RECOVERY FOLLOWING AN EXTREME CONDITIONING PROGRAM WORKOUT:

INFLUENCE OF TIME, ELECTROSTIMULATION,

AND DIETARY SUPPLEMENTATION

by

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ABSTRACT

Essential to training is optimal recovery. Insufficient recovery may lead to decrement in physiological and psychological status, resulting in decreased performance and potentially overtraining. Thus, investigating an appropriate time course of recovery and recovery enhancement methods are of value. Extreme Conditioning Programs (ECP) are metabolically and physically demanding forms of training that incorporate regular variation in exercises, high intensity, and high volume with minimal prescribed rest. There is currently no research evaluating recovery following an ECP workout. Three studies were conducted to evaluate recovery duration and enhancement methods following an ECP workout. In the first study, 24-hour (R24) and 48-hour (R48) recovery were evaluated in nine trained males following an ECP workout by assessment of a pre-workout performance battery (PRI) and a post-recovery PRI. The PRI consisted of a sit-and-reach test, shoulder reach flexibility test, countermovement jump (CMJ), bench press bar velocity and power, seated medicine ball toss, 1-minute push-up test, 250 m rowing ergometer test, and perceptual markers. Additionally, a composite recovery score (z-score of six PRI metrics) was developed for each study. The second study evaluated 30 minutes of upper-body low-frequency electrical stimulation (LFES), trained males (n = 9), as a strategy to enhance recovery following an ECP workout by assessment of a pre-workout PRI and PRI 24-hours post workout. In a similar design, study three evaluated the combination of branch chain amino acids (BCAA) and beta-hydroxy-beta-methylbutyrate (HMB) as a recovery strategy in ten trained males following an ECP workout. A placebo of sugar-free candy was used as a control in studies 2 and 3. Findings from study one indicated a significant decrement of the composite recovery score, performance of the CMJ, and bar velocity as well as increased perception of muscle pain at R24. However, only perception of muscle pain was altered at R48. Thus, R48 was a sufficient recovery duration and allowed restoration of performance following the ECP workout. Studies two and three had similar results, the recovery strategies did not attenuate the decrement in performance and alterations of perception associated with the ECP workout. Future research should explore recovery following differing ECP durations and modalities.

LIST OF ABBREVIATIONS AND SYMBOLS

bpm	Beats per minute
CMJ	Countermovement jump
ECP	Extreme conditioning program
LFES	Low-frequency electrical stimulation
PRI	Performance recovery indicator
RPR	Rating of perceived recovery

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INTRODUCTION

In order to maximize training and adaptations individuals must expose themselves to physiological and psychological overload. Thus, an efficient training program which improves performance will also likely induce acute fatigue. Although most adaptations from training occur during the recovery period (6), much of the research has focused on training methods with less investigation on recovering from the induced fatigue. The recovery period must be adequate, both in duration and quality, to promote complete repair of damages from training and allow an individual to return to baseline (restoring homeostasis) prior to subsequent training sessions (4). In addition, insufficient recovery following training or competition may lead to premature fatigue, decrements to performance, less resistance to future physical and psychological stress, and increased risk of overtraining (2, 4).

In a broad sense, recovery can be thought as encompassing three major components – 1) immediate recovery, 2) short-term recovery, and 3) training recovery (4). Immediate recovery refers to the time period between consecutive muscle contractions. Short-term recovery is defined as the duration between consecutive sets within a multi-bout training session. Training recovery is the time between successive sessions or events within competition. Except for periods of intentional overreaching, training recovery must lead to restoration of the physiological and psychological systems to allow for adaptation to training loads and a reduced risk of overtraining. As a result, it is necessary to examine an appropriate time course of recovery following various forms of physical activity. In addition, evaluation of methods to enhance training recovery is of value in potentially reducing the time required for complete training recovery, thus, allowing an individual to return to the training program in a shorter time period.

Recently, many high intensity training (HIT) programs have become increasingly popular. These programs are novel in that they incorporate components of traditional HIT and high intensity interval training (HIIT) with resistance training concepts and equipment as well as Olympic lifting, functional movement training, gymnastics, and bodyweight training. In 2010 an effort was made to delineate these new forms of HIT by coining the phrase "Extreme Conditioning Programs" (ECP) (3). ECPs typically consist of the aforementioned modalities performed at high intensities with little or no rest between sets. Although little research has been performed evaluating ECPs, it has been shown that these programs are metabolically and physically highly demanding, often resulting in maintenance of "vigorous intensity" (85% HR max or higher) throughout the workout (1, 5, 7, 9). Furthermore, it is well established that exercise poses challenges to the maintenance of homeostasis and disturbance is amplified as intensity increases (8). Thus, the nature of ECPs (highly intense with minimal rest during exercise) could result in excessive physiological strain and as a result research evaluating recovery following an ECP workout is needed.

The purpose of the following three studies was to investigate both the time course of recovery and two strategies to enhance recovery following an acute ECP workout. Time course of recovery was evaluated at 24-hours (R24) and 48-hours (R48) following a full-body, bodyweight ECP workout. The two methods to enhance recovery assessed were low-frequency electrical stimulation (LFES) and combined supplementation of branch chain amino acids (BCAA) and beta-hydroxy-beta-methylbutyrate (HMB) after completing an upper-body focused, bodyweight ECP workout. Recovery was assessed by completion of baseline performance and perceptual parameters and follow-up of those parameters following the respective training recovery duration with treatments and placebo.

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STUDY I

TIME COURSE OF RECOVERY IN TRAINED INDIVIDUALS FOLLOWING AN EXTREME CONDITIONING PROGRAM WORKOUT

Abstract

Increasing in popularity, Extreme Conditioning Programs (ECP) are metabolically and physically demanding forms of training. ECPs typically incorporate regular variation in exercise mode, high intensity, and high volume with short, or no, prescribed rest periods between sets. Without appropriate training recovery, performing these workouts on consecutive days could be overly demanding leading to performance decrements or overtraining. Despite their popularity, no research is available evaluating appropriate time course of recovery following an acute bout of ECP. The purpose of this study was to evaluate time course of recovery at 24-hours (R24) and 48-hours (R48) after an ECP workout. Nine well-trained and ECP experienced participants (age 22 ± 4) completed a baseline performance battery (PRI) of a sit-and-reach test, shoulder reach flexibility test, maximal countermovement jump, 3-repetition bench press assessing bar velocity and power, seated medicine ball toss, 1-minute push-up test, 250m rowing ergometer test, and perception of muscle pain and recovery, followed by a single ECP workout. Participants returned at R24 and R48 (counterbalanced) to assess performance change via completion of the PRI and perceptual markers. Additionally, a composite recovery score was calculated (z-score of six PRI metrics). A repeated measures ANOVA revealed a significant decrement of the composite recovery score (0.76 ± 3.01 vs R24 -1.48 ± 2.41; $p = 0.004$), CMJ (67.6 ± 4.3 vs R24 65.4 ± 4.6;

p = 0.01), mean concentric bar velocity (0.63 ± 0.061 vs R24 0.59 ± 0.053; p = 0.018), and increased perception of muscle pain (0-100mm scale) (11.2 ± 13.1 vs R24 34.4 ± 21.9; p = 0.002) at R24. However, only perception of muscle pain was altered at R48 (8.7 ± 6.5 vs R48 34.7 ± 30.5; p = 0.031). Analysis of individual data indicated that based on the composite recovery score, 4 of 9 participants were not recovered at R24. Additionally, at R24 two participants had a decrement in the CMJ, peak bar power, and seated medicine ball toss. However, all participants were recovered with no performance decrements at R48. These findings indicate that 48-hours was sufficient recovery following this ECP workout. However, individual time course of recovery should be monitored to insure optimal prescription of exercise.

