RESISTANCE TRAINING AND RECOVERY: INFLUENCE OF DIETARY SUPPLEMENTS, COMBINED TREATMENT THERAPIES, AND GENDER

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A DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Kinesiology
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2015

ABSTRACT

Many competitive and recreational athletes devote considerable time and attention designing exercise programs to optimize performance. Training variables, such as the exercise modality, the number of weekly training sessions, and the intensity and duration of each session are manipulated to elicit favorable adaptations. Equally important in exercise prescription is the establishment of adequate recovery between successive training sessions. The purpose of the proposed studies was to evaluate the effectiveness of common dietary supplements and, in a separate analysis, the use of an anti-inflammatory and nutritional intervention on recovery from resistance exercise in trained men and women. Additionally, the study served to evaluate the influence of gender on skeletal muscle recovery following an exhaustive bout of resistance exercise. After establishing a baseline load that elicits temporary muscular failure after 8–12 repetitions, participants completed 3 sets to failure on two consecutive under treatment and placebo conditions. Treatment conditions for Study I consisted of the current use of branched-chain amino acids (BCAA), beta-hydroxy-beta-methylbutyrate (HMB), and glutamine; placebo supplements (sugar pills) served as a control. The treatment condition for Study II was comprised ibuprofen, vitamins C and E, and a protein-carbohydrate recovery beverage, while flavored water and imitation vitamins (gummy candies) were used as a placebo. Study III compared 24 h training recovery in men versus women. Muscle pain and ratings of perceived exertion (RPE) were measured after each set, exercise, and workout using a 100–mm visual analog scale (VAS). Residual muscle pain and ratings of perceived recovery (RPR) were

measured 24 h after the initial workout. Muscle recovery was defined as the number of repetitions performed during the first set of repetitions on the second day of activity. The treatments used in Study I and Study II significantly enhanced performance-based training recovery for select exercise and allowed participants to perform more total repetitions for all exercises combined. The BCAA, HMB, and glutamine treatment significantly reduced residual muscle pain, but had no effect on RPR compared to a placebo. Additionally, this treatment significantly reduced skeletal muscle pain and RPE for select exercises. Additionally, the this treatment significantly reduced muscle pain and RPE during subsequent training 24 h after an exhaustive resistance bout. Conversely, a protein–carbohydrate beverage, vitamins C and E, and ibuprofen significantly enhanced RPR after 24 h passive recovery without influencing residual pain or muscle pain and RPE during subsequent activity. Lastly, while residual muscle pain was reduced in women compared to men 24 h after a fatiguing resistance session, no differences in performance or muscle pain and RPE during exercise were observed. Two treatment options may effectively enhance training recovery: (a) concurrent use of a protein–carbohydrate beverage, vitamins C and E, and ibuprofen, and (b) concurrent use of BCAA, HMB, and glutamine. These treatments significantly enhanced performance compared to a placebo and attenuated residual muscle pain or RPR. The former treatment also attenuated muscle pain and RPE during select exercises, possibly contributing to enhanced performance. Men and women respond similarly to 24 h passive rest. Coaches and physical therapist may use these treatments to accelerate recovery of muscle function and enhance training adaptations. However, the long–term effects remain unknown. Additionally, men and women may not require distinct recovery periods following damaging resistance exercise. However, while men and women recovered equally under control conditions, it is unknown whether any differences in training recovery are

present following ingestion of various ergogenic aids. Future research should evaluate the effects of chronic use of the treatments studied, as well the effect of as sex–related differences under these treatments.

LIST OF ABBREVIATIONS AND SYMBOLS

bpm	Beats per minute
HR	Heart rate
Kcal	Kilocalories
min	Minutes
mo	Months
PAR-Q	Physical activity readiness questionnaire
RPE	Rating of perceived exertion
RPR	Rating of perceived recovery
SD	Standard deviation
VAS	Visual analog scale
y	Years

ACKNOWLEDGEMENTS

I am thankful for all my past and current professors who helped reach this stage in academia. I am most indebted to Dr. Phil Bishop, the chairman of this dissertation, for helping me gain confidence as a researcher and for sharing his wisdom and experience to assist me throughout this dissertation. I would also like to thank all of my committee members, Dr. Johnathan Wingo, Dr. Mark Richardson, Dr. Matthew Curtner-Smith, and Dr. James Leeper for their time and contributions to this dissertation.

I also thank my family and friends for providing unconditional love and support throughout all aspects of my life. This dissertation would not be possible without you.

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INTRODUCTION

Recovery complements the four components of training: frequency, intensity, duration, and exercise modality to contribute to the overall adaptations to exercise; thus, recovery from a workout is vital if athletes are to maximize the benefits of training (3, 17, 31). Conversely, inadequate recovery may lead to performance decrements during subsequent training or competitive activity (3). Continuing to train despite insufficient recovery can lead to overtraining syndrome – a chronic condition characterized by staleness, excessive fatigue, impaired immune function, sleep disturbances, a sustained plateau or decline in performance, and additional deleterious effects (3, 34).

In the broadest sense, recovery can be viewed as encompassing three related components: (a) the intermittent period between two consecutive skeletal muscle contractions (immediate recovery), (b) the interval between two consecutive periods of training activity during a multi-bout training session (short-term recovery), and (c) training recovery– the recovery between two consecutive training sessions or competitions (5). Complete training recovery involves the reestablishment of homeostasis and return to baseline exercise capacity. Thus, by this definition, recovered individuals demonstrate the ability to reach or exceed their prior performance achievements during a subsequent workout (5). A wide variety of recovery tactics are commonplace in athletics and vary among individuals or in accordance with differing training paradigms. All recovery protocols can be assigned to one of two broad categories– active recovery or passive recovery.

Active Recovery

Active recovery involves continued low-intensity physical activity between intermittent bursts of high-intensity exercise or as a scheduled component of training recovery (3, 56). The premise behind active recovery is that sustained activity enhances the clearance of metabolic byproducts that accumulate during exercise leading to a quicker return to homeostasis (17, 53, 56). Thus, a quicker return to homeostasis may enhance performance by delaying fatigue or facilitating repair. However, the literature is equivocal with several investigators demonstrating greater power output during subsequent exercise when preceded by active versus passive recovery (7, 57), while others oppose this notion of enhanced performance with active recovery, arguing instead for passive rest (17, 53).

Passive Recovery

In contrast to active recovery, passive recovery involves complete cessation of exercise beyond the normal requirements of living. As with active recovery, the implementation of passive techniques is useful for achieving short-term and training recovery (13, 53). Included among these methods are practices such as massages, saunas, cryotherapy, anti-inflammatory analgesics, nutritional supplementation, and increased intake of carbohydrate and protein (5, 8, 24, 45). Current evidence indicates that 24 h of passive rest is insufficient to elicit full training recovery in nearly all individuals; yet, many athletes continue to engage in daily or even twice-a-day workouts (5, 18). Consequently, athletes may enter a subsequent exercise session in a pre-existing state of fatigue when prior training recovery is deficient. The highly fatigued athlete is often unwilling or unable to maintain the prior exercise intensity (2, 35). In effect, the training stimulus and resultant adaptations are attenuated (31). Continued practice of this training

regimen clearly does not allow for full recovery in many individuals and may therefore lead to an increased prevalence of overtraining among athletes (31, 34).

Consequently, the purpose of these proposed studies was to investigate two methods hypothesized to enhance 24-h training recovery from a single bout of exhaustive resistance training. These strategies include: (a) the concurrent use of BCAA, HMB, and glutamine, (b) a combination treatment consisting of an anti-inflammatory medication, vitamins C and E, and a protein beverage. Additionally, the proposed study sought to quantify any difference in training recovery between resistance-trained males and females.

STUDY I

Effect of Branched-chain Amino Acids, Beta-hydroxy-beta-methylbutyrate, and Glutamine on Recovery from Resistance Exercise

ABSTRACT

The purpose of this study was to evaluate the effects of the concurrent use of branched-chain amino acids (BCAA), beta-hydroxy-beta-methylbutyrate (HMB), and glutamine on recovery from resistance exercise. After establishing a baseline load to ensure momentary muscular failure after 8–12 repetitions, fourteen resistance-trained individuals (mean ± SD age = 21 ± 2 y; training duration = 48±30 mo; session duration = 65 ± 18 min; frequency = 4 ± 1d/wk.; males, n = 7, females, n = 7) completed two experimental protocols. Each protocol consisted of two exercise sessions (treatment and placebo) performed on consecutive days in a double-blind, randomized, and counter-balanced fashion. Experimental sessions consisted of three sets of 8–12 repetitions for six resistance exercises followed by an attempt to complete this same workout after 24 h. Muscle pain and ratings of perceived exertion (RPE) were assessed after each set, after each exercise, and following each workout using a 100–mm visual analog scale (VAS). Muscle pain and ratings of perceived recovery (RPR) were assessed 24 h after the initial workout. Performance–based training recovery after 24 h passive rest was significantly enhanced under treatment compared to placebo conditions for the leg extension (10 ± 3 vs. 11 ± 1; p = .03) and latissimus pull-down (10 ± vs. 11 ± 2; p = .02) exercises. No differences between treatment and placebo were observed for all remaining lifts. Additionally, total repetitions

performed during subsequent exercise was significantly greater under treatment compared to placebo (59 ± 7 vs. 62 ± 5; p = .03). Whereas RPR was similar between treatment and placebo (p > .05), residual muscle pain was significantly lower under the treatment (40 ± 23 vs. 29 ± 19; p = .01). Skeletal muscle pain during the subsequent workout was also lower under treatment compared to placebo for the leg press (45 ± 21 vs. 37 ± 14; p = .04) and shoulder press (47 ± 24 vs. 39 ± 17; p = .04). Similar levels of pain between treatment and placebo were observed for all other exercises (p > .05). On the second day of repetitions, RPE was significantly reduced under the treatment for the leg press (62 ± 16 vs. 55 ± 20; p = .02) and leg extension (61 ± 19 vs. 53 ± 20; p = .03), but did not differ for any of the remaining exercises (p > .05) or for the overall workout (placebo = 73 ± 18 vs. treatment = 70 ± 20; p > .05). A small but significant decrease in HR was observed under treatment compared to placebo for the chest press (144 ± 18 vs. 141 ± 20; p = .03) and shoulder press (140 ± 16 vs. 137 ± 18; p = .01) exercises only; similar responses in HR were observed between treatment and placebo during all additional lifts (p > .05). Combined ingestion of BCAA, HMB, and glutamine may reduce the signs and symptoms of exercise-induced muscle damage 24 h after an exhaustive resistance workout and slightly improve performance. Consuming these supplements before and after the initial workout reduced residual muscle pain as well as muscle pain and RPE during exercise, possibly by attenuating skeletal muscle damage or by accelerating muscle repair. Additionally, reduced muscle pain and RPE under the treatment may have attributed to enhanced performance during the subsequent workout. Additional research is necessary to understand the chronic effects of these supplements on training recovery. Further research examining the individual influence of each of these supplements is also warranted.

Key Words: muscle pain, resistance exercise

INTRODUCTION

Engaging in a fatiguing bout of resistance exercise beyond the accustomed volume or intensity is necessary for continued progression in weight lifting performance (31). Consequently, overloading the skeletal muscles is a common occurrence among many recreational and competitive athletes. The time necessary for training recovery is dependent in part on training volume; as athletes increase the volume of their workouts, more time is required to achieve full training recovery (31). Research in resistance-trained men and women demonstrates that a minimum of 48 h is often necessary to achieve full training recovery following an exhaustive resistance workout (18, 31, 40). Yet, many athletes continue training despite inadequate recovery from a prior workout.

Chronic continuation of under-recovery can lead to overtraining and, among other deleterious effects, may increase skeletal muscle pain and fatigue with concomitant reductions in skeletal muscle performance. Thus, developing strategies to accelerate training recovery can benefit athletic performance by reducing the propensity to train in an under-recovered state, and by allowing a more rapid muscle adaptation. Many supplements claim to provide an ergogenic effect by reducing muscle damage, attenuating pain, and enhancing training recovery (28). Included among these supplements are branched-chained amino acids (BCAA), Beta-hydroxy-beta-methylbutyrate (HMB), and Glutamine.

BCAA

BCAA include three essential amino acids (leucine, isoleucine, and valine) that regulate protein metabolism (14, 25, 50). Additionally, BCAA may enhance physiological and psychological responses to exercise, improve immune function, attenuate muscle protein degradation, and accelerate training recovery following endurance and resistance exercise (14,

25, 42, 49). Sharp and Pearson (49) and Howatson et al. (26) reported that consuming BCAA 2–3 wk prior to a bout of fatiguing exercise and during recovery reduced serum creatine kinase concentrations and attenuated muscle soreness, suggesting that BCAA defends against exercise-induced muscle damage. Further, Howatson et al. (26) assessed maximal voluntary contraction and reported greater recovery of peak force after 24 h with BCAA compared to a placebo. These findings are in agreement with recent work by Ra et al. (47), which revealed that BCAA in combination with taurine attenuated markers of skeletal muscle damage and reduced delayed-onset muscle soreness when consumed 2 wk prior to and 3 d following high-intensity eccentric exercise.

Shimomura et al. (50) postulated that BCAA supplementation must occur prior to exercise in order to evoke any ergogenic effects; when subjects ingested BCAA after squat exercise, muscle damage did not differ from placebo conditions. The authors further suggest that pre-exercise supplementation with BCAA may protect against muscle damage by lessening the release of essential amino acids from the skeletal muscle during activity (36, 50). In theory, any intervention that decreases muscle breakdown could promote enhanced recovery of muscle function subsequent activity and, consequently, enhanced training adaptations.

Other researches have postulated that the ergogenic effects of BCAA supplementation result from increased muscle protein synthesis during the recovery period Tipton et al. (58) or increased BCAA availability during the post-exercise period (39). Additionally, evidence suggests that consuming carbohydrates prior to BCAA supplementation may enhance their effects. This notion arises from the observation that insulin, which is released from the pancreas in response to increased circulating glucose concentrations, augments leucine-induced protein synthesis within the skeletal muscle (29, 50).

While many reports demonstrate a positive effect of BCAA supplementation on muscle recovery, other well-controlled studies have failed to demonstrate any ergogenic effect of BCAA supplementation (19, 43). Further, the preponderance of research evaluating the influence of BCAA supplementation on recovery from resistance training have utilized a 2–3 wk BCAA "loading phase," during which participants abstained training while consuming BCAA supplements at regular intervals (14, 49). At the end of this phase, participants then engaged in a bout of fatiguing resistance exercise. Although many of these studies reported a positive effect of BCAA on muscle recovery, it is important to note that many individuals involved in resistance training may not abstain from the activity for several weeks as the study protocol required. Thus, a prolonged loading phase may not be practical for these athletes. Additionally, in the studies in which only a single dose of BCAA was used prior to resistance exercise, the participants were generally untrained (27, 30, 33, 47, 50). Although these studies suggest that BCAA supplementation may reduce delayed-onset muscle soreness (DOMS) and attenuate muscle damage, the effects of DOMS are less pronounced in trained individuals (3). However, the primary beneficiaries of any supplement that enhances recovery from resistance training are those individuals who regularly partake in fatiguing resistance exercise.

While studies examining the influence of an acute dose of a leucine–carbohydrate beverage before and after exercise suggest that leucine is ineffective in enhancing muscle recovery beyond a carbohydrate beverage alone, the efficacy of concurrent supplementation with all three BCAA remains unclear (54). La Bounty et al. (32) demonstrated that acute supplementation with a combined leucine, isoleucine, and valine supplement enhanced markers of muscle protein synthesis beyond that of leucine alone, following 4 sets to failure at 80% of the 1 RM in trained individuals; however, the study did not address recovery of performance. No

studies have examined the influence of acute BCAA supplementation before and after resistance exercise on muscle recovery in resistance-trained men and women. Therefore, additional research is necessary to evaluate the influence of BCAA supplementation on skeletal muscle performance and recovery in trained athletes.

HMB

HMB is a leucine metabolite theorized to reduce muscle damage and accelerate skeletal muscle recovery from high-intensity exercise (22, 59, 63). The mechanisms responsible for the ergogenic effects of HMB may be attributed to an up-regulation of the mammalian target of rapamycin (mTOR) protein, leading to increased protein synthesis within the skeletal muscle (22). HMB supplementation may also attenuate muscle protein degradation via inhibition the ubiquitin-proteasome pathway, a system responsible for intracellular protein catabolism (22, 51).

Alternatively, HMB may reduce muscle degradation by attenuating the inflammatory response associated with exercise-induced muscle damage (59). Tumor necrosis factor alpha (TNF-α), a pro-inflammatory cytokine, is responsible for signaling neutrophils and macrophages to initiate the breakdown of damaged muscle tissue (59). Two other inflammatory cytokines, interleukin-1 (IL-1) and interleukin-6 (IL-6), along with reactive oxygen species, are released from the infiltrating neutrophils to promote cell breakdown and induce muscle-contractile dysfunction, increase protein catabolism, and impair protein synthesis within the muscle (59).

Townsend et al. (59) reported that supplementation with HMB before and after high-intensity resistance exercise attenuated TNF-1 expression during recovery, suggesting that HMB may enhance recovery by attenuating the initial immune response to exercise (59). Since muscle damage facilitates the immune response, it is possible that the decrease in TNF-1 expression was due to decreased muscle damage. This hypothesis is in line with reports by Rowlands and

Thomson (48) and Wilson et al. (65), which demonstrated that HMB supplementation reduced serum concentrations of CK and increased ratings of perceived recovery. When Gonzalez et al. (22) combined HMB supplementation with cold-water immersion, it enhanced recovery of average power and reduced markers of muscle damage; however, HMB and cold-water immersion alone failed to provide any ergogenic benefits over placebo.

The majority of research examining the influence of HMB supplementation has required participants to ingest HMB for one or more weeks prior to a bout of fatiguing endurance or resistance exercise (65). Only four studies have examined the effect of acute HMB supplementation prior to resistance exercise on markers of muscle damage in trained and untrained participants (22, 23, 64, 65), and only one of these studies has specifically addressed training recovery (65). Therefore, additional research is necessary to clarify the efficacy of acute HMB supplementation on recovery from resistance exercise in trained men and women. The current study will examine the influence of the concomitant use of HMB, BCAA and glutamine on recovery from resistance exercise in trained men and women.

Glutamine

Glutamine is a non-essential amino acid involved in a variety of metabolic and immune responses, and has been postulated to enhance training recovery and reduce muscle soreness by enhancing tissue repair, facilitating protein synthesis, and promoting muscle glycogen storage after exercise (9, 21, 55). The majority of research examining the potential ergogenic effects of glutamine supplementation has focused on prolonged endurance exercise lasting more than 2 h (10, 46, 55). These studies have demonstrated a significant decrease in glutamine concentrations following exercise, potentially a consequence of increased glutamine uptake by the liver and intestine (55). In contrast to the consistent decline in plasma glutamine observed following

prolonged endurance exercise, short-term exercise has been associated with increases, decreases, and no change in plasma glutamine concentrations (21, 55). These discrepancies likely arise from greater variations in the training protocols implemented during short-term exercise; studies utilizing high-volume eccentric exercise requiring greater muscle activation, force, and repetitions demonstrated greater declinations in plasma and intramuscular glutamine compared to lower-intensity exercise (6, 21, 55).

Street et al. (55) examined the effects of glutamine supplementation on muscle strength and soreness during a four-day recovery period following eccentric exercise. Study participants completed 100 drop jumps followed by ingestion of 0.3 $g \cdot kg^{-1}$ of glutamine or placebo immediately following and at 24, 48, and 78 h after exercise. The authors observed a decrease in maximal voluntary contraction under treatment and placebo conditions; however, this decrement was significantly lower for the glutamine group compared to the placebo group throughout the 96-h recovery period. Additionally, glutamine supplementation attenuated perceptions of muscle soreness for the duration of the recovery period (55).

