Journal of Strength and Conditioning Research, 2003, 17(1), 47–52

Effects of Ribose Supplementation on Repeated Sprint Performance in Men

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ABSTRACT

This study used a randomized, placebo-controlled, crossover design to evaluate the effects of oral ribose supplementation on short-term anaerobic performance. After familiarization, subjects performed 2 bouts of repeated cycle sprint exercise (six 10-second sprints with 60-second rest periods between sprints) in a single day. After the second exercise, bout subjects ingested 32 g of ribose or cellulose (4 × 8-g doses) during the next 36 hours. After supplementation, subjects returned to the laboratory to perform a single bout of cycle sprinting (as described above). After a 5-day washout period, subjects repeated the protocol, receiving the opposite supplement treatment. Ribose supplementation lead to statistically significant increases in mean power and peak power in sprint 2 (10.9 and 6.6%, respectively) and higher (although not significant) absolute values in sprints 1, 3, and 4. In conclusion, ribose supplementation did not show reproducible increases in performance across all 6 sprints. Therefore, within the framework of this investigation, it appears that ribose supplementation does not have a consistent or substantial effect on anaerobic cycle sprinting.

Key Words: anaerobic power, nucleotide synthesis, ergogenic aids, nucleotide depletion

Reference Data: Berardi, J.M., and T.N. Ziegenfuss. Effects of ribose supplementation on repeated sprint performance in men. *J. Strength Cond. Res. 17(1):47–52. 2003.*

Introduction

Numerous food supplements have flooded the market, promising a variety of positive effects including, but not limited to, increased vigor and energy, improved quality of life, and enhanced athletic performance. One such popular nutritional supplement is ribose. Ribose is a pentose (5 carbon) sugar present in small quantities in several foodstuffs. In addition, most of the body's ribose is synthesized endogenously through the pentose phosphate pathway. This substrate is used as a key component in both de novo nucleotide synthesis and in nucleotide salvage pathways, the most relevant to anaerobic performance being its incorporation into adenosine triphosphate (ATP). Skeletal muscle uses the high-energy phosphate bonds present in both adenosine diphosphate (ADP) and ATP to fuel muscular work during bouts of exercise. As a result, hydrolysis and depletion of adenine nucleotides during intense exercise is inevitable, especially in fast-twitch skeletal muscle fibers. In fact, research by Hellsten-Westing et al. (5, 6) has shown that the concentration of total adenine nucleotides ([TAN]; ATP, ADP, and adenosine monophosphate [AMP]) in skeletal muscle declines in response to acute and chronic (6 weeks) high-intensity cycle exercise. This research has important implications for ribose supplementation.

If increased skeletal muscle ribose availability during and after exercise could either increase the production of new nucleotides (de novo synthesis) or increase the recovery of lost nucleotides (salvage), then the administration of ribose would increase [TAN], improve performance, and improve recovery. Data indicate that increased in vitro ribose availability after exercise leads to a three- to fourfold increase in de novo nucleotide synthesis (14). If these data are applicable to skeletal muscle in vivo, ribose may increase the ability of skeletal muscle to regenerate lost nucleotides like ATP, ADP, and AMP. This could lead to improved intermittent exercise performance (as seen with creatine supplementation) or increased recovery between bouts of exercise. The latter mechanism is more likely.

In clinical populations, ribose has shown promise as an energy-providing supplement, enhancing de novo synthesis of purine nucleotides, reducing muscle cramping, and increasing exercise tolerance (3, 4, 15–17). However, ribose has also gained popularity in the athletic and fitness communities despite the lack of convincing data supporting its use. Manufacturers have suggested that oral supplementation of ribose can increase anaerobic performance because of its potential to improve skeletal muscle energy and nucleotide balance. Therefore, ribose is marketed as an anabolic agent and an ergogenic aid. No investigations have been conducted to examine the proposed ergogenic benefits of ribose in healthy populations, the very populations that are now embracing its use.

