# Effect of a 10-Week Strength Training Program and Recovery Drink on Body Composition, Muscular Strength and Endurance, and Anaerobic Power and Capacity

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**OBJECTIVE:** We investigated whether postexercise consumption of a supplement containing whey protein, amino acids, creatine, and carbohydrate combined with a strength training program promotes greater gains in fat-free mass (FFM), muscle strength and endurance, and anaerobic performance compared with an isocaloric, carbohydrate-only control drink combined with strength training.

**METHODS:** The study was double blind and randomized, and the experimental supplement was compared with a carbohydrate-only control. Forty-one males ($n = 20$ in control group, $n = 21$ in the supplement group; mean age, 22.2 y) participated in a 4 d/wk, 10-wk periodized strength training program. Subjects had to complete at least 70% of the workouts. Before and after 10 wk of strength training, subjects were tested for body composition by using hydrostatic weighing and skinfold thicknesses, one repetition maximum strength and muscular endurance for the bench press and 45-degree leg press, and anaerobic performance using a 30-s Wingate test. Thirty-three subjects (80.5%) completed the training program ($n = 15$ in control group, $n = 18$ in the supplement); these 33 subjects also completed all post-training test procedures. Data were analyzed with two-way analysis of variance with repeated measures on time. $P \leq 0.05$ was set as statistically significant. All statistical analyses, including calculation of effect size and power, were completed with SPSS 11.0.

**RESULTS:** Across groups, FFM increased during 10 wk of strength training. Although there was no statistically significant time × group interaction for FFM, there was a trend toward a greater increase in FFM for the supplement group (+3.4 kg) compared with the control group (+1.5 kg; $P = 0.077$). The effect size ($\eta^2 = 0.100$) was moderately large. Percentage of body fat declined and fat mass was unchanged; there were no differences between groups. One repetition maximum strength for the bench press and 45-degree leg press increased, but there were no differences between groups. Muscular endurance expressed as the number of repetitions completed with 85% of the one repetition maximum was unchanged; external work, which was estimated as repetitions completed × resistance used, increased for the 45-degree leg press but not for the bench press over the 10-wk training period; there were no time × group interactions for either measurement. Anaerobic power and capacity improved, but there were no differences between groups for these variables or for fatigue rate.

**CONCLUSIONS:** Consumption of a recovery drink after strength training workouts did not promote greater gains in FFM compared with consumption of a carbohydrate-only drink; however, a trend toward a greater increase in FFM in the supplement group suggests the need for longer-term studies. Performance variables such as muscle strength and endurance and anaerobic performance were not improved when compared with the carbohydrate-only group. *Nutrition* 2004;20:420–427. ©Elsevier Inc. 2004

**KEY WORDS:** creatine, fat-free mass, protein, resistance exercise

## INTRODUCTION

Research studies have demonstrated the effectiveness of creatine[1–3] and the importance of protein[4–6] for enhancing gains in muscle mass and strength. Creatine supplementation in conjunction with resistance training results in greater increases in fat-free mass (FFM)[1,2] and muscle fiber size[2] than does training alone. The effects of creatine supplementation on FFM and muscle size may be due in part to an improved capacity to perform repeated bouts of high-intensity exercise such as strength training exercise.[1,7–10] In addition, some studies have suggested that creatine may directly affect muscle growth,[11–14] whereas other studies have not supported these findings.[15,16] Regardless of the mechanisms of action, creatine supplementation enhances gains in FFM, muscle mass, and muscle strength when used in conjunction with a strength training program.[2,3]

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The increased protein needs of athletes have been recognized.[5,6,17,18] Protein supplementation also may improve gains in muscle mass when used in conjunction with strength training.[4] After 6 wk of resistance training, groups that received whey protein or whey protein plus creatine had significant increases in lean tissue mass, but the placebo group did not have a significant gain in lean mass.[4] However, not all studies have found protein supplementation to be beneficial for increasing muscle mass.[17]

In addition, optimizing the timing of nutrient intake may be essential for promoting maximal gains in muscle mass and strength in conjunction with a resistance training program. Ingestion of essential amino acids after heavy resistance exercise resulted in a change from net muscle protein degradation to net muscle protein synthesis.[19] When essential amino acids are ingested in combination with carbohydrates at 1 or 3 h after exercise, muscle protein synthesis is stimulated.[20] The greatest effect of a protein plus carbohydrate supplement on muscle protein synthesis is expected when the supplement is ingested immediately before or after the exercise bout.[20–23]

