Comparison of Creatine Monohydrate and Carbohydrate Supplementation on Repeated Jump Height Performance

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Abstract

Koenig, CA, Benardot, D, Cody, M, and Thompson, WR. Comparison of creatine monohydrate and carbohydrate supplementation on repeated jump height performance. *J Strength Cond Res* 22: 1081–1086, 2008—Creatine monohydrate (CrMH) supplementation aids the ability to maintain performance during repeated bouts of high-intensity exercise, including jump performance. However, carbohydrate supplementation may also provide similar benefits and is less expensive. This study compared the effects of an energy-free placebo, 2 different caloric concentrations of carbohydrate drinks, and a CrMH supplement on repeated jump heights. Sixty active males (mean age, 22 ± 3.2 years) performed 2 sets of countermovement static jump height tests (10 jumps over 60 seconds) separated by 5 days to determine the differential effects of the placebo, carbohydrate, and CrMH on jump height sustainability over 10 jumps. Subjects were randomly assigned to groups (15 subjects per group) to receive daily doses (×5 days) of carbohydrate drinks containing 100 or 250 kilocalories (kcal), a 25-g CrMH supplement, or an energy-free placebo. After 5 days, the CrMH group experienced a significant weight gain (+1.52; ±0.89 kg, $p < 0.01$), while the other groups did not. The 2 levels of carbohydrate and CrMH supplements were all significantly better at sustaining jump height than the energy-free placebo over the final 3–4 jumps. The 250-kcal carbohydrate-supplemented group experienced a level of benefit ($p < 0.01$) that was at least equal to that of the CrMH group ($p < 0.05$), suggesting that the higher dose of carbohydrate was as effective as CrMH in maintaining repeated bouts of high-intensity activity as measured by repeated static jumps. Given the equivalent performance improvement and the absence of weight gain, the carbohydrate supplementation could be considered the preferred option for weight-conscious power athletes involved in activities that require repeated- motion high-intensity activities.

Key Words high-intensity exercise, caloric supplement, ergogenic aid, exercise performance, glycolysis

Introduction

The benefits of creatine monohydrate (CrMH) supplementation have been studied since the 1920s (5). However, the greatest interest has occurred in the past decade, with special attention given to the potential advantages derived from CrMH on sports performance involving repeated bouts of high-intensity exercise. A series of studies, including several that used jump height tests, demonstrated significant improvements in the ability to maintain force after supplementation with CrMH (16,20,29). These improvements have been attributed to increased skeletal muscle free creatine and phosphocreatine (PCr) with a concomitant improvement in the resynthesis of adenosine triphosphate (ATP), both of which maintain the ability to perform work (3,12,14). Since ATP production during high-intensity exercise depends on skeletal muscle stores of PCr, insufficient stores are a limiting factor in repeated bouts of high-intensity exercise.

Anaerobic glycolysis and the PCr-ATP system are primary energy sources for repeated bouts of high-intensity exercise. Although the type and duration of activity influence fuel reliance, anaerobic energy systems do not respond in a purely sequential manner, and anaerobic glycolysis, like the PCr-ATP system, has an immediate impact on the ability to perform high-intensity exercise (2,10). The relationship between glycogen stores and performance in high-intensity exercise has been demonstrated in earlier studies (2,4). Nevertheless, the mechanism through which pre-exercise glycogen stores affect performance of repeated bouts of high-intensity exercise is not entirely clear. It is possible that these

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mechanisms include delayed depletion of whole-muscle glycogen levels, delayed depletion of glycogen in select compartments, including type II muscle and the sarcoplasmic reticulum (SR), and a delay in the accelerated use of PCr (2,4,9,11,30).