An exercise-induced decline in plasma and intramuscular glutamine has been observed following prolonged endurance exercise and short-term resistance exercise of sufficient intensity and volume (21, 55). Therefore, it is plausible that oral glutamine supplementation enhances recovery of muscle strength and attenuates muscle soreness by restoring plasma glutamine homeostasis and, consequently, by maintaining a positive net protein balance, promoting intramuscular glycogen synthesis, and protecting against exercise-induced muscle damage (55). This notion is supported by the observation that oral glutamine supplementation promoted a rapid rise in plasma glutamine concentrations, increasing values by ~50% in 30 min (11). Accordingly, glutamine may serve as an effective ergogenic aid for athletes in training; however,

inconsistent and conflicting results among studies of various durations, modalities, and intensities substantiates the necessity for further research before any definitive conclusions can be made. While studies focusing on the influencing of glutamine on recovery from prolonged endurance exercise generally demonstrate positive ergogenic effects , glutamine supplementation before and after short-term aerobic activity (< 2 h) and resistance exercise may enhance recovery only if the intensity is sufficient to substantially deplete glutamine stores (10, 55, 61). Additional research is necessary to determine the effectiveness of oral glutamine supplementation for enhancing recovery from short-term, high-intensity exercise during which substantial declines in plasma glutamine concentrations are conceivable. Therefore, the present study will examine the influence of glutamine supplementation on recovery from a fatiguing bout of whole-body resistance exercise in trained men and women.

The use of performance–enhancing supplements is a common practice among many recreational and competitive athletes (4, 28). While the use of many substances and practices have been banned from competitive sports, the use of various nutritional supplements and interventions remains a safe and legal practice among athletes (28). Included among these practices is the use of dietary supplements, including BCAA, HMB, and glutamine. Multiple product manufacturers have included two or more of these supplements into a single capsule or powder. Additionally, competitive and recreational lifters may simultaneously ingest several postulated ergogenic aids in hopes of maximizing training recovery. Therefore, it is important to understand the combined influence of these supplements on recovery from resistance training. The purpose of the present study was to examine the efficacy of concurrent supplementation with BCAA, HMB, and glutamine on recovery from resistance exercise in trained men and women.

We hypothesized that concurrent supplementation with BCAA, HMB, and glutamine would reduce exercise-induced skeletal muscle pain and ratings of perceived exertion (RPE) during resistance exercise, and that it would enhance muscle endurance, ratings of perceived recovery (RPR), and performance-based training recovery 24 h after a fatiguing resistance workout.

METHODS

Experimental Approach to the Problem

After a baseline load had been established, participants completed the experimental protocol under treatment and placebo conditions. Muscle endurance was defined as the number of repetitions performed for each exercise during the first set of each lift. Muscle recovery was defined as the ability to repeat the same number of repetitions during the first set of the subsequent workout as was performed on the previous day. All tests were double-blind with the treatment order counterbalanced. A one-week washout period separated baseline testing and the first experimental trial to ensure that all residual effects of the session had subsided. Participants were instructed to abstain from any strenuous exercise not associated with the study during this time. Participants then completed two experimental trials, each comprised of two resistance-training sessions separated by 24 h passive recovery. This recovery period was chosen to minimize the possibility that participants would experience full training recovery independently of treatment and placebo conditions. A second one-week washout period separated the two experimental trials.

On the first day of each experimental testing session, muscle pain and RPE were assessed after each set, after each exercise, and following completion of the workout using a 100-mm VAS. We choose to use the continuous VAS in place of the traditional 0-10 ordinal scales to

measure muscle pain and RPE, as the results are analyzed as continuous data. The number of repetitions performed was recorded after each set for all exercises. Additionally, baseline HR was recorded prior to the start of each trial and exercise HR was recorded after each set for all lifts. On the second day of repetitions, residual muscle pain and RPR were recorded prior to exercise, and muscle pain, RPE, and repetitions were recorded in the same manner as the previous day.

Subjects

Fourteen resistance-trained subjects (mean ± SD age = 21 ± 2 y; training duration = 48±30 mo; session duration = 65 ± 18 min; frequency = 4 ± 1d/wk.; males, n = 7, females, n = 7) participated in the study. Training history and physical characteristics for men and women are reported in Table 1. All participants were healthy, non-smoking volunteers who were free of any cardiovascular or metabolic disease and who were classified as having a low or moderate risk of experiencing a cardiovascular event during exercise according to guidelines established by the American College of Sports Medicine (ACSM). Individuals who reported partaking in the use of any exogenous steroids were excluded from participation in the study. This study population, aged 19-30, was chosen in order to minimize any confounding effects associated with age-related differences in skeletal muscle recovery between younger and older individuals (22) and to minimize any training effects associated with study participation. 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. All individuals interested in participating in the study completed an exercise history questionnaire to determine if they met the inclusion criteria for the study. After providing their written, informed consent, participants reported to the weightlifting facility located in the Aquatics Center at The University of Alabama

on five separate occasions. All volunteers were instructed to abstain from caffeine and alcohol for at least 24 h prior to each visit, and to abstain from vigorous exercise 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.

Procedures

Visit I. After participants provided informed consent, their age, height, body weight, and exercise history over the previous 3 months were collected and recorded. The participants then completed a series of tests designed to establish a baseline load that ensured momentary muscular failure after 8–12 repetitions. The following exercises were included in the assessment: (a) Seated chest press, (b) Seated latissimus pull-down, (c) Seated shoulder press, (d) Leg press, (e) Hamstring curl, and (f) Seated knee extension. The machine settings for each exercise during the baseline trial were recorded and used for all subsequent visits.

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 repetition maximum (RM) for each exercise. A 4-min rest period separated each attempted set, and a maximum of 3 attempts per exercise were allotted. If participants failed to achieve their 8–12 RM within 3 attempts, they were instructed to return to the facility after a 1–wk recovery period to re-attempt the failed exercises.

Visits II and IV. Participants were fitted with a HR monitor (Polar Electro Inc., Lake Success, NY) and rested quietly for 5 min before baseline HR was obtained and recorded. The sleep and nutritional history of the participant over the previous 24 h was documented for further analysis in the event that any unexpected or unusual results were observed that might have been

influenced by these factors. Participants then performed 3 sets to failure of each of the above lifts using the baseline load established during the preliminary session; the number of complete repetitions was recorded. Skeletal muscle pain, RPE, and HR were assessed following each lift set, each exercise, and after completing the workout. Participants were then instructed to abstain from all strenuous exercise not associated with the study and to return to the facility after 24 h.

BCAA, HMB, and Glutamine supplementation

The present study examined the concurrent use of BCAA, HMB, and glutamine on recovery from resistance training. Participants consumed two 6-g (five capsules) doses of BCAA plus Glutamine supplements (MET-Rx Nutrition, Inc; Boca Raton, FL; L-Leucine, 2.5 g; L-Valine, 1.5 g; L-Isoleucine, 1 g; L-Glutamine, 1 g) and three 1-g doses of HMB (MRM, Inc; Oceanside, CA). One BCAA plus glutamine supplement and one 1-g dose of HMB were consumed 1 h or 30 min prior to the initial workout, respectively. The second BCAA plus glutamine supplements were consumed immediately following the workout, while the second and third doses of HMB were consumed after 2 h and 6 h of recovery, respectively. These doses are consistent with instructions provided by the manufacturer and are not associated with any negative side effects (21, 26).

Placebo

The placebo was comprised of two doses of five imitation BCAA plus glutamine capsules (sugar pills; The Pharmacy at Midtown; Tuscaloosa, AL) and three doses of a placebo HMB capsule (sugar pill; The Pharmacy at Midtown; Tuscaloosa, AL). The first dose of placebo BCAA plus glutamine was administered 1 h prior to the initial work out; the second dose was consumed immediately following the workout. Administration of the placebo HMB was as follows: 30 min prior to the initial workout, 2 h after the workout, and 6 h after the initial trial.

In order to minimize any confounding effects of nutritional status on athletic performance, participants were instructed to maintain the same dietary patterns during the 24 h prior to each experimental session; participants completed a 24-h dietary history form in order to verify adherence to these procedures.

Visits III and V. Twenty-four hours after visits II and IV, participants returned to the facility to complete visits III and IV, respectively. The sleep and nutritional history of the participant over the previous 24 h were obtained and recorded, and participants were fitted with a heart rate monitor. Participants rested quietly for 5 min before baseline HR is obtained. Measures of perceived skeletal muscle pain and RPR were assessed prior to beginning the workout. 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 lift set, after each exercise, and at the end of the experimental session. Participants were instructed to abstain from all vigorous exercise not associated with the study during a one – week "washout" period following Visit III.

Statistical Analyses

One-way ANOVA was used to compare skeletal muscle pain, RPE, RPR, and performance-based training recovery between treatment and placebo conditions. The primary application of this treatment for these primary effects would be for athletes in training; therefore, individual analyses were performed by calculating the least significant difference for the sample. An effect size of .81 was determined to yield an alpha of .049 and was considered the minimum change necessary to yield statistical significance. Because only full repetitions were considered, participants were considered positive responders if their performance increased one or more repetitions. Participants whose performance decreased by one or more repetitions were

considered negative responders, and participants whose performance remained the same were considered non-responders. An alpha level of .05 was observed for statistical testing.

An a priori power analysis (G power; ANOVA: Repeated measures) revealed that a minimum of 10 participants was necessary to detect a difference of 0.9 repetitions between treatment and placebo conditions (effect size = 0.37, $\alpha = 0.05$, power = 80%, noncentrality parameter = 13.79, critical F = 5.32). The effect size used in this analysis was determined from the variance observed by McLester et al. (22). A sample size of 14 participants allowed for the detection of a 0.70 repetition increase following treatment vs. placebo conditions ($\alpha = 0.05$, power = 80%, correlation among variables = 0.8, noncentrality parameter = 9.32, critical F = 4.74). Therefore, if the treatment allowed participants to perform one additional repetition compared to placebo conditions, this difference should be detected.

RESULTS

Performance data are displayed in Table 2. Perceptual responses prior to activity and during activity on the second day of exercise are reported in Table 3 and Table 4, respectively. The number of repetitions performed for each exercise as well as the combined total did not differ between treatment and placebo on the first day of exercise ($p > .05$). Additionally, no differences in muscle pain or RPE were present between treatment and placebo on the first day of exercise ($p > .05$). Under the treatment, performance–based recovery increased for the leg extension (10 ± 3 vs. 11 ± 1 repetitions; $p = .03$) and latissimus pull–down (10 ± 1 vs. 11 ± 2 repetitions; $p = .02$) compared to placebo. Additionally, the total number of repetitions performed for all exercises combined was significantly greater under treatment compared to placebo (62 ± 5 vs. 59 ± 7; $p = .03$). The data indicated that 8 participants were positive responders, performing more total repetitions for all exercises combined on the second day of

exercise under the treatment compared to placebo. Five participants responded negatively to the treatment, performing fewer repetitions compared to placebo. Only one participant performed equally under treatment and placebo conditions and was considered a non-responder.

The treatment significantly reduced residual pain compared to a placebo (40 ± 23 vs. 29 ± 19 mm; $p = .01$). However, no differences in RPR were present between the two conditions ($p > .05$). Muscle pain during exercise was significantly lower under the treatment compared to placebo for leg press (45 ± 21 vs. 37 ± 14 mm; $p = .04$) and shoulder press (47 ± 24 vs. 39 vs. 17 mm; $p = .04$); no differences were observed for all other exercises or for the overall workout ($p > .05$). RPE was also lower under treatment compared to placebo for the leg press (62 ± 16 vs. 55 ± 20 mm; $p = .02$) and leg extension (61 ± 19 vs. 53 ± 20 mm; $p = .03$), but did not differ for all remaining lifts or for the overall workout ($p > .05$). A small but significant decrease in exercise HR was observed under treatment compared to placebo for the chest press (141 ± 20 vs. 144 ± 18 bpm; $p = .03$) and shoulder press (137 ± 18 vs. 140 ± 16 bpm; $p = .01$), but did not differ during all other exercises ($p > .05$). Additionally, no differences in baseline HR were observed between the two conditions ($p > .05$).

DISCUSSION

The results support the hypothesis that the concurrent use of BCAA, HMB, and glutamine would reduce muscle pain and RPE and enhance performance-based training recovery in resistance–trained men and women. Participants reported significantly less residual pain 24 h after a fatiguing resistance bout under treatment compared to placebo. Further, muscle pain during exercise was also lower under the treatment and was accompanied by reduced RPE. Although RPR did not differ between the two conditions, the treatment significantly enhanced performance–based recovery compared to a placebo, at least in some lifts. These results indicate

that co–ingestion of BCAA, HMB, and glutamine may help athletes recovery more quickly from training.

Exhaustive resistance exercise induces skeletal muscle damage, resulting in diminished subsequent performance and increased muscle soreness that peaks during the 24–48 h following the activity. This phenomenon is most pronounced in novice athletes; however, it is not uncommon for trained individuals to experience these effects, particularly if the exercise is of very high intensity or beyond the accustomed training volume of the individual. Previous research from our laboratory revealed that few participants, if any, fully recover within 24 h after performing 3 sets to failure of whole–body resistance exercise (5, 40). Despite the lack of recovery, many coaches require their athletes to attend daily practices; others require even more frequent training sessions without regard for athletes' recovery status. Athletes who engage in subsequent exercise without recovering from prior bouts may perform worse and may increase their risk of developing overtraining syndrome.

Current evidence supports an ergogenic role of BCAA, HMB, and glutamine for promoting muscle recovery in untrained individuals; however, the influence of these supplements on 24–h recovery in resistance–trained athletes in unclear. While research examining the influence of prolonged use of each of these supplements individually on muscle recovery is relatively abundant (20, 26, 44, 47, 49, 52), few studies have examined their effects on training recovery when consumed on a single occasion. Therefore, the purpose of this study was to examine the influence of a solitary BCAA, HMB, and glutamine treatment on muscle recovery in resistance–trained athletes.

BCAA

The BCAA found within human skeletal muscle include leucine, isoleucine, and valine, and account for ~14 – 18% and ~35% of the total and essential amino acid concentrations, respectively (50). In addition to regulating protein metabolism and promoting protein synthesis, BCAA suppress protein degradation (14, 50). During exercise, BCAA catabolism increases within the active muscle tissue. This concept has led to the idea that supplementation with BCAA prior to and after exercise may enhance muscle recovery and performance during subsequent activity (14, 19, 50). While research supports the notion that BCAA effectively reduce muscle damage and enhance recovery from resistance and prolonged endurance activities (14, 16, 38), the majority of resistance training studies have focused on chronic supplementation (26, 47, 49) or utilized only untrained individuals (19, 27, 30, 33, 50).

We sought to determine the influence of a supplement combination containing two 6–g doses of BCAA on muscle recovery in resistance–trained men and women. We hypothesized that acute use of our treatment would reduce muscle pain and RPE and enhance RPR and performance–based recovery compared to a placebo. While no differences in RPR were observed between the two conditions, our results suggest that a treatment combination containing BCAA reduced residual muscle pain and attenuated pain and RPE during subsequent exercise when consumed prior to and after an initial workout.

Shimomura et al (50) suggested that BCAA–mediated attenuation of exercise–induced muscle pain during the days following a damaging resistance bout is attributed to decreased muscle breakdown during exercise. When untrained females consumed a liquid mixture containing 5.5 g BCAA prior to 7 sets of 20 squats, serum myoglobin and plasma elastase concentrations (markers of muscle damage) were significantly lower compared to a placebo trial.

Additionally, while post–exercise levels of plasma BCAA were significantly lower than baseline under placebo conditions, significant elevations were observed following BCAA supplementation. Thus, BCAA supplementation prior to high–intensity activity may be necessary to enhance training recovery and reduce muscle pain during subsequent exercise. BCAA promote muscle protein synthesis and, consequently, consuming additional BCAA during recovery may be essential for maximizing any positive effects on subsequent performance (33). In our study, participants consumed one 6–g dose of BCAA prior to an initial resistance bout, and consumed a second 6–g dose immediately following the workout. Our results support the notion that supplementation with BCAA both before and after an exhaustive resistance bout attenuates residual muscle soreness and reduces muscle pain and RPE during subsequent activity following 24 h passive rest. Additionally, our data indicate that BCAA ingestion promoted recovery of muscle function, allowing participants to perform more repetitions compared to a placebo.

To date, research examining the influence of acute BCAA supplementation on recovery from resistance exercise has focused almost exclusively on prolonged use or on untrained participants. Therefore, we were able to provide relatively novel insight into to effects of acute BCAA supplementation on muscle recovery in resistance–trained individuals who are most likely to benefit from supplementation. Our data indicate that observations of reduced muscle soreness and enhanced recovery of muscle function reported in untrained men and women are also present in trained individuals. Similarly, our results are in line with reports of enhanced training recovery following chronic daily BCAA supplementation in trained participants (26). It is presumed that these effects were attributed in part to BCAA–mediated suppression of protein catabolism in tandem with enhanced protein synthesis. However, it is important to note that

BCAA supplementation in our study was part of a larger experimental treatment containing HMB and glutamine, and we are therefore unable to quantify the individual impact of BCAA on the overall effects. While chronic daily use of BCAA has been shown to enhance recovery (14, 26, 47, 49) and are not associated with any damaging health effects (4, 26), regular consumption of high doses may not be economically sustainable for many athletes. For these individuals, supplementation with BCAA only during the most intense training periods or competition may be sufficient to enhance recovery and performance.

Additionally, whereas BCAA have been shown to enhance muscle recovery via attenuation of muscle tissue breakdown, they may inhibit muscle hypertrophy through this same effect. The breakdown of muscle tissue during resistance exercise plays a crucial role in the mechanisms underlying muscle growth and, consequently; any product that influences muscle degradation may also affect muscle growth (3). However, further research is necessary to fully understand the effects of BCAA supplementation in trained weightlifters. Future studies should focus on the influence of acute and chronic BCAA use on muscle recovery and performance. Research involving long–term BCAA supplementation should also focus on its potential impact on muscle hypertrophy.

HMB

It has been suggested that ingestion of HMB prior to and following damaging resistance exercise may reduce soreness (63) and enhance recovery of muscle function during the 1–3 days following the initial workout (63, 65). Available evidence suggests that the ergogenic effects associated with HMB supplementation are attributed to decreased proteolysis and increased protein synthesis during exercise and recovery (64, 65). While conversion of dietary leucine to HMB is a naturally occurring process, one would need to ingest a nearly impossible 600 g of

high–quality protein in order to attain the ~60 g of leucine necessary to yield a enough HMB to be of any practical significance (63). Therefore, supplementation with pure HMB is the only practical means of attaining quantities sufficient for providing ergogenic effects.

Studies examining the effects of short and long–term HMB supplementation have demonstrated reduced damage and enhanced recovery in trained (65) and untrained (64) individuals following resistance (59, 62, 64, 65) and prolonged endurance (62) exercise. However, the majority of these studies have focused on daily HMB supplementation over the course of several weeks or more. Only two studies investigating the influence of acute HMB supplementation on recovery from resistance training have been conducted (64, 65), and only one of these studies involved trained individuals (65); both studies utilized only male participants. Therefore, we sought to explore the effects of acute HMB supplementation on recovery from resistance exercise in trained men and women.

Our data indicate that consuming one 1–g dose of HMB 30 min prior to an exhaustive resistance bout and two additional 1–g doses 2 h and 6 h following the workout reduces muscle pain and RPE while enhancing muscle performance during subsequent exercise after 24 h of passive recovery. These results support similar findings of enhanced performance-based recovery following HMB ingestion (62, 65). When resistance–trained men consumed a total of 3g /d of HMB or a placebo prior to and after a high–volume weightlifting session, serum creatine kinase concentrations during the 48 h following the workout were significantly lower in the HMB–treated vs. placebo group, suggesting that HMB suppressed exercise–induced muscle damage (65). Additionally, urinary 3-methylhistadine, an index of muscle breakdown, was substantially lower in the HMB compared to placebo group; however, this difference was not statistically significant. Participants in the HMB–supplemented group also reported enhanced

perceptions of recovery compared to those who received a placebo (63, 65). This observation contrasts our finding of no significant difference in RPR between treatment and placebo conditions; however, it supports our finding of enhanced performance–based recovery following a treatment containing 3g of HMB.

Wilson et al. (64) also studied the influence of acute supplementation with 3g of HMB before or after heavy eccentric exercise on indirect markers of skeletal muscle damage during a 72–h recovery period in untrained participants. The authors noted that while ingesting 3g of HMB prior to exercise attenuated the rise in lactate dehydrogenase concentrations throughout recovery, it had no effect on serum creatine kinase levels (64). Additionally, no differences between treatment and placebo conditions were observed when HMB was consumed after exercise, suggesting that HMB must be consumed before the workout if any benefits are to occur. A trend toward reduced muscle soreness was observed following pre–exercise ingestion of HMB; however, this difference was not statistically significant. The authors concluded that while HMB supplementation prior to exercise may attenuate the rise in serum lactate dehydrogenase concentrations, there is no clear effect of HMB supplementation on muscle damage or soreness in untrained individuals (64). In contrast, our results and the results obtained by Wilson et al. (65) in trained weightlifters provide clearer evidence enhanced recovery following HMB supplementation.

