ENHANCING SHORT-TERM RECOVERY AFTER HIGH-INTENSITY ANAEROBIC EXERCISE

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ABSTRACT

Al-Nawaiseh, AM, Pritchett, RC, and Bishop, PA. Enhancing short-term recovery after high-intensity anaerobic exercise. J Strength Cond Res 30(2): 320–325, 2016—This study examined the effects of antioxidant vitamins, ibuprofen, cold water submersion, and whey protein administered simultaneously on short-term recovery. Competitive athletes (n = 22) performed the protocol in 2 occasions (treatment and control) separated by 15 days in counterbalanced crossover design. Each occasion consisted of morning and afternoon sessions (AM and PM). In each session, participants performed 2 bouts of high-intensity anaerobic cycling separated by 30 minutes of rest. Each bout consisted of 3 Wingate tests (3 × 30-second Wingate tests) with 3 minutes of active recovery in between. Power output, rated perceived exertion (RPE), and pain scores were averaged and compared between the 2 sessions (AM vs. PM) and between the treatment vs. control (4 bouts). Creatine kinase (CK) levels were also measured 24 hours after the AM bout. Power output, CK, muscle soreness, and RPE were measured as recovery indices. Creatine kinase increased (p < 0.001) in both treatment and control 24 hours after the AM session. Performance results in the PM session for treatment/control were 832.5 ± 198.7/813.3 ± 187.6 W for peak power (PP), and 497.85 ± 120.7/486.1 ± 115 W for mean power (MP). Treatment was effective in maintaining MP (p = 0.034) in the PM sessions, but there was no significant effect of treatment on PP (p = 0.193), CK (p = 0.08), pain (p = 0.12), or RPE (p = 0.45). Treatment was helpful in protecting performance, but this was apparently not due to reduced muscle soreness or damage.

KEY WORDS recovery techniques, wingate testing, cryotherapy, whey protein

INTRODUCTION

Rapid recovery between workouts is important for optimal training. Furthermore, short-term recovery from competition for both recreational and competitive athletes is a major focus for athletes and their coaches. Short-term recovery is a key factor for better performance, especially in sports that require heats, semifinals, and finals, as part of competition schedule such as swimming and track and field. In these sports, fractions of a second separate competitors, making optimal performance and recovery between rounds critical to advance to the next round. Unfortunately, often the best performances (such as world records) are seen during heats or semifinals rather than in the finals. This may be due to athletes’ inability to recover; therefore, understanding short-term recovery and investigating for methods to speed recovery is of interest to athletes and coaches. Athletes have developed different methods to enhance short-term recovery and reduce fatigue based on the current understanding of fatigue mechanisms and muscle soreness.

Exercise-induced muscle damage is associated with inflammation, soreness, and therefore reduced performance. Exercise-induced muscle damage is due to biochemical stresses (oxidative stress) and mechanical stresses (contractions) leading to disruption of the muscle cell membrane and damaging the Z bands of the muscle fibers (1,4,5,11). This exercise-induced muscle damage has long been quantified using serum levels of skeletal muscle proteins and enzymes (creatine kinase [CK], troponin I, and myoglobin) (11) as markers of the damage. Different techniques have been used to reduce muscle damage and inflammation such as cryotherapy (ice), nonsteroidal anti-inflammatory drugs (NSAIDs) (analgesics and ibuprofen), and antioxidant vitamins (e.g., vitamin E, vitamin C, and β-carotene). Some of these techniques have been used based on scientifically hypothesized mechanisms, but the results have been inconsistent.

