Journal of Sports Science 5 (2017) 242-249
doi: 10.17265/2332-7839/2017.05.002

Effect of Combined anti-Inflammatory and Nutritional Supplements on Recovery from Resistance Exercise

Baggett SA[1], Cosio-Lima LM[1], Knapik JJ[2], Bishop PA[3] and Lee Y[1]

1. Department of Exercise Science and Community Health. University of West Florida, Pensacola FL 32514, USA

2. Tactical Research Unit, Bond University, Faculty of Health Sciences & Medicine, Robina, Queensland 4226, Australia

3. Liberty University, Lynchburg, VA 24515, USA

Abstract: This study examined the effects of combined anti-inflammatories and specific nutrients on recovery from resistance exercises. Trained individuals (n = 14) performed three sets to failure at a 8-12 repetition maximum load for six resistance exercises, then repeated this workout after 24 h. Participants consumed a protein-carbohydrate shake (330 ml; 20 g protein; 45 g carbohydrate), vitamin C (1000 mg), vitamin E (400 I.U.) and ibuprofen (100 mg) immediately after the initial workout. Another dose of vitamin C and ibuprofen were respectively consumed 1 h or 30 min before the second workout. On another occasion (counterbalanced) a placebo of flavored water, two imitation vitamins (gummy candies), and two replica ibuprofen (sugar pills) were consumed. A 10-cm visual analog scale (VAS) assessed pain, ratings of perceived exertion (RPE), and ratings of perceived recovery (RPR). Treatment enhanced performance–based recovery (repetitions after 24h) for the chest press (P < 0.010) and latissimus pull–down (P < 0.010). Within-condition comparisons revealed performance decrements (P < 0.050) after 24 h for 83% of the exercises under placebo, compared to 50% of exercises under treatment. Treatment enhanced RPR (P = 0.038) compared to placebo, but had no significant effects on residual (P = 0.215) or exercise (P > 0.050) pain. RPE was lower under the treatment for the chest press (P = 0.016) and overall workout (P = 0.038) on Day 1, but similar among all exercises on Day 2 (P > 0.050). This treatment may promote increases in performance without increasing pain or RPE.

Key words: Anti-oxidants, vitamins, Non-steroidal anti-inflammatory medication, weightlifting, perceived exertion.

1. Introduction

Different passive recovery techniques and treatments are hypothesized to reduce skeletal muscle pain and enhance subsequent exercise performance in athletics. Among these practices is the use of anti-inflammatories [1], supplementation with minerals and antioxidant vitamins [2], and higher intake of protein, carbohydrates, electrolytes, and fluids [3, 4]. Anti-inflammatory medications can reduce the pain and edema that accompany training and may expedite training recovery and restoration of performance capacity [5-8]. Similarly, supplemental antioxidants carry the potential to enhance exercise performance by reducing the detrimental effects of reactive oxygen species [2, 5, 6]. Additional nutritional interventions, such as increasing carbohydrate, protein, and fluid intake, may enhance recovery by increasing net muscle protein accumulation, replenishing glycogen stores, restoring caloric balance, and facilitating rehydration following excessive water loss [3, 4].

Evidence suggests that several of these methods independently reduce skeletal muscle pain, enhance recovery of muscle function [5], and augment second-day performance [9] in a portion of the athletic population. Conversely, these treatment methods are also associated with either no effect or a negative impact on exercise performance in others [9]. This disparate evidence may result from inter-individual differences within the studied sample.

Studies have suggested that concurrent use of anti-inflammatories combined with antioxidant vitamins and protein can assist in post-exercise

Corresponding author: Ludmila Cosio-Lima, Ph.D., professor, research fields: exercise and cardioprotection.

recover. Al Nawaiseh [10] showed that use of ibuprofen, vitamin C, vitamin E, and protein enhanced short-term recovery in trained athletes and competitive runners [11]. However, the combined influence of these supplements on training recovery in experienced weightlifters has not been investigated.