Optimizing the amount and timing of carbohydrate intake also may have a significant effect on muscle glycogen content and protein turnover. Carbohydrate ingestion immediately after exercise promotes glycogen synthesis.[24–26] This may decrease recovery time after strength training, enabling an increased training volume, which may enhance muscle mass and strength gains.[27] Consumption of a carbohydrate solution after resistance training can enhance the rate of muscle glycogen repletion.[28] Muscle glycogen content can be reduced by leg-extension exercise. In one study, muscle glycogen content 6 h after exercise had returned to 91% of initial values when a carbohydrate solution was consumed immediately after exercise and 1 h after exercise; however, muscle glycogen was only 75% of pre-exercise values when a placebo was consumed.[28] Postexercise supplementation with carbohydrate and amino acids is as effective as a carbohydrate-only supplement for promoting muscle glycogen synthesis.[29]

Carbohydrates also may be beneficial during postexercise recovery by enhancing protein turnover. Carbohydrate consumption induces increases in circulating insulin levels and skeletal muscle blood flow,[30] which may create a positive anabolic environment. Carbohydrate supplementation of 1 g/kg of body weight immediately after resistance training reduces myofibrillar protein breakdown.[31]

Research demonstrating that the ingestion of protein alone[21] or protein and carbohydrate[20,23] before or after resistance training exercise improves protein turnover, providing a basis for hypothesizing that supplementation with protein plus carbohydrate near the time of exercise will improve muscle mass. However, it has not been demonstrated that the transient improvements in protein turnover after consumption of protein plus carbohydrate postexercise result in greater gains in muscle mass over longer periods of training.

Companies that manufacture and market dietary supplements are designing specific products for athletes and fitness enthusiasts. Anabolic Recovery, which is marketed by MET-Rx (Boca Raton, FL, USA), was designed to enhance protein turnover and glycogen resynthesis after exercise. A more rapid recovery after strenuous exercise workouts may allow individuals to train with greater volume or intensity on subsequent days. Also, consumption of a postexercise supplement may shift protein turnover more in the direction of protein accretion, thus increasing gains in FFM. A product containing whey protein and specific amino acids, creatine, and carbohydrate would provide convenience and possibly enhance gains in FFM, muscle function, and anaerobic performance. The purpose of this study was to determine whether postexercise consumption of a supplement drink (Anabolic Recovery) containing whey protein, specific amino acids, creatine, and carbohydrate combined with a strength training program promotes greater improvement in FFM, muscle strength and endurance, and anaerobic power and capacity as compared with strength training and an isocaloric, carbohydrate-only drink.

TABLE I.

SUBJECT CHARACTERISTICS PRIOR TO TRAINING FOR PARTICIPANTS COMPLETING THE STUDY*

| | Placebo | Supplement |
|---|---|---|
| Subjects (*n*) | 15 | 18 |
| Age (y) | 22.1 ± 1.8 | 22.2 ± 3.0 |
| Body weight (kg) | 79.2 ± 15.7 | 83.6 ± 14.2 |
| Body fat (%) | 14.8 ± 7.2 | 17.8 ± 6.9 |

* Data are mean ± standard deviation.

## MATERIALS AND METHODS

### *Study Design*

The study was a double-blind, placebo-controlled design. Subjects were randomly assigned to the supplement group or the control group.

### *Subjects*

Forty-four males between ages 18 and 35 y (mean age, 22.2 y) were recruited for the study. Subjects had to be healthy based on a routine medical screening from the university health center or the subject's private physician. Subjects had to be physically active (minimum of 1 h and maximum of 5 h of strenuous exercise weekly on a regular basis) and have less than 24% body fat based on skinfold measurements and the equations of Jackson and Pollock[32] and Siri. Subjects were excluded from participation if they had routinely used medication or supplements within the past 30 d that might alter the study outcome; had a history of medical or surgical events that could affect the study outcome, including cardiovascular disease, metabolic, renal, hepatic, or musculoskeletal disorders; or had been diagnosed with phenylketonuria or another disease affecting amino acid metabolism. Subjects were permitted to continue with any aerobic exercise and recreational sports activities that they were doing before initiation of the study. Subjects were advised to not initiate any new aerobic exercise training during the study. Subject compliance with the program was monitored by weekly reviews of training notebooks, weekly questioning regarding supplement use and exercise training, and periodic checks of the university fitness center during "non-study" hours.

Subjects were fully informed of the requirements of their participation and of the potential benefits and risks. All subjects were required to sign an informed consent form. All procedures were reviewed and approved by the Mississippi State University Institutional Review Board.

Forty-one subjects ($n = 20$ in control group, $n = 21$ in the supplement group) completed all preliminary screening and testing procedures and started the strength training program. Subjects were similar with respect to age, body weight, and percentage of body fat (Table I) at the beginning of the study.

### *Experimental Supplement*

The study supplement was Anabolic Recovery Tropical Blast (MET-Rx). The composition of the supplement is detailed in Table II. The control drink contained 92 g of maltodextrin, so it was isocaloric in comparison with the study supplement. The compo-

TABLE II.

