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# The Effects of Four Weeks of Ribose Supplementation on Body Composition and Exercise Performance in Healthy, Young, Male Recreational Bodybuilders: A Double-Blind, Placebo-Controlled Trial

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## ABSTRACT

***Background:*** Ribose is a pentose sugar that is present in ribonucleic acids, riboflavin, nucleotides, and adenosine triphosphate. Whether exogenous ribose administration affects skeletal muscle concentrations of total adenine nucleotides is unknown. Whether supplementation with ribose positively affects body composition or exercise performance in recreational bodybuilders also is unknown.

***Objective:*** The purpose of this double-blind, placebo-controlled trial was to determine the effects of 4 weeks of ribose supplementation on body composition and exercise performance in healthy, young, male recreational bodybuilders.

***Methods:*** Healthy, male recreational bodybuilders aged 18 to 35 years were recruited and randomized to a ribose-supplemented group (10 g/d in powder formulation) or a placebo group (dextrose). Each subject participated in a heavy-resistance training program designed to increase skeletal muscle mass. Body composition (ie, body weight, body fat, lean body mass, fat mass, and bone mineral content) was assessed using dual-energy x-ray absorptiometry analysis. Muscular strength (as measured by a 1-repetition maximum-strength [1-RM] bench press) and total work performed (as measured by total repetitions for 10 sets of bench presses before muscular failure; 1-minute resting interval between sets) to muscular failure at a submaximal load (100% of pretest body weight) were ascertained. In addition, 24-hour dietary recalls were obtained before and after the study.

***Results:*** Twenty men (mean age ± SE, 23.9 ± 1.4 years) were enrolled; 19 subjects completed 24-hour dietary recalls and exercise performance testing; 12 subjects completed the study (24-hour dietary recalls, exercise performance,

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and body composition). No baseline differences were found between the 2 groups for any of the measured parameters. The ribose-supplemented group experienced a significant pretreatment-to-posttreatment increase in the total work performed, whereas the placebo group did not change significantly (24.5 ± 7.6 to 29.3 ± 7.5 repetitions; 19.6% ribose [$P = 0.028$] vs 34.1 ± 8.6 to 38.2 ± 8.0 repetitions, 12.0% placebo). In addition, the ribose-supplemented group experienced a significant increase in 1-RM bench press strength, whereas the placebo group did not change significantly (114.1 ± 13.6 to 117.7 ± 14.0 kg, 3.2% ribose [$P = 0.008$] vs 129.6 ± 14.2 to 131.8 ± 14.5 kg, 1.7% placebo). No pretreatment-to-posttreatment within-group or between-group differences were found for any of the measures of body composition or the 24-hour dietary data.

***Conclusion:*** The results of this study indicate that supplementation with ribose 10 g/d for 4 weeks resulted in significant increases in muscular strength and total work performed in recreational bodybuilders in this study, although no significant changes in body composition or 24-hour dietary data were found.

***Key words:*** supplement, sugar, diet, exercise. (*Curr Ther Res Clin Exp.* 2002; 63:486–495)

## INTRODUCTION

Ribose is a pentose sugar that is present in ribonucleic acids, riboflavin, nucleotides, and adenosine triphosphate (ATP).[1] In addition, ribose is used to synthesize ATP by the pentose phosphate pathway.[1] Under normal physiologic conditions, levels of the adenine nucleotides are maintained easily. However, intense exercise has been shown to have a profound impact on total adenine nucleotide (TAN) levels. Thus, it is possible that providing exogenous ribose might affect the resynthesis of ATP, thereby affecting skeletal muscle function.

For instance, in a study by Stathis et al,[2] high-intensity sprint training for 7 weeks decreased resting concentrations of ATP and TAN (TAN = ATP + adenosine diphosphate + adenosine monophosphate) by 18% to 19%. Van der Meulen et al[3] found that in rat tibialis anterior muscles that had been lengthened forcibly, ATP concentrations decreased by 9%, whereas no significant change was observed in isometrically exercised muscles. In a placebo-controlled study by Gross et al[4] in 9 healthy men, the acute ingestion of ribose (2 g every 5 minutes for 30 minutes) during bicycle exercise blunted the increase in plasma hypoxanthine level, suggesting a reduction in the ATP degradation, due to the fact that hypoxanthine is the primary metabolite of ATP degradation in humans.