The purpose of this study was to evaluate the influence of the combined use of ibuprofen, vitamins C and E, and a post-workout protein shake (milk protein and whey protein) on training recovery during resistance training. Specifically, this study aimed to determine if this intervention will improve performance, alter ratings of perceived recovery (RPR) and exertion (RPE), and reduce skeletal muscle pain during a resistance training session 24 h after an initial resistance workout. We hypothesized that some individuals would respond positively to the intervention while others would exhibit no response or respond negatively. We also hypothesized that the intervention would overall attenuate skeletal muscle pain, and reduce RPE during exercise while enhancing RPR and performance-based training recovery compared to a placebo.

2. Methods

This study was a double-blinded, placebo-controlled investigation of the effectiveness of an anti-inflammatory medication and specific nutrients on recovery from resistance training. Volunteers attended 5 sessions including a baseline, two treatment and two placebo sessions. Treatment and placebo sessions consisted of two consecutive days of exercise separated by 24 h with the inflammatory medication and nutrients (or placebo) provided between the consecutive days. A one week period followed the baseline, experimental and placebo sessions to allow adequate between-session recovery. Treatment and placebo sessions were counterbalanced. The same protocol was used for the administration of treatment and placebo supplements.

3. Subjects

Fourteen students (7 men and 7 women) were recruited from the University of Alabama by word of mouth. All 14 subjects recruited completed the study. Inclusion criteria included (1) ages 19-30 years; (2) non-smoker; (3) no signs or symptoms of cardiovascular or metabolic disease; (4) classification as low or moderate risk of experiencing a cardiovascular event during exercise using the guidelines for risk stratification established by the American College of Sports Medicine [12] and (5) no use of exogenous steroids. Younger participants were selected to avoid possible confounding effects associated age-related differences in skeletal muscle recovery [13]. Ethical approval was obtained from the Medical Institutional Review Board at The University of Alabama prior to study commencement and conformed to the Declaration of Helsinki. Interested participants completed an exercise history questionnaire to determine if they met the ACSM’s [12] resistance training recommendations for inclusion. After providing their written, informed consent, participants reported to the weightlifting facility in the Aquatics Center at The University of Alabama on the five separate sessions. All volunteers were instructed to abstain from caffeine and alcohol for at least 24 h prior to each visit, and to abstain from all exercise that would cause fatigue for at least 48 h or 1 wk prior to baseline and experimental testing sessions, respectively. Study participants verbally assented to adhere to these research procedures.

4. Procedures

On the first day under each condition, heart rate was measured before the start of exercise and after each weightlifting set. A continuous 10-cm visual analog scale (VAS) was used to assess muscle pain and rating of preserved exertion (RPE) after each set and at the end of the workout. Residual muscle pain and rating of perceived recovery (RPR) were assessed prior to start of exercise on the second day of each treatment or placebo session using the VAS. The VAS was chosen rather than a 0-10 scale to allow analysis of these measures as continuous data. The number of repetitions performed was recorded after each set for all exercises to assess muscle recovery.

4.1 Visit 1 (Baseline)

After providing informed consent, participants completed a questionnaire asking them about their age, height, body weight, and exercise history over the previous 3 months. The participants then completed a series of assessments designed to establish a baseline weightlifting load that ensured momentary muscular failure after 8-12 repetitions (8-12 repetition maximum [8-12 RM]). The exercises in order included in the assessment were: (1) seated chest press, (2) seated latissimus pull-down, (3) seated shoulder press, (4) leg press, (5) hamstring curl, and (6) seated knee extension. The resistance machine (Cybex International, Inc.) load (8-12 RM) for each exercise during the baseline trial was used for all subsequent visits.

Procedures for the assessments were as follows. Participants completed a warm-up using a light load that they could easily lift for 15 repetitions. Next, participants estimated the load required to induce fatigue after 8-12 repetitions. The load was adjusted until the participants reached their 8-12 RM for each exercise. A 4-min rest period separated each exercise and a maximum of three attempts per exercise were allowed. If participants failed to achieve their 8-12 RM within 3 attempts on an exercise, they were instructed to return to the facility after a 1-wk recovery period to re-attempt the failed exercise(s).