COMPOSITION OF THE ANABOLIC RECOVERY SUPPLEMENT*

| | Grams per 103-g serving |
|---|---|
| Total carbohydrate | 76 |
| Maltodextrin | 55 |
| Dextrose + fructose | 21 |
| Whey protein concentrate | 13 |
| Total fat | 1 |
| Creatine monohydrate | 3 |
| L-lysine | 0.840 |
| L-methionine | 0.840 |
| L-phenylalanine | 0.735 |
| L-glutamine | 0.530 |
| L-leucine | 0.530 |
| L-histidine | 0.420 |
| L-arginine | 0.420 |
| L-isoleucine | 0.260 |
| L-aspartic acid | 0.210 |
| L-valine | 0.110 |

* Total calories per serving, 370.
Placebo beverage contained 92 g of maltodextrin.

sition and purity of the supplement and control were verified independently by Covance Laboratories (Madison, WI, USA). Supplement and control materials were placed in coded bottles each day by a person who was not involved with any other aspect of the study. Subjects had to receive 70% of the control or supplement doses to remain in the study. The study blind was maintained until after all data had been entered into SPSS 11.0 (Chicago, IL, USA) for analysis, and no changes to the database were made after that time.

### Strength Training Program

Subjects participated in a 10-wk modified periodized strength training program consisting of resistance exercises for all major muscle groups of the body (Table III). After the sixth week of training, additional sets were added to keep the total training volume high while the intensity for the major exercises was increasing. Training volume was operationally defined as the total number of repetitions completed for the workout. Intensity was defined as the resistance used for each exercise. The program was designed to require approximately 1 h to complete. Subjects performed resistance exercises for the legs and abdominal muscles on Monday and Thursday and exercises for the chest, back, arms, and shoulders on Tuesday and Friday. Subjects completed three sets of 10 repetitions during the first 2 wk of training (Table IV). During weeks 3 through 6, subjects completed three sets of eight repetitions for all exercises except abdominal crunches (three sets of 10 repetitions). During weeks 7 and 8, subjects completed four sets of five repetitions (abdominal crunches, three sets of 10 repetitions). During weeks 9 and 10, subjects completed four sets of three repetitions for the major exercises, four sets of eight repetitions for the assistance and supplemental exercises, and four sets of 15 repetitions for the abdominal crunches. Subjects were instructed to use resistance so that it was very difficult to complete the final repetitions of the final set. If the subject could complete the prescribed number of repetitions for all sets, they were instructed to increase the weight used the next time that specific exercise was performed. Subjects were instructed to rest 90 s between sets and 2 min between exercises.

Subjects had to complete a minimum of 70% of the workouts to remain in the study. All workouts were supervised by research personnel associated with the study, with the exception of spring break week (week 6 of training). If subjects were on campus during spring break, they could work out under supervision and receive control or supplement drinks. If subjects were away from campus, they were encouraged to perform a workout as similar as possible to the prescribed workouts, but they could not receive supplement or control drinks.

### Testing

Before initiation of the strength training program and after completion of the 10-wk program, the following tests were conducted: 1) body composition was assessed by underwater weighing and skinfold measurements; 2) one repetition maximum (1-RM) muscle strength was determined for the bench press and 45-degree leg press exercises; 3) muscular endurance was assessed by measuring the number of repetitions completed with 85% of the 1-RM for the bench press and 45-degree leg press, and the estimated amount of external work completed; and, 4) anaerobic power, anaerobic capacity, fatigue rate, and fatigue index were measured using a 30-s Wingate leg cycle ergometer test.

### Body Weight

Body weight was measured on a Detecto scale (Cardinal Scale Manufacturing, Web City, MO, USA).

### Body Composition

HYDROSTATIC WEIGHING. For hydrostatic weighing, subjects completed a minimum of four and maximum of seven un-

TABLE III.

EXERCISES PERFORMED DURING THE 10-WEEK STRENGTH TRAINING PROGRAM

| Monday | Tuesday | Thursday | Friday |
|---|---|---|---|
| Squats* | Bench press* | Squats* | Inclined press* |
| Leg press* (weeks 1–5); 45-degree leg press (weeks 6–10) | Wide-grip lateral pulldown | 45-degree leg press* | Seated row |
| Leg curl | Shoulder press | Leg extension | Dumbell bench press |
| Calf raises | Seated row | Leg curls | Wide-grip lateral pulldown |
| Leg extension | Triceps pushdown | Calf raises | Triceps overhead extension |
| Abdominal crunch machine | Biceps curl | Abdominal crunch machine | Biceps curl (preacher bench) |

* Denotes major exercise; other exercises are categorized as assistance and supplemental exercises.

TABLE IV.