Whether exogenous ribose administration affects skeletal muscle concentrations of TAN is unknown. Whether supplementation with ribose positively affects body composition or exercise performance in trained individuals also is unknown. Thus, the purpose of this investigation was to assess the effects of ribose supplementation on body composition, muscular strength, and muscular endurance in healthy, young, male recreational bodybuilders.

## SUBJECTS AND METHODS

Healthy, young, male recreational bodybuilders were recruited from a university population using a posted advertisement. To participate in the study, subjects had to meet the following inclusion criteria: age, 18 to 35 years; good health (ie, free of any orthopedic, metabolic, cardiovascular, muscular, renal, or pulmonary condition that might affect the ability to exercise intensely), as determined using self-reporting; not currently receiving ribose; and performing resistance-training ≥3 times per week for the 6 months before the study.

Written informed consent was obtained from each subject, and the institutional review board of the university approved the experimental procedures. Subjects were not compensated for completing the study.

### Dietary Supplement

This study was a double-blind, placebo-controlled trial. For randomization to either a ribose-supplemented or placebo group, subjects were given numbered packets by a blinded graduate student. Only the principal investigator knew the randomization code; this was not revealed until after testing was completed. Subjects ingested either ribose 10 g/d or placebo (dextrose) for 4 weeks. Subjects were instructed to consume the supplement 30 to 60 minutes before (5 g) and 30 to 60 minutes after (5 g) training. On nontraining days (ie, every 4th day), subjects were instructed to consume the supplement at their convenience. The ribose and dextrose were provided to each subject in prewrapped foil packets. They were instructed to dissolve the supplement in water and then drink it.

Subjects were instructed not to change their dietary habits. Twenty-four–hour dietary recalls were obtained from all subjects before and after the treatment period. The energy and macronutrient intake of each subject was determined using computerized analyses (Nutribase '98, Cybersoft, Inc. Phoenix, Ariz). Subjects were not screened for the use of androgens (legal or illegal), dehydroepiandrosterone (DHEA), 7K-DHEA, or other anabolic compounds. However, no subject admitted to receiving legal or illegal androgens.

### Training

All subjects were instructed to follow a bodybuilding regimen (Table I). Subjects kept a training log so that investigators could ensure that they were complying with the regimen.

### Exercise Testing

After 3 warm-up sets, subjects were instructed to perform a 1-repetition, maximum-strength (1-RM), supine, free-weight bench press (ie, muscular strength test). Subsequently, the maximal number of full repetitions of the bench press at 100% of body weight was assessed. The subjects performed 10

Table I. Training regimen.*

| Training Days | Exercises |
|---|---|
| Day 1: chest, shoulders, triceps; choose 6 exercises | Bench press,†‡ incline bench press, dumbbell military press, front raises, cable crossovers, pectoral deck, dumbbell bench press, triceps kickbacks, lateral raises |
| Day 2: legs; perform all 6 exercises | Squats,‡ calf raises, leg extensions, leg curls, leg press, dumbbell lunges |
| Day 3: back, biceps; choose 6 exercises | Lateral pull-downs,‡ dumbbell rows, seated rows, hammer curls, reverse grip pull-downs, shoulder shrugs, dumbbell biceps curls |

*The following regimens were followed over the course of the study: week 1, 3 sets of 10 to 12 repetitions of each exercise; week 2, 3 sets of 8 to 10 repetitions of each exercise (increase resistance weight from previous week); week 3, 3 sets of 6 to 8 repetitions of each exercise (increase resistance weight from previous week); week 4, 3 sets of 3 to 5 repetitions (highest resistance weight used). Periodized, split-routine training consisted of 3 training days and 1 rest day (total of 21 training days, 7 rest days of the 4 weeks of training). All subjects used a periodized, split routine; periodized = a decrease in repetitions and an increase in weight; split routine = training upper body and then lower body on different days.
†Subjects performed the bench press exercise to momentary muscle failure during the last set.
‡Exercises each subject was required to complete at each training session.

total sets with a 1-minute resting interval between sets (ie. muscular endurance test) to measure total work performed. Performance tests were observed and the results recorded by the same individual, who was blinded to treatment.