Discrepancies in the data between studies involving trained individuals and those using only untrained participants may be attributed to methodological differences other than training status. In our study and the study by Wilson et al. (65), trained participants consumed 1 g HMB before exercise and an additional 2g HMB throughout recovery on the same day. Conversely, when Wilson et al. (64) studied HMB supplementation in untrained individuals, participants

consumed 3g of HMB either all before or all after exercise. Therefore, it is possible that distributing 3g HMB throughout the pre– and post–exercise periods was more effective than consuming an equal quantity as a single dose. However, this idea remains only speculation until further evidence is available.

Alternatively, it is possible that a difference in experimental protocols is responsible for the lack of consistency observed in untrained compared to trained participants. Our study and the Wilson et al. (65) study involving trained participants utilized an exercise protocol closely resembling a typical training session; both studies involved common machine or free-weight exercise targeting the upper and lower body. Conversely, in the Wilson et al. (64) study untrained participants performed 55 maximal eccentric contraction of the quadriceps muscles only. Further, the early study by Wilson et al. (64) studied the effects of HMB supplementation only on indirect markers of skeletal muscle damage, while their later study expanded to include the influence of HMB on performance-based measures of training recovery. Therefore, although HMB failed to provide any clear effects on muscle damage or soreness in untrained individuals, its effects on recovery of muscle function remained unknown. Lastly, although our study in trained participants is consistent with results reported by Wilson et al. (65), it is important to note that our treatment was part of a larger supplement combination involving BCAA and glutamine; therefore, we are unable to quantify the individual effects of HMB. Additional research is necessary to better understand the interaction between acute HMB supplementation and training status on recovery from resistance exercise in trained and untrained participants. Therefore, future studies should compare the effects of acute HMB supplementation on skeletal muscle damage and soreness, RPE, and training recovery in resistance–trained and untrained individuals.

Glutamine

Glutamine supplementation is believed to attenuate muscle damage and soreness and promote recovery of muscle function following high–volume resistance exercise or prolonged endurance activity (55). While the precise mechanisms underlying these effects remains unclear, glutamine supplementation is believed to extend exercise and expedite recovery by buffering acidosis, inhibiting muscle breakdown, and facilitating muscle protein synthesis (46, 55). Diminished proteolysis and advanced skeletal muscle repair with glutamine supplementation may reduce the prevalence of overtraining syndrome. Consequently, glutamine has become a popular ergogenic aid among athletes; however, inconsistencies in the research findings highlight the need for additional research to substantiate these purported benefits.

Evidence documented by Blomstrand and Gustavsson (6) suggests that a high-volume resistance bout significantly decreases glutamine concentrations in the contracting muscles. Similarly, Miles et al. (41) observed significant decreases in plasma glutamine concentrations during a 3–day recovery period following high–intensity eccentric exercise. While studies involving prolonged endurance exercise support the notion of reduced glutamine concentrations following activity, low–volume submaximal intensity exercise is not associated with any significant effects (10, 21, 55). Thus, it is possible that the ergogenic effects associated with glutamine supplementation are evident only when exercise is sufficiently stressful.

Because prolonged endurance exercise is associated with increased manifestations of muscle damage, including increased pain and decreased performance (55), much of the research examining the influence of glutamine supplementation on muscle recovery has involved continuous exercise for at least 2h in duration (10, 46, 55). When studies did examine the influence of glutamine on recovery from resistance training, the experimental protocol frequently

did not reflect a typical training session; many of these experiments involved repeated high–intensity eccentric contractions of a single exercise (21, 55). Alternatively, other studies in trained individuals have focused on the effects of prolonged glutamine supplementation on adaptations to resistance training rather than short–term effects on recovery. Therefore, we chose to study the influence of a supplement combination involving 2 g oral glutamine on recovery from a weightlifting session in trained men and women.

Our results support previous findings of enhanced recovery following glutamine supplementation (55). Participants reported reduced perceptions of muscle pain and exertion and were able to perform more repetitions during a subsequent resistance bout the following day. We speculate that these effects were due in part to the ergogenic influence of glutamine on muscle protein synthesis. While it is possible that glutamine supplementation attenuated muscle degradation in our study, this notion lacks sufficient support. Street et al. (55) studied the effects of 0.3 g/kg of glutamine on muscle damage, strength and soreness following repeated eccentric contractions of the quadriceps muscles. The authors reported that although glutamine supplementation failed to inhibit exercise–induced muscle damage, muscle soreness was significantly lower and strength was significantly greater in the intervention compared to the placebo group. Therefore, any effects attributed to glutamine supplementation arose from mechanisms other than blunted proteolysis. Our study measured only the influence of glutamine supplementation on performance, skeletal muscle pain, recovery, and RPE. Consequently, we are unable to document the effects of glutamine on muscle protein damage with our current data. Glutamine naturally converts to glutamate in the body through a process that releases ammonium ions (46). Renal excretion of these ions has been shown to buffer exercise–induced lactic acidosis, thereby providing a potential ergogenic effect of glutamine supplementation (46).

However, reductions in lactic acidosis and restoration of acid–base balance do not necessarily translate into enhanced performance (37). Marwood and Bowtell (37) demonstrated decreased plasma lactate concentrations in trained cyclists assigned to a glutamine supplementation group compared to a control group; however, no differences in oxygen uptake or oxidative metabolism were observed. Intense bouts of anaerobic activity are associated with elevated blood lactate and plasma ion concentrations and decreased pH levels (3, 46). Chasiotis et al. (12) demonstrated that lower cellular pH is accompanied by impaired performance during high–intensity exercise. Similarly, Costill et al. (15) noted enhanced performance during repeated bouts of high–intensity exercise after increasing pH levels of the blood and extracellular fluid.

Whereas lactic acid produced during exercise is cleared relatively quickly during recovery, it is possible that glutamine supplementation in our study suppressed the short–term rise in blood lactate levels during each weightlifting exercise. However, further research is needed to validate this hypothesis.

In contrast to our results, Antonio et al. (1) reported that dietary supplementation with 0.3 g/kg of oral glutamine 1 h after resistance exercise failed to enhance subsequent performance compared to a placebo in trained athletes. These contrasting results may be due to differences in training volume between the two studies leading to accompanying differences in glutamine depletion and muscle damage. In the study by Antonio et al. (1), participants completed 2 sets to failure at 200% or 100% of their body weight for the leg press and bench press exercises, respectively. Conversely, our protocol required participants to complete 3 sets to failure at their 8–12 RM for 3 upper–body and 3 lower–body exercises. We believe that the greater training volume in our study was sufficient to reduce muscle and plasma glutamine concentrations and, consequently, augment the ergogenic influence of glutamine supplementation (6). It is important

to note, however, that the quantity of glutamine used in our study is markedly lower than the ~15–20 g often used in previous research (46). Therefore, although our protocol likely reduced glutamine concentrations, our treatment may not have fully restored these decrements.

Welbourne (60) reported greater concentrations of plasma bicarbonate, growth hormone, and glutamine following ingestion of 2 g glutamine. Similarly, Ziegler et al. (66) studied the effects of a 7–g dose of supplemental glutamine on post–exercise concentrations of plasma glutamine and noted a significant increase compared to a placebo. Most supplement manufacturers produce glutamine tablets or capsules in doses of 250 mg, 500 mg, or 1000 mg and recommend consuming 1 g/d in order to receive its effects. Therefore, consuming excessive quantities is not practical for the typical consumer. Consequently, we chose to remain within the recommendations set by the manufacturer of the product (MET-Rx Nutrition, Inc; Boca Raton, FL) in order to provide a more practical approach.

Glutamine supplementation is associated with reduced muscle soreness and enhanced recovery of muscle function via reductions in muscle protein break down, increased protein synthesis, and protection against metabolic acidosis. However, these claims remain controversial due to inconsistent results among studies examining the ergogenic effects of glutamine. Our results favor the idea of enhanced recovery in resistance–trained participants following acute supplementation with a treatment combination containing 2 g glutamine consumed before and after an exhaustive weightlifting bout. However, the individual influence (if any) of glutamine in our study and the underlying mechanisms through which these effects occurred are unknown. Additional research is necessary to understand the effects of acute glutamine supplementation on recovery from resistance exercise. Future studies should evaluate the effects of glutamine alone on markers of training recovery in resistance–trained men and women. Additionally, studies

involving glutamine in various doses should be conducted to provide further insight into a potential dose–response relationship associated with supplementation.

In summary, adequate training recovery is essential for both the competitive and recreational athlete. Consequently, any intervention that enhances recovery may help athletes maximize their training while avoiding the deleterious effects of overtraining syndrome. We studied the combined influence of three common supplements theorized to enhance training recovery: BCAA, HMB, and glutamine. Our results indicate that this treatment effectively reduced residual muscle pain following an exhaustive resistance bout in trained men and women. Additionally, our treatment reduced muscle pain and RPE during exercise and enhanced performance-based training recovery compared to a placebo.

PRACTICAL APPLICATIONS

Athletes may accelerate recovery and enhance their performance by implementing this treatment combination into their regular training regimen. Additionally, our treatment combination might assist patients undergoing a rehabilitation program following muscle injury. However, additional research is necessary to understand the long–term effects of this treatment.as well as the individual influence of each of its constituents.

The methodology used in the current study did not allow us to analyze the physiological mechanisms responsible for any differences between treatment and control conditions. Additionally, although the inclusion of BCAA, HMB, and glutamine in a single treatment optimized the chances of discovering an effective recovery technique, it also meant that we were unable to evaluate the individual effects of each dietary supplement. The possibility remains that one or more individual treatments interacted with one another to influence the overall effect–either positively or negatively. It is also possible that one or two of the treatments had no effect.

REFERENCES

1. Antonio J, Sanders MS, Kalman D, Woodgate D, and Street C. The effects of high-dose glutamine ingestion on weightlifting performance. *Journal of strength and conditioning research / National Strength & Conditioning Association* 16: 157-160, 2002.

2. Asmussen E. Muscle fatigue. *Medicine & Science in Sports & Exercise* 25: 412-420, 1993.

3. Baechle TR and Earle RW. *Essentials of Strength Training and Conditioning.* Human Kinetics, 2008.

4. Benardot D. *Advanced Sports Nutrition.* Human Kinetics, 2006.

5. Bishop PA, Jones E, and Woods AK. Recovery from training: a brief review: brief review. *Journal of strength and conditioning research / National Strength & Conditioning Association* 22: 1015-1024, 2008.

6. Blomstrand E and Essen-Gustavsson B. Changes in amino acid concentration in plasma and type I and type II fibres during resistance exercise and recovery in human subjects. *Amino Acids* 37: 629-636, 2009.

7. Bogdanis GC, Nevill ME, Boobis LH, Lakomy HK, and Nevill AM. Recovery of power output and muscle metabolites following 30 s of maximal sprint cycling in man. *The Journal of physiology* 482 (Pt 2): 467-480, 1995.

8. Bosak A, Bishop P, Green J, and Hawver G. Impact of cold water immersion on 5km racing performance. *Sport Journal* 12: 9p, 2009.

9. Bowtell JL, Gelly K, Jackman ML, Patel A, Simeoni M, and Rennie MJ. Effect of oral glutamine on whole body carbohydrate storage during recovery from exhaustive exercise. *Journal of applied physiology* 86: 1770-1777, 1999.

10. Castell L. Glutamine supplementation in vitro and in vivo, in exercise and in immunodepression. *Sports medicine (Auckland, NZ)* 33: 323-345, 2003.

11. Castell LM and Newsholme EA. The effects of oral glutamine supplementation on athletes after prolonged, exhaustive exercise. *Nutrition* 13: 738-742, 1997.

12. Chasiotis D, Hultman E, and Sahlin K. Acidotic depression of cyclic AMP accumulation and phosphorylase b to a transformation in skeletal muscle of man. *The Journal of physiology* 335: 197-204, 1983.

13. Connolly DA, Brennan KM, and Lauzon CD. Effects of active versus passive recovery on power output during repeated bouts of short term, high intensity exercise. *Journal of Sports Science and Medicine* 2: 47-51, 2003.

14. Coombes JS and McNaughton LR. Effects of branched-chain amino acid supplementation on serum creatine kinase and lactate dehydrogenase after prolonged exercise. *The Journal of sports medicine and physical fitness* 40: 240-246, 2000.

15. Costill DL, Verstappen F, Kuipers H, Janssen E, and Fink W. Acid-base balance during repeated bouts of exercise: influence of HCO3. *Int J Sports Med* 5: 228-231, 1984.

16. Crowe MJ, Weatherson JN, and Bowden BF. Effects of dietary leucine supplementation on exercise performance. *European Journal of Applied Physiology* 97: 664, 2006.

17. Dupont G, Moalla W, Guinhouya C, Ahmaidi S, and Berthoin S. Passive versus active recovery during high-intensity intermittent exercises. *Medicine and science in sports and exercise* 36: 302-308, 2004.

18. Feigenbaum MS and Pollock ML. Prescription of resistance training for health and disease. *Medicine and science in sports and exercise* 31: 38-45, 1999.

19. Ferreira MP, Li R, Cooke M, Kreider RB, and Willoughby DS. Periexercise coingestion of branched-chain amino acids and carbohydrate in men does not preferentially augment resistance exercise-induced increases in phosphatidylinositol 3 kinase/protein kinase B-mammalian target of rapamycin pathway markers indicative of muscle protein synthesis. *Nutrition research (New York, NY)* 34: 191-198, 2014.

20. Gallagher P, Carrithers J, Godard M, Schulze K, and Trappe S. Beta-hydroxy-beta-methylbutyrate ingestion, part I: effects on strength and fat free mass. *Medicine and science in sports and exercise* 32: 2109 - 2115, 2000.

21. Gleeson M. Dosing and efficacy of glutamine supplementation in human exercise and sport training. *The Journal of nutrition* 138: 2045s-2049s, 2008.

22. Gonzalez AM, Stout JR, Jajtner AR, Townsend JR, Wells AJ, Beyer KS, Boone CH, Pruna GJ, Mangine GT, Scanlon TM, Bohner JD, Oliveira LP, Fragala MS, and Hoffman JR. Effects of beta-hydroxy-beta-methylbutyrate free acid and cold water immersion on post-exercise markers of muscle damage. *Amino Acids* 46: 1501-1511, 2014.

23. Gonzalez AM, Stout JR, Jajtner AR, Townsend JR, Wells AJ, Beyer KS, Boone CH, Pruna GJ, Mangine GT, Scanlon TM, Bohner JD, Oliveira LP, Fragala MS, and Hoffman JR. Effects of β-hydroxy-β-methylbutyrate free acid and cold water immersion on post-exercise markers of muscle damage. *Amino Acids* 46: 1501-1511, 2014.

24. Hasson SM, Daniels JC, Divine JG, Niebuhr BR, Richmond S, Stein PG, and Williams J. Effect of ibuprofen use on muscle soreness, damage, and performance: a preliminary investigation. *Medicine and science in sports and exercise* 25: 9-17, 1993.

25. Howatson G, Hoad M, Goodall S, Tallent J, Bell P, and French D. Exercise-induced muscle damage is reduced in resistance-trained males by branched chain amino acids: a

randomized, double-blind, placebo controlled study. *Journal of the International Society of Sports Nutrition* 9: 20, 2012.

26. Howatson G, Hoad M, Goodall S, Tallent J, Bell PG, and French DN. Exercise-induced muscle damage is reduced in resistance-trained males by branched chain amino acids: a randomized, double-blind, placebo controlled study. *Journal of the International Society of Sports Nutrition* 9: 20, 2012.

27. Jackman SR, Witard OC, and Jeukendrup AE. Branched-Chain Amino Acid Ingestion Can Ameliorate Soreness from Eccentric Exercise. *Medicine & Science in Sports & Exercise* 42: 962-970, 2010.

28. Juhn M. Popular sports supplements and ergogenic aids. *Sports medicine (Auckland, NZ)* 33: 921-939, 2003.

29. Kimball SR and Jefferson LS. Signaling pathways and molecular mechanisms through which branched-chain amino acids mediate translational control of protein synthesis. *The Journal of nutrition* 136: 227s-231s, 2006.

30. Kirby T, Triplett N, Haines T, Skinner J, Fairbrother K, and McBride J. Effect of leucine supplementation on indices of muscle damage following drop jumps and resistance exercise. *Amino Acids* 42: 1987, 2012.

31. Kraemer WJ and Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Medicine and science in sports and exercise* 36: 674-688, 2004.

32. La Bounty P, Campbell B, Oetken A, and Willoughby D. The effects of oral BCAAs and leucine supplementation combined with an acute lower-body resistance exercise on mTOR and 4E-BP1 activation in humans: preliminary findings. *Journal of the International Society of Sports Nutrition* 5: P21, 2008.

33. Leahy DT and Pintauro SJ. Branched-chain amino Acid plus glucose supplement reduces exercise-induced delayed onset muscle soreness in college-age females. *ISRN Nutrition* 2013: 921972-921972, 2013.

34. Lehmann M, Foster C, and Keul J. Overtraining in endurance athletes: a brief review. *Medicine & Science in Sports & Exercise* 25: 854-862, 1993.

35. MacIntosh BR and Rassier DE. What Is Fatigue? *Canadian Journal of Applied Physiology* 27: 42-55, 2002.

36. MacLean DA, Graham TE, and Saltin B. Branched-chain amino acids augment ammonia metabolism while attenuating protein breakdown during exercise. *The American journal of physiology* 267: E1010-1022, 1994.

37. Marwood S and Bowtell JL. Effects of glutamine and hyperoxia on pulmonary oxygen uptake and muscle deoxygenation kinetics. *Eur J Appl Physiol* 99: 149-161, 2007.

38. Matsumoto K, Mizuno M, Mizuno T, Dilling-Hansen B, Lahoz A, Bertelsen V, Munster H, Jordening H, Hamada K, and Doi T. Branched-chain amino acids and arginine supplementation attenuates skeletal muscle proteolysis induced by moderate exercise in young individuals. *Int J Sports Med* 28: 531-538, 2007.

39. McKenzie S, Phillips SM, Carter SL, Lowther S, Gibala MJ, and Tarnopolsky MA. Endurance exercise training attenuates leucine oxidation and BCOAD activation during exercise in humans. *American journal of physiology Endocrinology and metabolism* 278: E580-587, 2000.

40. McLester JR, Bishop PA, Smith J, Wyers L, Dale B, Kozusko J, Richardson M, Nevett ME, and Lomax R. A series of studies--a practical protocol for testing muscular endurance recovery. *Journal of strength and conditioning research / National Strength & Conditioning Association* 17: 259-273, 2003.

41. Miles MP, Naukam RJ, Hackney AC, and Clarkson PM. Blood leukocyte and glutamine fluctuations after eccentric exercise. *Int J Sports Med* 20: 322-327, 1999.

42. Negro M, Giardina S, Marzani B, and Marzatico F. Branched-chain amino acid supplementation does not enhance athletic performance but affects muscle recovery and the immune system. *The Journal of sports medicine and physical fitness* 48: 347-351, 2008.

43. Nosaka K. Muscle damage and amino acid supplementation: Does it aid recovery from muscle damage? *International SportMed Journal* 8: 54-67, 2007.

44. Panton L, Rathmacher J, Baier S, and Nissen S. Nutritional supplementation of the leucine metabolite beta-hydroxy-beta-methylbutyrate (hmb) during resistance training. *Nutrition* 16: 734 - 739, 2000.

45. Peake JM, Suzuki K, and Coombes JS. The influence of antioxidant supplementation on markers of inflammation and the relationship to oxidative stress after exercise. *The Journal of nutritional biochemistry* 18: 357-371, 2007.

46. Phillips GC. Glutamine: the nonessential amino acid for performance enhancement. *Current sports medicine reports* 6: 265-268, 2007.

47. Ra SG, Miyazaki T, Ishikura K, Nagayama H, Komine S, Nakata Y, Maeda S, Matsuzaki Y, and Ohmori H. Combined effect of branched-chain amino acids and taurine supplementation on delayed onset muscle soreness and muscle damage in high-intensity eccentric exercise. *Journal of the International Society of Sports Nutrition* 10: 51, 2013.