Key Words: extreme conditioning programs, high intensity training, training recovery

Introduction

Due to the recent popularization of many high-intensity training programs, a 2010 collaborative effort by the Consortium for Health and Military Performance (CHAMP) and the American College of Sports Medicine (ACSM) coined the phrase “Extreme Conditioning Programs” (ECP) as a change in nomenclature from high intensity training (3). ECPs are multifaceted routines that include components of resistance training, Olympic lifting, bodyweight training, functional movement training, and circuit training. Additionally, ECPs are typically characterized by a high number of repetitions and high training intensities with short, or no, prescribed rest periods between sets (3). Because of these training protocols, each workout can be metabolically and physically highly demanding.

Much of the allure of ECPs is the perceived ability to train multiple fitness domains (muscular strength, muscular endurance, cardiorespiratory, etc.) and induce a high caloric expenditure within one relatively short (~20-30 minutes) workout period. This goal for ECPs is supported by some research (1, 12, 15, 21, 30, 31). Although the current literature evaluating the acute physiological responses to ECPs is limited, the research available does indicate that many ECPs would be classified as “vigorous” intensity based on ACSM guidelines (1, 10, 21, 22, 31). The nature of this demanding form of conditioning (highly intense with minimal rest during exercise) could result in excessive physiological strain. When performed over consecutive days, various physiological systems may be extensively taxed without appropriate recovery, potentially leading to performance decrement or, overtraining.

The primary action of training recovery is to resolve the major causes of fatigue or muscle damage (4). Additionally, to allow for appropriate adaptations to training overload an optimal training recovery period should be employed allowing an individual to return to baseline (restoring homeostasis) prior to subsequent sessions (4). Thus, ensuring optimal recovery from any type of physical activity is an integral component of training, and insufficient recovery may lead to early fatigue, less resistance to subsequent physical strain, deleterious effects on performance, and potential for increased risk of injury and overtraining (3, 4, 24). As a result of the great physical demands placed upon the individual during high-intensity exercise, there may be high levels of fatigue following an ECP workout (3, 20, 22).

Previous research has evaluated the time course of recovery from a variety of acute exercise exposures, such as resistance training (9, 17, 19, 24, 28), various distances of running (5, 7, 13), high intensity repeated sprint performance (23), rowing performance after high intensity resistance training (11), and high intensity soccer training (29). McLester et al. (24) evaluated the time course of recovery in trained young male participants (age 18 to 30) following resistance training. Participants established a 10-rep maximum (10RM) on 8 separate exercises then performed either 3 sets or 7 sets (counterbalanced) to momentary failure of the 8 exercises using the 10RM weight. Participants then returned at 24, 48, 72, and 96 hours (counterbalanced) to replicate the workout. None of the participants in either group were able to replicate performance (maximal repetitions to momentary failure) after 24-hours of recovery (R24). After 48-hours of recovery (R48) there was no significant difference from baseline in either group. However, there was a high variability between participants with some not recovering at 96 hours.

It was noted by de Castro et al. (9) that serum creatine kinase values were significantly increased at R24 but had returned to baseline values after R48 following a comparable training protocol. Additionally, Gee et al. (11) evaluated recovery following a bout of full-body high intensity resistance training at R24, R48, and 72-hours (R72) in male rowers. Recovery was assessed via replication of countermovement jump (CMJ), 250-meter rowing ergometer sprint (250m), plasma creatine kinase, and perceived muscle soreness following the fatiguing workout. All variables were significantly different than baseline at R24. Rowing 250m times and creatine kinase levels returned to baseline values by R48 but CMJ remained depressed until R72. Perceived soreness was elevated at all time points. The evidence from these studies suggest that R48 may be an appropriate time course of recovery following a high intensity resistance training protocol, although some individuals may not recover for several days.

Bosak et al. (5) evaluated 5km running performance following a time course of recovery of R24 and R72 in trained runners (n = 12). Performance of the 5 km was significantly reduced at R24, however, there were no differences at R72. Laurent et al. (23) evaluated the time course of recovery in both men and women (n = 16) following 24 maximal intensity repeated 30 meter sprints. The researchers found that participants were able to replicate sprint performance following R24. Additionally, Sjokvist et al. (29) determined that female soccer players were able to replicate baseline performance of a 20 meter sprint and 5 bound jump for distance at R24 following high intensity sport specific soccer drills. CMJ and session rating of perceived exertion returned to baseline at R48.

As demonstrated in these studies, fatigue following exercise can be varied and is dependent on the nature of the exercise. This will result in variation in the durations necessary to return to baseline values (4). Although several studies have evaluated the time course of recovery from a variety of acute exercise exposures, no research is currently available assessing the appropriate time course of recovery from an ECP workout. Research in this area may enable practitioners to more effectively prescribe and periodize ECP workouts that maximize training whilst minimizing the risks of under-recovering. Therefore, the purpose of this study was to evaluate recovery after 24-hours (R24) and 48-hours (R48) following an ECP bout.

Methods

Participants

Ethical approval was obtained from the University's Institutional Review Board. Nine healthy male volunteers, between 18-29 years, completed this study. The population in this study was chosen in order to reduce cardiovascular risk, minimize any confounding effects associated with age-related differences in skeletal muscle recovery between younger and older individuals (24), and to minimize any training effects associated with study participation.

All potential participants in the study completed an exercise history questionnaire to determine if they met the inclusion criteria for the study. All accepted participants were healthy, non-smoking volunteers who were free of any cardiovascular or metabolic disease and who were classified as low or moderate risk according to guidelines established by the American College of Sports Medicine (ACSM) (26). Additionally, all participants reported participating in an ECP at least 4 days per week for a minimum of 6 months and were familiar with the experimental ECP workout prior to acceptance into the study. Individuals who reported the use of any exogenous steroids were excluded from participation in the study. Prior to participation, written informed consent was obtained from all participants. Descriptive characteristics are reported in Table 1.

Experimental Design

To examine the time course of recovery required for restoration of performance after an acute ECP workout, this study analyzed performance changes via a performance recovery indicator (PRI) test battery. The PRI consisted of seven performance tests: (sit-and-reach test, shoulder reach flexibility test, maximal countermovement jump (CMJ), bar velocity and power of 3 repetition bench press at 70% of 1RM, seated medicine ball toss, maximal push-up test, and 250m rowing ergometer test) and perceptual responses. These tests were selected as a non-fatiguing battery that could be performed on consecutive days without affecting the recovery assessment. Additionally, the participants' familiarity with the PRI items was a factor in selection to optimize the sensitivity of the protocol, as well as the ease of assessment replication for practitioners in the field. The definition of a recovered participant in this study was an individual who replicated or exceeded the baseline values of the PRI (4). A similar definition of a recovered participant has been established in previous work (11, 29).