The bulk of the literature has investigated effects on recovery markers but has not reported the impact on performance. Most research has focused on recovery from aerobic performance rather than from anaerobic performance (with the exception of weightlifting). Peterson et al. (9) reported that a treatment of ibuprofen and acetaminophen
had no significant effects on inflammatory cell concentrations, CK activity, or on muscle soreness 24 hours after eccentric exercise when compared with a placebo and that both treatments suppressed protein synthesis and prostaglandins. However, the authors did not report the fatigue, pace, nor performance changes among participants. Petersen et al. (8) found no beneficial effect of 14 days of vitamin C supplementation on inflammation parameters, including CK levels, after a 90-minute 5% downhill run at 75% VO\textsubscript{2}max, suggesting no effect on free radicals and exercise-induced inflammatory response. Thompson et al. (12) showed similar results with a 90-minute intermittent shuttle run and the use of vitamin C on CK levels, myoglobin, muscle soreness, and function. However, Pizza et al. (10) found that 800 mg·d\textsuperscript{-1} doses of ibuprofen lowered CK activity relative to placebo 3 days after eccentric arm exercise. Tokmakidis et al. (13) supported the benefit of ibuprofen in lowering CK levels, reporting lower muscle soreness after eccentric leg curl exercises but saw no benefits in restoring muscle function.

Over-the-counter anti-inflammatory drugs (ibuprofen), antioxidant vitamins (vitamins C and E), cryotherapy (ice and cold water), and protein supplementation are commonly used to enhance recovery. Because all of these recovery approaches are frequently used simultaneously but randomly, it is important to investigate their combined effect, as the combination may influence the impact of these approaches in different ways. There are possible contradictory effects of the combinations. For example, NSAIDs may reduce edema but may suppress protein synthesis (9). Ingesting protein supplements that are rich in essential amino acids may partly counter this effect. Cryotherapy, despite the proposed effect of attenuating edema in skeletal muscles (14), interferes with the supposed beneficial effects of enhanced blood flow and, therefore, quick return to homeostasis.

Antioxidant vitamins (E and C), NSAIDs (ibuprofen), cryotherapy, and protein supplements are some of the most common aids to enhance short-term recovery. Frequently, athletes use more than one of these methods at the same time. The main purpose of this study was to examine the simultaneous effectiveness of commonly used methods to enhance short-term recovery of high-intensity anaerobic exercise. This study investigated the simultaneous use of antioxidant vitamins, amino acids, cryotherapy (cold water immersion), and NSAIDs (ibuprofen) for their potential to reduce exercise-induced muscle damage, suppress the soreness sensation, attenuate drop in power output, and recover anaerobic performance ability in a short period of time. It was hypothesized that the combination would enhance recovery from exercise.

**Methods**

**Experimental Approach to the Problem**

The effectiveness of simultaneous use of multiple methods on short-term recovery from high-intensity anaerobic exercise was examined in a repeated measures crossover design. The short-term recovery indices after high-intensity anaerobic exercise were performance, CK as a muscle damage marker, muscle soreness (pain), and rated perceived exertion (RPE). Competitive athletes who could tolerate high-intensity exercise were tested to improve the external validity of the study, because using those participants could facilitate detecting small differences and because their performance was less likely to vary due to mood changes or learning. Participants performed the protocol on 2 occasions with at least 1 week in between. In the control week, participants were asked to quit any supplement use for at least 72 hours before exercise and 24 hours after exercise.

**Subjects**

Competitive athletes \(n = 22\) who exercised more than 6 h·wk\textsuperscript{-1} volunteered for the study. Participants were competitive Division I college athletes, college-club athletes, or, in some cases, athletes who were no longer eligible for college competition. They were informed about the risks and benefits of the study, signed an institutional review board approved informed consent, and filled out a health and fitness questionnaire. Twenty-two subjects (11 males and 11 females) completed the study. Descriptive data are presented in Table 1.

**Procedures**

Participants reported to the laboratory for familiarization of the study procedures, and skinfolds, VO\textsubscript{2}max, height, and weight were measured. Participants were introduced to the Wingate test and performed one 30-second Wingate test for familiarization.