SETS AND REPETITIONS FOR THE 10-WK PERIODIZED STRENGTH TRAINING PROGRAM*

| Weeks 1–2 | Weeks 3–6 | Weeks 7–8 | Weeks 9–10 |
|---|---|---|---|
| 3 sets × 10 repetitions | 3 sets × 8 repetitions | 4 sets × 5 repetitions | Major exercises: 4 sets × 3 repetitions; other exercises: 4 × 8 |

* Protocol includes all exercises except abdominal crunches; crunches were 3 × 10 repetitions for weeks 1 to 8, and 4 sets × 15 repetitions for weeks 9 to 10.

derwater weighing trials. The mean of the two highest underwater weights was accepted as the true underwater weight. Body volume was corrected for residual lung volume and by 0.1 L for intestinal gas volume. Residual lung volume was estimated by using forced vital capacity, which was measured with a respirometer (Sensor-Medics, Yorba Linda, CA, USA). The average of the two highest values obtained from three trials was used as the accepted value for forced vital capacity. Residual lung volume was calculated with the equations of Grimby and Soderholm.[33] Percentage of body fat was derived from body density using Siri's equation, and fat mass and FFM were calculated from body weight and percentage of body fat. Because the estimation of residual lung volume from forced vital capacity may have increased the error in body composition determined from hydrostatic weighing, percentage of body fat and the absolute amount of fat mass and FFM were determined from a skinfold assessment.

SKINFOLD ASSESSMENT. Skinfold measurements were taken at three sites (chest, abdomen, and thigh) using Lange skinfold calipers. The same individual performed all skinfold measurements before and after the strength training program. The reliabilities of measurements by the investigator were $r^2 = 0.996$ for the chest, $r^2 = 0.997$ for the abdominal skinfold, and $r^2 = 0.996$ for the thigh. The equation of Jackson and Pollock[32] was used to calculate body density from the skinfold values; body fat was calculated from body density with Siri's equation.

### *Muscular Strength and Endurance*

The 1-RM for the bench press was measured with an olympic free weight bar and weighted plates. The 1-RM leg press was determined on a 45-degree leg press (Paramount Fitness Corporation, Los Angeles, CA, USA). Subjects were required to lower the resistance so that 90 degrees of knee flexion was achieved. A "touch-and-go" technique was used by subjects for the 1-RM tests. General guidelines for 1-RM strength testing were followed.[34] Subjects completed one to three warmup sets depending on their estimated 1-RM bench press and leg press. If the subject was successful at lifting the weight one time, the resistance was increased 5 to 10 lb for the bench press and 25 to 90 lb for the 45-degree leg press for the next lift. Subjects recovered for 2 to 3 min between attempts. The resistance was increased until the subject failed to complete a lift. If the subject failed to complete the first attempt or failed to complete an attempt after a large increase in weight, the resistance was reduced 5 to 10 lb for the bench press and 10 to 45 lb for the 45-degree leg press for subsequent attempts. All 1-RM determinations were made with no more than six attempts. The resistance lifted for the 1-RM was converted to kilograms and recorded to the nearest 0.1 kg.

After determination of the 1-RM, subjects were tested for muscular endurance using 85% of their 1-RM. A minimum of 10 min and maximum of 15 min were permitted after completion of the 1-RM determination and assessment of muscular endurance for each lift. For all lifts, a touch-and-go technique was used. Subjects were not required to pause between the eccentric and concentric phases of a repetition, and subjects were not permitted to "bounce" the resistance. Proper technique was required for all 1-RM and muscle endurance measurements.[35] The external work performed during the muscular endurance test was estimated as the number of repetitions completed multiplied by the resistance used.

### *Anaerobic Capacity and Power and Fatigue Rate*

Subjects performed a 30-s maximal cycle exercise test on an Excalibur Sport Cycle ergometer (Medgraphics, St. Paul, MN, USA). Subjects were permitted a general warmup period that included walking or jogging, cycling, and stretching. Immediately before the 30-s test, all subjects completed 1 min of cycling at 50 W. At the start of the test, the resistance was increased to 0.070 multiplied by body mass (kg). Subjects pedaled as rapidly as possible with verbal encouragement from the researchers. Anaerobic capacity and power and fatigue rate were calculated with the Wingate 1.12 software program (Lode, Groningen, Netherlands). Anaerobic power was calculated as the quotient of peak power and body weight, and anaerobic capacity was calculated as the quotient of mean power and body weight. Fatigue rate was calculated as the difference between peak power and the lowest power output divided by the time from peak power to the lowest power output. The fatigue index was expressed as a percentage: (highest power output − lowest power/highest power) × 100.

### *Statistical Analysis*

Data were analyzed with two-way analysis of variance (time × group) with repeated measures on time. $P \leq 0.05$ was set as the level of statistical significance. Because analysis of variance did not indicate any significant differences for any of the variables measured, no post hoc *t* tests were used. Effect sizes were calculated as $\eta^2$,[36] and power was calculated. All statistical analyses were performed using SPSS 11.0 for Windows.