4.2 Visits II and IV

Participants were fitted with a HR monitor (Polar Electro Inc., Lake Success, NY) and sat quietly for 5 min before baseline HR was obtained and recorded. Participants then performed 3 consecutive sets to failure of each of the above exercises using the baseline load established during the baseline session; the number of complete repetitions was recorded. Skeletal muscle pain, and RPE were assessed following each set and after completing the workout. At the end of the session, participants were instructed to abstain from all strenuous exercise and to return to the facility after 24 h.

4.3 Visits III and V

Twenty-four hours after visits II and IV, participants returned to the facility to complete visits III and IV, respectively. Participants rested quietly for 5 min before baseline HR and perceived skeletal muscle pain and RPR were assessed prior to beginning the exercises. After initial pain data was recorded, participants attempted to repeat the same workout performed the previous day. Skeletal muscle pain, RPE, and HR were assessed following each set and at the end of the workout. Participants were instructed to abstain from all vigorous exercise during a one-week “washout” period following Visit III.

4.4 Treatment and Placebo

During the 24-h period following the initial workout under treatment condition, participants received the following: (1) Two 100-mg doses of ibuprofen, (2) two 1000-mg doses of vitamin C, (3) one 400-I.U. dose of vitamin E, and (4) a protein recovery shake (330 ml) that also contained carbohydrates and electrolytes (Gatorade®, PepsiCo, Inc., Purchase, NY). The protein shake and one dose each of vitamin C, vitamin E, and ibuprofen were administered immediately following the initial workout. The second dose of vitamins C and E were administered one hour prior to the subsequent workout, and the second dose of ibuprofen was administered 30 min before the subsequent workout [11].

The placebo included (1) two capsules containing lactose identical in appearance and weight to the ibuprofen capsules from the treatment condition, (2) two imitation vitamins (Jolly Rancher ® gummies candy, The Hershey Company ®, Hershey, PA), (3) 330 ml of flavored water (Crystal Light®, Kraft Food

Group, Inc., Northfield, IL). The placebo was administered using the same protocol as the treatment trial. The treatment and placebo contents were provided in brown bags packaged by a non-investigator to ensure double-blind control. Participants were instructed to maintain the same dietary patterns during the 24 h prior to each visit, such that the only difference in nutrition results from differences in treatment interventions.

5. Statistical Analyses

A one-way ANOVA was used to compare skeletal muscle pain, RPE, RPR, and training recovery (repetitions completed) between and within treatment and placebo conditions. An alpha level of 0.05 was set for statistical testing.

6. Results

Table 1 shows the training history and participant characteristics obtained during the baseline session. Table 2 displays the performance data for the first set of each exercise. No differences (P > 0.05) in performance were observed between treatment and placebo on the baseline day. Between-condition comparisons revealed enhanced performance under the treatment session compared to the placebo session for the chest press, latissimus pull-down, and total repetitions following 24 h passive recovery (P < 0.05)

Table 3 shows residual muscle pain and RPR prior to activity on the second day of exercise. RPR was higher (P < 0.05) in the treatment condition compared to the placebo, but there was no significant difference (P > 0.05) in residual muscle pain.

Table 4 presents perceptual responses during activity on Day 1 and Day 2 of exercise. Participants reported reduced RPE under the placebo for the chest press and overall workout on Day 1 (P < 0.05); no differences in were observed Day 2 (P > 0.05).

Table 1 Training history and participant characteristics.