**Treatment Administration.** In the treatment trial, participants were provided with 2 oral doses of 1,000 mg of vitamin C (ascorbic acid with citrus bioflavonoids; General Nutrition Corp., Pittsburgh, PA, USA) and 400 IU of vitamin E soft gel capsules (d-α-tocopherol; General Nutrition Corp.). The first dose was taken with dinner the night before the exercise protocol, and the second dose was taken on the morning of the exercise test. The morning doses were consumed at least 1 hour before the blood sample was taken. Ibuprofen doses (400 mg; 2 ADVIL liqui gels, 200 mg capsules; Wyeth

**Table 1.** Participant characteristics (mean ± SD) \((n = 22)\).

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Body weight (kg)</th>
<th>Age (y)</th>
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<tbody>
<tr>
<td>Females</td>
<td>11</td>
<td>69.7 ± 9.0</td>
<td>21.3 ± 2.5</td>
</tr>
<tr>
<td>Males</td>
<td>11</td>
<td>83.2 ± 0.6</td>
<td>21.6 ± 1.9</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>76.5 ± 11.83</td>
<td>21.5 ± 2.2</td>
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Consumer Healthcare, Madison, NJ, USA) were given to participants 30 minutes before each exercise session. The protein supplement, 23 g of whey protein (10.6 g essential amino acids [EAA], 7.3 g of conditionally EAA, and 5.6 g of non-EAA ON Sunrise, FL, USA), was mixed with 200 ml of skimmed milk to form a protein shake. The protein shake was given to participants within 3 minutes of finishing each exercise session in the treatment trial. Three to 5 minutes after the end of each exercise session, participants submerged their lower body in cold (10–12.5°C) water for 10 minutes.

Participants were randomly assigned in counterbalanced order to start the first week as a treatment or as a control (nontreatment). Participants were asked to quit any kind of exercise and all kinds of supplements 48 and 72 hours before exercise protocols, respectively. Recruited participants were asked not to volunteer for this study if they were on any major supplements.

The testing protocol consisted of 2 exercise sessions with 6.5–7 hours between AM and PM sessions to replicate morning and afternoon workouts or heats. Each 2-bout session began with a 15-minute warm-up (stretching and cycling). Each bout consisted of three 30-second Wingate power tests with 3 minutes of active recovery (60 RPM with no resistance) in between. After the 27th minute, a second warm-up for 3 minutes preceded the second Wingate bout for a total of six 30-second Wingate tests per session (Figure 1). All Wingate tests were performed using 7.5% of body weight as a resistance (2). The resistance was applied to the ergometer (E224 Monark, Stockholm, Sweden) after a 10-second countdown. Participants used the countdown time to accelerate peddling speed. Computer software (SMI Inc., St Cloud, MN, USA) was linked to the ergometer wheel to collect power output values (peak power [PP], relative PP [PP/kg], mean power [MP], relative MP [MP/kg], minimum power [Min-P], relative Min-P [Min-P/kg], and fatigue index [FI]). Participants rated their RPE and muscle soreness sensation (pain) before and after each Wingate test. Muscle soreness was assessed using a 10-cm visual analog scale (6) with anchor points "no pain at all" at the left end and "unbearable pain" at the right end. Rated perceived exertion was determined using a 6–20 point scale (3). Heart rate (Polar Electro Inc., Kempele, Tähted, Finland) was measured throughout the Wingate tests.

Table 2. Power output during treatment and control trials (n = 22).*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (mean ± SD)</th>
<th>Treatment (mean ± SD)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>AM session</td>
<td>PM session</td>
</tr>
<tr>
<td>PP</td>
<td>801 ± 180</td>
<td>813 ± 188</td>
</tr>
<tr>
<td>Relative PP (PP/kg)</td>
<td>10.4 ± 1.4</td>
<td>10.6 ± 1.4</td>
</tr>
<tr>
<td>MP†</td>
<td>496 ± 114</td>
<td>486 ± 115</td>
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<tr>
<td>Relative MP† (MP/kg)</td>
<td>6.5 ± 0.97</td>
<td>6.4 ± 1</td>
</tr>
<tr>
<td>Minimum power (Min-P)</td>
<td>340 ± 79.5</td>
<td>337 ± 75</td>
</tr>
<tr>
<td>Relative minimum power (Min-P/kg)</td>
<td>4.5 ± 0.84</td>
<td>4.3 ± 0.85</td>
</tr>
<tr>
<td>FI</td>
<td>56.6 ± 9.7</td>
<td>57.4 ± 9.3</td>
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*PP = peak power; MP = mean power; FI = fatigue index.
†There were statistically significant differences between treatment and control in PM sessions. Differences between AM and PM sessions were also significant in control trial.
Finland) was assessed before and after each Wingate test and 5 minutes after each exercise bout.