## RESULTS

### *Workouts Completed and Doses of Supplement or Control Drink Received*

Thirty-three subjects (80.5%) completed the training program and follow-up testing ($n = 15$ in control group, $n = 18$ in supplement group). There were no differences between groups for the number of supervised and total workouts completed or the number of doses of supplement or control consumed (Table V). For those who completed the study, subjects in the control group completed 85.8% of the workouts and subjects in the supplement group completed 84.8% of all workouts. Subjects in the control group consumed 82.8% of the possible doses, and subjects in the supplement group consumed 80.8% of the possible doses. (The difference between the number of supervised workouts and supple-

TABLE V.

WORKOUTS COMPLETED AND DOSAGES OF SUPPLEMENT RECEIVED*

| | Placebo | Supplement |
|---|---|---|
| Number of supervised workouts | 33.2 ± 2.4 | 32.6 ± 3.2 |
| Total number of workouts | 34.3 ± 2.6 | 33.9 ± 3.4 |
| Supplement/placebo doses received | 33.1 ± 2.4 | 32.3 ± 3.2 |

* Data are mean ± standard deviation.
Supervised workouts are those during which a research team member was present to observe the workout. Total number of workouts includes resistance training sessions completed without supervision during the sixth week (spring break week) of the study (refer to MATERIALS AND METHODS for additional detail).

ment or control doses received was due to missed dosages due to spillage [two times] and a subject leaving without receiving his drink [one time].)

### *Body Composition (Figure 1)*

Analysis of variance indicated that body weight increased across groups over the 10-wk strength training period. However, there were no differences between groups or time × group interaction. Although percentage of body fat declined during the 10-wk study, there were no differences between groups or time × group interaction. FFM increased during the 10-wk strength training program. For FFM, the time × group interaction was not statistically significant at an $\alpha$ level of 0.05. However, there was a trend toward a greater increase in FFM for the supplement group (+3.4 kg) compared with the control group (+1.5 kg; $P = 0.077$). The effect size for FFM was moderately large ($\eta^2 = 0.100$).[36] The data collected for percentage of body fat, fat mass, and FFM using skinfold thicknesses supported the data from hydrostatic weighing. Most significantly, there was a trend toward a greater increase in FFM in the supplement group than in the control group ($P = 0.081$), and the effect size was moderately large ($\eta^2 = 0.095$). Across groups, fat mass did not change significantly over time, although there was a trend toward a reduction ($P = 0.071$; $\eta^2 = 0.105$). More importantly, there were no differences between groups or time × group interaction.

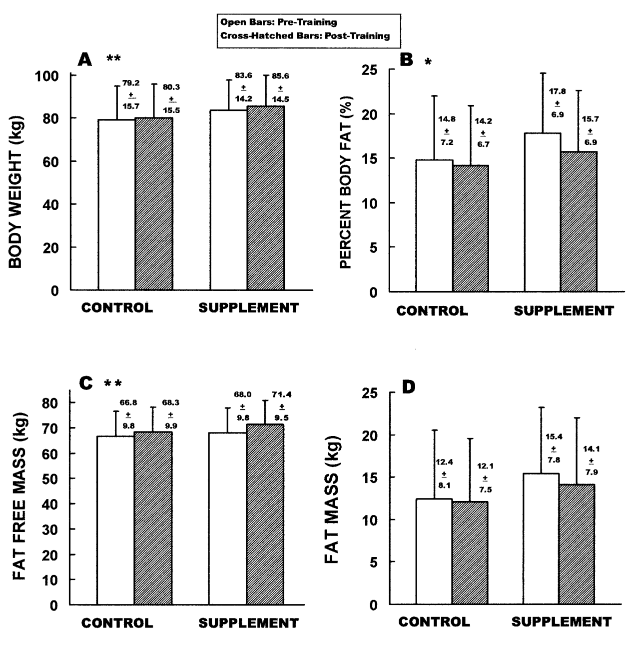


FIG. 1. (A–D) Effect of strength training and postexercise supplementation on body weight and body composition. Percentage of body fat was determined with hydrostatic weighing. Fat-free mass and fat mass were calculated from body weight and percentage of body fat. *$P < 0.05$, before versus after training; **$P < 0.001$, before versus after training.

TABLE VI.