48. Rowlands DS and Thomson JS. Effects of beta-hydroxy-beta-methylbutyrate supplementation during resistance training on strength, body composition, and muscle damage in trained and untrained young men: a meta-analysis. *Journal of strength and conditioning research / National Strength & Conditioning Association* 23: 836-846, 2009.

49. Sharp CP and Pearson DR. Amino acid supplements and recovery from high-intensity resistance training. *Journal of strength and conditioning research / National Strength & Conditioning Association* 24: 1125-1130, 2010.

50. Shimomura Y, Inaguma A, Watanabe S, Yamamoto Y, Muramatsu Y, Bajotto G, Sato J, Shimomura N, Kobayashi H, and Mawatari K. Branched-chain amino acid supplementation before squat exercise and delayed-onset muscle soreness. *International journal of sport nutrition and exercise metabolism* 20: 236-244, 2010.

51. Smith H, Mukerji P, and Tisdale M. Attenuation of proteasome-induced proteolysis in skeletal muscle by {beta}-hydroxy-{beta}-methylbutyrate in cancer-induced muscle loss. *Cancer Res* 65: 277 - 283, 2005.

52. Smith H, Wyke S, and Tisdale M. Mechanism of the attenuation of proteolysis-inducing factor stimulated protein degradation in muscle by beta-hydroxy-beta-methylbutyrate. *Cancer Res* 64: 8731 - 8735, 2004.

53. Spencer M, Bishop D, Dawson B, Goodman C, and Duffield R. Metabolism and performance in repeated cycle sprints: active versus passive recovery. *Medicine and science in sports and exercise* 38: 1492-1499, 2006.

54. Stock MS, Young JC, Golding LA, Kruskall LJ, Tandy RD, Conway-Klaassen JM, and Beck TW. The effects of adding leucine to pre and postexercise carbohydrate beverages on acute muscle recovery from resistance training. *Journal of strength and conditioning research / National Strength & Conditioning Association* 24: 2211-2219, 2010.

55. Street B, Byrne C, and Eston R. Glutamine Supplementation in Recovery From Eccentric Exercise Attenuates Strength Loss and Muscle Soreness. *Journal of Exercise Science & Fitness* 9: 116-122, 2011.

56. Tessitore A, Meeusen R, Pagano R, Benvenuti C, Tiberi M, and Capranica L. Effectiveness of active versus passive recovery strategies after futsal games. *Journal of strength and conditioning research / National Strength & Conditioning Association* 22: 1402-1412, 2008.

57. Thiriet P, Gozal D, Wouassi D, Oumarou T, Gelas H, and Lacour JR. The effect of various recovery modalities on subsequent performance, in consecutive supramaximal exercise. *The Journal of sports medicine and physical fitness* 33: 118-129, 1993.

58. Tipton KD, Rasmussen BB, Miller SL, Wolf SE, Owens-Stovall SK, Petrini BE, and Wolfe RR. Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise. *American journal of physiology Endocrinology and metabolism* 281: E197-206, 2001.

59. Townsend JR, Fragala MS, Jajtner AR, Gonzalez AM, Wells AJ, Mangine GT, Robinson EHt, McCormack WP, Beyer KS, Pruna GJ, Boone CH, Scanlon TM, Bohner JD, Stout JR, and Hoffman JR. beta-Hydroxy-beta-methylbutyrate (HMB)-free acid attenuates circulating TNF-alpha and TNFR1 expression postresistance exercise. *Journal of applied physiology* 115: 1173-1182, 2013.

60. Welbourne TC. Increased plasma bicarbonate and growth hormone after an oral glutamine load. *The American journal of clinical nutrition* 61: 1058-1061, 1995.

61. Wernerman J. Clinical use of glutamine supplementation. *The Journal of nutrition* 138: 2040s-2044s, 2008.

62. Wilson G, Wilson J, and Manninen A. Effects of beta-hydroxy-beta-methylbutyrate (HMB) on exercise performance and body composition across varying levels of age, sex, and training experience: a review. *Nutr Metab (Lond)* 5: 1, 2008.

63. Wilson J, Fitschen P, Campbell B, Wilson G, Zanchi N, Taylor L, Wilborn C, Kalman D, Stout J, Hoffman J, Ziegenfuss T, Lopez H, Kreider R, Smith-Ryan A, and Antonio J. International Society of Sports Nutrition Position Stand: beta-hydroxy-beta-methylbutyrate (HMB). *Journal of the International Society of Sports Nutrition* 10: 6, 2013.

64. Wilson J, Kim J, Lee S, Rathmacher J, Dalmau B, Kingsley J, Koch H, Manninen A, Saadat R, and Panton L. Acute and timing effects of beta-hydroxy-beta-methylbutyrate (HMB) on indirect markers of skeletal muscle damage. *Nutr Metab* 6: 6, 2009.

65. Wilson J, Lowery R, Joy J, Walters J, Baier S, Fuller J, Stout J, Norton L, Sikorski E, and Wilson S. beta-Hydroxy-beta-methylbutyrate free acid reduces markers of exercise-induced muscle damage and improves recovery in resistance-trained men. *Br J Nutr* 3: 1 - 7, 2013.

66. Ziegler TR, Benfell K, Smith RJ, Young LS, Brown E, Ferrari-Baliviera E, Lowe DK, and Wilmore DW. Safety and metabolic effects of L-glutamine administration in humans. *JPEN J Parenter Enteral Nutr* 14: 137s-146s, 1990.

TABLES

Table 1.1 Training History and Participant Characteristics

Training History

	Participants(n)	Training (months)	Frequency (days/ wk)	Average session (min)
Total	14	48 (30)	4 (1)	65 (18)
Males	7	53 (34)	4 (1)	66 (13)
Females	7	43 (28)	4 (1)	64 (23)

Participant Characteristics

	Participants (n)	Height (cm)	Weight (kg)	Age (y)
Total	14	170 (10)	71 (12)	21 (2)
Males	7	178 (6)	80 (11)	21 (2)
Females	7	163 (7)	62 (7)	20 (1)

Data are presented as means (SD).

Table 1.2. 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	11 (1)	11 (2)	11 (2)	12 (1)	11 (2)	11 (1)	65 (3)
	Placebo	11 (1)	11 (1)	11 (1)	11 (1)	10 (2)	11 (1)	65 (6)
Day 2	Treatment	10 (2)	*11 (2)	10 (2)	11 (2)	10 (2)	*11 (1)	*62 (5)
	Placebo	10 (2)	10 (1)	10 (2)	10 (2)	9 (2)	10 (3)	59 (7)

* Significantly greater than placebo trial ($p < .05$). Data are presented as means (SD) for repetitions performed during the first set of each exercise.

Table 1.3. Residual Muscle Pain (mm) and RPR (mm) Following Exhaustive Resistance Exercise and 24 h Passive Rest

	Residual muscle pain	Ratings of perceived Recovery (RPR)
Treatment	*29 (19)	6 (2)
Placebo	40 (23)	6 (2)

* Significantly less than placebo trial ($p < .05$). Data are presented as means (SD).

Table 1.4. Perceptual Responses to Resistance Exercise After 24 h Passive Rest

Day 1

		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Overall workout
Pain	Treatment	48 (23)	41 (23)	45 (24)	40 (21)	38 (19)	48 (20)	57 (22)
	Placebo	43 (17)	39 (19)	45 (19)	38 (15)	39 (14)	47 (16)	55 (16)
RPE	Treatment	60 (21)	54 (23)	53 (21)	60 (24)	59 (15)	63 (19)	72 (18)
	Placebo	64 (18)	56 (15)	57 (18)	64 (18)	63 (17)	69 (19)	73 (17)

Day 2

		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Overall workout
Pain	Treatment	43 (20)	49 (24)	*39 (17)	*37 (14)	41 (14)	43 (16)	43 (20)
	Placebo	47 (21)	41 (19)	47 (24)	46 (12)	45 (19)	50 (20)	47 (21)
RPE	Treatment	61 (18)	52 (20)	55 (21)	*55 (20)	55 (15)	*53 (20)	61 (18)
	Placebo	59 (17)	55 (22)	61 (19)	62 (16)	61 (17)	61 (19)	59 (17)

Data are presented as means (SD) for muscle pain and RPE using a 100-mm visual analog scale. No significant differences were present between treatment and placebo ($p > .05$).

STUDY II

Effect of Combined Anti-inflammatory and Nutritional Supplements on Recovery from Resistance Exercise

ABSTRACT

The purpose of this study was to evaluate the effects of concurrent use of ibuprofen, vitamins C and E, and a protein–carbohydrate recovery shake on skeletal muscle pain, endurance, and recovery. Fourteen resistance-trained individuals (mean ± SD age = 22 ± 3y; training duration = 33± 33mo; session duration = 77 ± 23 min; frequency = 4 ± 1d/wk.; males, n = 7, females, n = 7) completed two experimental protocols, each consisting of two exercise sessions performed on consecutive days. On the first day, participants completed three sets of 8–12 repetitions at a load that ensured momentary muscular failure after each set. After 24 h, participants attempted to repeat this same workout. On one occasion, participants consumed a protein-carbohydrate shake (330 ml; 20 g protein; 45 g CHO) and one dose each of vitamin C (1000 mg), vitamin E (400 I.U.) and ibuprofen (100 mg) immediately after the initial workout. A second dose of vitamin C and ibuprofen were respectively consumed 1h or 30 min before the subsequent workout. On another occasion (counterbalanced) a placebo comprised of flavored water, two doses of an imitation vitamin (gummy candy), and two doses of placebo ibuprofen (sugar pill) was consumed in the same manner as the study treatment. Muscle pain and ratings of perceived exertion (RPE) were assessed following each set, exercise, and workout using a 100–mm visual analog scale (VAS). Residual pain and ratings of perceived recovery (RPR) were assessed after 24 h. Performance–based recovery was measured as the number of repetitions performed on the second day of exercise. The treatment enhanced performance–based recovery for the chest press (9 ± 2 vs. 8± 2; $p = .004$) and latissimus pull-down (10 ± 2 vs. 9 ± 2; $p < .001$)

and reduced HR during the leg press (125± 16 vs. 133 ± 16; p = .005) and leg extension exercises (125 ± 15 vs. 131 ± 20; p = .049). When comparisons were made within each treatment, a significant (p < .05) decline in performance for all exercises was observed after 24 h under placebo conditions compared to decreased performance in only 50% of the exercises under treatment conditions. Whereas the treatment significantly enhanced RPR (6 ± 1 vs. 5 ± 1; p = .039) compared to a placebo, no differences in residual muscle pain (p > .05) were observed. Additionally, no differences in RPE or muscle pain between treatment and placebo were observed during exercise. The concurrent use of ibuprofen, vitamins C and E, and a protein–carbohydrate shake may effectively enhance RPR and performance-based recovery for the muscles in the chest and back following exhaustive resistance exercise. After 24 h of passive rest, athletes were able to perform more repetitions under treatment compared to placebo for the chest press and latissimus pull-down, regardless of no significant changes in muscle pan or RPE. Additionally, the treatment attenuated the performance decrements observed during subsequent exercise. This combined treatment may benefit athletes by speeding recovery. However, the long–term impact of this treatment remains unstudied.

Key Words: carbohydrate, electrolytes, ibuprofen, muscle endurance, protein, recovery, resistance exercise, vitamin C, vitamin E

INTRODUCTION

Many different passive recovery techniques and treatments are theorized to reduce skeletal muscle pain and enhance subsequent exercise performance in athletics. Included among these practices is the use of anti-inflammatory analgesics (e.g. ibuprofen) (15), cryotherapy (10), massage therapy (32), stretching (17), supplementation with minerals and antioxidant vitamins (16), and increased intake of protein, carbohydrates, electrolytes, and fluids (6, 21). For example, anti-inflammatory medications can reduce the pain and edema that accompany training and, consequently, may expedite training recovery and restoration of performance capacity (4, 24). Similarly, supplemental antioxidants carry the potential to enhance exercise performance by reducing the detrimental effects of reactive oxygen species (4, 16, 24). 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 by facilitating rehydration following excessive water loss (6, 21).

Evidence suggests that several of these methods independently reduce skeletal muscle pain and enhance recovery of muscle function (4), and enhance second-day performance (10) 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 other individuals (10). This disparate evidence may result in part from inter-individual differences within the studied sample. For example, Bosak et al. (10) examined the influence of cold-water immersion following a 5 km run on next-day performance in 12 male and female runners. Whereas this treatment enhanced second-day performance in 3 participants, it also negatively impacted performance in 7 individuals.

The concurrent use of ibuprofen, vitamin C, vitamin E, and protein has been shown to enhance short-term recovery in trained athletes (1). Additionally, Shaw demonstrated that these supplements enhance training recovery in competitive runners (29). However, the combined influence of these supplements on training recovery in experienced weightlifters is unknown. The purpose of this study was to evaluate the influence of the combined use of ibuprofen, vitamins C and E, and 330 ml (11 fl. oz.) protein recovery shake (milk protein and whey protein) containing carbohydrates and electrolytes (270 kcal, 20 g protein, 45 g carbohydrate, 320 mg sodium, 680 mg potassium; Gatorade®, PepsiCo, Inc., Purchase, NY) on training recovery. Specifically, the study aimed to determine if this treatment is an effective approach for improving performance and rating of perceived recovery (RPR), reducing skeletal muscle pain, rating of perceived exertion (RPE), and heart rate (HR) during resistance exercise 24 h after an initial resistance workout.

We hypothesized that the treatment would attenuate skeletal muscle pain, RPE, and HR during exercise while enhancing RPR and performance–based training recovery compared to a placebo. We also hypothesized that several individuals would respond positively to the treatment while others would exhibit no response or respond negatively to the treatment.

METHODS

Experimental Approach to the Problem

After establishing a baseline load to ensure momentary muscular failure after 10-12 repetitions, participants completed two experimental protocols, each comprised of two resistance-training sessions separated by 24 h passive recovery. This recovery period was chosen to minimize the possibility that participants would experience full training recovery independently of treatment and placebo conditions. Participants completed each protocol under

treatment and placebo conditions in a double-blind, randomized and counter-balanced order. Muscle endurance was defined as the number of repetitions performed for each exercise during the first set of each lift. Muscle recovery was defined as the ability to repeat the same number of repetitions during the first set of the subsequent workout as was performed on the previous day.

In order to ensure that the baseline testing session did not influence the subsequent trial, participants were required to refrain from fatiguing exercise during a one-week washout period. A second one-week washout period separated the two experimental trials. On the first day of repetitions under each condition, HR was measured before the start of exercise after each set for each lift. A continuous 100-cm VAS was used to assess muscle pain and RPE after each set, lift, and workout. We chose to use the VAS rather than a 0-10 scale to allow us to appropriately analyze these measures as continuous data. The number of repetitions performed was recorded after each set for all exercises. Residual muscle pain and RPR were assessed prior to start of the resistance session on the second day of each trial. Muscle pain and RPE were measured after each set, lift, and at the end of the workout. The number of repetitions performed during each set was recorded to assess muscle recovery.

Subjects

Fourteen participants (mean ± SD age = 22 ± 3y; training duration = 33± 33mo; session duration = 77 ± 23 min; frequency = 4 ± 1d/wk.; males, n = 7, females, n = 7) completed the study. Complete training history and participant characteristics are reported in Table 1. This study population, aged 19-30, was chosen in order to any confounding effects associated age-related differences in skeletal muscle recovery between younger and older individuals (22) and to minimize any training effects associated with study participation. Training history and participant characteristics are reported in Table 1. All participants were non-smokers who

reported no diagnoses, signs or signs or symptoms of cardiovascular or metabolic disease. All participants were classified as having a 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 (ACSM) (23). Individuals who reported using any exogenous steroids were excluded from participation in the study.

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. All individuals interested in participating in the study completed an exercise history questionnaire to determine if they met the inclusion criteria for the study. After providing their written, informed consent, participants reported to the weightlifting facility located in the Aquatics Center at The University of Alabama on five separate occasions. All volunteers were instructed to abstain from caffeine and alcohol for at least 24 h prior to each visit, and to abstain from vigorous exercise 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.

Procedures

The exercise protocol for was identical to that previously described for Baggett et al. (3) (in review as Study I); however, the treatment and placebo conditions differed.

Visit I. Participants completed a series of tests to establish a baseline load that ensured momentary muscular failure after 8–12 repetitions. These procedures were identical to those described by Baggett et al. (3) (in review as Study I).

Visits II and IV. The experimental workout for *Visits II and IV* was identical to that described previously (3) (in review as Study I). During the 24-h period following the initial workout

under treatment conditions, participants received the following: (a) Two 100–mg doses of ibuprofen. This dose remained below the maximal single (200 mg) and daily (400 mg) over-the-counter doses, as high concentrations of ibuprofen may attenuate muscle protein synthesis. (b) Two 1000–mg doses of vitamin C and one 400–I.U. dose of vitamin E. Previous research from our laboratory demonstrated that a treatment containing three 1000–mg doses of vitamin C and three 800–mg doses of vitamin E may enhance training recovery (29). Fitzgerald (13) reported that a daily intake of vitamin E in excess of 400 I.U. was associated with an increased risk of death from all causes; therefore, the dose did not exceed 400 I.U. of vitamin E for the present study. The treatment also included: (c) a protein recovery shake (330 ml) that also contained carbohydrates and electrolytes (270 kcal, 20 g protein, 45 g carbohydrate, 320 mg sodium, 680 mg potassium; Gatorade®, PepsiCo, Inc., Purchase, NY). The recovery 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 will be administered 30 min before the subsequent workout (29). The placebo was comprised of: (a) two empty capsules identical in appearance to the ibuprofen capsules from the treatment condition, (b) two imitation vitamins (Jolly Rancher ® gummies candy, The Hershey Company ®, Hershey, PA) that mimicked the appearance of common over-the-counter multi-vitamins, and (c) 330 ml (11 fl. oz.) of flavored water (Crystal Light®, Kraft Food Group, Inc., Northfield, IL). The flavored water, one placebo ibuprofen, and one imitation vitamin were administered immediately following the initial trial. The second placebo ibuprofen and imitation vitamin were administered 1 h prior to the second experimental trial. 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. The order of administration of treatment and placebo conditions were counter-balanced. The treatment and placebo order was randomly assigned, and the researcher and participants were blinded to each condition.

Visits III and V. Participants completed 3 sets to failure for 3 upper–body and 3 lower–body exercises, then attempted to repeat their performance after 24 h. The reader is referred to Baggett et al. (3) (in review as study I) for a more detailed description of these methods.

Statistical Analyses

One-way ANOVA was used to compare skeletal muscle pain, RPE, RPR, and training recovery between treatment and placebo conditions. The primary application of this treatment is for athletes in training; therefore, individual analyses were performed by calculating the least significant difference for the sample. An effect size of .81 was determined to yield an alpha of .049 and was considered the minimum change necessary to yield statistical significance. Because only full repetitions were considered, participants were considered positive responders if their performance increased one or more repetitions. Participants whose performance decreased by one or more repetitions were considered negative responders, and participants whose performance remained the same were considered non-responders. An alpha level of .05 was set for statistical testing.

A power analysis (G power; ANOVA: Repeated measures) revealed that a minimum of 10 participants was necessary to detect a difference of 0.9 repetitions between treatment and placebo conditions (effect size = 0.37, $\alpha = 0.05$, power = 80%, noncentrality parameter = 13.79, critical F = 5.32). Fourteen participants completed the study. Therefore, if the treatment allowed participants to perform one additional repetition compared to placebo conditions, this difference

should be detected. The effect sized used in this analysis was determined from the variance observed by McLester et al. (22).

RESULTS

Performance data are displayed in Table 2. Perceptual responses prior to activity and during activity on the second day of exercise are reported in Table 3 and Table 4, respectively. No differences in performance or perceptual responses were observed between treatment and placebo on the first day of exercise ($p > .05$). The treatment significantly enhanced RPR (6 ± 1 vs. 5 ± 1; $p = .039$) and performance-based recovery for the chest press (9 ± 2 vs. 8 ± 2 repetitions; $p = .004$) and latissimus pull-down (10 ± 2 vs. 9 ± 2 repetitions; $p < .001$) exercises compared to placebo. Additionally, within-trial comparisons revealed that the treatment attenuated the performance decrements observed during subsequent exercise. Whereas a significant decline in performance for all exercises was observed after 24 h under placebo conditions ($p < .05$), performance was reduced in only 50% of the exercises under the treatment ($p < .05$). No changes in performance were observed for the remaining exercises ($p > .05$). Additionally, no differences in residual muscle pain or muscle pain and RPE during exercise were observed between treatment and placebo ($P > .05$). Exercise HR was significantly lower during the leg press (125 ± 16 vs. 133 ± 16; $p = .005$) and leg extension (125 ± 15 vs. 131 ± 20; $p = .049$) exercises under treatment compared to placebo conditions on the second day of exercise, but failed to differ at baseline and during activity for all other exercises ($p > .05$). Additionally, baseline and exercise HR did not differ between conditions during the first day of repetitions ($p > .05$).