While studies have demonstrated that CrMH supplementation results in enhanced free creatine and PCr stores, not all research findings support the idea that CrMH has the ability to improve or maintain power or the level of work performed (3,12,14). Importantly, most studies that report performance benefits resulting from CrMH supplementation have failed to account for the potential energy (4 $kcal \cdot g^{-1}$) that could be derived from the carbon chain of creatine. Therefore, it is difficult to ascertain whether improvements should be attributed to enhanced ATP resynthesis from CrMH or whether improvements could be, at least in part, attributable to the increased energy availability represented by the intake of creatine. The increased provision of energy could serve to spare muscle glycogen that, in turn, could benefit performance in repeated bouts of high-intensity exercise. This issue is particularly important for athletes because studies and surveys have indicated that many athletes fail to meet their predicted daily energy needs (8,28), and energy deficits can decrease performance in anaerobic activities (19).

The purpose of this study was to compare the effects of CrMH supplementation to the effects of an energy-equivalent (100-kcal) carbohydrate-based supplement, and a higher (250-kcal) carbohydrate-based supplement, on repeated jump performance. It was hypothesized that the 250-kcal carbohydrate supplement, the 100-kcal supplement, and the CrMH supplement would all result in improved repeated jump-height performance compared to an energy-free placebo. A finding of similar performance benefits between carbohydrate and CrMH supplementation would demonstrate the importance of an adequate energy intake and maximizing glycogen stores. In addition, these results may help to clarify the reported benefits of CrMH on repeated bouts of high-intensity exercise.

Methods

Experimental Approach to the Problem

It is well established that CrMH supplementation helps to sustain performance in activities involving repeated bouts of high-intensity exercise (including repeated jump height tests) that are separated by brief periods of rest (16,20,29). Since earlier studies compared CrMH supplementation to an energy-free placebo, it remained unclear whether the enhanced formation of PCr or the carbon-based energy of CrMH contributed to the performance improvements. The 25 g of CrMH commonly used in these studies would add 100 kcal if the carbon chains provided by CrMH were catabolized for energy. Comparing a CrMH supplement to carbohydrate supplements containing 100 or 250 kcal and to an energy-free placebo would help to clarify whether energy intake is responsible for some or all the improvements contributed to CrMH supplementation, while also demonstrating whether a carbohydrate supplementation could be an effective alternative to CrMH supplementation for sustaining performance in activities involving repeated bouts of high intensity.

Subjects

Seventy-one volunteers were recruited to participate in the study, 60 of whom completed the full protocol. All subjects were healthy, college-age males (22 ± 3 years; range, 18–35) who used the Georgia State University Student Recreation Center (Atlanta, GA) or the Neal Army Fitness Center (Atlanta, GA). Individuals who reported a personal or family history of diabetes, liver disease, renal disease, unstable weight, or previous CrMH supplementation were excluded from participating in this study. The 60 subjects completing the study had an average weight of 81.7 ± 14.1 kg, an average height of 178.5 ± 7.5 cm, and a calculated body mass index (BMI) of 25.4 ± 3.4 $kg \cdot m^2$.

All subjects were recreational athletes with a self-reported history of engaging in regular physical activity. Precise data on duration of activity were not collected. Nine subjects began testing but were dropped from the experiment because of noncompliance with the prescribed administration of the supplement- or placebo-containing beverages. A 10th subject withdrew after reporting gastrointestinal (GI) side effects, and an 11th subject was removed for inconsistencies in clothing worn and an incomplete dietary intake record. A total of 11 originally recruited subjects (15%) were dropped from the study. There was no difference in average height, weight, and BMI between the original and remaining subjects for any of the treatment and control groups ($p \geq 0.05$).

Procedures

This study was approved by the Institutional Review Board for human subjects' protection at Georgia State University. All volunteers gave their written informed consent before testing. Subjects completed a health questionnaire that focused on their use of drugs, dietary supplements, allergies, and medication; for renal disease; and the occurrence of other diseases that might affect skeletal muscle metabolism. Measurements of height, weight, weight history, and standing reach were recorded during the initial visit. A registered dietitian performed a 24-hour food recall on the date of the baseline jump height test and repeated the 24-hour food recall and weight measures on the date of the second jump height test.