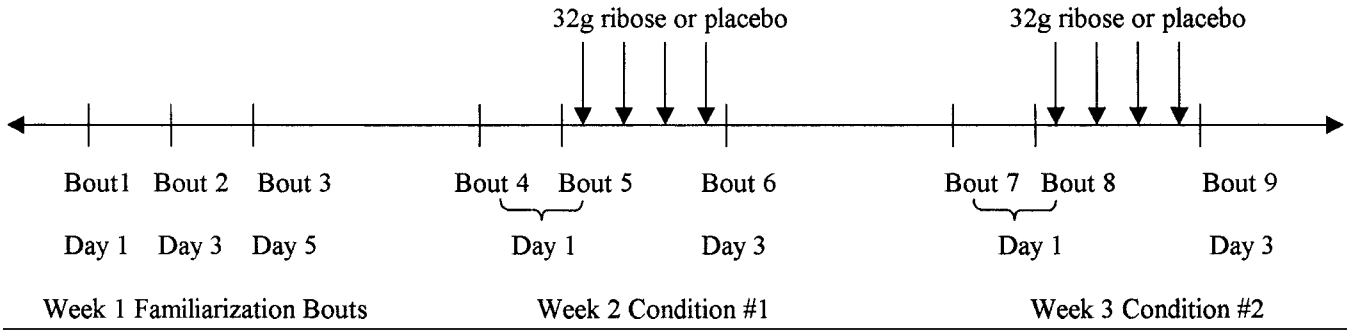

Figure 1. Supplement and exercise schedule.

Therefore, the purpose of this investigation was to determine whether oral ribose supplementation could improve anaerobic performance or recovery in young healthy men.

Methods

Experimental Approach to the Problem

Because bouts of repeated 10-second cycle sprints have been shown to both acutely and chronically deplete skeletal muscle [TAN], we have chosen this model to investigate the efficacy of ribose supplementation (5, 6). It is assumed that if ribose supplementation can aid in the salvage or de novo synthesis of skeletal muscle nucleotides during or after this type of exercise, performance within a single bout of cycle sprinting as well as recovery between intense bouts of cycle sprinting should be improved. Because substantial de novo synthesis of nucleotides is a lengthy process, any improvements within a single bout could only be explained by nucleotide salvage. On the other hand, both the salvage and de novo synthesis of nucleotides after exercise could contribute to enhanced recovery between exercise bouts. These improvements would therefore manifest one of two ways. First, if ribose supplementation can increase the salvage of nucleotides during the 60-second recovery period between sprints, the performance decrements seen between successive sprints would be reduced and each subsequent sprint performance would show less of a power decrement with ribose supplementation when compared with placebo administration. Second, if ribose supplementation can increase the salvage or de novo synthesis of nucleotides during the 36-hour recovery period between bouts of repeated sprint exercise, peak and mean power values during the first sprint of each bout would be higher because of a higher initial level of [TAN]. In addition, each subsequent sprint may show higher values in the ribose condition when compared with placebo administration. In this investigation we did not expect to see reductions in the performance within a single bout of exercise (by way of nucleotide salvage) between the ribose and placebo conditions. However, we did hypothesize that ribose supplementation would lead improved exercise recovery between successive bouts of sprint exercise due to an increase in de novo nucleotide synthesis.

Subjects

After institutional review board approval, a total of 8 men (mean ± *SD*, age 20.6 ± 2.5 years, height 175.26 ± 6.07 cm, weight 75.19 ± 7.77 kg, percent fat 7.9 ± 3.8%) were recruited from the student population at Eastern Michigan University. All subjects were former competitive athletes who remained recreationally active (>3 anaerobic and or aerobic exercise sessions per week) at the time of the study. Subjects were omnivorous and did not report using any medications or nutritional supplements. All subjects provided informed consent after receiving a complete description of the study. All had extensive cycle sprint experience as defined by previous participation in at least 3 studies involving cycle ergometry within a 2-year period (greater than 18 total bouts of similar cycle sprint exercise).

At the onset of each testing session, height, body mass, and body composition (estimated using the 7-site athlete skinfold equation; 7) were recorded. Subjects were instructed to abstain from both exercise and alcohol for 24 hours before each testing day. Subjects were also instructed to maintain a consistent nutritional intake during the course of their participation in this investigation with the only dietary change being the administration of the treatment. Because this is a repeated-measures investigation (within subjects comparison), any further dietary control would be unnecessary for it would have little effect on the results. Because dietary factors (short of extreme glycogen depletion) would have little effect on this very short-duration alactic anaerobic effort, we believed that there was no pressing need for increasing the subject burden by attempting to control the diet.

Performance Testing

Each subject performed 9 identical exercise bouts on a regularly calibrated Monark cycle ergometer (Figure 1). Each exercise bout consisted of a 5-minute warm-up with a constant load of 1 kg, followed by six 10-

second maximal sprints against a load of 0.075 kg·kg body mass^{-1}. In addition, each sprint during a given exercise bout was separated by 60 seconds of unweighted pedaling. Flywheel revolutions were recorded (computer-interfaced optical sensor), and both mean and peak power values were calculated for each sprint.