For both tests, subjects had their feet fully planted on the floor and their hips and scapulas maintained contact with the bench at all times; a slight lumbar lordosis was allowed. The concentric phase of the repetitions was performed as quickly as possible and the eccentric phase was performed with a controlled descent. Hands were positioned slightly wider apart than shoulder width.

## Body Composition

Body composition was assessed using whole-body scans with dual-energy x-ray absorptiometry (DEXA; DPX-IQ, Lunar Corp, Madison, Wis). Subjects lay supine on the DEXA device, with their bodies centered along the midline of the table. Their arms were held against their torsos, and their feet were approximately 15 cm apart. Subjects lay completely motionless during the scan, which lasted ~25 minutes. Pretest and posttest scans were performed with the subject in a fasted state before performance testing. The use of DEXA as a method for estimating body composition has been validated.[5,6] The ranges of coefficients of variation for fat mass and lean body mass were estimated to be 1.8% to 6.4% and 0.6% to 3.1%, respectively.[7,8] To ensure quality control, the DEXA device was calibrated daily using the standard calibration block provided by the manufacturer.

### Statistical Analysis

Pretreatment-to-posttreatment differences in the 1-RM bench press, total work performed (defined as total repetitions for 10 sets of bench presses before muscular failure), dietary recall, and body composition were analyzed using a paired *t* test. An unpaired *t* test was used to assess between-group differences in performance of bench presses (1-RM and total work performed), body composition, and dietary intake. Statistical significance was set at $P < 0.05$; data are shown as mean ± SE. Data were analyzed using SigmaStat (SPSS Inc, Chicago, Ill).

## RESULTS

Twenty men (mean age ± SE, 23.9 ± 1.4 years) were enrolled; 19 subjects completed 24-hour dietary recalls and exercise performance testing (ribose-supplemented group, n = 10; placebo group, n = 9); 12 subjects completed the study (24-hour dietary recalls, exercise performance, and body composition) (ribose-supplemented group, n = 4; placebo group, n = 8). No significant baseline differences were found between the 2 groups in mean age, height, body weight (Table II), body composition (Tables II and III), or performance measures (Table IV). However, the ribose-supplemented group experienced a significant increase in the pretreatment-to-posttreatment total work performed ($P = 0.028$), whereas the placebo group did not change significantly (24.5 ± 7.6 to 29.3 ± 7.5 repetitions; 19.6% ribose vs 34.1 ± 8.6 to 38.2 ± 8.0 repetitions, 12.0% placebo). Similarly, the ribose-supplemented group experienced a significant increase in 1-RM bench press strength ($P = 0.008$), whereas the placebo group did not change significantly (114.1 ± 13.6 to 117.7 ± 14.0 kg, 3.2% ribose vs 129.6 ± 14.2 to 131.8 ± 14.5 kg, 1.7% placebo). No pretreatment-to-posttreatment differences were found for any of the measurements of body composition or the 24-hour dietary data (Table V).

One subject was withdrawn from the study because he did not complete the posttest regimen. Also, 5 subjects from the ribose-supplemented group and 2 from the placebo group did not complete DEXA due to subject unavailability.

**Table II.** Baseline physical characteristics of all study patients (N = 19). Values are presented as mean ± SE.*

| Study Group | Age, y | Height, cm | Body Weight, kg | Body Fat, % |
|---|---|---|---|---|
| Ribose-supplemented (n = 10) | 24.8 ± 3.7 | 180.6 ± 1.6 | 88.1 ± 4.5 | 12.8 ± 2.2 |
| Placebo (n = 9) | 23.6 ± 1.4 | 179.3 ± 2.5 | 92.7 ± 8.3 | 18.2 ± 3.6 |

*No significant differences were found between the 2 groups.