The data indicated that 10 participants were positive responders, performing more repetitions on the second day of exercise under the treatment compared to placebo. Two

participants performed fewer repetitions under the treatment and were considered negative responders. Additionally, two participants performed equally under both conditions and were considered non-responders to the treatment.

DISCUSSION

Performance–based training recovery

Participants were able to execute a significantly 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 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 all 6 exercise performed during the subsequent workout under placebo conditions, the treatment was associated with impaired next-day performance during only 50% of these exercises. Athletes may use these supplements to increase training volume, which in turn may promote gains in muscle strength and endurance. Further, any advancement in muscle strength and endurance has the capacity to translate into enhanced athletic performance or facilitate restoration of muscle function when incorporated as part of an injury rehabilitation program. 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.

Perceptual responses

Our findings contrast previous reports of reduced symptoms of skeletal muscle damage following exhaustive exercise when supplementing with vitamins C and E, protein,

carbohydrates, and anti-inflammatories, either alone or in various combinations with one another (8, 9, 25). Although RPR was enhanced under treatment compared to placebo, no differences in muscle pain or RPE were observed. While these similarities in perceptual responses to exercise between treatment and placebo conditions may indicate similarities in muscle damage, it is noteworthy to mention that performance-based measures were enhanced under the treatment compared to placebo. Thus, despite performing more repetitions, participants failed to experience any differences in muscle pain or RPE. Consequently, it is possible that the treatment attenuated exercise-induced muscle damage or accelerated muscle repair, but any reduction in symptoms remained undetected due to the greater volume of work performed. Therefore, the influence of these supplements on perceptual indices of muscle damage in our study remains inconclusive.

Protein–carbohydrate beverage

Our treatment combination included a protein–carbohydrate shake, which was consumed within 10 min following the conclusion of the first experimental workout under treatment conditions. Participants were able to perform a significantly 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 (12).

The literature demonstrates that prolonged or intense exercise depletes muscle glycogen stores and, if not replenished, augments fatigue and impairs muscle performance during subsequent exercise (25). Thus, post–exercise carbohydrate consumption is an important factor influencing restoration of glycogen balance and training recovery. Carbohydrate consumption alone, however, may not be sufficient to maximize training recovery. Heavy resistance exercise

is associated with skeletal muscle damage and proteolysis, making muscle protein synthesis an important consideration during recovery (18). Post–exercise protein consumption has been postulated to facilitate net muscle protein accretion by stimulating muscle protein synthesis or attenuating its breakdown (5, 6, 12). Maximal rates of protein synthesis during the early phases of recovery occur with the consumption of ~20 g of intact protein, or with ~9 g of essential amino acids. Due to the independent benefits associated with protein and carbohydrate consumption during the recovery period, it has been postulated that co-consumption of these macronutrients may enhance recovery beyond that of either alone (5). Beelen et al (5) indicated that co–ingestion of carbohydrate and protein during early hours of recovery favorably influences subsequent exercise performance, making it a viable treatment option for athletes who train or compete multiple times on the same or consecutive days.

Antioxidants

During exercise, production of reactive oxygen species (ROS) within the contracting skeletal muscle increases in proportion to exercise intensity and antioxidant capacity. Accumulation of high levels of ROS is postulated to impair muscle function and contribute to fatigue (7). Bentley et al. (7) tested the hypothesis that antioxidant supplementation may reduce oxidative stress and enhance muscle performance during exercise. The researchers examined the effects of acute antioxidant supplementation on time to exhaustion in trained cyclists. In their study, supplementation with antioxidants attenuated the rise in blood lactate concentrations and extended time to exhaustion compared to a placebo. The authors postulated that the observed ergogenic effects were attributed to an enhanced vasodilator response and, consequently, improved circulation and lactic acid clearance (7). Similarly, previous research from our laboratory demonstrated treatment combinations containing Vitamins C and E enhanced short–

term and training recovery following repeated 30-s Wingate tests and endurance running, respectively (1, 29).

In the current study, we 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 A on training recovery following exhaustive resistance exercise. Our data support the notion that antioxidants attenuate fatigue and enhance skeletal muscle recovery, at least for some lifts. 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 previous reports 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 (29).

Similarly, Jakeman and Maxwell (20) examined the effect of vitamin C supplementation on recovery of strength and muscle function following damaging eccentric exercise. The authors reported a more rapid recovery following 21 days of daily supplementation with 400 mg vitamin C compared to a placebo. Interestingly, the authors noted that vitamin C consumption also enhanced muscle recovery compared to vitamin E supplementation, suggesting that vitamin C may provide greater ergogenic benefits. 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 (31). Satoshi et al. (26) and Itoh et al. (19) reported reductions in exercise–induced muscle damage following 4 wk of daily vitamin E supplementation compared to a placebo. Similarly, reductions in markers of muscle breakdown were observed when participants supplemented with

800 I.U. of vitamin E per day for 48 days, suggesting that regular consumption of vitamin E may protect against muscle breakdown during damaging eccentric exercise (11).

In the present study, we included vitamins C and E, among other potential ergogenic aids, as a single treatment. Thus, we are 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 (31). Daily consumption of 200 mg of vitamin C with 400 I.U. of vitamin E during the 4.5 wk preceding a marathon attenuated the increase in creatine kinase during the race compared to a placebo (31). Thus, the results point to reduced muscle damage during strenuous endurance activity following regular co-ingestion of vitamins C and E. In a study examining the influence of combined supplementation with vitamins C and E on indices of oxidative stress in competitive basketball players in season, the ratio of lipoperoxides to antioxidant capacity was decreased, indicating reduced oxidative stress following consumption of the antioxidants compared to a placebo (28). Additionally, the authors also noted that substantial declines in plasma vitamin C concentrations observed in the control group were not present in the supplemented group (28). It has been postulated that discrepancies in the data regarding the influence of antioxidant supplementation may be due to differences in plasma concentrations; ergogenic effects of antioxidant supplementation may be more pronounced when plasma concentrations are low (31). The results of Shroder et al. (28) indicate that regular training and competition may reduce circulating vitamin C concentrations, thereby augmenting the effectiveness of supplementation among athletes.

To date, 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 (11, 28, 31). Few studies have examined the influence of acute supplementation with these vitamins. Therefore, 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 of reduced muscle damage and enhanced recovery following prolonged supplementation with vitamins C and E, suggesting that isolated consumption of these antioxidants may be sufficient to attenuate muscle breakdown and promote training recovery. 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 (13). Therefore, athletes may supplement with vitamin E only during the peak of training and competition, allowing them to receive the potential ergogenic benefits of the antioxidant while avoiding any harmful effects associated with prolonged use. Additionally, co-ingestion of vitamins C and E may provide greater benefits than consuming either of these antioxidants alone, likely by providing increased protection against cellular damage and oxidative stress.

Ibuprofen

Heavy resistance exercise induces muscle damage that can lead to residual pain at rest and during subsequent exercise (27). The magnitude and duration of exercise–induced muscle damage is dependent on training status. Untrained individuals and athletes performing unaccustomed exercise experience the most pronounced effects; however, exhaustive resistance exercise, such as multiple sets until failure, is still associated with residual muscle pain and decreased next–day performance in trained athletes (2, 32). Non-steroidal anti-inflammatory drugs (NSAIDS) are postulated to attenuate exercise–induced muscle damage and, consequently, reduce muscle pain and enhance performance during subsequent exercise (4, 27). Our results

support the notion of a recovery–enhancing effect of NSAIDS. Included in our treatment combination were two 200–mg doses of ibuprofen; one dose was consumed immediately after the initial experimental trial while the second dose was consumed 1 h prior to the subsequent workout. Participants reported similar levels of pain and RPE under treatment and placebo conditions, despite performing significantly more repetitions following the treatment. We speculate that our observations were attributed, at least in part, to the ibuprofen. Schoenfield (27) reported that exercise–induced muscle soreness results 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 (14, 24, 27). 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 (27, 30). NSAIDs function by blocking cyclooxygenase, an enzyme necessary for achieving maximal muscle growth in response to training overload (24, 27). 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.

We tested the hypothesis that a treatment combination comprised of an NSAID (ibuprofen), antioxidant vitamins C and E, and a protein–carbohydrate beverage would enhance recovery in resistance–trained men and women compared to placebo; our results partially confirmed this notion. Under the treatment, participants were able to perform significantly more repetitions for select upper-body exercises, and the decline in performance between successive

days was reduced by 50% compared to placebo. While RPR was enhanced under the treatment compared to a placebo, no differences in residual pain were observed. Muscle pain and RPE also failed to differ between the treatment and placebo; however, it is possible that decreased symptoms of muscle damage were blunted by increases in repetitions performed. Performance-based measures of skeletal muscle recovery provide more-practical training applications for athletes than perceptual responses. Consequently, our overall data support previous reports of enhanced recovery following the use of each of these treatments individually or in various combinations with one another.

It is important to note that our study examined only the influence of acute use of these treatments on recovery from resistance exercise; therefore, we are unable to state the effectiveness of chronic use of these treatments on training recovery. Thus, additional research is necessary to examine the influence of chronic use of this treatment combination. We speculate that the collective use of ibuprofen, vitamins C and E, and a protein–carbohydrate beverage provides 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. It is also possible that one or more of the studied treatments had no effect on recovery.

PRACTICAL APPLICATIONS

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 and physical therapy patients 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. Alternatively, individuals seeking advanced training recovery over a prolonged period may choose to modify the current treatment; specifically, ibuprofen consumption could be minimized.

REFERENCES

1. Al Nawaiseh AM. Enhancing short-term recovery after high-intensity anaerobic exercise. *Medicine & Science in Sports & Exercise* 39: S 307, 2007.

2. Baechle TR and Earle RW. *Essentials of Strength Training and Conditioning.* Human Kinetics, 2008.

3. Baggett S, Wingo J, Richardson M, Curtner-Smith M, Leeper J, and Bishop P. Effects of branched-chain amino acids, beta-hydroxy-beta-methylbutyrate, and glutamine on recovery from resistance training. The University of Alabama, 2015.

4. Baldwin Lanier A. Use of nonsteroidal anti-inflammatory drugs following exercise-induced muscle injury. *Sports medicine (Auckland, NZ)* 33: 177-185, 2003.

5. Beelen M, Burke LM, Gibala MJ, and Van Loon LJ. Nutritional strategies to promote postexercise recovery. *International journal of sport nutrition and exercise metabolism* 20: 515-532, 2010.

6. Benardot D. *Advanced Sports Nutrition.* Human Kinetics, 2006.

7. Bentley DJ, Dank S, Coupland R, Midgley A, and Spence I. Acute antioxidant supplementation improves endurance performance in trained athletes. *Research in sports medicine (Print)* 20: 1-12, 2012.

8. Bishop PA, Jones E, and Woods AK. Recovery from training: a brief review: brief review. *Journal of strength and conditioning research / National Strength & Conditioning Association* 22: 1015-1024, 2008.

9. Bloomer RJ. The Role of Nutritional Supplements in the Prevention and Treatment of Resistance Exercise-Induced Skeletal Muscle Injury. *Sports Medicine* 37: 519-534, 2007.

10. Bosak A, Bishop P, Green J, and Hawver G. Impact of cold water immersion on 5km racing performance. *Sport Journal* 12: 9p, 2009.

11. Cannon JG, Meydani SN, Fielding RA, Fiatarone MA, Meydani M, Farhangmehr M, Orencole SF, Blumberg JB, and Evans WJ. Acute phase response in exercise. II. Associations between vitamin E, cytokines, and muscle proteolysis. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* 260: R1235-R1240, 1991.

12. Cermak NM, de Groot LC, Saris WH, and van Loon LJ. Protein supplementation augments the adaptive response of skeletal muscle to resistance-type exercise training: a meta-analysis. *The American journal of clinical nutrition* 96: 1454-1464, 2012.

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

14. Hasson SM, Daniels JC, Divine JG, Niebuhr BR, Richmond S, Stein PG, and Williams J. Effect of ibuprofen use on muscle soreness, damage, and performance: a preliminary investigation. *Medicine and science in sports and exercise* 25: 9-17, 1993.

15. Hasson SM, Daniels JC, Divine JG, Niebuhr BR, Richmond S, Stein PG, and Williams JH. Effect of ibuprofen use on muscle soreness, damage, and performance: a preliminary investigation. *Medicine and science in sports and exercise* 25: 9-17, 1993.

16. Haymes EM. Vitamin and mineral supplementation to athletes. *International journal of sport nutrition* 1: 146-169, 1991.

17. Herbert RD and de Noronha M. Stretching to prevent or reduce muscle soreness after exercise. *The Cochrane database of systematic reviews*: CD004577, 2007.

18. Howatson G, Hoad M, Goodall S, Tallent J, Bell P, and French D. Exercise-induced muscle damage is reduced in resistance-trained males by branched chain amino acids: a randomized, double-blind, placebo controlled study. *Journal of the International Society of Sports Nutrition* 9: 20, 2012.

19. Itoh H, Ohkuwa T, Yamazaki Y, Shimoda T, Wakayama A, Tamura S, Yamamoto T, Sato Y, and Miyamura M. Vitamin E supplementation attenuates leakage of enzymes following 6 successive days of running training. *International journal of sports medicine* 21: 369-374, 2000.

20. Jakemanl P and Maxwell S. Effect of antioxidant vitamin supplementation on muscle function after eccentric exercise. *European journal of applied physiology and occupational physiology* 67: 426-430, 1993.

21. Maughan RJ and Shirreffs SM. Recovery from prolonged exercise: restoration of water and electrolyte balance. *Journal of sports sciences* 15: 297-303, 1997.

22. McLester JR, Bishop PA, Smith J, Wyers L, Dale B, Kozusko J, Richardson M, Nevett ME, and Lomax R. A series of studies--a practical protocol for testing muscular endurance recovery. *Journal of strength and conditioning research / National Strength & Conditioning Association* 17: 259-273, 2003.

23. Pescatello LS and Medicine ACoS. *ACSM's Guidelines for Exercise Testing and Prescription.* Wolters Kluwer/Lippincott Williams & Wilkins Health, 2013.

24. Peterson JM, Trappe TA, Mylona E, White F, Lambert CP, Evans WJ, and Pizza FX. Ibuprofen and acetaminophen: effect on muscle inflammation after eccentric exercise. *Medicine and science in sports and exercise* 35: 892-896, 2003.

25. Pritchett KL, Pritchett RC, and Bishop P. Nutritional strategies for post-exercise recovery: a review. *South African Journal of Sports Medicine* 23: 20-25, 2011.

26. Satoshi S, Kiyoji T, Hiroyo K, and Fumio N. Exercise-induced lipid peroxidation and leakage of enzymes before and after vitamin E supplementation. *International Journal of Biochemistry* 21: 835-838, 1989.

27. Schoenfeld BJ. The Use of Nonsteroidal Anti-Inflammatory Drugs for Exercise-Induced Muscle Damage. *Sports medicine* 42: 1017-1028, 2012.

28. Schröder H, Navarro E, Tramullas A, Mora J, and Galiano D. Nutrition antioxidant status and oxidative stress in professional basketball players: effects of a three compound antioxidative supplement. *International journal of sports medicine* 21: 146-150, 2000.

29. Shaw KR. Recovery following aerobic exercise: modalities and masters runners. Doctoral Dissertation. Tuscaloosa, AL: The University of Alabama, 2013.

30. Trappe TA, White F, Lambert CP, Cesar D, Hellerstein M, and Evans WJ. Effect of ibuprofen and acetaminophen on postexercise muscle protein synthesis. *American Journal of Physiology - Endocrinology and Metabolism* 282: E551-E556, 2002.

31. Urso ML and Clarkson PM. Oxidative stress, exercise, and antioxidant supplementation. *Toxicology* 189: 41-54, 2003.

32. Zainuddin Z, Newton M, Sacco P, and Nosaka K. Effects of massage on delayed-onset muscle soreness, swelling, and recovery of muscle function. *Journal of athletic training* 40: 174-180, 2005.

TABLES

Table 2.1. Training History and Participant Characteristics

Training History

	Participants(n)	Training (months)	Frequency (days/ wk)	Average session (min)
Total	14	33 (33)	4 (1)	77 (23)
Males	7	32 (37)	4 (1)	75 (23)
Females	7	33 (32)	4 (1)	79 (26)

Participant Characteristics

	Participants (n)	Height (cm)	Weight (kg)	Age (y)
Total	14	174 (8)	75.9 (15.7)	22 (3)
Males	7	175 (8)	80.9 (17.9)	23 (4)
Females	7	169 (8)	66.7 (13.3)	21 (1)

Data are presented as means (SD).

Table 2.2. 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)
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)

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

Table 2.3. 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)

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

Table 2.4. Perceptual Responses to Resistance Exercise After 24 h Passive Recovery

Day 1

		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Overall workout
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)
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)

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)
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)

Data are presented as means (SD) for muscle pain and RPE using a 100-mm visual analog scale. No significant differences were present between treatment and placebo ($p > .05$).

STUDY III

Skeletal Muscle Recovery from Resistance Exercise in Trained Men and Women

ABSTRACT

Estrogen is believed to protect against exercise–induced muscle and damage due to its antioxidant properties and potential to promote stabilization of the skeletal muscle membrane. This notion has led to the belief that compared to men, women experience reduced indices of muscle damage and enhanced training recovery following damaging resistance exercise. The purpose of the current study was to quantify the differences in muscle pain, RPE and training recovery between men and women. Twenty–eight participants (mean ± SD age = 22 ± 3 y; average training duration = 40 ± 32 mo; session duration = 71 ± 21 min; frequency = 4 ± 1d/wk.; males, n = 14, females, n = 14) completed two experimental testing sessions after establishing a baseline load designed to induce momentary muscular failure after 8–12 repetitions. For the first experimental session, participants completed three sets of 8–12 repetitions for six resistance exercises. Participants returned to the facility after 24 h to attempt to complete this same workout. Measures of perceived muscle pain and RPR were assessed after each set, after each exercise, and following each workout using a 100–mm visual analog scale (VAS). Muscle pain was reassessed immediately prior to the second workout, along with ratings perceived recovery (RPR). Residual muscle pain was significantly lower in women compared to men 24 h after an exhaustive resistance workout (31± 15 vs. 50 ± 20; p = .01).

However, no discernable differences in muscle pain and RPE during exercise were detected between men and women ($p > .05$). A significant decrease in performance from the first to second day of repetitions was observed in both men (63 ± 7 vs. 58 58 ± 8; $p = .01$) and women (64 ± 5 vs. 56 ± 10; $p = .002$); however, the change in performance was similar between the two groups ($p = .21$). Additionally, no differences in RPR (5 ± 2 vs. 6 ± 1; $p = .21$) or performance–based recovery ($p > .05$ for all exercises) were observed between men and women. Exercise HR was significantly lower in women compared to men for all upper–body and most lower–body exercises on both experimental testing sessions ($p < .05$). Our data indicate that with the exception of RPR, perceptual responses and performance-based measures of muscle recovery are similar between men and women during the 24 h following damaging resistance exercise. Residual pain was lower in women; however, this difference did not extend into the subsequent workout. Although HR was significantly lower in women than in men, this difference was observed on both days of exercise and likely reflects differences in the absolute load lifted rather than hormone–related differences between men and women. Coaches and physical therapists may provide similar recovery periods for their male and female athletes or clients.

Key Words: Sex differences, Muscle endurance, Muscle pain, RPE

INTRODUCTION

In recent years, considerable attention has been directed toward understanding the influence of sex differences on the physiological responses to exercise training; however, relatively few studies have examined the effect of sex differences on training recovery (12). Clearly, men and women differ with respect to body size, total body mass, body composition, body fat distribution, and muscle mass (2). Additionally, distinct differences in circulating concentrations of sex hormones – the androgens and the estrogens / progestins – are present at rest; whereas androgens predominate in males, the estrogens and progestins predominate in females (2, 18, 26).