Participants completed five separate trials within 21 days. Trial 1 consisted of attainment of initial informed consent, familiarization of procedures, and assessment of 1 repetition maximum (1RM) bench press. Trials 2 and 4 consisted of a baseline PRI assessment followed by the ECP workout. Following the ECP workout participants returned to the testing facility (trials 3 and 5) at R24 and R48 (counterbalanced) to replicate the PRI (Figure 1). The recovery periods were randomly assigned to participants in a counterbalanced order after completion of the initial trial. The level of recovery was assessed at R24 and R48 based upon baseline comparison of the PRI tests. A similar protocol to assess recovery after fatiguing exercise has been utilized in previous research (11, 17, 23, 24, 29).

Procedures

Each trial, participants arrived at the testing facility at the same time of day at least 3-hours post-absorptive, were instructed to adequately hydrate, abstain from caffeine 4-hours prior and alcohol 24-hours prior to each testing session. In addition, participants were instructed to refrain from any exercise (except the experimental trials) at least 48 hours preceding any trial. Participants were also instructed to get at least 8 hours sleep and to replicate dietary intake on the day of and immediately prior to testing. A questionnaire was utilized to evaluate participant adherence to the requested instructions before commencement of each trial.

For the first trial, participants were provided initial informed consent, completed a 1 repetition maximum (1RM) bench press protocol, and were familiarized with all PRI measurements and the experimental ECP workout. Prior to the 1RM bench press, participants were allowed a 5-10-minute dynamic warm-up of their choosing. The 1RM bench press protocol followed the suggested guidelines by the National Strength and Conditioning Association (25). Additionally, participants' height and body mass were collected using a calibrated stadiometer and beam-balance scale (Detecto, Webb City, MO) and body fat percentage was estimated utilizing a three-site skin-fold measurement (Lange Caliper, Beta Technology Inc., Deer Park, NY) and the equations developed by Jackson and Pollock (16).

Prior to commencement of each trial, participants were familiarized with the rating of perceived exertion (RPE), skeletal muscle pain, and RPR scales. A 0-100mm visual analog scale

(VAS) was used to assess all three perceptual ratings. Participants were then fitted with a HR monitor (Polar Electro Inc., Lake Success, NY) and HR was recorded continuously throughout the trial.

Each participant was then allowed to perform a 5 to 10-minute dynamic warm-up of their choosing (the same warm-up was completed prior to each trial). A 5-min rest period followed the warm-up. After the 5-min rest period, participants indicated skeletal muscle pain and RPR. The participants then completed two attempts at the sit-and-reach test followed by one attempt per arm of the shoulder reach flexibility test. Participants then completed four CMJs, interspersed with 30 seconds recovery between jumps followed by 3 repetitions of the bench press at 70% of 1RM (1RM was determined in trial 1). Mean concentric velocity and peak concentric power of the 3 repetitions was assessed with a linear position transducer (GymAware, Kinetic Performance Technology Pty Ltd., Mitchell ACT, Australia) (18), the highest value of the 3 repetitions were analyzed.

Following the bench press, participants completed four attempts of a seated medicine ball toss using a 4.5kg medicine ball. Each toss was interspersed with a 1-minute rest period and a 5-minute rest period following the final toss. After the rest period, participants completed a 1-minute push-up test (2) paced via a metronome maintaining 45 push-ups per minute. There was an additional 5-minute rest period after the 1-minute push-up test, then participants completed the 250-m rowing ergometer test (11) followed by 10 minutes of recovery. Two-minutes after completion of the test, participants attributed an RPE for the rowing ergometer test.

Following completion of the PRI participants performed the ECP workout. Participants returned to the testing facility after a previously randomly assigned recovery period (R24 and R48) (counterbalanced) and replicated the PRI tests during sessions 2 and 4.

ECP Workout. The fatiguing ECP workout utilized in this study consisted the CrossFit Workout "Cindy". This ECP workout consisted of as many rounds possible of 5 pull-ups, 10 push-ups, and 15 air squats (body-weight squats) in 20-minutes. Participants were asked to perform this workout at maximal intensity.

The ECP workout required that the participants complete all prescribed repetitions for the movement before moving on to the next exercise. Each movement was standardized for all participants. Pull-up standards required the participant to start hanging from a bar with arms fully extended, pull their chin just above the bar, and then return to the starting position. This movement could be completed through kipping or butterfly kipping variations. Push-up standards required participants to start in a plank position on the toes with the arms fully extended and hands on the ground directly beneath the shoulders. Participants then lowered the body until the chest met the ground, and then return to the starting position. Air-squat standards required participants to perform a traditional bodyweight squat until the hips passed below the knees, and then return to the starting position. Failure to achieve these standards required the participant to repeat the repetition of that movement until successfully performed.

Performance Recovery Indicators. Hamstring, hip, and low back flexibilities were assessed via the Canadian Trunk Forward Flexion test using a sit-and-reach box with the "zero point" set at 23 cm. The methods for this assessment are described in the ninth edition of ACSM's Guidelines for Exercise Testing and Prescription (26). Shoulder flexibility was assessed via the shoulder reach flexibility test. Participants raised the right arm overhead, bent the right elbow, and let the right palm rest on the back of the neck or between the shoulder blades. Then the participant reached behind the back with the left hand and attempted to touch the right hand. A measurement in centimeters was taken of the distance between the hands (negative measurement) or the overlap of the fingers (positive measurement). The procedure was replicated on the opposite arm.

The CMJs were performed utilizing a jump mat system (Just Jump, Probotics, Huntsville, AL). Participants were educated on how to perform a CMJ during trial 1. The CMJ requires that the participant be in an upright posture with feet shoulder width apart. The participant then descended into a semi-squat position while simultaneously swinging the arms back to prepare for the jump. The arms swing forward overhead as the participant jumped vertically landing on both feet at the same time. Participants performed four CMJ with 30 seconds between attempts; the highest CMJ was utilized for data analysis. The CMJ is commonly used as a measure of power (14) and to assess functional performance following exercise (6, 7, 11, 29).

Bar velocity and power were measured by assessment of mean concentric velocity and peak power during 3 repetitions of 70% of 1RM bench press (18). During trial 1, participants completed a 1RM bench press protocol. The measurements were assessed via a linear position transducer (GymAware, Kinetic Performance Technology Pty Ltd., Mitchell ACT, Australia).