Subjects reported to the laboratory for the first week of testing 3 days after the last of 3 familiarization rides between 0800 and 1100 hours for their AM depletion bout. After a recuperation time of 4–6 hours, subjects returned to the laboratory for their PM depletion bout, the second exercise session of the day. Thirty-six hours after the PM depletion trial, subjects reported to the laboratory for their first supplemented performance trail (trial 1).

After a 5-day washout period, subjects returned to the laboratory for week 2 of testing. During week 2, the testing procedures were identical to those of week 1. The depletion and performance trials were administered at the same time each day in an attempt to avoid potential diurnal variations in performance.

Ribose Supplementation

The subjects were randomly assigned in a double-blinded fashion to receive either powdered ribose supplementation or a powdered cellulose placebo during week 1. In a counterbalanced (crossover) fashion, subjects received the opposite treatment during week 2. The treatments were color, flavor, and volume matched by dissolution in 500 ml of distilled H_2O and 1 g of sugar-free orange Kool-Aid. The purity of the ribose supplement (provided by Nutritech, Inc.) was confirmed by San Rafael Chemical Services (Salt Lake City, UT). Ribose content was analyzed by thermospray mass spectrometry and determined to be 957 ± 95 mg·g^{-1}.

Based on pilot data, 8-g doses were selected. One 8-g dose of the supplement or placebo beverage was ingested immediately after each of the PM depletion trials. The next day, subjects ingested 2 identical supplement beverages, one with breakfast and the other with dinner. Each of these beverages also contained 8 g of ribose, for a total of 16 g on day 2. On the third day, subjects ingested a final 8-g dose about 2 hours before the performance testing (see Figure 1 for a complete description of the exercise and supplementation protocol).

Statistical Analyses

Mean and peak power values for all 6 sprints are expressed in watts·kg body mass^{-1}. A 2-way, repeated-measures analysis of variance (supplement [ribose and placebo] × trial [trial 1 and trial 2]) with repeated measures on both factors was used to examine differences in mean and peak power. Significant interactions were probed further using the Newman-Keuls post hoc test. Effect size calculations were used to determine the magnitude of treatment differences. In all analyses, statistical significance was established a priori at $p \leq 0.10$. This level of significance was chosen because of the well-known variability typically observed in exercise performance, namely, cycle sprint performances. With this variability, there is a large potential to commit a type II error (accepting the null hypothesis even when there is a treatment effect); therefore, we attempted to minimize this statistical bias with a more liberal statistical standard.

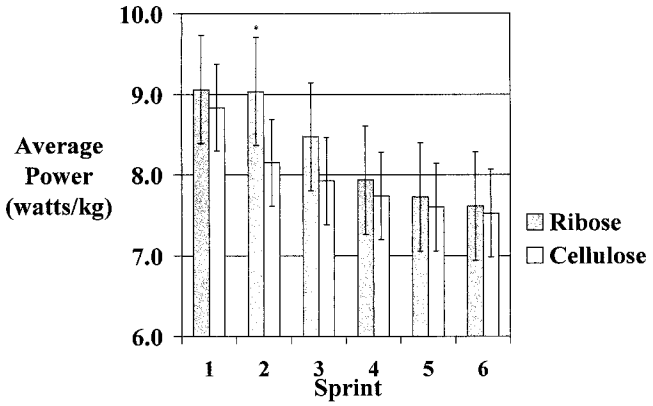

Figure 2. Average power (mean ± *SD*) by condition in young men (*, $p = 0.03$).

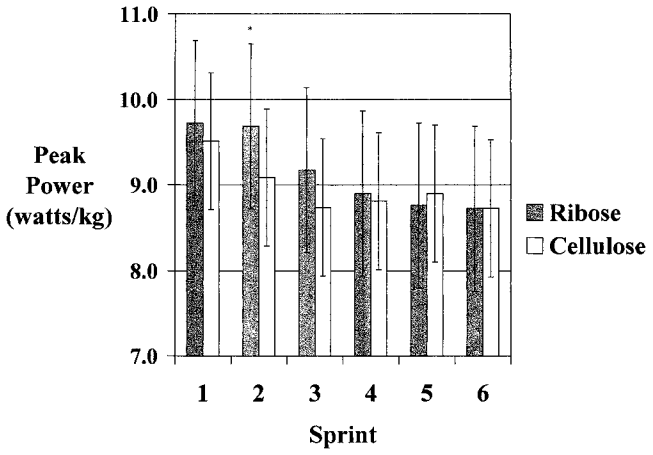

Figure 3. Peak power (mean ± *SD*) by condition in young men (*, $p = 0.09$).