Animal studies consistently demonstrate increased markers of muscle damage in male versus female rats, whereas estrogen therapy appears to attenuate the exercise-induced muscle damage in male and ovariectomized female rats (1, 4, 30). These results have led to the notion that estrogen protects against exercise–induced muscle damage; however, results from human studies are conflicting and inconsistent (5). Similarly, it has been hypothesized that that fluctuations is estrogen and progesterone that occur with the normal female menstrual cycle may influence muscle damage and recovery (21). Markofski and Braun (21) evaluated the influence of menstrual cycle phase on contraction-induced muscle damage in females and determined that differences in estrogen concentrations did not significantly influence muscle pain or performance during concentric exercise. Greater strength decrements and higher creatine kinase concentrations were observed during the luteal phase of the menstrual cycle; however, these differences did not become evident until after 96 h of passive recovery (21).

Exercise–induced hormonal alterations also differ between men and women; males typically demonstrate a significant increase in serum testosterone levels in response to heavy

resistance exercise, while females tend to demonstrate no change or increase only slightly (2, 19). Anthropometric and hormonal differences between males and females at rest and in response to exercise demonstrate the capacity to alter caloric requirements, influence aerobic and anaerobic muscle performance, and affect substrate utilization (13, 28, 29). Additionally, sex differences may markedly influence the post-exercise period, thereby necessitating different recovery strategies for men and women (28). For example, the peak power output generated by males during anaerobic cycling typically exceeds that of females by approximately 60% (20, 23, 33) and may consequently necessitate different recovery strategies following maximal performance exercise. Tarnopolsky (29) suggested that female athletes demonstrate a greater capacity for lipid oxidation during prolonged exercise, whereas their male counterparts exhibit a greater propensity for muscle glycogen utilization and protein catabolism (28). Interestingly, however, women demonstrate reduced fatty acid oxidation during the post-exercise period compared to their male counterparts (11, 13). These results suggest that men and women may respond differently to various recovery strategies and after different workout modalities. Therefore, it is important to quantify these potential differences between men and women in order to establish optimal recovery guidelines.

The purpose of the proposed study was to examine the potential differences in skeletal muscle pain, muscle endurance, ratings of perceived exertion (RPE), ratings of perceived recovery (RPR), heart rate (HR) and training recovery between men and women 24 h after a bout of exhaustive resistance exercise. We hypothesized that residual pain and RPR after 24 h of passive recovery would be lower in women compared to men following an exhaustive bout of resistance exercise. Additionally, we hypothesized that women would report reduced feelings muscle pain and RPE during a subsequent bout of weightlifting compared to men. It was also

hypothesized that that performance–based recovery would be enhanced in women vs. men after 24 h of passive recovery.

METHODS

Experimental Approach to the Problem

Participants completed a baseline testing session to determine a load that allowed for 8-12 repetitions before momentary muscular failure for 6 upper–body and 6 lower–body exercises. participants completed two experimental protocols, each comprised of two resistance-training Following baseline testing, participants were require to refrain from fatiguing exercise during a one-week washout period to ensure that any residual effects of the testing had subsided before partaking in the experimental workouts. Participants then completed three sets to failure for all exercises using the baseline load. Following the workout, participants refrained from exercise for 24 h before returning to the facility repeat the same procedure. Muscle endurance was defined as the number of repetitions performed for each exercise during the first set of each lift. Muscle recovery was assessed as the number of repetitions performed during the first set for each lift on the subsequent day. Baseline HR was recorded after a 5-min seated rested period prior to the start of the trial, and exercise HR was recorded after each set, lift, and workout. Additionally, a continuous 100-cm VAS was used to assess muscle pain and RPE after each set, after each lift, and following the workout. The number of repetitions performed was recorded after each set for all exercises. Residual muscle pain and RPR were assessed prior to start of the resistance session on the second day of each trial.

Subjects

Participant characteristics and training history are reported in Table 1. Twenty-eight participants (14 males and 14 females) completed the study. A sensitivity power analysis (G

power; ANOVA: Fixed effects) was performed prior to the study to compute the required effect size given alpha ($\alpha = 0.05$), power (80%), and sample size (28 participants; 2 groups). These data yielded an effect size of 0.55 (noncentrality parameter = 8.47, critical F = 4.23) and is sufficient to detect a statistically significant difference in muscle recovery between males and females. To minimize any variation associated with differences in training status, only resistance-trained individuals were included for participation in the study. Further, men and women were matched for training status based on the number of months they had met the ACSM guidelines for resistance training. All participants were healthy, non-smokers free from any cardiovascular or metabolic disease and not taking any prescription medications or steroids; the use of oral contraceptives was permitted in females.

Procedures

Participants reported to the weightlifting facility on three separate occasions. The menstrual cycle phase of female participants was recorded at the start of each trial.

Visit I. Participants completed a series of tests to establish a baseline load that ensured momentary muscular failure after 8-12 repetitions for 3 upper-body and 3 lower-body exercises. The experimental procedures for the first visit are identical to those described by Baggett et al. (3) (in review as Study I).

Visit II. Participants performed 3 sets to failure for all lifts using the baseline load established during Visit I. A detailed description of the experimental workout used during Visit II has been previously described (3). Muscle pain and RPE, were measured after each set and following the workout, and the number of repetitions performed during each set was recorded.

Visit III. Participants returned to the facility after 24 h of passive rest and attempted to complete to repeat the same workout performed the previous day. Prior to exercise, residual muscle pain

and RPR were recorded. Muscle pain and RPE were recorded following each lift and at the end of the workout (3).

Statistical Analyses

One-way ANOVA was used to compare skeletal muscle pain, RPE, RPR, muscle endurance, and training recovery between men and women. The primary application of this treatment is for athletes in training; therefore, individual analyses were performed by calculating the least significant difference for the sample. Participants whose performance increased by an amount greater than or equal to the least significant difference were considered positive responders, participants whose performance decreases by an amount greater than or equal to the least significant difference were considered negative responders, and participants whose performance changed by an amount less than the least significant difference were considered non–responders. An alpha of .05 was observed for statistical testing.

RESULTS

Performance data are displayed in Table 2. Perceptual responses prior to activity and during activity on the second day of exercise are reported in Table 3 and Table 4, respectively. Muscle performance on the first day of exercise was similar between men and women for each exercise ($p > .05$ for all lifts) as well as for total work performed (men = 58 ± 8 vs. women = 56 ± 10 repetitions; $p = .57$). However, the absolute load lifted for each exercise was significantly ($p < .001$) greater for men compared to women for all lifts (Table 6). Muscle pain and RPE were also similar between men and women on the first day of exercise. Additionally, no differences in RPR (men = 5 ± 2 vs. women = 6 ± 1; $p = .21$) or performance–based recovery ($p = .05$ for all lifts) were present between men and women after 24 h of passive recovery. Residual muscle pain was significantly lower in women compared to men 24 h after an exhaustive

resistance bout (31 ± 15 vs. 50 ± 20 mm; p = .01); however, muscle pain during exercise was similar between men and women for each lift (p > .05 for all lifts) and for the overall workout (men = 62 ± 21 vs. women = 56 ± 20 mm; p = .42). No differences in RPE were observed between men and women throughout the study (p > .05). During the initial workout, HR was similar between men and women during the leg extension exercise (137 ± 8 vs. 135 ± 15 bpm; p = .83), but was significantly lower in women for all other exercises (p < .05). On the second day of exercise, a marginally non–significant difference in HR was observed between men and women for the leg extension (men = 140 ± 13 vs. women = 121 ± 32 bpm; p = .05), but was significantly lower in women compared to men for all remaining lifts (p < .05). A comparison of HR data between men and women on both days of exercise is displayed in Table 5.

DISCUSSION

We tested the hypothesis that indices of training recovery would be improved in women compared to men following exhaustive resistance exercise. Contrary to our hypotheses, RPE, RPR, and performance–based recovery did not differ between men and women. Although residual muscle pain prior to the subsequent exercise bout was significantly lower in women compared to men, no differences were observed during exercise. Exercise HR was lower on the first day of exercise and remained lower after 24 h passive recovery. Exercise–induced muscle damage in animal models and human participants has been studied extensively in recent years; however, researchers have yet to achieve a clear consensus regarding any sex differences in muscle injury and recovery (5-7, 14, 24, 31). It has been hypothesized that estrogen attenuates muscle breakdown and accentuates repair (31). While compelling evidence obtained from rodent models supports this notion, the results of human studies are less consistent (7, 22, 24, 31). However, evidence indicating reduced manifestations of muscle damage in women

compared to men is often reported (25, 27, 31). Estrogen possesses antioxidant properties and the potential to facilitate membrane stabilization within the skeletal muscle (31). These effects provide a potential mechanism through which estrogen may protect against muscle damage and, given the relatively greater estrogen levels in women vs. men, may account for reduced indices of muscle damage in female participants (31).

Exercise HR accounted for the largest experimental differences between men and women in our study. Women demonstrated a significantly lower HR for all upper–body and most lower–body exercises. However, these differences were present on both days of repetitions and, consequently, are likely a reflection of the greater loads lifted by male participants. If the lower HR in women had resulted from enhanced recovery, then we expect that at least one of the following would have been observed: (1) lower HR in women compared to men, but only on the second day of repetitions only and not resulting from reduced performance (2) lower HR in women compared to men on the second day of repetitions, despite improved performance. These criteria were not met. We speculate that the greater absolute load lifted by men contributed to differences in HR observed in the present study. Thus, our results favor the viewpoint that no distinguishable sex differences in exercise–induced muscle damage or recovery occurred as evidenced in our measures (5).

Histological evidence obtained by Komulainen et al. (17) indicated that female rats experience diminished muscle fiber swelling and reduced indices of structural damage compared to their male counterparts for up to 96 h following downhill running. The researchers also noted significantly reduced levels of beta-glucuronidase, a lysosomal enzyme indicative of muscle damage, in female vs. male rats (17). Similarly, Enns and Tiidus (10) and Enns et. al. (9) observed diminished beta-glucuronidase activity following downhill running in ovariectomized

rats supplemented with estrogen compared to a sham–supplemented group. Likewise, in a study examining the effects of hormone replacement therapy on exercise–induced muscle damage in postmenopausal women, those receiving estrogen demonstrated reduced markers of skeletal muscle damage compared to a control group (8).

In a well–controlled study by Kerksick et al. (16), experimental testing in females was restricted to the mid–luteal phase of the menstrual cycle when both estrogen and progesterone are elevated. The authors noted reduced perceptions of muscle soreness following damaging exercise in women vs. men, suggesting that estrogen may protect against exercise–induced muscle damage. However, no differences in lactate dehydrogenase or strength loss were observed between men and women, suggesting that estrogen may not influence these measures (16). Additionally, Markofski and Braun (21) studied the effects of menstrual cycle phase on markers of muscle damage and recovery and determined that the influence of estrogen levels on signs and symptoms of skeletal muscle damage is limited. It is possible that the relatively small difference in estrogen levels between women in the follicular vs. luteal phase of the menstrual cycle compared to estrogen concentrations in men vs. women accounted for these discrepancies. Alternatively, estrogen may not exert any observable influence on muscle damage or recovery.

Our results contradict previous reports of blunted exercise–induced muscle damage with elevated estrogen levels. With the exception of reduced residual pain in women compared to men, our data failed to demonstrate any significant sex–related differences in training recovery following an exhaustive resistance workout. In a critical review of the literature, Clarkson and Hubal (5) emphasized the importance of exercising caution when using creatine kinase as a reliable index of skeletal muscle damage. Increases in creatine kinase levels during exercise demonstrate substantial variability and, consequently, any observed differences between men and

women are not necessarily indicative of a sex–related effect (5). Similarly, studies examining exercise–induced muscle damage among pre–menarchial, menarchial, and post–menopausal women failed to demonstrate any differences among the groups, indicating that estrogen did not protect against muscle damage (5). Therefore, it is important to note that when more–reliable indicators of muscle damage are used to study the effects of estrogen on muscle damage, the protective effects associated with estrogen are diminished (32). In fact, when Warren et al. (32) used more–reliable measures of skeletal muscle injury following electrical stimulation of 150 maximal eccentric contractions, they noted greater muscle damage in estradiol–treated vs. estradiol–deficient mice.

Studies involving human participants have also reported diminished estrogen–associated protection against muscle injury when using advanced measures of muscle damage (27). Research by Stupka et al. (27) directly measured skeletal muscle injury following damaging eccentric exercise in men and women; muscle biopsy results showed no discernable differences in muscle damage or repair between the two groups.

Our study does not provide any direct or chemical measures of skeletal muscle damage. However, Hubal and Clarkson (15) reported that increased muscle pain and reduced performance are valid indicators of skeletal muscle damage. Thus, our finding of reduced residual pain in women compared to men suggests that muscle damage may have been attenuated in this group. Conversely, men and women experienced similar decreases in performance from the first to the second day of repetitions, suggesting that estrogen does not protect against muscle damage. Additionally, no differences in muscle pain during exercise were observed between men and women 24 h after damaging resistance exercise, suggesting that estrogen does not provide a

protective effect. Had women experienced attenuated muscle protein breakdown or advanced repair, reduced pain and RPE during subsequent exercise would be expected.

Similarly, no differences in performance–based recovery were observed when comparing men and women. Thus, even if blood or chemical measures had differed significantly, they would be of little practical application. Studies involving sample sizes in excess of 100 participants with the power to detect even small differences have demonstrated equal exercise–induced strength decrements and muscle soreness in men and women (15). Therefore, although persuasive evidence demonstrates a protective effect of estrogen against exercise–induced muscle damage, equally compelling evidence fails to support this notion; our data support the latter.

In summary, we studied sex differences in recovery from exhaustive resistance exercise in trained men and women. In contrast to our hypothesis, no differences in muscle pain, RPE, RPR, or performance–based recovery were observed between men and women. However, residual muscle pain was lower in women compared to men, indicating a potential protective effect of estrogen. Women demonstrated a significantly lower HR than men during both days of exercise. However, the lower HR observed in women 24 h after exhaustive resistance exercise likely does not reflect improved recovery compared to men. Overall, our results suggests that elevated estrogen levels in women compared to men are not associated with any practical differences in training recovery. However, further research is needed to understand the role of sex hormones on muscle damage, repair, and function following strenuous exercise.

PRACTICAL APPLICATIONS

Twenty-four hours of passive rest is insufficient for attaining full training recovery in both men and women. Additionally, because men and women recovery similarly after 24 h, coaches and physical therapists may establish similar recovery periods for their male and female athletes and clients. However, these results apply only to resistance-trained individuals not taking any dietary supplements or ergogenic aids.

REFERENCES

1. Amelink GJ and Bar PR. Exercise-induced muscle protein leakage in the rat. Effects of hormonal manipulation. *Journal of the neurological sciences* 76: 61-68, 1986.

2. Baechle TR and Earle RW. *Essentials of Strength Training and Conditioning.* Human Kinetics, 2008.

3. Baggett S, Wingo J, Richardson M, Curtner-Smith M, Leeper J, and Bishop P. Effects of branched-chain amino acids, beta-hydroxy-beta-methylbutyrate, and glutamine on recovery from resistance training. The University of Alabama, 2015.

4. Bar PR, Amelink GJ, Oldenburg B, and Blankenstein MA. Prevention of exercise-induced muscle membrane damage by oestradiol. *Life sciences* 42: 2677-2681, 1988.

5. Clarkson PM and Hubal MJ. Are women less susceptible to exercise-induced muscle damage? *Current opinion in clinical nutrition and metabolic care* 4: 527-531, 2001.

6. Dannecker E, Koltyn K, Riley 3rd J, and Robinson M. Sex differences in delayed onset muscle soreness. *The Journal of sports medicine and physical fitness* 43: 78-84, 2003.

7. Dannecker EA, Liu Y, Rector RS, Thomas TR, Fillingim RB, and Robinson ME. Sex differences in exercise-induced muscle pain and muscle damage. *The Journal of Pain* 13: 1242-1249, 2012.

8. Dieli-Conwright CM, Spektor TM, Rice JC, Sattler FR, and Schroeder ET. Hormone therapy attenuates exercise-induced skeletal muscle damage in postmenopausal women. *Journal of applied physiology* 107: 853-858, 2009.

9. Enns D, Iqbal S, and Tiidus P. Oestrogen receptors mediate oestrogen-induced increases in post-exercise rat skeletal muscle satellite cells. *Acta physiologica* 194: 81-93, 2008.

10. Enns DL and Tiidus PM. Estrogen influences satellite cell activation and proliferation following downhill running in rats. *Journal of applied physiology* 104: 347-353, 2008.

11. Gonzales JU and Scheuermann BW. Absence of gender differences in the fatigability of the forearm muscles during intermittent isometric handgrip exercise. *Journal of sports science & medicine* 6: 98-105, 2007.

12. Hausswirth C and Le Meur Y. Physiological and nutritional aspects of post-exercise recovery: specific recommendations for female athletes. *Sports medicine (Auckland, NZ)* 41: 861-882, 2011.

13. Henderson GC, Fattor JA, Horning MA, Faghihnia N, Johnson ML, Luke-Zeitoun M, and Brooks GA. Glucoregulation is more precise in women than in men during postexercise recovery. *The American journal of clinical nutrition* 87: 1686-1694, 2008.

14. Hubal and Clarkson. Counterpoint: Estrgen and sex do not significantly influence post-exercise indexes of muscle damage, inflammation, and repair- rebuttal. *Journal of applied physiology* 106: 1014-1015, 2009.

15. Hubal MJ and Clarkson PM. Counterpoint: Estrogen and sex do not significantly influence post-exercise indexes of muscle damage, inflammation, and repair. *Journal of applied physiology* 106: 1012-1014; discussion 1014, 1022, 2009.

16. Kerksick C, Taylor L, Harvey A, and Willoughby D. Gender-related differences in muscle injury, oxidative stress, and apoptosis. *Medicine+ Science in Sports+ Exercise* 40: 1772, 2008.

17. Komulainen J, Koskinen S, Kalliokoski R, Takala T, and Vihko V. Gender differences in skeletal muscle fibre damage after eccentrically biased downhill running in rats. *Acta physiologica scandinavica* 165: 57-64, 1999.

18. Kraemer WJ, Gordon SE, Fleck SJ, Marchitelli LJ, Mello R, Dziados JE, Friedl K, Harman E, Maresh C, and Fry AC. Endogenous anabolic hormonal and growth factor responses to heavy resistance exercise in males and females. *International Journal of Sports Medicine* 12: 228-235, 1991.

19. Kraemer WJ and Ratamess NA. Hormonal Responses and Adaptations to Resistance Exercise and Training. *Sports Medicine* 35: 339-361, 2005.

20. Mageean AL, Alexander RP, and Mier CM. Repeated Sprint Performance in Male and Female College Athletes Matched for VO2max Relative to Fat Free Mass. *International Journal of Exercise Science* 4: 229-237, 2011.

21. Markofski MM and Braun WA. Influence of menstrual cycle on indices of contraction-induced muscle damage. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 2014.

22. Mogil JS and Bailey AL. Sex and gender differences in pain and analgesia. *Prog Brain Res* 186: 141-157, 2010.

23. Perez-Gomez J, Rodriguez GV, Ara I, Olmedillas H, Chavarren J, González-Henriquez JJ, Dorado C, and Calbet JAL. Role of muscle mass on sprint performance: gender differences? *European Journal of Applied Physiology* 102: 685, 2008.

24. Racine M, Tousignant-Laflamme Y, Kloda LA, Dion D, Dupuis G, and Choinière M. A systematic literature review of 10years of research on sex/gender and experimental pain

perception–Part 1: Are there really differences between women and men? *Pain* 153: 602-618, 2012.

25. Sewright KA, Hubal MJ, Kearns A, Holbrook MT, and Clarkson PM. Sex differences in response to maximal eccentric exercise. *Medicine and science in sports and exercise* 40: 242-251, 2008.

26. Stocco DM and Clark BJ. Regulation of the Acute Production of Steroids in Steroidogenic Cells*. *Endocrine reviews* 17: 221-244, 1996.

27. Stupka N, Lowther S, Chorneyko K, Bourgeois J, Hogben C, and Tarnopolsky M. Gender differences in muscle inflammation after eccentric exercise. *Journal of applied physiology* 89: 2325-2332, 2000.