**Blood Samples**. Forearm antecubital venous blood samples were collected at the student health center by a registered nurse on 2 occasions for each trial (pre-exercise and post-exercise on treatment or control trials). First, a blood sample was collected before the AM session to assess pre-exercise CK levels, and a second blood sample (post sample) was collected 24 hours after the presample to assess exercise-induced changes in CK.

**Statistical Analyses**
Wingate results, pain, and RPE were analyzed by bout and also averaged for each of the 2 sessions (AM and PM). The Statistical Package for Social Sciences (SPSS 12.0.1 and 13.0) was used to conduct a multivariate analysis of variance and one-way repeated measures analysis of variance to compare treatment and control. When significance was detected, the Bonferroni multiple comparison procedure was used (7). Greenhouse-Geisser corrections were applied as necessary. One-tailed $\alpha < 0.05$ was established a priori.

**RESULTS**

**Power Indices**
Descriptive results for power measures are shown in Table 2. There were no statistically significant treatment effects on PP ($p = 0.193$), Min-P ($p = 0.892$), Min-P/kg ($p = 0.407$), or FI ($p = 0.529$). Although a trend for a positive treatment effect on relative PP in the PM session was observed, the interaction treatment $\times$ time was not significant.

There was a statistically significant treatment $\times$ time interaction indicating that MP ($p = 0.017$) and relative MP ($p = 0.010$) dropped significantly in the afternoon session in the control trial, but not for the treatment trial. As seen in Figure 2 and Table 2, MP and relative MP were significantly higher ($p = 0.017$) and ($p = 0.010$), respectively, for treatment compared with control in the PM session.

**Creatine Kinase**
The muscle damage marker CK was analyzed using data from 16 participants (7 males and 9 females). As can be seen in Figure 3, although the exercise protocol induced a statistically significant increase in CK levels ($\text{CK}_{\text{Post}} = 155.5 \text{ U} \cdot \text{L}^{-1}$) compared with pre-exercise levels ($\text{CK}_{\text{Pre}} = 100.5 \text{ U} \cdot \text{L}^{-1}, p < 0.001$), there was no treatment effect on CK levels ($p = 0.64$) in general nor on the 24-hour
postexercise CK levels ($p = 0.08$). Although not significant, it should be noted that there was a trend (Figure 3) for the treatment to reduce CK levels postexercise compared with control.

**Muscle Pain Rating and Rated Perceived Exertion**

Results indicate a statistically significant difference in pain rating ($p < 0.001$) and RPE ($p < 0.001$) between, before, and after exercise sessions. As seen in Figure 4, although the treatment $\times$ time interaction was not statistically significant ($p = 0.12$), pain rating tended to increase much more in the control trial compared with the treatment trial for the PM sessions. No significant treatment effect was seen for RPE ($p = 0.45$).

**Comparisons by Bouts**

Because it was hypothesized that the treatment could affect recovery between bouts, main power indices by bout are presented in Figures 4–6. Significant differences ($p < 0.001$) were seen between bouts in PP and relative PP. Bonferroni multiple comparison procedures indicated a significantly higher PP in bout 3 (first exercise bout in PM session; $X_3 = 830$ W) than bout 2 (second bout in AM session; $X_2 = 795$ W). There were no treatment effects on the between-bout differences seen in PP and relative PP ($p = 0.19$ and $p = 0.259$, respectively).