After the initial (baseline) countermovement static jump height test, subjects were randomly placed (using a computer-generated random numbers table) into 4 groups of 15 each. The participants received daily doses of either sucrose-based carbohydrate supplements containing 100 kcal or 250 kcal, a 25-g CrMH supplement (Pro Performance Creatine Monohydrate; General Nutrition Centers Inc., Pittsburgh, PA), or an energy-free placebo containing aspartame. Twenty-five grams of CrMH represents a median value to the 20–30 g commonly used for the loading phase of CrMH supplementation

TABLE 1. Dietary intake of subjects ($N = 60$).

	Day 1		Day 5	
	Mean ± *SD*	Range	Mean ± *SD*	Range
Kcal	2673 ± 1150	855–6340	2691 ± 1020	677–6051
Carbohydrate (g)	336 ± 162	56–814	351 ± 155	60–1019
Protein (g)	118 ± 61	13–297	112 ± 59	16–325
Fat (g)	95 ± 59	20–301	93 ± 46	17–258

(1,17,18). All 4 of the supplements were mixed into energy-free, orange-flavored beverages that had nearly identical appearances, although beverages had distinctly different sweetness intensities. Subjects consumed their assigned beverages under supervision for 5 consecutive days. Thirty minutes after supplement ingestion on the 5th day, a second countermovement static jump height test was performed. The beverages required agitation immediately before consumption to ensure that there was no discernable difference between the beverages consumed by the 4 groups. Subjects were not informed of the supplement that they were ingesting until after completion of the second jump height test (single blind).

The ability to maintain high-intensity exercise was measured through a series of 10 maximum effort, countermovement jumps completed over the course of 60 seconds. Jump height tests were performed on days 1 (baseline) and 5 of the protocol. Each test consisted of 10 jumps, separated by 6-second intervals. Vertical jump heights were assessed by measuring total jump height achieved and subtracting maximum standing reach (previously determined) using a commercially available jump measurement device (Vertec; Sports Import Inc., Columbus, OH). The initial jump height test served as baseline data and was performed after a complete explanation of the procedures. Jumps began from the standing position and involved a preparatory countermovement. Both the baseline and follow-up tests were performed at approximately the same time of day. Subjects were asked to wear shorts and gym shoes to minimize differences caused by other types of foot wear and clothing. Subjects were also instructed to avoid food consumption within 2 hours of the testing but to otherwise maintain normal dietary patterns and not to begin ingesting nutritional supplements during the course of the study.

Statistical Analyses

The 24-hour diet recalls were recorded and analyzed using Nutrition Pro (First DataBank Inc., San Bruno, CA) to verify that participants maintained a consistent energy intake over the course of the study. A probability of $p < 0.05$ was used to determine significance. Descriptive statistics were obtained on subject heights, weights, BMI, dietary factors (kcal, carbohydrate, protein, fat intake), and jump heights. A series of 1-way analyses of variance (ANOVA) were used to analyze the significance of changes in jump heights between the baseline and second static jump height tests within and between groups. Bonferroni-corrected post hoc tests were also used to assess the significance of difference in jump heights between the treatment groups and control group. One-way ANOVA with Bonferroni post hoc tests were also used to analyze subject physical characteristics (height, weight, BMI, weight history) and dietary intakes in an attempt to identify significance of differences. Pearson's correlations were performed on all data to assess the degree of relationship between different variables.

RESULTS

Descriptive statistics were obtained on subject heights, weights, BMI, dietary factors (kcal, carbohydrate, protein, fat intake), and jump heights. There were no statistical differences between groups on these variables at baseline ($p \geq 0.05$).

Dietary Intake and Side Effects

Dietary characteristics for all subjects who completed testing ($N = 60$) are displayed in Table 1. Analysis of participants' dietary intake indicated that no significant differences were present in total kilocalories, carbohydrate, protein, or fat intake across time or between groups.