28. Tarnopolsky LJ, MacDougall JD, Atkinson SA, Tarnopolsky MA, and Sutton JR. Gender differences in substrate for endurance exercise. *Journal of applied physiology* 68: 302-308, 1990.

29. Tarnopolsky MA. Gender differences in metabolism; nutrition and supplements. *Journal Of Science And Medicine In Sport / Sports Medicine Australia* 3: 287-298, 2000.

30. Tiidus PM. Can estrogens diminish exercise induced muscle damage? *Canadian journal of applied physiology = Revue canadienne de physiologie appliquee* 20: 26-38, 1995.

31. Tiidus PM and Enns DL. Point:Counterpoint: Estrogen and sex do/do not influence post-exercise indexes of muscle damage, inflammation, and repair. *J Appl Phys* 106: 1014-1015, 2009.

32. Warren GL, Lowe DA, Inman CL, Orr OM, Hogan HA, Bloomfield SA, and Armstrong R. Estradiol effect on anterior crural muscles-tibial bone relationship and susceptibility to injury. *Journal of applied physiology* 80: 1660-1665, 1996.

33. Weber CL, Chia M, and Inbar O. Gender differences in anaerobic power of the arms and legs - A scaling issue. *Medicine and science in sports and exercise* 38: 129-137, 2006.

TABLES

Table 3.1. Training history and Participant Characteristics

Training History

	Participants (n)	Training (months)	Frequency (days/wk.)	Average session (min)
Total	28	40 (32)	4 (1)	71 (21)
Males	14	43 (36)	4 (1)	71 (18)
Females	14	38 (29)	4 (1)	71 (25)

Participant characteristics

	Participants (n)	Height (cm)	Weight (kg)	Age (y)
Total	28	171 (9)	72 (14)	22 (3)
Males	14	177 (7)	80 (14)	22 (3)
Females	14	166 (8)	64 (10)	22 (3)

Data are presented as means (SD).

Table 3.2. 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	Men	10 (2)	11 (2)	10 (2)	11 (2)	10 (2)	11 (1)	63 (7)
	Women	11 (2)	11 (2)	11 (1)	11 (2)	11 (2)	10 (1)	64 (5)
Day 2	Men	9 (2)	10 (2)	10 (2)	9 (2)	10 (3)	10 (1)	58 (8)
	Women	10 (2)	10 (2)	10 (2)	10 (2)	9 (1)	9 (3)	56 (10)

Data are reported as means (SD) for repetitions performed during the first set of each exercise.

Table 3.3. Residual pain (mm) and RPR (mm) Following Exhaustive Resistance Exercise and 24 h Passive Rest

	Residual muscle pain	Ratings of perceived recovery (RPR)
Men	50 (20)*	5 (2)
Women	31 (15)	6 (1)

*Significantly greater than in women. Data are presented as means (SD).

Table 3.4. Perceptual Responses to Resistance Exercise After 24 h Passive Rest

Day 1

		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Overall workout
Pain	Men	36 (24)	38 (21)	48 (20)	45 (20)	39 (21)	44 (21)	55 (18)
	Women	45 (19)	37 (21)	44 (18)	44 (21)	38 (15)	50 (16)	58 (18)
RPE	Men	55 (25)	55 (16)	53 (22)	61 (22)	60 (23)	64 (24)	69 (16)
	Women	58 (17)	52 (18)	58 (19)	57 (21)	50 (17)	60 (17)	67 (18)

Day 2

		Chest press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension	Overall workout
Pain	Men	47 (23)	43 (20)	49 (25)	51 (23)	47 (19)	50 (21)	62 (21)
	Women	46 (18)	41 (17)	43 (20)	43 (12)	43 (14)	51 (17)	56 (20)
RPE	Men	60 (18)	56 (21)	62 (18)	62 (18)	58 (16)	60 (20)	72 (16)
	Women	55 (15)	54 (20)	58 (21)	57 (14)	57 (18)	58 (16)	71 (17)

Data are presented as means (SD) for muscle pain and RPE using a 100-mm visual analog scale. No significant differences were present between men and women ($p > .05$).

Table 3.5. Heart Rate (bpm) in Men and Women During Resistance Exercise.

		Chest press	Latissimus Pull-down	Shoulder press	Leg press	Leg curl	Leg extension
Day 1	Men	150 (18)*	148 (14)*	150 (16)*	146 (15)	146 (16)*	140 (13)*
	Women	126 (12)	132 (16)	127 (15)	134 (15)	130 (12)	135 (15)
Day 2	Men	147 (19)*	146 (17)*	147 (17)*	146 (16)*	140 (13)†	147 (13)*
	Women	127 (16)	131 (17)	129 (12)	133 (13)	121 (32)	132 (15)

*Denotes significant difference between men and women ($P < .05$). †Denotes marginally-significant difference between men and women ($p = .05$). Data are presented as means (SD).

Table 3.6. Comparison of Exercise Load between Men and Women.

Absolute Load

	Chest Press	Latissimus pull-down	Shoulder press	Leg press	Leg curl	Leg extension
Men	*63 (12)	*54 (8)	*36 (19)	*212 (63)	*48 (13)	*53 (13)
Women	25 (3)	31 (4)	17 (14)	103 (15)	25 (3)	30 (6)
Load per kg Body Mass						
Men	*0.8 (0.1)	*0.7 (.1)	*0.4 (.1)	*2.7 (.8)	*0.6 (.1)	*0.7 (.2)
Women	0.4 (0.1)	0.5 (.1)	0.3 (.1)	1.6 (.2)	0.4 (.1)	0.5 (.1)

*Significantly greater than in women ($p < .001$). Data are presented as means (SD) for load (kg) lifted for each exercise.

APPENDIX

Baseline Testing Protocol

1. The participants will complete a warm up using a light load that they can easily lift for 15 repetitions for each of the following exercises: (a) Seated chest press, (b) Seated latissimus pull-down, (c) Seated shoulder press, (d) Leg press, (e) Hamstring curl, and (f) Seated knee extension.

2. Participants will estimate the load required to induce fatigue after 8 – 12 repetitions and will lift until momentary muscular failure or for 12 repetitions using this load.

3. If muscular failure was not achieved by the 12^{th} repetition, the load will be increased 2.3 to 5.6 kg (depending on the specific machine). If muscular failure was achieved prior to the 8^{th} repetition, then the load will be decreased by 2.3 to 5.6 kg.

4. The load will be adjusted accordingly until the participant achieves momentary muscular failure after 8 – 12 repetitions. This will be the baseline load for the participant. A 4-min rest period will separate each attempt.

5. A one-week washout period will be implemented after establishing the participant's baseline load.

Experimental Session Protocol

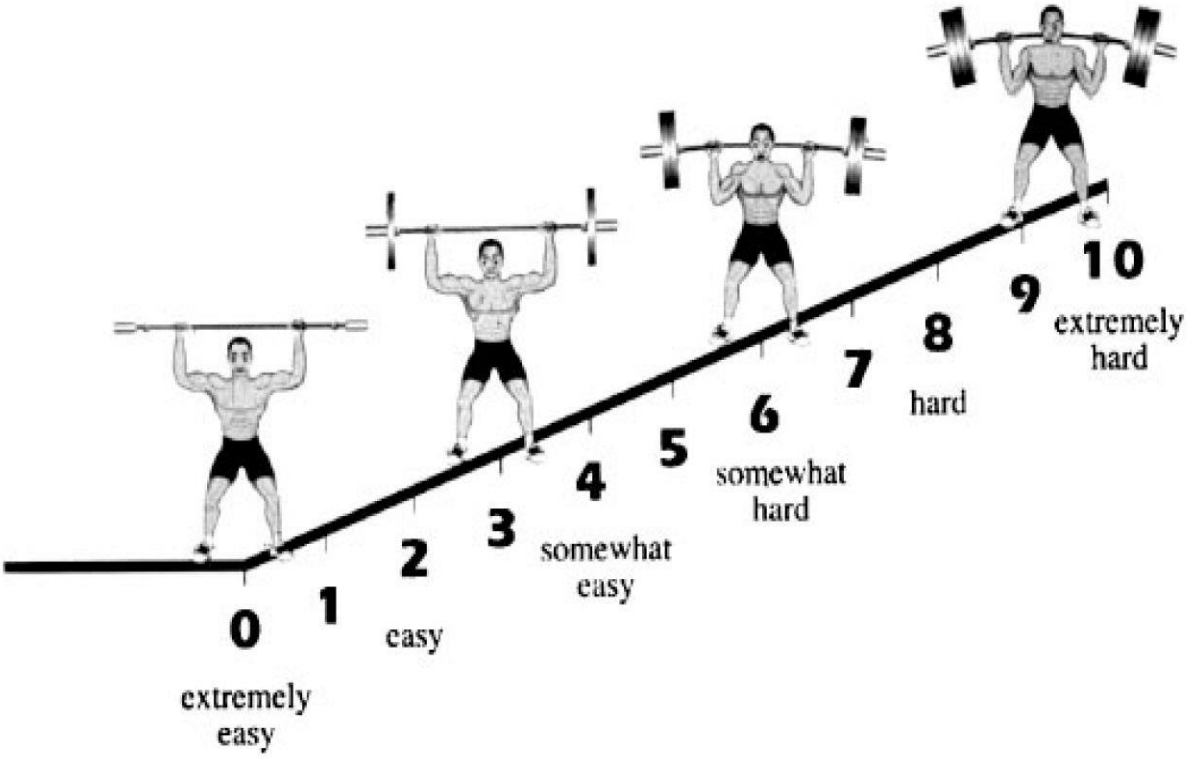
1. The sleep and nutritional history of the participant over the previous 24 h will be assessed.

2. Participants will complete 3 sets of 8 – 12 repetitions using the baseline load established for each exercise. Muscle pain and RPE will be assessed after each set, each exercise, and at the end of the workout. Muscle endurance will be measured as the number of repetitions performed.

3. Participants will return to the facility after 24 h. Perceived skeletal muscle pain, RPR, and sleep and nutritional history over the previous 24 h will be assessed.

4. The participants will then attempt to complete the same workout performed the previous day. Perceived muscle pain and RPE will be assessed after each set, each exercise, and at the end of the workout. Muscle recovery will be measured as the number of repetitions performed.

OMNI RPE Scale



Visual Analog Scale RPE

How hard is your exertion?

Extremely easy | Somewhat easy | Somewhat hard | Extremely hard

Extremely easy | Somewhat easy | Somewhat hard | Extremely hard

Extremely easy | Somewhat easy | Somewhat hard | Extremely hard

Extremely easy | Somewhat easy | Somewhat hard | Extremely hard

Extremely easy | Somewhat easy | Somewhat hard | Extremely hard

Extremely easy | Somewhat easy | Somewhat hard | Extremely hard

PERCEIVED SKELETAL MUSCLE PAIN

0 – 10 Pain scale

How much pain do you feel right now?

0 No pain at all

1 Very small amount of pain

2

3 Small amount of pain

4

5 Moderate amount of pain

6

7 Quite a bit of pain

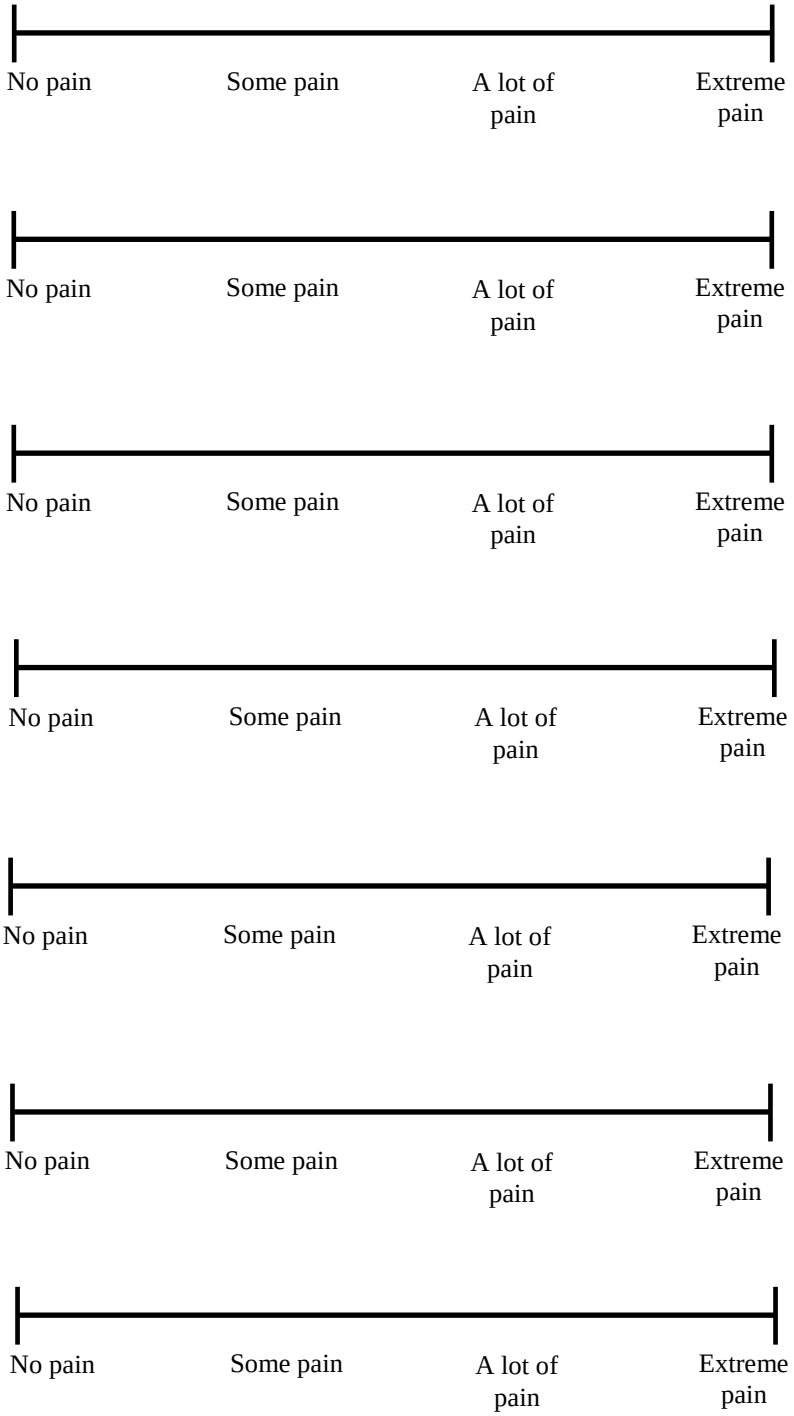
8

9 Extreme amount of pain

10 Very extreme amount of pain

Visual analog scale for skeletal muscle pain

How much pain do you feel right now?



PERCEIVED RECOVERY STATUS SCALE

Perceived Recovery Status Scale

10	Very well recovered / Highly energetic	Expect Improved Performance
9		
8	Well recovered / Somewhat energetic	
7		
6	Moderately recovered	Expect Similar Performance
5	Adequately recovered	
4	Somewhat recovered	
3		
2	Not well recovered / Somewhat tired	Expect Declined Performance
1		
0	Very poorly recovered/ Extremely tired	

Sleep and Nutritional History

ID _____
Date _____
Time _____

1. How many hours of sleep did you get last night? (please circle one)

   1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12

2. How many hours of sleep do you normally get? (please circle one)

   1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12

3. How many hours has it been since your last meal or snack? (please circle one)

   1 **1.5** 2 **2.5** 3 **3.5** 4 **4.5** 5 **5.5** 6 **6.5** 7 **7.5** 8 **8.5** 9 **9.5** 10 **10.5** 11 **11.5** 12 **12.5** 13 **13.5** 14 **14.5** 15

4. When did you last have:

   · a cup of coffee, tea, or caffeine? _____

   · cigarettes? _____

   · drugs (including aspirin)? _____

   · alcohol? _____

   · herbal/dietary supplements? _____

5. How many glasses of water or other beverages have you consumed in the last 24 hours?

   1 2 3 4 5 6 7 8 9 10 11 12 13 14

6. When did you last consume water or another beverage? _____How much? _____ (glasses)

7. What sort of physical activity did you perform yesterday?

8. What sort of physical activity have you performed today?

9. Describe your general feelings by checking one of the following:

_____excellent	_____good	_____very bad
_____very, very good	_____neither good nor bad	_____very, very bad
_____very good	_____bad	_____terrible

10. List all food and beverage items that you consumed yesterday:

Breakfast:

Lunch:

Dinner:

Other:

11. List all food and beverage items that you consumed today:

Breakfast:

Lunch:

Dinner:

Other:

Health Screening Questionnaire for Potential Healthy Subjects

Health History

HEALTH HABITS AND PERSONAL SAFETY	
ALL QUESTIONS CONTAINED IN THIS QUESTIONNAIRE ARE OPTIONAL AND WILL BE KEPT STRICTLY CONFIDENTIAL.	
Aerobic Exercise	☐ Sedentary (No exercise)
	☐ Mild exercise (i.e., climb stairs, walk 3 blocks, golf)
	☐ Occasional vigorous exercise (i.e., work or recreation, less than 4x/week for 30 min.)
Resistance Training	☐ No experience and not currently training (never resistance trained)
	☐ Some experience and not currently training (have trained in the past but not currently)
	☐ Currently Training (total body ≥ 2 days per week)

PERSONAL HEALTH HISTORY
Check if you have, or have had, any symptoms in the following areas to a significant degree and briefly explain.

☐	Allergies	☐	Chest Pain or Shortness of Breath	Briefly explain if you checked any boxes to the left:
☐	Arthritis	☐	Back Pain	
☐	Asthma	☐	Orthopedic Problems	
☐	Diabetes	☐	Recent Surgery	
☐	Dizziness	☐	High Blood Pressure	
☐	Epilepsy	☐	Dysmenorrhea (females only)	
☐	Migraines	☐	Pregnant* (currently)	

**If you should become pregnant during the term of which the class is in session, please inform the instructor so that your exercise can be modified appropriately. A physician's consent is encouraged for continued participation.*

List your prescribed drugs or medications you take on a regular basis		
Name the Drug	Reason	Frequency Taken

Please check the box below to state you are have answered all of the questions above to the best of your knowledge and wish to participate in the physical activity requirements of the class.			
☐	Print Name:	Signature:	Date:

Physical Activity Readiness Questionnaire (Par-Q)

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____ DATE _____

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority) _____ WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

CSEP | SCPE

EXERCISE HISTORY QUESTIONNAIRE

1. Over the past **3 months**, how many **training sessions per week** have you completed for each of the following muscle groups?

Chest____ Shoulders____ Abdomen____ Back ____ Hips ____ Legs ____ Arms____

2. Over the past **3 months**, how many **sets per week** have you completed for each of the following muscle groups?

Chest____ Shoulders____ Abdomen____ Back ____ Hips ____ Legs ____ Arms____

3. Over the past **3 months**, how many **repetitions per set** have you completed for each of the following muscle groups?

Chest____ Shoulders____ Abdomen____ Back ____ Hips ____ Legs ____ Arms____

4. How long have you been training?

_____ months _____ years

5. How long is your typical workout?

_____ minutes per session

Consent to Participate in a Research Study

Study Title: *Influence of Branched-chaim Amino Acids, Beta-hydroxy-beta-methylbutyrate, and Glutamine on Muscle Pain and Recovery in Trained Men and Women*

Principal Investigator: Sara A. Baggett, MA
Graduate Student
Department of Kinesiology

Faculty Sponsor: Phillip A. Bishop, EdD
Professor
Department of Kinesiology

You are being asked to take part in a research study.

This study is titled *Influence of Branched-chaim Amino Acids, Beta-hydroxy-beta-methylbutyrate, and Glutamine on Muscle Pain and Recovery in Trained Men and Women.* It is part of a larger study titled *"Resistance Training and Recovery: Influence of Dietary Supplements, Combined Treatment Therapies, and Gender."* The study is being done by Sara A. Baggett, a Doctoral Student at The University of Alabama. She is under the supervision of Dr. Phillip A. Bishop, a professor at The University of Alabama. Part of this study is funded by a private company. Ms. Baggett is not receiving extra compensation from this funding, but Dr. Bishop may.