For the seated medicine ball toss participants sat on the floor with legs extended and back against a wall to prevent movement at the hip. Participants held the medicine ball with their hands on either side of the ball and forearms positioned parallel to the ground. Participants were instructed to throw the medicine ball, using a chest pass technique, as far and straight as possible. The distance the ball first made contact with the floor was recorded to the nearest cm. A tape measure was secured to the floor starting from the end of the participants' shoe. A 4.5 kg medicine ball was used and 1-minute rest between attempts. To minimize variance, the highest and lowest medicine ball toss was removed and the average of the two remaining values was used for data analysis. A similar protocol has been utilized to assess upper-body power in athletes (8).

The 1-minute push-up test has been shown to be an acceptable assessment of muscular endurance (26). The push-up method described by Baumgartner et al. (2002) (2) was used in this study. Participants' began in a prone position with hands shoulder-width apart. The "down" position of the push-up consisted of the participants' body (from chest to thighs) making contact with the ground. The "up" position consisted of the participants' arms in full extension and body in a straight line (from the shoulder to the ankle). Participants were placed on a metronome to maintain a rate of 45 push-ups per minute and continued until no more push-ups could be performed with correct form, the pace could not be maintained, or they completed 45 push-ups. A push-up was counted when the participant successfully reached the "up" position.

A 250m rowing ergometer test was employed to assess anaerobic performance. The test was performed on an air-braked rowing ergometer (Concept 2 Model D, Concept 2, Inc., Morrisville, VT). For the test, the rowing ergometer was set with a drag factor of 140. This was a maximal effort test with time to completion and mean power output recorded from the display on the ergometer. A similar protocol has been used in previous research that featured a short-duration rowing test as a performance test of recovery (11).

Perceptual Measures. Three perceptual measures were utilized during this study to assess participants' RPE, skeletal muscle pain, and rating of perceived recovery (RPR). All perceptual measures utilized a continuous 0-100 mm visual analog scale (VAS). The RPE VAS was anchored on the left with "No Exertion" and the right with "Maximal Exertion". Skeletal Muscle Pain VAS scale was anchored on the left with "No Pain" and on the right with "Extreme Pain". The RPR VAS scale was anchored on the left with "Not Recovered at ALL" and right with

"Completely Recovered". Participants' RPE was recorded two-minutes after completion of the rowing ergometer performance tests and the ECP workout. Participants reported RPR and skeletal muscle pain 5-minutes after warm-up during each trial.

Data Analysis

Data was analyzed using SPSS Statistics version 18.0 (Somers, NY). A repeated-measures analysis of variance (ANOVA) was utilized in order to detect any significant change in PRI results between sessions performed at respective baselines, R24 and R48. When appropriate, a post hoc Fisher's LSD follow-up was performed to further identify where significant differences. A paired-samples t-test was used to detect differences in RPE and rounds completed during the ECP workout between R24 and R48.

To evaluate recovery via a single metric capturing recovery status, we converted raw scores of the CMJ, mean concentric bar velocity, peak bar power, seated medicine ball toss, 1-minute push-up, and 250m rowing ergometer test to z-scores using the mean and standard deviation used from combined data of the 4 separate trials of the current study. The composite recovery score was then calculated for each individual as the sum of the six event z-scores. A repeated-measures ANOVA was utilized to compare the composite recovery scores.

In order to evaluate individual responses, data from each individual were compared to the least significant difference for the sample. Participants were classified as either positive-responders (performance increased greater than or equal to the least significant difference), negative-responders (performance decreased greater-than or equal to the least significant difference), or non-responders (smaller change in performance relative to the least significant difference). An alpha level of 0.05 was observed for statistical testing.

Results

All participants followed requested instructions concerning sleep and dietary intake required for this study. A paired-samples t-test revealed that there were no significant mean differences found between R24 and R48 for rounds completed of the ECP workout (R24: 20.4 ± 4.2 vs R48: 20.2 ± 4.5; p = 0.67) or for VAS RPE of the ECP workout (R24: 89.4 ± 6.3 vs R48: 93.0 ± 7.9; p = 0.25). Participants average heart rate during the ECP workout was R24: 178.0 ± 10.8 BPM (90% age-predicted heart rate max) vs R48: 177.4 ± 10.8 BPM (89% age-predicted heart rate max).

Table 2 contains individual composite recovery scores as well as group means and standard deviations. Mean values for PRI can be found in Table 3. The composite recovery score for R24 (-1.49 ± 2.41) was significantly lower than baseline (0.76 ± 3.01) (p = 0.004); however there was no difference at R48 compared to baseline (p = 0.24).

There were three PRI metrics that were significantly altered from baseline at R24. They included CMJ (R24 baseline: 67.6 ± 4.3 cm vs R24: 65.4 ± 4.6 cm; p = 0.01), mean bar velocity (R24 baseline: 0.627 ± 0.061 m/s vs R24: 0.589 ± 0.053 m/s; p = 0.018), and rating of muscle pain (R24 baseline: 11.2 ± 13.1 vs R24: 34.4 ± 21.9; p = 0.002). Only rating of muscle pain was significantly altered at R48 (34.7 ± 30.5) than at R48 baseline (8.7 ± 6.5) (p = 0.031).

Individual data analysis revealed that for the composite recovery score there were 4 participants that were negative responders at R24 and classified as not recovered (least significant difference = 2.7). All 9 participants were non-responders at R48 and thus were fully recovered. Additionally, we saw 2 negative responders (not recovered) at R24 for the CMJ (least significant difference = 3.8 cm). It is of note that one of the negative responders at R24 was a positive responder at R48. All other participants were non-responders in the CMJ at R48.

There were 2 negative responders (not recovered) at R24 for peak bar power (least significant difference = 170 W) but all participants were non-responders at R48. Individual analysis of the seated medicine ball toss indicated that there were 2 negative responders (not recovered) (least significant difference = 34 cm) at R24, although all participants were non-responders at R48. No other PRI measurements had negative or positive responders at any time point.

Discussion

An optimal training recovery period should be employed to allow for appropriate adaptations to training overload and maximization of performance. Time course of recovery has been evaluated in multiple modes of training; including, resistance training (9, 11, 17, 24), 5 km performance (5), soccer training (29), and repeated sprint performance (23), among several other modalities. Additionally, a study was recently published evaluating 1-hour time course of recovery of the autonomic nervous system following an ECP workout (22). However, no research is currently available analyzing the time course of recovery of performance or perceptual responses following an ECP workout. Thus, the purpose of this study was to evaluate restoration of performance after a time-period of 24-hours (R24) or 48-hours (R48) following an acute ECP bout.

Due to multiple performance measurements of recovery in this study, we calculated a composite recovery score to evaluate recovery using a single value. This was done to allow an interpretation of the total recovery process. Our data shows that at R24 there was a decrement of the composite recovery score ($p = 0.004$), CMJ ($p = 0.01$), mean bar velocity ($p = 0.018$) as well as an increased perception of muscle pain ($p = 0.002$). The only metric that resulted in a significant difference from baseline at R48 was perception of muscle pain ($p = 0.031$). The results of this study support our hypothesis that, under the circumstances of this study, R24 would not be a sufficient duration to allow for full recovery from the ECP workout but performance would be restored by R48. Although performance was restored by R48, skeletal muscle pain should still be taken into consideration as it has been linked to skeletal muscle alterations (27).