Creatine monohydrate supplementation resulted in a significant increase ($p < 0.001$) of 1.52 ± 0.89 kg in body weight compared

TABLE 2. Pre- and postsupplementation mass (kg).

		Presupplementation		Postsupplementation		
	No	Mean ± *SD*	Range	Mean ± *SD*	Range	Change
Placebo (group 1)	15	81.1 ± 15.2	53.6–101.4	80.9 ± 15.2	53.2–101.4	−0.2
100 kcal (group 2)	15	83.1 ± 18.7	59.1–129.1	83.1 ± 18.3	59.5–128.2	n/a
250 kcal (group 3)	15	82.3 ± 12.3	66.1–105.9	82.4 ± 12.0	67.0–105.9	+0.1
Creatine (group 4)	15	80.3 ± 10.0	69.5–101.4	81.8 ± 9.6	70.5–101.4	+1.5*

n/a = not available.
*Creatine group showed a significant change compared to baseline weight and other groups.

Table 3. Difference in jump height after intervention (post–baseline jump heights [cm]).

Jump	Group 1 (placebo)	Group 2 (100 kcal)	Group 3 (250 kcal)	Group 4 (creatine)	p
1	1.44 ± 3.02	2.37 ± 2.67	1.61 ± 4.01	2.03 ± 2.18	0.835
2	1.19 ± 2.62	2.46 ± 3.53	1.44 ± 2.54	0.170 ± 2.03	0.163
3	0.000 ± 3.91	1.27 ± 2.72	0.846 ± 3.12	0.932 ± 2.82	0.728
4	0.084 ± 2.62	0.508 ± 1.57	1.86 ± 1.96	1.52 ± 2.54	0.106
5	−0.084 ± 2.64	0.762 ± 2.39	1.52 ± 2.64	0.846 ± 2.69	0.415
6	0.170 ± 3.15	1.35 ± 2.01	1.52 ± 2.21	0.338 ± 1.88	0.289
7	−0.762 ± 2.44	0.084 ± 1.63	2.20 ± 2.11	1.02 ± 2.90	0.006*
8	−0.592 ± 2.74	0.424 ± 2.29	2.46 ± 2.51	2.29 ± 2.77	0.004†
9	−0.932 ± 2.46	0.846 ± 1.57	2.29 ± 3.33	2.72 ± 1.78	0.000†
10	−1.35 ± 2.34	1.19 ± 2.18	3.38 ± 2.95	2.97 ± 2.24	0.000‡

Values are mean ± *SD*.
*Placebo significantly lower than 250-kcal group.
†Placebo significantly lower than 250-kcal and creatine groups.
‡Placebo significantly lower than 100-kcal, 250-kcal, and creatine groups.

to baseline weights; body weights of the other groups remained unchanged. All 15 subjects in the CrMH group gained weight, with the largest increase being 3.2 kg. In contrast, no significant differences were seen in weights between baseline and day 5 in either the placebo or the 100- and 250-kcal groups. The weight gain in the CrMH group is consistent with the 1- to 3-kg weight gain reported in the literature (1,3,23,29). A complete breakdown of subjects' presupplementation and postsupplementation weights, by group, is shown in Table 2.

Gastrointestinal problems were reported by 4 participants. Three subjects (2 taking CrMH and 1 taking the placebo) who completed the study reported GI distress (2 with diarrhea and 1 with stomach discomfort), and 1 subject (taking CrMH) who did not complete the study reported experiencing GI discomfort.