Results

All 8 subjects completed the protocol. Statistical analyses revealed a significant condition by time interaction for both mean and peak power (Figures 2 and 3). However, the values for mean and peak power were only statistically different for the ribose condition in sprint 2 ($p = 0.03$ and 0.09, respectively). During sprint 2, subjects receiving ribose supplementation recorded mean power values that were 10.9% higher than those receiving placebo (9.04 vs. 8.15 W·kg^{-1}; ef-

fect size = 1.2). Also, during sprint 2, subjects receiving ribose supplementation recorded peak power values that were 6.6% higher than those receiving placebo (9.69 vs. 9.09 $W \cdot kg^{-1}$; effect size = 0.68). Absolute mean power values for all other sprints (1, 3, 4, 5, and 6) appeared higher in the ribose condition, although these data were not statistically significant (percent increase = 2.5, 6.9, 2.6, 1.6, and 1.2% and effect size = 0.32, 0.80, 0.40, 0.15, and 0.14, respectively). Absolute peak power values for 3 of the other sprints (1, 3, and 4) also appeared higher in the ribose condition, although these data were not statistically significant (percent increase = 2.2, 5, and 0.3% and effect size = 0.28, 0.39, and 0.11, respectively).

Discussion

Despite research showing the benefits of ribose supplementation in clinical populations, this is the first investigation examining the ergogenic effect of ribose supplementation in healthy, athletic men. The ribose treatment was well tolerated, and no adverse effects were reported. Body mass and therefore testing loads remained constant throughout the investigation.

The main finding of this investigation is that ribose supplementation did not yield consistent and statistically significant increases in mean or peak power in men with extensive training in anaerobic cycling. These data run counter to our original hypothesis. Because this hypothesis was based on a theoretical model as well as on clinical data of patients with adenylate disorders, large metabolic differences between subject populations may explain the fact that effects are seen in one group and not in the other.

Although absolute values for mean power appeared greater in all 6 sprints in the ribose condition, whereas the absolute values for peak power appeared greater in 4 of the 6 sprints in the ribose condition, the only significant finding was the increase in both peak and mean power during sprint 2. On examination of the raw data, the percent increases in mean and peak power observed during sprint 2 ($p = 0.03$, 10.9%; $p = 0.09$, 6.6%) as well as the effect sizes of the increases (1.2 and 0.68) were quite large. However, although mean and peak power values for sprint 3 also showed moderate increases (6.9 and 5%, respectively) as well as moderate effect sizes (0.8 and 0.4), these data were not statistically significant. Further examination of data from sprints 1, 4, 5, and 6 did not suggest the potential for any true or reliable increase in performance with ribose supplementation. All in all, these data do not conclusively support the contention that ribose can significantly affect performance. The data do suggest that there may be a marginal benefit with ribose supplementation, but this effect, if real, must be small and inconsistent.

Variables potentially contributing to the data variability in this study include moderate statistical power, high variability of the dependent variable (cycle sprinting), duration of the treatment washout period, and supplement dose. These variables will be addressed below.

First, a post hoc power analysis was conducted to determine the relative ability of this protocol to show true treatment effects that might have existed. As a result of this power analysis, we determined that our statistical power was moderate; thus, a sample size of 20–24 subjects would have yielded consistent and significant performance improvements with ribose supplementation across all sprints. This, of course, operates under the assumption that the data collected in the larger subject sample would be similar to the data reported in this investigation.

Although repeated cycle sprint tasks similar to those used in this study have been performed in a number of other investigations (1, 2, 5, 6, 8, 9, 11), we were unaware of any published research examining the reliability of this specific protocol. To this end, our laboratory has conducted an investigation examining the reliability of this protocol using intraclass correlation coefficients and coefficients of variation (unpublished data). This investigation showed that in our laboratory repeated cycle sprints are moderately reproducible. Coefficients of variation within a single day as well as over several days for mean power were between 8 and 12% and for peak power were between 10 and 18%. In addition, intraclass correlation coefficients for mean power were between 0.63 and 0.90 and for peak power were between 0.69 and 0.93. Based on these data, we have estimated that performance changes of at least 8% for average power and 11% for peak power may be necessary to achieve statistical significance when tests are performed 1 week apart. Thus, a relatively large performance effect is necessary to achieve statistical significance using this test in similar groups of subjects. The performance differences seen in our subjects ranged from 0.3 to 10.9%. Such changes would be difficult to detect within the framework of this current study. Future investigations may choose to use more sensitive measures when examining the effects of ribose supplementation on anaerobic performance.