Due to lack of published data evaluating ECPs, it is difficult to directly compare our results to previous research. The current study evaluated an ECP workout consisting of 20-minutes of bodyweight resistance movements (push-ups, pull-ups, and squats). The R24 trial resulted in an average of 105 push-ups, 207 pull-ups, and 300 squats and the R48 trial resulted in an average of 105 push-ups, 201 pull-ups, and 300 squats. This high volume bodyweight resistance training effort was also performed at what would be considered vigorous intensity by ACSM standards (26) as indicated by average heart rate during the ECP workout. Since traditional resistance training results in a very different metabolic response, it may be most appropriate to compare the results of this study to both high intensity resistance training protocols as well as other modes of high intensity training.

McLester et al. (24) evaluated time course of recovery in ten resistance trained males aged 18-30 years following either 3 sets or 7 sets of 8 exercises (5 upper-body and 3 lower-body) using a 10RM load to momentary failure. Similar to the present study, it was determined that recovery was significantly reduced at R24, for both protocols, as assessed through ability to perform maximum repetitions at the 10RM load and mean performance returned to baseline by R48. Additionally, there was no difference in time course of recovery between 3 sets and 7 sets. However, responses were highly variable among participants with some not recovering even at 96 hours.

Jones et al. (17) performed a study with a similar protocol (only 3 sets per exercise) indicating that 70% of participants returned to baseline values after R48 (n = 10). Additionally, de Castro et al. (9) evaluated the time course of recovery of serum creatine kinase (CK) following a protocol similar to that of Jones et al. (17), with a 90-second interval between sets. Comparable to the above mentioned findings indicating a recovery decrement at R24, CK levels were significantly higher after 24-hours of recovery compared to baseline. The mean CK values at 48-hours and 72-hours after the exercise protocol were not different from baseline. This suggests that muscle damage experienced during the high intensity resistance training protocol may have been repaired by R48.

Gee et al. (11) evaluated recovery following a bout of full-body high intensity resistance training at R24, R48, and 72-hours (R72) in male club rowers. Variables consisted of a countermovement jump (CMJ), 250-meter rowing ergometer sprint (250m), plasma creatine kinase, and perceived muscle soreness. At R24, CMJ and 250m performance were decreased significantly from baseline. However, by R48 250m returned to baseline values but CMJ remained depressed until R72. Creatine kinase levels returned to baseline at R48 and perceived soreness was elevated at all time points.

The results of the present study appear to be similar to those of the above studies indicating that, following a full-body high intensity resistance training protocol, performance was decreased at R24 but restored by R48 and that perceived muscle pain or soreness was elevated beyond R48. Although, it should be noted that McLester et al. (24) and Jones et al. (17) found that muscular endurance was depressed at R24 following a high intensity resistance training protocol and we saw no impact on muscular endurance (assessed through a 1-minute push-up test) at R24 following the ECP workout. Additionally, Gee et al. (11) saw a decrement in 250m rowing performance at R24 and we saw no impact on 250m rowing performance at any time point. Furthermore, Gee at al. found that CMJ didn't return to baseline until R72. This is in contrast to the present study showing a return of CMJ performance at R48. We postulate that these differences were due to the nature of the training protocol. The ECP workout evaluated in this study consisted of only bodyweight movements. Thus, we speculate that the higher resistance training load seen in the previously noted studies potentially led to greater fatigue in relation to power production, muscular endurance, and anaerobic performance than the ECP workout in this study, despite a higher volume of work in the ECP workout. This notion may be supported by McLester et al. as they noted no difference in time course of recovery between differing volumes of work (3 sets vs 7 sets) utilizing the same load.

Bosak et al. (5) investigated the time course of recovery following 5km running performance in trained individuals. While exercise modality differed compared to the ECP workout in the present study, intensity (assessed through HR) and duration of activity were similar. Recovery was assessed through replication of 5 km performance at R24 and R72. Results of that study indicated that performance was significantly reduced at R24 but returned to baseline by R72. While R48 was not evaluated, it is of note that a running performance of similar duration and cardiovascular intensity to the ECP workout in our study elicited a decrement in performance at R24.

Due to individual variability, individual data were analyzed in the present study regarding the various indicators of recovery. For the composite recovery score, four participants were negative responders at R24 and classified as not recovered; however, all participants were non-responders at R48 and thus were fully recovered. We saw 2 negative responders at R24 for the CMJ. Interestingly, one of the negative responders at R24 was a positive responder (individual score was greater than least significant difference) at R48. All other participants were non-responders at R48 for the CMJ. There were two negative responders at R24 for peak bar power but all participants were non-responders at R48. Individual analysis of the seated medicine ball toss revealed that there were 2 negative responders at R24, although all participants were non-responders at R48. All individuals were non-responders on the 1-minute push-up test and 250m rowing ergometer test. The individual analyses indicate that many participants appeared to be recovered by R24 and supports our findings (R48 is a sufficient recovery duration) in that all participants were fully recovered by R48 following this ECP workout.

Conclusion

The results of this study demonstrated that 48 hours was sufficient for recovery following the ECP workout evaluated under the conditions of this study; however, individual responses may vary and thus monitoring individual time course of recovery may provide practitioners the opportunity to most effectively prescribe ECP workouts. We did not see alterations of muscular endurance, anaerobic performance, flexibility, or perception of recovery, as assessed through the PRI, at any time point. This appears to indicate that this ECP workout primarily resulted in decrements of power and velocity and increased perception of muscle pain following 24-hours of recovery. Thus, practitioners should consider the impact this ECP workout may have on power, velocity, and muscle pain. Future research should focus on recovery following ECP workouts of various time domains and those workouts that include an external load in addition to body weight.