**Table III.** Body composition of the subjects who completed the study (N = 12). Values are presented as mean ± SE.*

| Study Group | Body Weight, kg | Body Fat, % | Lean Body Mass, kg | Fat Mass, kg | Bone Mineral Content, kg |
|---|---|---|---|---|---|
| Ribose-supplemented (n = 5) | | | | | |
| Pretreatment | 88.1 ± 4.5 | 12.8 ± 2.2 | 71.5 ± 3.0 | 11.3 ± 2.1 | 4.2 ± 0.2 |
| Posttreatment | 88.0 ± 4.5 | 12.6 ± 2.0 | 71.1 ± 3.0 | 10.8 ± 1.7 | 4.1 ± 0.1 |
| Placebo (n = 7) | | | | | |
| Pretreatment | 92.7 ± 8.3 | 18.2 ± 3.6 | 71.0 ± 3.2 | 18.4 ± 5.2 | 4.3 ± 0.2 |
| Posttreatment | 92.3 ± 8.2 | 17.4 ± 3.0 | 72.1 ± 3.6 | 17.4 ± 4.4 | 4.4 ± 0.2 |

*No between-group differences were found at baseline for any of the measures. No significant pretreatment-to-posttreatment between-group differences were found.

## DISCUSSION AND CONCLUSIONS

Previous investigations have examined acute ribose ingestion using various measures of metabolic activity. Early work from Zollner et al[9] showed that oral administration of ribose may be used as a therapy for myoadenylate deaminase deficiency. Early work from Gross et al[10] and Segal and Foley[11] found that ingested ribose is absorbed efficiently from the small intestine (88%–100%) in healthy men. and that the ingested ribose is converted to glucose by the pentose phosphate pathway or to nucleotides by ribose-5-phosphate or phosphoribosyl pyrophosphate. For instance, in a study by Gross et al[4] in healthy men who ingested ribose (2 g every 5 minutes for 30 minutes) during bicycle exercise, the increase in the plasma hypoxanthine level was less than with no ribose and the plasma lactate level was higher. In the subjects who received ribose, the higher plasma lactate level suggests that carbohydrate degradation

**Table IV.** Exercise performance of all study patients (N = 19). Values are presented as mean ± SE.

| Study Group | 1-RM BP, kg | Total Work Performed* |
|---|---|---|
| Ribose-supplemented (n = 10) | | |
| Pretreatment | 114.1 ± 13.6 | 24.5 ± 7.6 |
| Posttreatment | 117.7 ± 14.0† | 29.3 ± 7.5‡ |
| Change, % | 3.2 | 19.6 |
| Placebo (n = 9) | | |
| Pretreatment | 129.6 ± 14.2 | 34.1 ± 8.6 |
| Posttreatment | 131.8 ± 14.5 | 38.2 ± 8.0 |
| Change, % | 1.7 | 12.0 |

1-RM BP = 1-repetition maximum-strength bench press.
*Defined as total repetitions for 10 sets of bench presses before muscular failure.
†$P = 0.008$ (pretreatment vs posttreatment difference).
‡$P = 0.028$ (pretreatment vs posttreatment difference).

**Table V.** Reported dietary intake for all study patients (N = 19). Values are presented as mean ± SE.*†

| Study Group | Energy, kcal‡ | Carbohydrate, g | Protein, g | Fat, g | Protein, g/kg body weight |
|---|---|---|---|---|---|
| Ribose-supplemented (n = 10) | 2496 ± 389 | 274 ± 50 | 126 ± 15 | 76 ± 16 | 1.43 ± 0.15 |
| Placebo (n = 9) | 2100 ± 259 | 256 ± 39 | 113 ± 15 | 62 ± 12 | 1.26 ± 0.18 |

*Each value is the mean of the pretreatment and posttreatment 24-hour dietary recall.
†No significant between-group differences were found.
‡Conversion factor: 1 kcal = 4.1840 kJ.

might have been elevated and that ribose itself might have been degraded to lactate and used as an additional fuel source. In addition, the smaller increase in plasma hypoxanthine levels suggests less ATP degradation. Thus, ribose might serve as an additional energy source and a precursor to nucleotide resynthesis.