It is difficult to know if the washout period we used was long enough because of the lack of detailed pharmacokinetic and pharmacodynamic investigations using oral ribose supplementation in humans. However, an analysis of the dependent variable based on the order of supplementation was performed to assess if there was an order effect (4 subjects received ribose first, whereas 4 other subjects received placebo first). This analysis showed no performance differences between subjects based on the order of supplementation. This suggests that there may not have been a need for a longer washout period.

With respect to the supplement ingestion, the typical dose of ribose recommended by supplement manufacturers is currently 3 $g \cdot d^{-1}$. Because this study showed no clear effect with 32 g (4 × 8-g doses) taken during a 36-hour period, the ingestion of 3 g per day would most likely be ineffective. We are unable to speculate whether even larger doses may be necessary for a substantial performance effect; however, because of the high costs of ribose, even at the doses used in this study, ribose does not appear to be a cost-effective supplement.

This investigation has been an initial step toward examining the effects of ribose supplementation on anaerobic performance in healthy men. Despite marketing claims that ribose is a potent ergogenic aid, the benefits of ribose supplementation in healthy men remain relatively unproven. Before any major conclusion can be drawn, these data require clarification by future work. Because this investigation did not show a clear increase in performance but did indicate that there may be some small trend toward increased performance, future research with more sensitive measures may have a greater ability to discern the extent to which ribose may affect anaerobic performance.

Although this preliminary investigation only examined the ergogenic potential of ribose supplementation, plasma concentrations and biochemical parameters should also be examined in future. Blood ribose concentrations should be monitored to determine the bioavailability and peak plasma concentrations of oral ribose supplementation. Gross et al. (4) found that the intestinal absorption rate of orally administered ribose was 87.8–99.8% of the intake at doses of up to 200 $mg \cdot kg^{-1} \cdot h^{-1}$. In terms of the safety of such doses, a number of subsequent trials showed that intakes of 50–60 g per day were well tolerated without discernable side effects (4, 10, 13, 17). Suggestions for future biochemical measures include monitoring the effects of ribose on changes in baseline adenine nucleotide concentrations or on changes in muscle energetics during recovery from acute exercise and chronic exercise training. Such investigations might include the use of muscle biopsy or nuclear magnetic resonance to determine muscle phosphate concentrations. Although we did not directly measure whether adenine nucleotides were depleted as a result of our depletion trials, similar cycle sprint protocols have indicated that this type of high-intensity exercise does in fact deplete [TAN] in skeletal muscle (5, 6, 12). Future investigations should be conducted to verify that [TAN] depletion protocols such as this one are successful.

This study has demonstrated that although significant increases were seen in peak and mean power for 1 of the 6 sprints, ribose supplementation fails to increase overall anaerobic power. We hesitate to conclude that ribose has no effect on anaerobic performance, however, because of the fact that this disparity may be a result of the relative insensitivity of the test. Future investigations should attempt similar protocols with more sensitive performance tests as well as monitor [TAN] and blood concentrations of ribose.

Practical Applications

Because oral ribose supplementation is being successfully used to increase exercise intolerance in clinical populations, we have endeavored to determine whether this phenomenon would also be observed in healthy populations. If ribose could indeed improve [TAN] and adenine nucleotide resynthesis after intense intermittent exercise, it could have potential applications in a number of athletic endeavors requiring anaerobic power and muscular work. Because of the speculation that this might be the case, many athletes have been reporting improved performance using multiple daily doses of 3–5 g of ribose. This investigation has not revealed any clear performance increases with oral ribose supplementation using doses even higher than those commonly ingested. Therefore, with the current high-price tag of oral ribose supplements, ribose does not appear to be a cost-effective supplement for athletes. Of course, more data are necessary before we can conclude whether ribose supplementation can offer an ergogenic benefit to athletes. Because the theoretical benefits of ribose supplementation are similar to the benefits that creatine supplementation may offer, creatine seems like a less expensive and more effective choice.

Note: John M. Berardi is now with the University of Western Ontario, London, ON, Canada N6A 3K7.

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Acknowledgments

This project was funded in part by a research grant from Nutratech, Inc. We thank Dennis Kerrigan, MSc, for his assistance in the completion of this project.

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