Exercise Performance

There was no significant difference between groups at baseline for 10 jumps, but the 100-kcal, 250-kcal, and 25-g CrMH groups all showed a significant improvement in the ability to maintain jump heights on the second jump test trial compared to the energy-free placebo (Table 3). The 250-kcal group showed a significant improvement in mean jump height for the last 4 jumps, with increasing improvements compared to baseline (jump 7: +2.97 cm, $p < 0.005$; jump 8: +3.05 cm, $p < 0.013$; jump 9: +3.23 cm, $p < 0.003$; jump 10: +4.75 cm, $p < 0.001$). The CrMH group showed a significant increase in mean jump height for the final 3 jumps (jump 8: +2.87 cm, $p < 0.021$; jump 9: +3.56 cm, $p < 0.001$; jump 10: +4.32 cm, $p < 0.001$). The 100-kcal group was slightly less effective, only showing a significant improvement for jump 10 (2.54 cm, $p < 0.036$). A detailed breakdown differences in jump heights is shown in Table 3.

Discussion

The results of this study demonstrated that short-term supplementation with carbohydrate (100 or 250 kcal) and CrMH (calorically equivalent to 100 kcal of carbohydrate) supplements all helped to sustain jump performance over 10 sequential jumps. Although all 3 groups receiving a carbohydrate or CrMH supplement showed an improved ability to maintain jump heights, the 250-kcal and CrMH groups outperformed the 100-kcal group, with the benefits in the 250-kcal group being observed 1 jump earlier than in the CrMH subjects. In must also be noted that the CrMH group experienced benefits despite an average weight gain of 1.5 kg. This increase in weight could be a handicap for performance in weight-supported activities, including jumping.

The 24-hour diet recall did not reveal any significant difference in energy intake or macronutrient composition at baseline compared to day 5 or between groups, suggesting that dietary habits did not explain any of the observed differences between test groups. To determine the adequacy of energy intake, this study used the average of 3 formulas established to estimate energy intake (the formula developed by the National Academy of Sciences, Harris-Benedict, and Schofield equation) in conjunction with an activity factor and a separate factor to adjust for the underreporting of daily intake (15,25). Even when adjusted by 10% for the potential underreporting commonly associated with self-report methods of estimating food intake, the assessed energy intake of this group of subjects (2673 ± 1150 kcal at baseline and 2691 ± 1021 kcal on day 5) averaged 300 kcal below their mean predicted energy requirement (3250 kcal) (17).

While these results support previous studies that demonstrated the beneficial role of CrMH on repeated bouts of high-intensity exercise (3,6,16,20,22) and jump height tests specifically (16,20,29), they raise additional questions regarding the possibility that improved performance in the CrMH group could be from the additional energy provided by the CrMH rather than from the enhanced resynthesis of PCr.

The 25 g of CrMH would add 100 kcal if the carbon chains represented were catabolized for energy. It is unclear whether this energy contribution would be meaningful from a performance standpoint, but it is necessary to discuss the products provided using a common energy-based denominator. If the improved performance was from the additional energy provided by the CrMH, that, in turn, would raise questions about the source of the creatine-derived benefits reported in the earlier studies that did not account for the energy provided by the loading doses. The impact of additional energy may be even more important when subjects are in an energy-deficient state, as was suggested in this study (−300 to −560 kcal) (19).

Another possible conclusion is that carbohydrate and CrMH have separate pathways for producing similar results. The results of this study indicated that a 250-kcal carbohydrate-based oral supplement improves performance in repeated bouts of high-intensity exercise as much as CrMH. These results support earlier studies that demonstrated the influence of high carbohydrate diets on performance of repeated bouts of high-intensity exercise (2,4) and the value of pre-event oral carbohydrate supplementation on performance (7,21). Another recent study by Hatfield et al. (13) that used loaded jump squats showed mixed results. This study did not demonstrate a significant impact in acute training when comparing a high carbohydrate diet to a 50% carbohydrate diet, but did show a significantly enhanced mean power output when the high-carbohydrate diet was compared to a self-selected (baseline) diet.