EFFECT OF A 10-WK STRENGTH TRAINING PROGRAM AND POSTEXERCISE SUPPLEMENT ON 1-REPETITION MAXIMUM (1-RM) BENCH PRESS STRENGTH AND MUSCULAR ENDURANCE*

| | Control | Supplement |
|---|---|---|
| 45 degree leg press 1-RM (kg)†† | | |
| Pretraining | 254.7 ± 64.8 | 269.7 ± 67.2 |
| Post-training | 324.2 ± 74.0 | 348.4 ± 72.7 |
| 45 degree leg press muscular endurance (repetitions) | | |
| Pretraining | 8.4 ± 4.1 | 9.2 ± 4.8 |
| Post-training | 10.3 ± 6.2 | 11.2 ± 6.0 |
| 45 degree leg press endurance (external work, kg)† | | |
| Pretraining | 1817.8 ± 901.4 | 2116.8 ± 1441.3 |
| Post-training | 2827.8 ± 1963.7 | 3224.0 ± 1996.2 |

* Data are mean ± standard deviation. 1-RM strength was measured for the 45-degree leg press (Paramount Fitness Corporation, Los Angeles, CA). Muscular endurance was measured as the number of repetitions completed with 85% of the 1-RM for the 45 degree leg press, and external work was estimated as the product of the resistance used and the number of repetitions completed.
† $P < 0.01$, before versus after.
†† $P < 0.001$, before versus after training.
1-RM, one repetition maximum.

### *Muscle Strength and Muscular Endurance (Tables VI and VII)*

Although muscular strength as assessed by the 1-RM for the 45-degree leg press and bench press increased over the 10-wk strength training period, there were no differences between the supplement and control groups. There were no differences for muscular endurance, which was determined as the number of repetitions that could be completed with 85% of the 1-RM. Estimated external work (repetitions completed × resistance used) for the leg press increased over the 10-wk training period, but there was no time × group interaction. Estimated external work for the bench press did not change significantly over the 10-wk training period, although there was a trend toward an increase ($P = 0.055$; moderate effect size, $\eta^2 = 0.06$). There was no significant time × group interaction for external work completed for the bench press.

### *Anaerobic Power and Capacity, and Fatigue Rate/Index as Assessed With a 30-s Wingate Cycle Test (Table VII)*

Anaerobic power and capacity improved over the 10-wk training period. There were no differences between groups for these variables. Across groups, there was an increased fatigue rate after the 10 wk of strength training. There were no differences between groups for fatigue rate. When fatigue was expressed as a percent-

TABLE VII.

EFFECT OF A 10-WK STRENGTH TRAINING PROGRAM AND POSTEXERCISE SUPPLEMENT ON 1-REPETITION MAXIMUM LEG PRESS STRENGTH AND MUSCULAR ENDURANCE*

| | Control | Supplement |
|---|---|---|
| Bench press 1-RM (kg)† | | |
| Pretraining | 92.0 ± 23.1 | 96.5 ± 25.8 |
| Post-training | 104.5 ± 28.3 | 108.7 ± 27.3 |
| Bench press muscular endurance (repetitions) | | |
| Pretraining | 4.6 ± 1.5 | 4.3 ± 1.3 |
| Post-training | 4.3 ± 1.6 | 5.0 ± 1.8 |
| Bench press endurance (external work, kg) | | |
| Pretraining | 346.8 ± 106.1 | 361.6 ± 143.4 |
| Post-training | 362.0 ± 124.9 | 448.2 ± 151.9 |

* Data are mean ± standard deviation. 1-RM strength was measured for the free weight bench press. Muscular endurance was measured as the number of repetitions completed with 85% of the 1-RM for the 45 degree leg press, and external work was estimated as the product of the resistance used and the number of repetitions completed.
† $P < 0.001$, before versus after training.
1-RM, one repetition maximum.

age ([highest power output − lowest power/highest power] × 100), i.e., fatigue index, there were no significant changes over time, between groups, or for the time × group interaction.

## DISCUSSION

Postexercise consumption of a drink containing creatine, whey protein, amino acids, and carbohydrates did not result in greater improvements in body composition, muscle strength and endurance, and anaerobic performance compared with the carbohydrate-only drink during a 10-wk strength training program. Although the postexercise supplement did not promote greater gains in FFM than did consumption of a carbohydrate-only drink, a trend toward a greater increase in FFM in the supplement group and a moderately large effect size suggest the need for longer-term studies. The supplement group increased FFM 5.0% compared with 2.2% for the control group ($P = 0.077$). Also, the results from the skinfold measurements corroborated the hydrostatic weighing data.

TABLE VIII.