There were statistically significant differences in MP between bouts ($p < 0.005$). The interaction bout $\times$ treatment was statistically significant ($p = 0.009$). Figure 5 shows higher MP in bout 4 with treatment compared with control. In addition, the treatment helped significantly ($p < 0.05$) in preserving relative PP between bout 3 and bout 4 compared with the significant decrease between the same bouts in the control trial. Additionally, as seen in Figure 6, the treatment showed significantly higher ($p \leq 0.05$) relative MP in bout 4 compared with control.

**Discussion**

This study examined multiple recovery indices in well-trained competitive athletes who exercised more than 6 h·wk$^{-1}$. Participants performed concentric exercise and were able to induce significant change from pre-exercise to postexercise in the muscle damage marker CK. Mean power was higher in the treatment condition. We consider MP to be the key performance measure. Mean power in this protocol represents the second-by-second averaged power output for the duration of the 30-second test. Mean power and relative MP were not a function of a single performance like PP or relative PP. Absolute and relative MP recovered significantly better in the PM session with the use of the treatment. Further detailed analysis indicated that MP and relative MP during bout 4 was higher than treatment trial compared with the control trial. It should be noted that in this study, we were unable to use a placebo for the control condition in part due to limitations related to the use of cryotherapy.

Exercise-induced muscle membrane damage causes leakage of CK into the blood stream. The protocol used in this study increased CK levels 24 hours after the pre-exercise sample in both treatment and control trials. This significant increase in CK levels is important because it was induced with completely concentric exercise with no eccentric component. Most of the changes in CK levels reported in the literature resulted from eccentric exercise and downhill running.

There was no treatment effect on CK. However, a trend toward reduced muscle damage was seen, suggesting that a larger sample size may have revealed a difference. This
finding supports the finding of Peterson et al. (9) for the effect of ibuprofen and Petersen et al. (8) for the effect of vitamin C on reducing CK after eccentric exercise and downhill running, respectively. Thompson et al. (12) reported similar results regarding vitamin C effects on CK levels.

Our findings regarding CK levels do not support the findings of Pizza et al. (10), who reported that similar ibuprofen doses lowered CK activity relative to a placebo 3 days after eccentric arm exercise, although this may be attributed to different measurement times and exercise protocols. Our findings do not support Tokmakidis et al. (13), who found that ibuprofen doses (400 mg every 8 hours for 48 hours) had benefits in lowering CK levels, reducing muscle soreness, but did not restore muscle function compared with placebo. It should be noted that they induced hamstring muscle damage using 6 sets of 10 eccentric repetitions with 100% of the concentric 1 repetition maximum. Their performance tested was a vertical jump, which is somewhat equivalent to PP in this study. In their study, the damage was induced in a muscle group that is not the primary mover in their test. Participants who participated in that study were not trained before the experiment, which could have made them prone to muscle damage and delayed soreness, which would not be true in this study, and which used competitive athletes.

Our results suggest that although the combined use of ibuprofen, cryotherapy, vitamins C and E, and protein drink did not significantly help in protecting from muscle damage and soreness, the combination did help in restoring important muscle function and boosted short-term recovery from high-intensity anaerobic performance.

**Practical Applications**

In conclusion, the anaerobic exercise protocol we used (multiple 30-second Wingate tests) was sufficient to alter performance, CK levels, RPE, and muscle soreness in competitive college athletes. The combined use of antioxidant vitamins, an NSAID (ibuprofen), 10 minutes of lower body cold water submersion, and 23 g whey protein shake (10 g EAA) helped in restoring MP and relative MP. The afternoon session performance, more particularly the last bout (bout No. 4), was most affected by the treatment.

The treatment used may help athletes who participate in high-intensity anaerobic exercise or competition more than once a day to better maintain their MP. Based on the findings of this study, we recommend, after consulting their physician or athletic trainer, using the combined treatment for athletes who participate in multiple anaerobic exercise bouts that last about 30 seconds and allow short-term recovery. We recommend further investigation of the mechanisms of action produced by intervention and conducting in depth analysis for possible substance interaction. In working with athletes, it is important to consider individual responses that may be different from group mean responses.

**Acknowledgments**

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**References**