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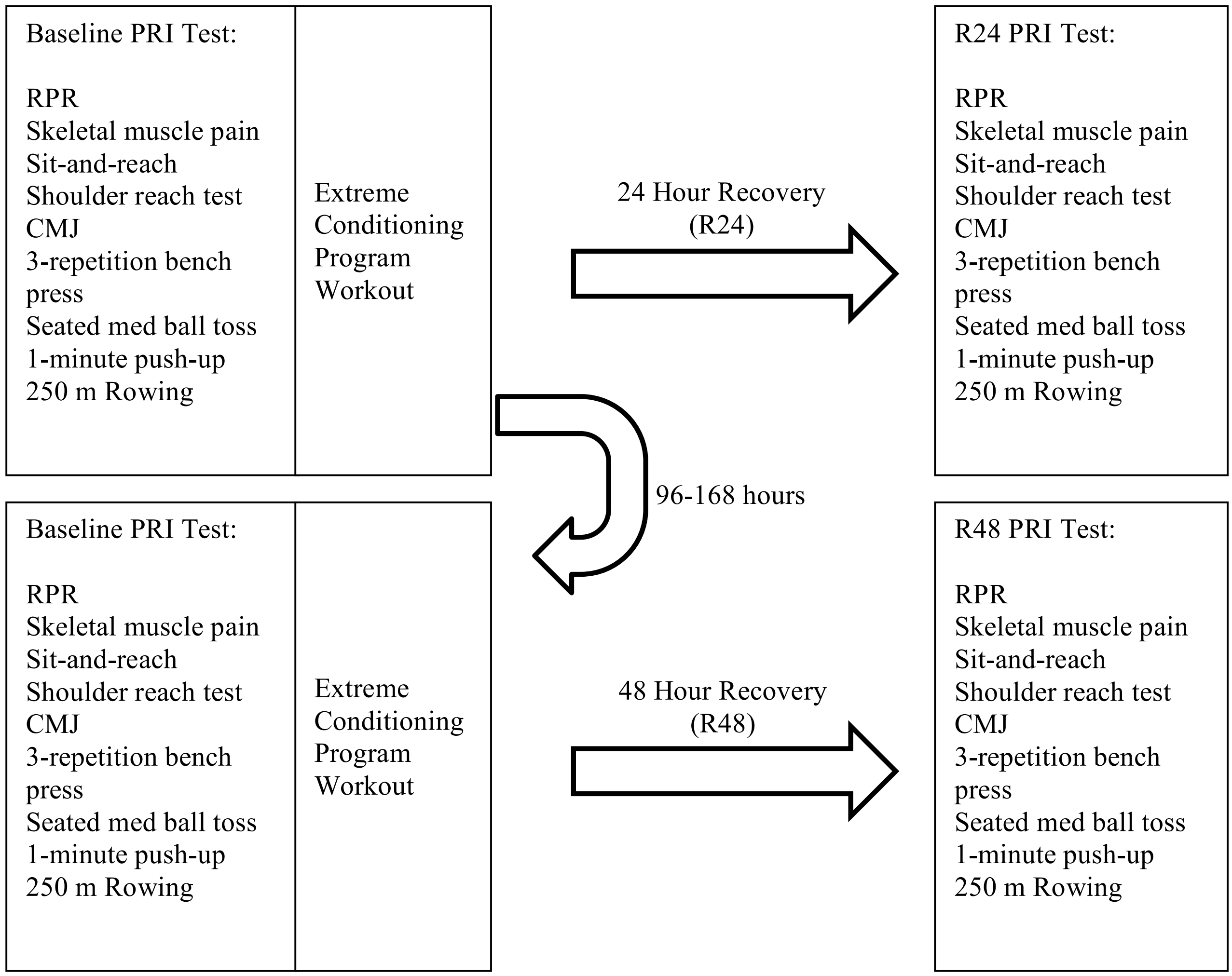

Figure 1.1. Study design (counterbalanced order)

Table 1.1. Descriptive characteristics of participants (n = 9).

Variable	Mean ± SD	Min	Max
Age (y)	21.7 ± 4.1	18	29
Weight (kg)	80.8 ± 5.3	76.0	98.1
Height (cm)	175.9 ± 7.5	166.0	190.0
Body fat (%)	10.3 ± 2.1	7.7	15.4
ECP Experience (y)	2.5 ± 1.0	1.0	4.0

Table 1.2. Composite recovery z-scores for each participant (n = 9).

Participant	R24 Baseline	R24	R48 Baseline	R48
1	6.39	3.49	5.42	4.40
2	4.04	-1.78	-0.05	1.86
3	-1.96	-4.78	-0.54	-2.58
4	0.07	-0.92	1.16	1.05
5	-1.62	-3.50	-2.11	-3.80
6	-1.02	-2.39	2.23	2.07
7	0.35	0.05	0.42	-2.32
8	2.82	-0.55	1.12	1.62
9	-2.19	-3.07	-1.64	-1.71
Mean ± SD	0.76 ± 3.01	-1.49 ± 2.41*	0.67 ± 2.25	0.07 ± 2.74

*Significant difference between R24 and R24 baseline (p = 0.004).
R48 was not significantly different than R48 baseline (p = 0.24).

Table 1.3. Mean ± SD PRI time course results (n = 9).

Variable	R24 Baseline	R24	R48 Baseline	R48	P-value
Shoulder Right (cm)	-1.1 ± 9.8	-1.8 ± 9.1	0.9 ± 9.3	-1.9 ± 9.4	0.546
Shoulder Left (cm)	-3.9 ± 8.7	-4.8 ± 8.0	-3.1 ± 7.2	-4.1 ± 7.9	0.431
Sit and Reach (cm)	33.7 ± 5.6	33.3 ± 5.3	33.4 ± 6.0	32.9 ± 6.3	0.416
CMJ (cm)	67.6 ± 4.3	65.4 ± 4.6*	67.9 ± 6.5	66.8 ± 6.0	0.050
Bar Velocity (m/s)	0.627 ± 0.061	0.589 ± 0.053#	0.631 ± 0.061	0.616 ± 0.062	0.016
Bar Power (W)	692.9 ± 187.0	641.1 ± 144.6	673.3 ± 152.0	659.7 ± 145.9	0.079
Med. Ball Toss (cm)	237.2 ± 37.6	221.3 ± 30.6	228.7 ± 26.3	227.3 ± 28.1	0.232
1-minute Push Up	34.3 ± 6.6	33.6 ± 7.2	34.7 ± 6.2	34.3 ± 7.1	0.639
250m Row (s)	42.8 ± 1.3	43.0 ± 1.4	42.6 ± 1.2	42.5 ± 1.0	0.463
Perceived Muscle Pain	11.2 ± 13.1	34.4 ± 21.9@	8.7 ± 6.5	34.7 ± 30.5**	0.002
Perceived Recovery	86.1 ± 15.9	73.2 ± 14.2	87.3 ± 9.7	77.8 ± 17.9	0.037

* Significant difference between R24 and R24 baseline ($p = 0.01$).
# Significant difference between R24 and R24 baseline ($p = 0.018$).
@ Significant difference between R24 and baseline ($p = 0.002$).
** Significant difference between R48 and R48 baseline ($p = 0.031$).

STUDY II

EFFECT OF LOW FREQUENCY ELECTRICAL STIMULATION ON TRAINING RECOVERY FOLLOWING AN EXTREME CONDITIONING PROGRAMWORKOUT

Abstract

An increasingly popular modality of training recovery among athletes is low-frequency electrical stimulation (LFES). No studies have been conducted analyzing the impact of any recovery enhancement method following an extreme conditioning program (ECP) workout. The purpose of this study was to evaluate LFES as a strategy to enhance training recovery and perceptual response following an ECP workout. Nine well-trained experienced participants completed a baseline performance battery (PRI) of a shoulder reach flexibility test, maximal countermovement jump, bench press assessing bar velocity and peak power, seated medicine ball toss, 1-minute push-up test, and 250 m rowing ergometer test, as well as perceptual markers, followed by an upper-body focused ECP workout. After the ECP workout participants received either 30-minutes of LFES to the upper-body or a placebo and passive rest. Participants returned 24-hours after completing the ECP workout to assess performance change via completion of the PRI. A composite recovery score was developed (z-score of six PRI metrics) and a two-way ANOVA revealed a main effect of time indicating participant fatigue as a result of the ECP workout (pre 1.95 ± 1.23 vs post 1.06 ± 1.07, mean ± SE; $p = 0.046$). However, there was no enhancement to the composite recovery score or any metric of the PRI from LFES treatment.