An important issue with all supplement regimens is safety. Pliml et al[12] raised concerns about the effects of ribose supplementation on cell proliferation by assessing the effects of the supplement on lymphocytes. When lymphocytes were incubated with concentrations of ribose associated with a high oral dose (3.5 mM) and 2-fold that dose (7.0 mM), no significant decreases in the proliferation of lymphocytes were noted. Furthermore, in our study, no adverse events (ie, diarrhea, gastrointestinal distress, muscle cramping) were noted.

Ours is the first study to assess the effects of ribose supplementation on body composition and exercise performance in recreational bodybuilders. The ribose-supplemented group experienced a significant increase in muscular strength (1-RM bench press) and total work performed; no such changes were found in the placebo group. This improvement may be related to the role that ribose might play in the phosphagen energy system.

In a study by Tesch et al,[13] strength-trained athletes performed 5 sets of 4 lower-body resistance exercises. Each set was executed until momentary muscular failure. Biopsies obtained from the vastus lateralis muscles before and after the session revealed significant reductions in ATP, phosphocreatine, and glycogen. Regarding a long-term response, Stathis et al[2] found that 7 weeks of sprint training produced an 18% to 19% reduction in skeletal muscle ATP and TAN concentrations. Hellsten-Westing et al[14] also found that TAN concentrations were reduced in the vastus lateralis muscles of male subjects who performed high-intensity bicycle training 3 times per week for 6 weeks. Although we did not measure ATP or TAN concentrations, we would posit that the bodybuilding regimen followed by our subjects could produce significant reductions in resting plasma ATP and TAN levels. Thus, we surmise that the provision of

exogenous ribose might ameliorate the decrease in resting plasma ATP and TAN levels seen after several weeks of intense resistance training.

Alternatively, ribose supplementation might augment resting ATP and TAN levels. Tullson and Terjung[15] showed that the addition of ribose to skeletal muscle perfusate augmented adenine nucleotide salvage and de novo synthesis. If this occurred in skeletal muscle, it could conceivably translate into an improvement in muscular strength because of the role the phosphagen system plays in short-term, high-intensity exercise (as measured in our study).

On the other hand, no significant changes in body composition were found in our study, perhaps because these subjects were already resistance trained. Some studies[16,17] have shown that 4 weeks of resistance training produced significant gains in whole muscle and muscle fiber cross-sectional area. However, in resistance-trained subjects, it is likely that a training regimen lasting 10 to 12 weeks is necessary to elicit significant increases in whole muscle or muscle fiber cross-sectional area.[18,19] We speculate, however, that a longer treatment duration (ie, 10–12 weeks) could result in greater gains in lean body mass in a ribose-supplemented group. For instance, our data suggest that ribose supplementation induces greater percentage gains in muscular strength and endurance, suggesting that an athlete who trains more intensely during the supplementation period would have greater gains in lean body mass.

However, the greater relative gains in muscular strength and endurance in the ribose-supplemented group may have been due in part to the fact that they seemed to be less trained than the placebo group (ie, at the start of the investigation, the placebo group was 15.5 kg stronger and had greater muscular endurance [10 more repetitions on average] than did the ribose-supplemented group). Although these initial differences were not statistically significant, the initial training status of the subjects may have affected the outcome of the performance changes.

The data in our study show that no significant differences were found in macronutrient (ie, total calories, carbohydrate, protein, fat) intake between the 2 groups. However, the average protein intake in the 2 groups was slightly less than is currently recommended for resistance-trained athletes. Work by Lemon[20] has clearly demonstrated that protein requirements for active individuals are $\geq$100% greater than the recommended daily allowance (ie, 1.6–1.8 g/kg per day). Thus, it is possible that the lower protein intakes reported in the present study might have impeded the ability to accrue skeletal muscle or lean body mass. Also, dietary intake data derived from personal disclosure might consistently underestimate food consumption.[21] Thus, the role of diet vis à vis ribose supplementation is unclear at this time.

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