While carbohydrate supplements appear to be of some benefit, the mechanism is not entirely clear. Wootton and Williams (31) believed that, as creatine stores are exhausted, demand for muscle glycogen increases in an attempt to maintain energy production. Since it is well established that a high-carbohydrate diet increases blood glucose concentrations and skeletal muscle glycogen content, the increased glucose and glycogen may help maintain performance after free creatine and PCr levels are depleted. Another possibility is that the increase in both glucose concentrations and skeletal muscle glycogen stores spare muscle creatine. All these mechanisms have been proposed by various researchers (9,11,30).

Depletion of skeletal muscle glycogen stores to a level needed to negatively affect anaerobic exercise seems unlikely. Several studies have recorded decreases in muscle glycogen concentrations of only 25–40% after multiple bouts of high-intensity exercise (24,26). At this level, muscle glycogen and blood glucose are not likely to be sufficiently depleted so as to be a limiting factor. It has also been reported that during repeated bouts of high-intensity exercise, the contribution of glycolysis decreases over time. Gaitanos et al. (10) reported only a 16% contribution from glycolysis in the 15th and final 6-second bout of maximal exercise.

Depletion of glycogen in type II muscle fibers or select compartments including the SR may represent a better possibility by which glycogen depletion negatively affects performance. The possibility of region-specific glycogen depletion, including depletion of type II muscle fibers and the SR, has been demonstrated in multiple studies (9,11,30). Depletion of glycogen in the SR specifically could influence calcium flux, in turn negatively affecting muscle contraction. If oral carbohydrate supplementation prevents the depletion of total skeletal muscle glycogen, type II muscle fiber glycogen, depletion of glycogen in the SR, reduction in the rate of glycogen breakdown, or increase glycogen synthesis during recovery periods, it would, in turn, enhance performance. There is also the possibility that carbohydrate supplements influence athletic performance through central brain mechanisms and perceptional fatigue.

The 1.5-kg average increase in body weight that was observed after the 5 days of 25 g of CrMH administration (loading dose) was consistent with the 1–3 kg reported in the literature and was likely due to water retention (1,3,23,29). Although specific data on the secondary effects of CrMH supplementation, other than weight gain, were not methodically collected, there were several reports by participants of GI disturbances, including 2 individuals reporting diarrhea and 2 reporting stomach discomfort. Three of 4 experiencing GI disturbances were from the CrMH group, and the fourth was in the placebo (artificial sweetener) group. Similar GI disturbances have been observed with CrMH supplementation (18,27); however, the literature does not establish them as commonly associated with CrMH supplementation (1,23).

Creatine monohydrate supplementation is a proven method for increasing both skeletal muscle free creatine and PCr stores and enhancing performance in repeated bouts of high-intensity anaerobic exercise (3,6,12,14,16,20,22,29). One variable not controlled for in research involving CrMH supplementation is the additional energy (4 $kcal \cdot g^{-1}$) received from the creatine. The additional energy may promote creatine synthesis or spare muscle glycogen. Like CrMH, oral carbohydrate supplements enhance performance in repeated bouts of high-intensity exercise (7,21). While it is not known whether the additional energy, the form of the energy (carbohydrates), or a combination of these factors resulted in the performance benefit observed, a traditional 250-kcal carbohydrate supplement produced similar performance benefits as supplementation with CrMH.

Practical Applications

This study suggests that short-term supplementation with either CrMH or carbohydrate supplements containing 100 or 250 kcal can improve the ability to maintain performance during repeated bouts of high-intensity activity. While the CrMH supplementation outperformed a calorically equivalent carbohydrate supplement, the 250-kcal carbohydrate supplement demonstrated near equivalence with CrMH in helping subjects sustain jump height. This finding suggests that additional carbohydrate calories may provide benefits that are similar to CrMH in maintaining repeated bouts of high-intensity activity. Given the equivalent performance improvement and the absence of weight gain, the carbohydrate supplementation could be considered the preferred option for weight-conscious power athletes involved in activities that require repeated-motion high-intensity activities.

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