	Participants (n)	Training history			Participant characteristics			
		Training (months)	Frequency (days/ wk)	Average session (min)	Age (y)	Weight (kg)	Height (cm)	BMI (kg/m^2)
Total	14	33 (33)	4 (1)	77 (23)	22 (3)	75.9 (15.7)	174 (8)	24.9 (3.7)
Males	7	32 (37)	4 (1)	75 (23)	23 (4)	80.9 (17.9)	175 (8)	26.1 (4.2)
Females	7	33 (32)	4 (1)	79 (26)	21 (1)	66.7 (13.3)	169 (8)	23.3 (2.9)

Data are presented as means (SD).

Table 2 Performance-based training recovery following 24 h passive rest.

		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Total repetitions
Day 1	Treatment	10 (2)	10 (1)	10 (2)	11 (2)	11 (1)	11 (2)	63 (7)
	Placebo	10 (2)	10 (2)	10 (1)	11 (2)	11 (2)	11 (2)	63 (8)
	P-value	0.671	0.648	0.720	0.850	0.500	0.265	0.956
Day 2	Treatment	*9 (2)	*10 (2)	9 (3)	10 (2)	11 (2)	10 (2)	*59 (9)
	Placebo	8 (2)	9 (2)	9 (1)	9 (2)	10 (2)	9 (2)	55 (8)
	P-value	0.004	0.048	0.500	0.084	0.094	0.252	0.019

*Significantly greater than placebo. Data are presented as means (SD) for the number of repetitions performed during the first set of each exercise.

Table 3 Residual Pain (mm) and RPR (mm) following exhaustive resistance exercise and 24 h passive rest.

	Residual muscle pain	Ratings of perceived recovery (RPR)
Treatment	37 (22)	* 6 (1)
Placebo	41 (16)	5 (1)
P-value	0.215	0.038

*Significantly greater than placebo trial. Data are presented as means (SD).

Table 4 Perceptual responses to resistance exercise after 24 h passive recovery.

		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Overall workout
Day 1								
Pain	Treatment	41 (24)	38 (20)	55 (20)	43 (23)	30 (18)	41 (22)	63 (19)
	Placebo	39 (25)	47 (23)	55 (21)	43 (24)	38 (21)	48 (22)	58 (19)
	P-value	0.471	0.613	0.935	0.983	0.082	0.196	0.118
RPE	Treatment	54 (21)	49 (20)	54 (18)	54 (23)	43 (22)	49 (23)	69 (16)
	Placebo	50 (22)	49 (25)	54 (23)	54 (25)	47 (20)	56 (20)	63 (15)
	P-value	0.016*	0.906	0.988	0.988	0.147	0.177	0.038*
Day 2								
		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Overall workout
Pain	Treatment	42 (23)	38 (20)	49 (19)	43 (17)	39 (19)	45 (26)	61 (17)
	Placebo	47 (20)	43 (18)	46 (21)	48 (15)	44 (15)	50 (18)	60 (17)
	P-value	0.403	0.364	0.466	0.151	0.166	0.305	0.881
RPE	Treatment	58 (22)	52 (15)	58 (17)	56 (17)	48 (21)	51 (24)	69 (15)
	Placebo	55 (16)	53 (22)	58 (20)	57 (16)	54 (16)	57 (18)	70 (14)
	P-value	0.611	0.820	0.961	0.814	0.176	0.178	0.710

Data are presented as means (SD) for muscle pain and RPE using a 100-mm visual analog scale. *Significantly lower than treatment.

7. Discussion

7.1 Performance–Based Training Recovery

Participants executed a greater number of repetitions during the succeeding workout and for select exercises after consuming an anti-inflammatory and nutritional supplements compared to a placebo. Although performance differences were observed during the chest press and latissimus pull-down exercises only, it is worthwhile to note that our treatment also attenuated the total decline in performance typically observed after heavy resistance exercise. Whereas 3 sets to failure at 8-12 RM on two consecutive days resulted in a significant decline in performance for 83% of the exercises performed during the subsequent workout under placebo conditions, the treatment was associated with impaired next-day performance during only 50% of these exercises. The data suggests that athletes may use these supplements to increase training volume, which in turn may promote gains in muscle strength and endurance. However, it is important to note that our results reflect only the acute effects of the treatment. Additional research is necessary to understand how long-term use of these supplements affects training.