What is this study about?
This study has three parts. You are being asked to participate in the first part (Part I), which is being done to find out if taking branched-chain amino acids, beta-hydroxy-beta-methylbutyrate, and glutamine can help with recovery after a weight-lifting workout. Part II is titled "*The Effect of a Combined Anti-inflammatory and Nutritional Treatment on Muscle Pain and Endurance in Trained Men and Women*," and is being done to find out if a combination of treatments can improve recovery after a weight-lifting workout. Part III is titled "*Skeletal Muscle Recovery from Resistance Exercise in Men and Women*," and is being done to find out if men and women respond the same to 24 hours of rest after a weight-lifting workout. The information from this study is important because it could be used to help athletes better to recover from exercise and to improve their performance.

Why have I been asked to take part in this study?
You have been asked to be in this study because you are healthy, physically active, and able to perform the tasks that will let us measure the values we need.

How many people will be in this study?
A total of 16 people will be in this part (Part I) of the study. Part II will have 16 participants and Part III will have 20 participants.

Please Initial

Visit 1_____ Visit 2_____ Visit 3_____ Visit 4_____ Visit 5_____

What will I be asked to do in the study?
You will do things in the following order.

1. You will fill out a survey of your past and current health. Based on this survey, if you qualify and agree to take part, you will be asked to perform certain tasks.

2. We will obtain your age, height, and weight.

3. You will then complete six different exercises. These exercise include: (a) Seated chest press, (b) Seated shoulder press, (c) Seated latissimus pull-down, (d) Hip extension (leg press), (e) Knee flexion (leg curl), and (f) Seated knee extension (leg extension).

4. Each exercise will start with a 15-repetition warm up using a light load.

5. After the warm up, you will estimate a load that will allow you to perform the exercise at least 8 times, but no more than 12 times to momentary fatigue. You will then lift until you cannot complete the lift the right way.

6. If you could not lift the weight at least 8 times, then you will attempt to do so again using a lighter weight and after resting for 4 minutes. If you could perform more than 12 repetitions, then you will rest for 4 minutes before performing the exercise again with a heavier load.

7. We will continue to adjust the weight until we find the load that allows you to correctly perform at least 8, but no more than 12 repetitions. If it takes more than 3 tries to identify your proper weight for a lift, measurements for that lift will be rescheduled at your convenience.

8. You will then rest for one week. You will be asked not to do any exercise that is very tiring during this time.

9. You will then return to the Aquatics Center. You will consume one dose of a branched-chain amino acid plus glutamine supplement or a placebo one (1) hour before you come in. You will also consume one dose of a beta-hydroxy-beta-methylbutyrate supplement or a placebo thirty (30) minutes before you come in. These supplements will have been given to you with instructions following the baseline visit.

10. You will then complete 3 sets of 8 – 12 repetitions each for all of the same exercises that you did before. You will be asked about your feelings of pain and effort after each set, after each exercise, and after you finish the workout.

11. You will be given a second dose of branched-chain amino acids plus glutamine or placebo and will be asked to consume the supplements right away. You will also be

Please Initial

Visit 1_____ Visit 2_____ Visit 3_____ Visit 4_____ Visit 5_____

given two doses of beta-hydroxy-beta-methylbutyrate or placebo with instructions to consume one supplement after resting for two (2) hours and consume the other after resting for six (6) hours. Neither you nor I will know which is treatment and which is placebo.

11. You will then rest for 24 hours.

12. You will return to the Aquatics Center after 24 hours. We will give you a heart rate monitor, which you will place on yourself according to the instructions we give you. You will be asked about how recovered you feel on a scale of 0 – 10 and by placing a mark on a 10-cm line. You will also be asked about how energetic you feel and about your sleep and nutritional history over the last 24 hours.

13. You will then attempt to complete the same workout that you did the day before. You will be asked about your feelings of pain and effort after each set, exercise, and after the workout.

14. You will rest for one week. During this time, you will be asked not to do any exercise that makes you feel very tired.

15. After resting for one week, you will repeat steps 9 – 13, but under the opposite condition. You will not know which condition (treatment or placebo) you are receiving.

How long will each visit last?
Each visit will last about 1 – 1.5 hours.

Will I receive money to be in this study?
You will not be compensated for participating in this study.

Will being in this study cost me money?
Being in this study will not cost you anything other than your time and travel cost for getting to and from the testing place.

Can the researcher take me out of the study?
The study staff may take you out of the study if they feel that something happened that means you no longer meet the study requirements, or if you cannot follow study directions.

What are the benefits (good things) that may happen to me if I am in the study?
You will learn about your personal recovery response after a workout. You will know if this experimental recovery method had a good, bad, or no effect on your performance.

What are the benefits to scientists or society?
The results of this study will tell us if the treatment can really help exercisers recover better after a workout. This is important because not recovering enough can hurt your ability to get the most

out of your workout. We want to use these results to help come up with the best way to recovery and get more benefits from a workout.

What are the risks (dangers or harms) to me if I am in the study?
All exercise can be dangerous, including lifting weights. The exercise that we are asking you to do is likely to cause a normal and safe level of discomfort that should go away soon after stopping the exercise.

How will the risks be minimized?
Risks will be minimized by:

- Only allowing you to participate in the study if you are healthy
- Only allowing to you participate if you are a trained weight lifter
- Stopping a test if you show any signs of illness

Someone trained in CPR will be present for all trials, and we are only 5 minutes from a hospital if an emergency occurs. In the event an injury occurs, treatment will be available, including first aid and emergency treatment as needed. Beyond first aid, care for such injuries will be billed in the ordinary manner to you or your insurance company. Neither the Principal Investigator nor the University of Alabama has made provision for payment of costs associated with any injury resulting from being in this study. You will be informed if significant new findings arise, that might affect your willingness to continue in the study.

How will my privacy be protected?
Your privacy will be protected by asking you any medical-related questions in a private room or at a site of your choosing. Medically related information collected about you will not have your name on it.

How will my confidentiality be protected?
Information about you will be kept confidential. Your medical information will be kept in a locked office and for only the duration of the study. No data sheet with your information will have your name on it. Only study personnel will have access to your information and data.

What are my alternatives to being in this study? Do I have other choices?
The other choice is to not take part in the study.

What are my rights as a participant in this study?
To be in this study is voluntary. It is your free choice. You can refuse to be in the study. If you start the study, you can stop at any time for any reason. There will be no negative result on your relations with The University of Alabama.

The University of Alabama Institutional Review Board (IRB) is the committee that protects the rights of people in research studies. The IRB may review study records from time to time to be sure that people in research studies are being treated fairly and that the study is being carried out as planned.

Please Initial

Visit 1_____ Visit 2_____ Visit 3_____ Visit 4_____ Visit 5_____

Who do I call if I have questions or problems?
If you have questions about the study right now, please ask them. If you have questions about the study later on, please call the investigator, Sara Baggett, at 850-418-1179, or her faculty advisor, Dr. Phillip A. Bishop, at 205-348-8370. If you have questions about your rights as a person taking part in a research study, you may call Ms. Tanta Myles, the Research Compliance Officer of the University at 205-348-8461 or toll-free at 1-877-820-3066.
You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach Website at **http://osp.ua.edu/site/PRCO_Welcome.html**. You may email us at **participantoutreach@bama.ua.edu**.

After you participate, you are encouraged to complete the survey for research participants that is online at the outreach website or you may ask the investigator for a copy of it and mail it to the University of Alabama Office for Research Compliance, Box 870127, 358 Rose Administration Building, Tuscaloosa, AL 35487-0127.

I have read this consent form. I have had an opportunity to ask questions. I understand what I will be asked to do. I freely agree to take part in the study. I will receive a copy of this consent form to keep.

_____ _____
Signature of Research Participant Date

_____ _____
Investigator Date

_____ _____
Witness Date

UNIVERSITY OF ALABAMA IRB
CONSENT FORM APPROVED: 12-22-14
EXPIRATION DATE: 11-13-15

Please Initial

Visit 1_____ Visit 2_____ Visit 3_____ Visit 4_____ Visit 5_____

Consent to Participate in a Research Study

Study Title: The Effect of a Combined Anti-inflammatory and Nutritional Treatment on Muscle Pain and Endurance in Trained Men and Women

Principal Investigator: Sara A. Baggett, MA
Graduate Student
Department of Kinesiology

Faculty Sponsor: Phillip A. Bishop, EdD
Professor
Department of Kinesiology

You are being asked to take part in a research study.

This study is titled *The Effect of a Combined Anti-inflammatory and Nutritional Treatment on Muscle Pain and Endurance in Trained Men and Women.* It is part of a larger study titled *"Resistance Training and Recovery: Influence of Dietary Supplements, Combined Treatment Therapies, and Gender."* It is part of a larger study titled *"Resistance Training and Recovery: Influence of Dietary Supplements, Combined Treatment Therapies, and Gender."* The study is being done by Sara A. Baggett, a Doctoral Student at The University of Alabama. She is under the supervision of Dr. Phillip A. Bishop, a professor at The University of Alabama. Part of this study is funded by a private company. Ms. Baggett is not receiving extra compensation from this funding, but Dr. Bishop may.

What is this study about?
This study has three parts. You are being asked to participate in the second part (Part II), which is being done to find out if a combination of treatments can improve recovery after a weight-lifting workout. Part I is titled "*Influence of Branched-chaim Amino Acids, Beta-hydroxy-beta-methylbutyrate, and Glutamine on Muscle Pain and Recovery in Trained Men and Women,*" and is being done to find out if taking branched-chain amino acids, beta-hydroxy-beta-methylbutyrate, and glutamine can help with recovery after a weight-lifting workout. Part III is titled "*Skeletal Muscle Recovery from Resistance Exercise in Men and Women,*" and is being done to find out if men and women respond the same to 24 hours of rest after a weight-lifting workout. The information from this study is important because it could be used to help athletes to recover from exercise and to improve their performance.

Why have I been asked to take part in this study?
You have been asked to be in this study because you are healthy, physically active, and able to perform the tasks that will let us measure the values we need.

How many people will be in this study?
A total of 16 people will be in this part (Part II) of the study. Part I will have 20 people and Part III will have 20 people (10 males and 10 females).

What will I be asked to do in the study?
You will do things in the following order.

1. You will fill out a survey of your past and current health. Based on this survey, if you meet our needs and agree to take part, you will be asked to perform certain tasks.

2. We will obtain your age, height, and weight.

3. You will then complete six different exercises. These exercise include: (a) Seated chest press, (b) Seated shoulder press, (c) Seated latissimus pull-down, (d) Hip extension (leg press), (e) Knee flexion (leg curl), and (f) seated knee extension (leg extension).

4. Each exercise will start with a 15-repetition warm up using a light load.

5. After the warm up, you will estimate a load that will allow you to perform the exercise at least 8 times, but no more than 12 times to momentary fatigue. You will then lift until you cannot complete the lift the right way.

6. If you could not lift the weight at least 8 times, then you will attempt to do so again using a lighter weight and after resting for 4 minutes. If you could perform more than 12 repetitions, then you will rest for 4 minutes before performing the exercise again with a heavier load.

7. We will continue to adjust the weight until we find the load that allows you to correctly perform at least 8, but no more than 12 repetitions until momentary fatigue. You will then lift until you cannot complete the lift the right way. If it takes more than 3 tries to identify your proper weight for a lift, that lift will be rescheduled at your convenience.

8. You will then rest for one week. You will be asked not to do any exercise that is very tiring during this time.

9. You will then return to the Aquatics Center. We will ask you about your sleep and nutrition history over the last 24 hours.

10. You will then complete 3 sets of 8 – 12 repetitions each for all of the same exercises that you did before. You will be asked about your feelings of pain and effort after each set, after each exercise, and after you finish the workout.

11. You will be given one of two treatment combinations. We will not know which treatment you are receiving.

12. You will then rest for 24 hours.

13. You will return to the Aquatics Center after 24 hours. You will be asked about how recovered you feel on a scale of 0 – 10 and by placing a mark on a 10 – cm line. You will also be asked about your sleep and nutritional history over the last 24 hours.

14. You will then attempt to complete the same workout that you did the day before. You will be asked about your feelings of pain and effort after each set, exercise, and after the workout.

15. You will rest for one week. During this time, you will be asked not to do any exercise that makes you feel very tired.

16. After resting for one week, you will repeat steps 9 – 14, but will be given the opposite treatment.

How long will each visit last?
Each visit will last about 1 hour.

Will I receive money to be in this study?
You will not receive any money to be in this study.

Will being in this study cost me money?
Being in this study will not cost you anything other than your time and travel cost for getting to and from the testing place.

Can the researcher take me out of the study?
The study staff may take you out of the study if they feel that something happened that means you no longer meet the study requirements, or if you cannot follow study directions.

What are the benefits (good things) that may happen to me if I am in the study?
You will learn about your personal response to different recovery methods after a workout. You will know if each recovery method had a good, bad, or no effect on your performance.

What are the benefits to scientists or society?
The results of this study will tell us if the treatment can really help exercisers recover better after a workout. This is important because not recovering enough can hurt your ability to get the most out of your workout. We want to use these results to come up with the best way to recovery and get more benefits from a workout.

What are the risks (dangers or harms) to me if I am in the study?
All exercise can be dangerous, including lifting weights. The exercise that we are asking you to do is likely to cause a normal and safe level of discomfort that should go away soon after stopping the exercise.

How will the risks be minimized?
Risks will be minimized by:

- Only allowing you to participate in the study if you are healthy

- Only allowing to you participate if you are a trained weight lifter
- Stopping a test if you show any signs of illness

Someone trained in CPR will be present for all trials, and we are only 5 minutes from a hospital if an emergency occurs. In the event an injury occurs, treatment will be available, including first aid and emergency treatment as needed. Beyond first aid, care for such injuries will be billed in the ordinary manner to you or your insurance company. Neither the Principal Investigator nor the University of Alabama has made provision for payment of costs associated with any injury resulting from being in this study. You will be informed if significant new findings arise, that might affect your willingness to continue in the study.

How will my privacy be protected?
Your privacy will be protected by asking you any medical-related questions in a private room or at a site of your choosing. Medically related information collected about you will not have your name on it.

How will my confidentiality be protected?
Information about you will be kept confidential. Your medical information will be kept in a locked office and for only the duration of the study. No data sheet with your information will have your name on it. Only study personnel will have access to your information and data.

What are my alternatives to being in this study? Do I have other choices?
The other choice is to not take part in the study.

What are my rights as a participant in this study?
To be in this study is voluntary. It is your free choice. You can refuse to be in the study. If you start the study, you can stop at any time for any reason. There will be no negative result on your relations with The University of Alabama.

The University of Alabama Institutional Review Board (IRB) is the committee that protects the rights of people in research studies. The IRB may review study records from time to time to be sure that people in research studies are being treated fairly and that the study is being carried out as planned.

Who do I call if I have questions or problems?
If you have questions about the study right now, please ask them. If you have questions about the study later on, please call the investigator, Sara Baggett, at 850-418-1179, or her faculty advisor, Dr. Phillip A. Bishop, at 205-348-8370. If you have questions about your rights as a person taking part in a research study, you may call Ms. Tanta Myles, the Research Compliance Officer of the University at 205-348-8461 or toll-free at 1-877-820-3066.

You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach Website at **http://osp.ua.edu/site/PRCO_Welcome.html**. You may email us at **participantoutreach@bama.ua.edu**.

UNIVERSITY OF ALABAMA IRB
CONSENT FORM APPROVED: 12-22-14
EXPIRATION DATE: 11-13-15

After you participate, you are encouraged to complete the survey for research participants that is online at the outreach website or you may ask the investigator for a copy of it and mail it to the University of Alabama Office for Research Compliance, Box 870127, 358 Rose Administration Building, Tuscaloosa, AL 35487-0127.

I have read this consent form. I have had an opportunity to ask questions. I understand what I will be asked to do. I freely agree to take part in the study. I will receive a copy of this consent form to keep.

Signature of Research Participant	Date
Investigator	Date
Witness	Date

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Consent to Participate in a Research Study

Study Title: Skeletal Muscle Recovery from Resistance Exercise in Men and Women.

Principal Investigator: Sara A. Baggett, MA
Graduate Student
Department of Kinesiology

Faculty Sponsor: Phillip A. Bishop, EdD
Professor
Department of Kinesiology

You are being asked to take part in a research study.

This study is titled *Skeletal Muscle Recovery from Resistance Exercise in Men and Women.* It is part of a larger study titled *"Resistance Training and Recovery: Influence of Dietary Supplements, Combined Treatment Therapies, and Gender."* The study is being done by Sara A. Baggett, a Doctoral Student at The University of Alabama. She is under the supervision of Dr. Phillip A. Bishop, a professor at The University of Alabama. Part of this study is funded by a private company. Ms. Baggett is not receiving extra compensation from this funding, but Dr. Bishop may.

What is this study about?
This study has three parts. You are being asked to participate in the third part (Part III), which is being done to find out if men and women respond the same to 24 hours of rest after a weight-lifting workout. Part I is titled "*Influence of Branched-chaim Amino Acids, Beta-hydroxy-beta-methylbutyrate, and Glutamine on Muscle Pain and Recovery in Trained Men and Women,*" and is being done to find out if taking branched-chain amino acids, beta-hydroxy-beta-methylbutyrate, and glutamine can help with recovery after a weight-lifting workout. Part II is titled "*The Effect of a Combined Anti-inflammatory and Nutritional Treatment on Muscle Pain and Endurance in Trained Men and Women,*" and is being done to find out if a combination of treatments can improve recovery after a weight-lifting workout. The information from this study is important because it could be used to help athletes to recover from exercise and to improve their performance.

Why have I been asked to take part in this study?
You have been asked to be in this study because you are healthy, physically active, and able to perform the tasks that will let us measure the values we need.

How many people will be in this study?
A total of 20 people (10 males and 10 females) will complete this part (Part III) of the study. Part I will have 20 people and Part II will have 16 people.

What will I be asked to do in the study?
You will do things in the following order.

1. You will fill out a survey of your past and current health. Based on this survey, if you meet our needs and agree to take part, you will be asked to perform certain tasks.

2. We will obtain your age, height, and weight.

3. You will then complete six different exercises. These exercise include (a) Seated chest press, (b) Seated shoulder press, (c) Seated latissimus pull-down, (d) Hip extension (leg press), (e) Knee flexion (leg curl), and (f) seated knee extension (leg extension).

4. Each exercise will start with a 15-repetition warm up using a light load.

5. After the warm up, you will estimate a load that will allow you to perform the exercise at least 8 times, but no more than 12 times to momentary fatigue. You will then lift until you cannot complete the lift the right way.

6. If you could not lift the weight at least 8 times, then you will attempt to do so again using a lighter weight and after resting for 4 minutes. If you could perform more than 12 repetitions, then you will rest for 4 minutes before performing the exercise again with a heavier load.

7. We will continue to adjust the weight until we find the load that allows you to correctly perform at least 8, but no more than 12 repetitions. If it takes more than 3 tries to identify your proper weight for a lift, that lift will be rescheduled at your convenience.

8. You will then rest for one week. You will be asked not to do any exercise that is very tiring during this time.

9. You will then return to the Aquatics Center. We will ask you about your sleep and nutrition history over the last 24 hours.

10. You will then complete 3 sets of 8 – 12 repetitions each for all of the same exercises that you did before. You will be asked about your feelings of pain and effort after each set, after each exercise, and after you finish the workout. We are not testing the effect of any treatment methods with this study, so no treatment will be given.

11. You will then rest for 24 hours.

12. You will return to the Aquatics Center after 24 hours. You will be asked about how recovered you feel on a scale of 0 – 10 and by placing a mark on a 10 – cm line. You will also be asked about your sleep and nutritional history over the last 24 hours.

14. You will then attempt to complete the same workout that you did the day before. You will be asked about your feelings of pain and effort after each set, exercise, and after the workout.

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What are the benefits to scientists or society?
The results of this study will tell us if men and women differ in their response to 24 hours of rest after a hard workout. This is important because not recovering enough can hurt your ability to get the most out of your workout. We want to use these results to come up with the best way for men and women to recovery and get more benefits from a workout.

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Someone trained in CPR will be present for all trials, and we are only 5 minutes from a hospital if an emergency occurs. In the event an injury occurs, treatment will be available, including first aid and emergency treatment as needed. Beyond first aid, care for such injuries will be billed in the ordinary manner to you or your insurance company. Neither the Principal Investigator nor the University of Alabama has made provision for payment of costs associated with any injury resulting from being in this study. You will be informed if significant new findings arise, that might affect your willingness to continue in the study.

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