EFFECT OF A 10-WK STRENGTH TRAINING PROGRAM AND POSTEXERCISE RECOVERY SUPPLEMENT ON ANAEROBIC POWER AND CAPACITY AND FATIGUE RATE AND INDEX*

| | Placebo | Supplement |
|---|---|---|
| Anaerobic power (W/kg)§ | | |
| Pretraining | 13.6 ± 1.5 | 12.8 ± 2.1 |
| Post-training‡ | 15.1 ± 2.1 | 13.6 ± 2.2 |
| Anaerobic capacity (W/kg)† | | |
| Pretraining | 8.3 ± 0.9 | 8.0 ± 1.0 |
| Post-training | 8.4 ± 1.0 | 8.3 ± 1.2 |
| Fatigue rate (W/s)‡ | | |
| Pretraining | 27.6 ± 6.0 | 28.3 ± 8.4 |
| Post-training | 32.6 ± 7.0 | 29.9 ± 8.2 |
| Fatigue index (%) | | |
| Pretraining | 65.4 ± 9.4 | 64.6 ± 12.9 |
| Post-training | 70.9 ± 8.7 | 65.4 ± 10.2 |

* Data are mean ± standard deviation.
† $P = 0.05$, before versus after training.
‡ $P < 0.01$, before versus after training.
§ $P < 0.001$, before versus after training.
A 30-s Wingate cycle ergometer test, with a pedaling resistance of 0.070 × body weight (kg), was used to assess anaerobic power and capacity and the subject's resistance to fatigue during very high-intensity exercise.

Few studies have examined the effects of a supplement containing more than one compound on body composition or muscular strength.[4,37,38] Supplementation of whey protein plus creatine during 6 wk of resistance training resulted in a 6.5% increase in lean body mass, which was greater than the 3.8% gain in the group receiving whey protein.[4] Lean body mass did not increase in the placebo group. Only one published study has examined the effects of the immediate postexercise consumption of a supplement containing more than one compound on body composition and muscle strength over a comparable time period.[37] For subjects consuming creatine (10 g) plus dextrose or an isocaloric protein (10 g) and dextrose supplement immediately after exercise, there were no differences for changes in FFM, muscle fiber size, muscle strength, and fatigue index after an 8-wk strength training program.[37] There was no placebo group in this study, so it is unclear whether improvements for the measured variables were due to training alone or whether the supplements contributed to the gains.

It is likely that a significant portion of any increase in FFM that occurs with a supplement containing creatine, protein, amino acids and carbohydrate is due to the creatine. Studies have reported increases in FFM of similar magnitude with strength training and creatine supplementation.[1,3,39] After a 12-wk resistance training program, a group receiving creatine increased FFM by 6.3% compared with a placebo group that had a 3.1% increase in FFM.[3] Kreider et al.[38] compared a supplement containing creatine (15.75 g/d), glucose (99 g/d), taurine, and electrolytes with a similar supplement without creatine in National Collegiate Athletic Association division I football players. The group receiving the creatine-containing supplement gained 2.4 kg of fat and bone-free mass compared with a 1.3-kg gain in the group receiving the creatine-free supplement.

Although strength training and creatine have been shown to enhance gains in muscle fiber size and strength,[3] some of the increase in FFM may have been due to intracellular water retention.[40] Studies have reported increases of 0.6 to 1.1 kg in body weight within 5 to 7 d of beginning creatine supplementation.[9,38,41] Recent research has shown that the rapid weight gain with creatine supplementation may result in an increase in FFM that is not due to actual muscle growth. After 7 d of creatine supplementation, body weight was increased 1.0 kg; however, when the change in FFM was determined with air-displacement plethysmography, the calculated increase in FFM was 1.7 kg.[42] The use of hydrostatic weighing may result in a similar discrepancy, because both methods measure body volume to calculate body density and percentage of body fat. It is likely that a significant portion of the increase in FFM for the supplement group in the present study may have been due to intracellular water retention.

The decline in the percentage of body fat over the 10-wk strength training program ($P < 0.05$) is largely due to the increased FFM, although there was a trend toward a decreased fat mass ($P = 0.071$). There were no differences between the supplement and control groups for changes in percentage of body fat and fat mass during the study. No change in percentage of body fat was reported after 10 wk of strength training alone or strength training plus creatine supplementation in collegiate football players.[1] Despite a trend toward a decreased fat mass, the results of this study are not surprising because strength training workouts do not induce appreciable changes in fat mass, and the supplement is designed to promote gains in muscle mass and not to promote fat loss.

The increases in 1-RM strength for the bench press and 45-degree leg press exercises are consistent with studies showing gains in muscular strength after participation in resistance training programs of similar duration.[43,44] The group receiving the postexercise supplement did not increase 1-RM strength to a greater extent than the control group. Several studies have reported greater increases in muscular strength when resistance training programs of 4 to 12 wk in duration were accompanied by supplementation with creatine[1–4,7] or creatine plus protein.[4] Ten weeks of resistance training and creatine supplementation in women resulted in greater gains for the squat and leg press, but not for the bench press, compared with resistance training only.[2]