7.2 Perceptual Responses

Contrary to our hypotheses, the treatment failed to reduce muscle pain and RPE during exercise. However, it is important to note that participants demonstrated enhanced performance following the treatment vs. placebo. Thus, pain and RPE remained equal despite performing more repetitions under the treatment. Therefore, an effect on RPE cannot be ruled out, as the lower RPE values reported on Day 1 of placebo were undetectable on Day 2.

7.3 Protein-Carbohydrate Beverage

Participants were able to perform a greater number of repetitions with similar pain and RPE under treatment compared to placebo. These observations are consistent with previous reports of enhanced muscle recovery associated with post-exercise consumption of carbohydrates and protein [14]. Post-exercise protein consumption has been postulated to facilitate net muscle protein accretion by stimulating muscle protein synthesis or attenuating its breakdown [3, 14, 15]. Beelen and colleagues [15] reported that co-ingestion of carbohydrate and protein during early hours of recovery favorably influenced subsequent exercise performance, suggesting that it may be a viable treatment option for athletes who train or compete multiple times on the same or consecutive days.

7.4 Antioxidants

The current study, sought to determine the influence of a treatment combination that included two 1000-g doses of vitamin C and one 400-I.U. dose of vitamin E on training recovery following exhaustive resistance exercise. Although we used a combination of substances and it is difficult to ascribe effects to a single compound, our data tend to support the notion that antioxidants may have assisted in attenuating fatigue and enhance skeletal muscle recovery, at least for some exercises and for the total workout. We speculate that the observed increases in RPR and performance in the absence of any significant changes in muscle pain or RPE are due in part to an antioxidant-mediated decline in oxidative stress. This notion is in agreement with a previous report of reduced indices of muscle damage following consumption of 3000 mg vitamin C compared to a placebo during the three days prior to and four days after fatiguing exercise [11].

However, an ergogenic role for vitamin E in the present study is still plausible. As with vitamin C, supplementation with vitamin E has been shown to protect cellular membranes against oxidative damage and muscle injury associated with exercise [16]. In the present study, we included vitamins C and E, among other potential ergogenic aids, as a single treatment. Thus, as noted above, we were unable to separate the influence of each of these supplements on the overall response. However, combining vitamins C and E as part of a single treatment is not uncommon, and has even been shown to enhance the ergogenic potential beyond either of the antioxidants alone [16].

The majority of research surrounding antioxidant supplementation, particularly the use of vitamins C and E, has focused on the effects of prolonged daily consumption on exercise-induced muscle damage [16-18]. Few studies have examined the influence of acute supplementation with these vitamins. We chose to study the combined effect of vitamins C and E as part of a larger overall treatment on muscle recovery following exhaustive resistance exercise in trained men and women. Our results support previous claims enhanced recovery following prolonged supplementation with vitamins C and E. However, we cannot know if these vitamins alone produced the enhanced performance since a number of other substances were also ingested. Prolonged use of vitamin E in excess of 400 I.U. per day is associated with early mortality and, consequently, avoiding prolonged daily consumption of high doses of vitamin E may be important [19]. Therefore, athletes may chose to supplement with vitamin E only during the peak of training and competition, to allow them to receive the potential ergogenic benefits of the antioxidant.