Analysis of individual data demonstrated one positive responder to LFES treatment compared to placebo assessed through peak bar power on the bench press. These findings suggest that acute LFES treatment, under the conditions of this study, did not attenuate the decrement in performance and alterations of perception associated with an upper-body focused ECP workout.

Key Words: electrical stimulation, extreme conditioning programs, training recovery, recovery enhancement

Introduction

Recovery refers to the restoration of the physiological and psychological processes (38) (toward homeostasis), potentially allowing a return of performance to the pre-fatigued state. Bishop et al. (6) defined "training recovery" as the recovery between consecutive workouts or competitions. Athletes often experience incomplete recovery between training sessions due to the short duration between successive bouts and high degrees of fatigue (6, 16). Partial recovery may lead to less than optimal physiological and psychological status, potentially resulting in deleterious effects on performance during subsequent activity (2, 6). Continued training exposure while under-recovered may lead to early fatigue, less resistance to subsequent physical strain, and, in more severe cases, potential for increased risk of injury and overtraining syndrome (2, 6). An athlete's ability to recover to a near pre-fatigued state during the short duration between training sessions or competitive events is multifactorial (20) with some researchers indicating peripheral fatigue (e.g., metabolic product accumulation, depleted glucose supplies, blood flow alterations, lowered phosphocreatine concentrations, local muscular inflammation, etc.) and delayed onset muscle soreness (DOMS) as two of the major limiting factors (6, 13, 30).

Furthermore, many recreational, amateur, and professional competitions consist of numerous events, over the course of one or multiple days, involving high intensity bouts of activity. In these events, small performance differences separate competitors. Thus, accelerated between-competition recovery may allow athletes the opportunity to gain a competitive advantage through performance restoration, making recovery between events of great importance to athletes and coaches (6).

As a result, many researchers and commercial companies have invested resources into developing new, or maximizing current, recovery methods. Thus, a number of recovery modalities have been utilized in an attempt to enhance training recovery, including: massage, cryotherapy, contrast temperature water immersion, hyperbaric oxygen therapy, nonsteroidal anti-inflammatory drugs, various ergogenic supplements, compression garments, and active recovery (2, 6).

An increasingly popular modality of post-exercise recovery among athletes is low-frequency electrical stimulation (LFES) (22). LFES results in visible muscle contractions via motor threshold electrical stimulation with electrodes placed directly over the muscle motor point (25). The concept behind LFES is similar to that of active recovery (increased vasodilation, increased blood flow, metabolite redistribution, etc.) through electrically stimulated local muscular contractions inducing a muscle pump effect (21, 25). Some studies have even indicated that blood flow is increased more so through LFES than in voluntary muscular contractions (39, 41). Additionally, LFES may elicit an analgesic effect (1, 25, 36), resulting in decreased muscle pain.

However, little evidence is available evaluating the efficacy of LFES as a training recovery intervention for the purpose of enhancing performance. In 2011, Westcott et al. (43) had 14 participants complete fatiguing eccentric leg extension exercises. Following the exercise stimulus, participants had LFES treatment to the right leg and no treatment on the left. Westcott et al. demonstrated a significant improvement in muscle recovery and endurance 24-hours following the fatiguing exercise in the right leg compared to the left. Additionally, it was demonstrated that participants indicated a significantly lower rating of muscle soreness in the right leg compared to the left. Tessitore et al. (36) evaluated four 20-minute recovery strategies (passive, land based aerobic exercise, water-aerobic exercise, and LFES) on anaerobic performance and perceptual response 5-hours following a standardized soccer training session. Results indicated that there was no main effect of any recovery intervention on anaerobic performances, however, LFES and dry land aerobic exercise did improve perceptual responses to muscle pain.

Malone et al. (25) (2014) performed a review of thirteen studies with eleven using physical performance measures and nine evaluating perceptual response after the recovery intervention to assess the effect of LFES. The authors determined that of the 13 studies evaluated, 9 found a positive effect of LFES for at least one outcome parameter (blood lactate, performance, and perceptual rating). Although, only 2 studies demonstrated a positive effect for performance, 4 studies found benefits of LFES on perceptual ratings of pain. Overall, the authors suggested that LFES is not more effective than passive or active recovery for enhancing subsequent performance. However, indicate that caution should be exercised when interpreting the findings due to considerable heterogeneity that existed between the 13 study protocols evaluated. With this noted, LFES as a training recovery modality needs further investigation in a variety of recovery durations, exercise stimuli, and methods of application.

Extreme Conditioning Programs (ECP) training and competition could benefit from LFES as a training recovery strategy. ECPs often combine components of resistance training, Olympic lifting, bodyweight training, functional movement training, circuit training, and high intensity interval training (HIIT) into workouts with high volume repetitions and short, or no, prescribed rest periods between sets (4, 14). Thus, each workout is metabolically and physically highly demanding.

As ECPs have grown in popularity, extreme conditioning has emerged as a competitive amateur and professional sport. These events are highly intense and often mimic the ECP style of training. Consequently, it is crucial for these athletes to maximize training recovery to enhance subsequent performance.

Currently, no research is available evaluating any training recovery method following an ECP workout. Additionally, no research has assessed the impact of LFES on perceptual responses following a bout of ECP. Thus, the purpose of this study was to evaluate LFES as a strategy to enhance training recovery and perceptual response following an ECP workout.

Methods

Participants

Ethical approval was obtained from the University's Institutional Review Board. Nine healthy males (between 18-30 years old) volunteers completed this study. This study's sample was chosen in order to reduce cardiovascular risk, minimize any confounding effects associated with age-related differences in skeletal muscle recovery between younger and older individuals (29), and to minimize effects associated training age. Additionally, although female participation was solicited, no females volunteered to participate in this study. All participants were healthy, non-smoking volunteers who were free of any cardiovascular or metabolic disease and who were classified as low or moderate risk according to guidelines established by the American College of Sports Medicine (ACSM) (33).

All individuals interested in participating in the study completed an exercise history questionnaire to determine if they met the inclusion criteria for the study. All participants reported participating in an ECP at least 4 days per week for a minimum of 6 months. In addition, all participants were familiar with the experimental ECP workout prior to acceptance into the study. Individuals who reported the use of any exogenous steroids were excluded from participation in the study. Prior to participation, written informed consent was obtained from all participants. Descriptive characteristics are reported in Table 1.

Experimental Design

To examine the effect of LFES on training recovery and perceptual response following an ECP bout, this study analyzed performance changes via a performance recovery indicator (PRI) test. The PRI consisted of six performance tests (shoulder reach flexibility test, maximal countermovement jump (CMJ), mean velocity and peak power of a 3 repetition bench press at 70% of 1RM, seated medicine ball toss, 1-minute push-up test, and 250 m rowing ergometer test) and three perceptual responses (rating of perceived exertion (RPE), skeletal muscle pain, and rating of perceived recovery (RPR)). All three perceptual ratings were assessed via a 0-100mm visual analog scale (VAS). The VAS was used instead of the traditional ordinal scales to analyze the results as continuous data.

