either the placebo or creatine.

Creatine supplementation resulted in an increase ($p \leq .05$) in average power output (Figure 1) during the extension phase of the 50-repetition trial from 103.6 ±

![Figure 1 — Average power in preferred quadriceps extension (a) and flexion (b) generated during a 50 repetition, 180 deg · s⁻¹ MVC ($p < .05$). Values are expressed as mean ± SEM.](image)
7.1 W (mean ± SEM) pretrial to 112 ± 7 W post-trial. There was no difference in average power output for the 50-repetition extension phase in the control group across trials.

The results of the flexion phase of the 50-repetition test (Figure 1b) showed an increase (p ≤ .05) in average power output from pre- to post-trial in the creatine group of 58.9 ± 5.3 W to 64.9 ± 5.2 W, respectively. The placebo group showed no difference in average flexion power output measured by the 50-repetition test.

Extension time to peak torque in the 50-repetition test (Figure 2) decreased (p ≤ .05) from 255.5 ± 11 ms pretrial to 223.6 ± 3 ms post-trial in the creatine group, while no difference was noted in the control group.

No changes were found between groups or across trials in body composition, body weight, fat-free mass (body weight – fat weight), thigh circumference, or mid-thigh skin fold thickness.

**Discussion**

This study demonstrated an increase in quadriceps muscle performance in women as a result of creatine supplementation of 0.5 g · kg⁻¹ FFM each day for 5 days. The results of the present study support the hypothesis that creatine supplementation increases quadriceps contractile function in women. After 5 days of creatine monohydrate supplementation of 0.5 g · kg⁻¹ FFM (one fourth dose 4 times daily), there was a significant (p ≤ .05) increase in average power in quadriceps extension and

![Figure 2 — Time to peak torque (ms) in preferred quadriceps extension during a 50 repetition, 180 deg · s⁻¹ MVC (p < .05). Values are expressed as mean ± SEM.](image_url)
flexion phases of maximal voluntary concentric contractions of the preferred quadriceps muscle at 180 deg · s⁻¹ for 50 repetitions. There was also a significant decrease in time to peak torque in the extension phase of the 50-repetition test. These results concur with earlier findings in men that creatine supplementation increases muscle power (6, 9, 11, 17, 28, 31, 33). Unlike reports of weight gain in men and in some women in the majority of creatine studies previously conducted, we found no increase in body weight. It has been hypothesized that the weight gain accompanying creatine supplementation is due to either water retention or an increase in fat-free mass (20, 33, 34). Our finding of no body mass change is consistent with others who studied creatine supplementation for 5 to 7 days in women (13). Level of physical fitness and its possible effect upon creatine storage is not well defined. We did not measure pre-experiment levels of creatine and hence do not know the specific increase, if any, in available creatine phosphate due to supplementation that may have occurred.

Both the control and creatine groups were matched for menstrual cycle phase. Because all subjects were tested within their cycle phase, it was assumed that ovarian hormone concentrations remained balanced between groups. To test the effect of menstrual cycle phase on creatine supplementation, it would be necessary to measure women during transition from one phase to the next. Elucidating the effect of cycle phase on creatine supplementation was not a purpose of this study.

Time to peak torque during quadriceps extension was decreased by creatine supplementation. Since type II muscle fibers tend to preferentially store creatine (4), and the mass of the quadriceps (extensors) is greater than the flexors, it follows that the extensor muscles should generate their maximum force more rapidly than the smaller flexor muscles. This may explain why the decrease in time to peak torque was seen only in the extension phase.

While we found no difference in the 5-repetition MVC measurements, Greenhaff et al. (11) found significant creatine-induced increases in leg strength in 9 male and 3 female subjects after 10 concentric MVCs in an initial bout of exercise. Although Greenhaff and his co-workers did not differentiate between genders, their work suggests that we did not have our subjects contract their quadriceps through enough cycles to identify the effect of creatine on peak torque and absolute torque. Future creatine supplementation studies using isokinetic strength tests of more than five maximum concentric contractions may elucidate this possible limitation to our study. We did find that creatine supplements caused peak torque values to be reached (p ≤ .05) sooner (repetition 5 post-trial vs. repetition 9 pretrial in the 50-repetition test) providing support for the Greenhaff et al. (11) position.

We have found that creatine monohydrate supplementation of 0.5 g · kg⁻¹ FFM daily for 5 days improves muscle performance in women without gains in thigh circumference or body weight. No deleterious effects were seen, which suggests short-term creatine supplementation is probably a safe and effective means of increasing strength (30). Additional research is needed to expand the study of gender-related differences in response to the effect of creatine supplementation.

References


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