7.5 Ibuprofen

Non-steroidal anti-inflammatory drugs (NSAIDS) are postulated to attenuate exercise–induced muscle damage, reduce muscle pain, and enhance performance during subsequent exercise [5, 20]. Our results demonstrated similar levels of pain and RPE between the two conditions despite a significant increase in repetitions. It is possible that enhanced performance under the treatment masked any reductions in perceptual responses to the exercise, and that this outcome is partially attributed to the effects of ibuprofen. Our observations might be attributed, at least in part, to the ibuprofen. Schoenfield [20] suggested that exercise-induced muscle soreness may result from increased sensitization of nociceptors (pain-sensitive nerve endings) caused by noxious chemicals and byproducts of tissue breakdown. Swelling within the muscle tissues intensifies this pain by exerting additional pressure on nociceptors. Because high-intensity resistance exercise induces acute muscle injury and initiation of the inflammatory response, any remedy that reduces inflammation may attenuate pain and enhance physical function [1, 6, 20]. However, athletes seeking to implement ibuprofen or other NSAIDs into their training regimen should exercise caution, as chronic use of anti-inflammatories may inhibit muscle hypertrophy [8, 20]. NSAIDs function by blocking cyclooxygenase, an enzyme necessary for achieving maximal muscle growth in response to training overload [6, 20]. Thus, only acute use of ibuprofen should be used to treat muscle soreness during times of critical importance, such as competition or during the peak volume phases of a training program.

It is important to note that our study examined only the influence of acute use of the treatments on recovery from resistance exercise. Additional research might focus on longer-term use with the caveat that some substances may have negative effects with chronic use. We speculate that the collective use of ibuprofen, vitamins C and E, and a protein-carbohydrate beverage might provide greater ergogenic benefits than any of these treatments alone; however, further research is necessary to test this conjecture. Additionally, we are unable to provide insight into the physiological mechanisms responsible for any differences between treatment and control conditions. While incorporating multiple recovery techniques into a single treatment enhanced our ability to discover an effective treatment, it also hindered us from determining the individual effects of each component. It is possible that one or more individual treatments may interact with one another to influence the overall effect—whether positively or negatively.

8. Conclusions

Acute use of ibuprofen, vitamins C and E, and a protein-carbohydrate shake enhanced 24-h RPR and performance-based training recovery following exhaustive resistance exercise in trained men and women. Thus, athletes may benefit from implementing this recovery approach into their training or rehabilitation program. However, because chronic use of ibuprofen and large quantities of vitamin E are associated with negative effects, the treatment used in the current study should be implemented only during the peak of training and competition, or when advanced recovery is imperative.

Acknowledgment, Authorships, Declarations

The study was conducted in the Aquatic Center weight room at the University of Alabama, Tuscaloosa, Alabama. No outside funding source was used to support this research. The researchers would like to thank Dr. Jared Hornsby, Saul Sibayan, and Madison Knighton (Elmore) for their role in holding the double-blind code and assisting with data collection.

The study was designed by Sara Baggett and Phillip Bishop; data were collected by Sara Baggett and analyzed and interpreted by Sara Baggett, Phillip Bishop, Ludmila Cosio-Lima, and Joseph Knapik. Manuscript preparation and critical review of the manuscript were undertaken by Sara Baggett, Phillip Bishop, Ludmila Cosio-Lima, Joseph Knapik and Youngil Lee. All authors approved the final version of the paper.

References

[1] Hasson, S. M., Daniels J. C., Divine J. G., Niebuhr, B. R., Richmond, S., Stein, P. G., and Williams, J. 1993. "Effect of Ibuprofen Use on Muscle Soreness, Damage, and Performance: A Preliminary Investigation." *Medicine and Science in Sports and Exercise* 25 (1): 9-17.

[2] Haymes, E. M. 1991. "Vitamin and Mineral Supplementation to Athletes." *International Journal of Sport Nutrition* 1 (2): 146-69.

[3] Benardot, D. 2006. *Advanced Sports Nutrition.* Champaign, IL: Human Kinetics.

[4] Maughan, R. J., and Shirreffs, S. M. 1997. "Recovery from Prolonged Exercise: Restoration of Water and Electrolyte Balance." *Journal of Sports Sciences* 15 (3):

297-303.

[5] Baldwin Lanier, A. 2003. "Use of Nonsteroidal anti-Inflammatory Drugs Following Exercise-Induced Muscle Injury." *Sports Medicine* 33 (3): 177-85.