Muscle creatine levels were not determined in the present study. The creatine dosage of 3 g after each workout may not have been sufficient to increase muscle creatine levels. Although daily supplementation with 3 g has been shown to increase muscle creatine levels,[45] studies showing greater increases in bench press, squat, and leg press 1-RM typically used much larger doses of creatine.[1–4,7] In the present study, subjects received the supplement containing creatine only after workouts, which was a maximum of 4 d/wk. However, even if the low dose of creatine was ineffective, the protein in the supplement may promote increases in strength.[34] During an 8-wk strength training program, similar gains in 1-RM were observed for 16 different machine resistance exercise in subjects consuming a creatine-dextrose or isocaloric protein-dextrose supplement immediately postexercise.[37] This study did not have a placebo group but does suggest that a protein plus carbohydrate supplement may be as effective as creatine plus carbohydrate in some studies. However, during 6 wk of a high-volume, heavy-load strength training program, the group receiving a whey protein plus creatine supplement had greater gains in 1-RM bench press, but not in 1-RM squat, compared with a group receiving only whey protein and a placebo group.[4]

Muscle endurance, measured as the number of repetitions completed with 85% of the 1-RM for the bench press and 45° leg press, did not increase as a result of the 10 wk of strength training. When muscle endurance was expressed as estimated external work, there was an increase across groups for the 45-degree leg press and a trend toward an improvement for the bench press. These different results can be explained by the fact that the number of repetitions completed with 85% of 1-RM is a test of relative muscular endurance, and the estimated external work is a measure of absolute muscular endurance. The increased estimated external work for the 45-degree leg press and a trend toward an increase for the bench press are likely due to increases in muscular strength. The lack of improvement for relative muscular endurance may have been due to the fact that the training program did not emphasize muscular endurance. Most importantly, there were no differences between the supplement and control groups for muscular endurance when assessed as repetitions completed or estimated external work.

Creatine is most effective when subjects are required to perform multiple bouts of high-intensity exercise[2,9,46]; however, creatine may improve muscular endurance when only a single bout of exercise is performed if that work bout is of sufficient duration.[46,47] Twenty-eight days of creatine supplementation resulted in a greater increase in the number of repetitions completed with 70% of 1-RM for the bench press compared with placebo.[7] In addition to the lack of effect of the supplement on muscular strength and endurance during the bench press and leg press exercises, the present study found no difference between groups for anaerobic power or capacity and fatigue rate and fatigue index during a single 30-s Wingate test. Many studies have shown improvements in mean power, total work completed, or fatigue index during a single bout of cycle ergometer sprinting (or the first bout of multiple bouts)[7,47,48] or during multiple bouts.[49] However, the present study is consistent with other reports of no effect of creatine supplementation on mean power, total work, or fatigue rate or index during a single bout of cycle ergometer sprinting[49,50] or no increase in mean power output during repeated bouts of an arm or leg Wingate test.[51,52]

It is important to note that the control beverage used in this study may have affected the outcome. The control drink contained 92 g of maltodextrin, so it was isocaloric in comparison with the supplement. Consumption of carbohydrate immediately after exercise may enhance protein turnover[31] and glycogen synthesis.[24–26,28] Consumption of the isocaloric, carbohydrate-containing control drink may have enhanced recovery and promoted increases in FFM, so that differences between the control and supplement groups were lessened. However, during a 28-d resistance and agility training program, fat and bone-free mass increased to a greater extent in a group receiving a creatine plus glucose supplement compared with a group receiving only glucose.[38] Unlike the present study, the supplement was not administered immediately postexercise. We suggest that future studies compare similar supplements containing combinations of creatine, protein, and/or carbohydrate with inert placebos to more effectively assess supplement effectiveness.

Ideally, the statistical power for detecting a group $\times$ time interaction would be 0.80 or greater. The powers for the ability to detect a time $\times$ group interaction for FFM (the major variable of interest) were 0.425 for hydrostatic weighing and 0.416 for skinfold thicknesses. Power for other variables was lower. Before the study, the number of subjects who would be needed to detect a statistically significant change in FFM ($\alpha = 0.05$) with a power of 0.80 was estimated as 19 subjects per group. The study ended with 15 subjects in the control group and 18 subjects in the supplement group. Although fewer subjects than desired completed the study, the major problem was a greater variability than anticipated. The moderately large effect size for FFM suggests that postexercise supplements, such the one tested in this present study merit further study.

In summary, a 10-wk strength training program combined with a postexercise recovery drink containing creatine, whey protein, amino acids, and carbohydrate did not alter body weight, percentage of body fat, FFM, or fat mass compared with an isocaloric, carbohydrate-only control drink. There was a trend toward a greater gain in FFM in the supplement group than in the control group; therefore, longer-term studies may be needed to determine whether postexercise recovery supplements have any effect on FFM. The postexercise supplement did not result in greater improvements in 1-RM bench press and leg press strength or muscular endurance and anaerobic power and capacity.

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