[6] Peterson, J. M., Trappe, T. A., Mylona, E., White, F., Lambert, C. P., Evans W. J., and Pizza, F. X. 2003. "Ibuprofen and Acetaminophen: Effect on Muscle Inflammation after Eccentric Exercise." *Medicine and Science in Sports and Exercise* 35 (6): 892-6.

[7] Tokmakidis, S. P., Kokkinidis, E. A., Smilios, I., and Douda, H. 2003. "The Effects of Ibuprofen on Delayed Muscle Soreness and Muscular Performance after Eccentric Exercise." *Journal of Strength Conditioning Research* 17 (1): 53-9.

[8] Trappe, T. A., White, F., Lambert, C. P., Cesar, D., Hellerstein, M., and Evans, W. J. 2002. "Effect of Ibuprofen and Acetaminophen on Postexercise Muscle Protein Synthesis." *American Journal of Physiology-Endocrinology and Metabolism* 282 (3): E551-6.

[9] Bosak, A., Bishop, P., Green, J., and Hawver, G. 2009. "Impact of Cold Water Immersion on 5km Racing Performance." *Sport Journal* 12 (1): 9.

[10] Al Nawaiseh, A. M., Pritchet, R. C., and Bishop, P. A. 2016. "Enhancing Short-Term Recovery after High-inTensity Anaerobic Exercise." *Journal of Strength and Conditioning Research* 30 (2): 320-5.

[11] Shaw, K. R. 2013. "Recovery Following Aerobic Exercise: Modalities and Masters Runners." Ph.D. dissertation, The University of Alabama.

[12] ACSM's Guidelines for Exercise Testing and Prescription. 2014. Baltimore, MD: Wolters Kluwer/Lippincott Williams & Wilkins Health.

[13] McLester, J. R., Bishop, P. A., Smith, J., Wyers, L., Dale, B., Kozusko, J., Richardson, M., Nevett, M. E., and Lomax, R. 2003. "A Series of Studies—A Practical Protocol for Testing Muscular Endurance Recovery." *Journal of Strength and Conditioning Research* 17 (2): 259-73.

[14] Cermak, N. M., De Groot, L. C., Saris, W. H., and Van Loon, L. J. 2012. "Protein Supplementation Augments the Adaptive Response of Skeletal Muscle to Resistance-Type Exercise Training: A Meta-Analysis." *The American Journal of Clinical Nutrition* 96 (6): 1454-64.

[15] Beelen, M., Burke, L. M., Gibala, M. J., and Van Loon, L. J. 2010. "Nutritional Strategies to Promote Postexercise Recovery." *International Journal of Sport Nutrition and Exercise Metabolism* 20 (6): 515-32.

[16] Urso, M. L., and Clarkson, P. M. 2003. "Oxidative Stress, Exercise, and Antioxidant Supplementation." *Toxicology* 189 (1-2): 41-54.

[17] Cannon, J. G., Meydani, S. N., Fielding, R. A., Fiatarone, M. A., Meydani, M., Farhangmehr, M., Orencole, S. F., Blumberg, J. B., and Evans, W. J. 1991. "Acute Phase Response in Exercise. II. Associations Between Vitamin E, Cytokines, and Muscle Proteolysis." *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* 260 (6Pt 2): R1235-40.

[18] Schröder, H., Navarro, E., Tramullas, A., Mora, J., and Galiano, D. 2000. "Nutrition Antioxidant Status and Oxidative Stress in Professional Basketball Players: Effects of a Three Compound Antioxidative Supplement." *International Journal of Sports Medicine* 21 (2): 146-50.

[19] Fitzgerald, M. 2005. *Runner's World the Cutting-Edge Runner: How to Use the Latest Science and Technology to Run Longer, Stronger, and Faster*. Rodale Press, Incorporated. Emmause, PA.

[20] Schoenfeld, B. J. 2012. "The Use of Nonsteroidal Anti-inflammatory Drugs for Exercise-Induced Muscle Damage." *Sports Medicine* 42 (12): 1017-28.