These tests were selected as a non-fatiguing battery that could be performed on consecutive days without affecting the recovery assessment. Additionally, the participants' familiarity with the PRI items was a factor in selection to optimize the sensitivity of the protocol, as well as the ease of assessment replication for practitioners in the field. The definition of a recovered participant in this study was an individual who replicated or exceeded the baseline values of the PRI (6). A similar definition of a recovered participant has been established in previous work (12, 34).

In a repeated measures counterbalanced design, participants completed five separate trials within 14 days (Figure 1). Trial 1 consisted of familiarization with testing protocols and attainment of a 1 repetition maximum bench press. Trials 2 and 4 consisted of a baseline PRI assessment followed by the ECP workout. After completion of the ECP workout, participants received a randomly assigned recovery intervention (LFES or a placebo supplement) (in counterbalanced order). Placebo was comprised of sugar-free soft candy (Jelly Belly Gummi Bears, Fairfield, CA). Trials 3 and 5 consisted of replication of the PRI and occurred 24-hours following completion of trials 2 and 4, respectively. The level of recovery assessed 24-hours after completion of the ECP workout was based upon baseline comparison of the PRI test items. A similar protocol to assess recovery after fatiguing exercise has been utilized in previous research (12, 29, 34).

Procedures

For each trial, participants arrived to the testing facility at the same time of day at least 3-hours post-absorptive and were instructed to adequately hydrate as well as abstain from caffeine and alcohol 24-hours prior to each testing session. In addition, participants were instructed to refrain from any exercise (except the experimental trials) at least 48 hours preceding any trial. Participants were also instructed to get at least 8 hours sleep and to replicate dietary intake on the day of, and immediately prior to, testing. A questionnaire was utilized to evaluate participant adherence to the requested instructions before commencement of each trial.

On the first trial, participants provided initial informed consent, completed a 1-repetition maximum (1RM) bench press protocol, and were familiarized with all PRI measurements and the experimental ECP workout. Prior to the 1RM bench press participants were allowed a 5-10-minute dynamic warm-up. The 1RM bench press protocol followed the suggested guidelines by the National Strength and Conditioning Association (31). Additionally, participant's height and body mass were measured using a calibrated stadiometer and beam-balance scale (Detecto, Webb City, MO). Participants' body fat percentage was estimated during trial 1 utilizing a three-site skin-fold measurement (Lange Caliper, Beta Technology Inc., Deer Park, NY) and the equations developed by Jackson and Pollock (18).

Prior to data collection during all 5 trials, participants were familiarized with the rating of perceived exertion (RPE), skeletal muscle pain, and RPR scales. All three perceptual ratings were assessed via a 0-100mm visual analog scale (VAS). Participants were then fitted with a HR monitor (Polar Electro Inc., Lake Success, NY) and HR was recorded continuously throughout the trial.

Each participant was then allowed to perform a 5 to 10-minute dynamic warm-up of their choosing (the same warm-up was completed prior to each trial). Following the warm-up, participants were allowed a 5-min rest period. After the 5-min rest period, participants indicated skeletal muscle pain and RPR followed by one attempt per arm of the shoulder reach flexibility test. Next, participants completed four CMJ, interspersed with 30 seconds recovery between jumps. Participants then performed a standardized bench press warm-up leading to 70% of 1 RM, then completed 3 repetitions of the bench press at 70% of 1RM (1RM was determined in trial 1). Mean concentric velocity and peak concentric power of the 3 repetitions was assessed with a linear position transducer (GymAware, Kinetic Performance Technology Pty Ltd., Mitchell ACT, Australia) (19) and the highest value of the 3 repetitions was analyzed. Following the bench press, participants completed four attempts of a seated medicine ball toss using a 4.5kg medicine ball. Each toss was interspersed with a 1-minute rest period and a 5-minute rest period following the final toss. After the 5-minute rest period participants completed a 1-minute push-up test (3) paced with a metronome to maintain a pace of 45 push-ups per minute. An additional 5-minute rest period was allowed, and then participants completed the 250 m rowing ergometer test (12) followed by 10 minutes of recovery. Two minutes after completion of the rowing ergometer test, participants reported an RPE for the rowing ergometer test.

Following completion of the PRI, participants performed the ECP workout. After completing the ECP workout, participants were seated for 5 minutes. During this time the participants receiving LFES were prepped and electrodes were placed. Five-minutes after completing the ECP workout, participants began the 30-minute recovery period (LFES or placebo). The placebo was comprised of thirteen sugar-free soft candies (Jelly Belly Gummi Bears, Fairfield, CA) administered over 2 doses and passive recovery. Two minutes following the recovery period participants were asked to report skeletal muscle pain and RPR. Participants were instructed to abstain from all exercise and recovery strategies and return to the testing facility after 24-hours to replicate the warm-up protocol and PRI.

ECP Workout. The ECP workout utilized in this study was the CrossFit Workout "J.T.". This ECP workout is a time-to-completion effort, consisting of handstand push-ups, ring dips, and push-ups. The repetition scheme for this ECP workout is 21 handstand push-ups, 21 ring dips, 21 push-ups, 15 handstand push-ups, 15 ring dips, 15 push-ups, 9 handstand push-ups, 9 ring dips, and 9 push-ups. Participants were asked to perform this workout at maximal intensity. Time to completion was recorded.

The ECP workout required that the individual complete all prescribed repetitions for the movement before moving on to the next exercise. Each movement was standardized for all participants. Handstand push-ups standards required participants to begin upside-down, against a wall with arms and legs extended. Participants then descended until the head touched the ground and returned to the starting position for the repetition to be successful. Ring dips consisted of the participant starting on the gymnastics rings, with arms extended along the sides of the body. Participants then bent at the elbow and descend until the anterior portion of the shoulder broke the plane of the elbow. Push-ups followed the traditional method with a requirement of touching the chest on the ground at the lower portion of each repetition. For the purposes of this study, traditional or “kipping” technique was allowed for the handstand push-ups and ring dips. However, participants were required to utilize the same technique for all trials. Failure to achieve these standards required the participant to repeat the repetition of that movement until successfully performed.

Performance Recovery Indicators. Shoulder flexibility was assessed via the shoulder reach flexibility test. Participants raised the right arm overhead, bent the right elbow and let the right palm rest on the back of the neck or between the shoulder blades. Then the participant reached behind the back with the left hand and attempted to touch the right hand. A measurement in centimeters was taken of the distance between the hands or the overlap of the fingers. The procedure was replicated on the opposite arm.

The CMJs were performed utilizing a jump mat system (Just Jump, Probotics, Huntsville, AL). Participants were educated on how to perform a CMJ during trial 1. The CMJ required that the participant be in an upright posture with feet shoulder width apart. The participant then descended into a semi-squat position while simultaneously swinging the arms back to prepare for the jump. The arms swung forward overhead as the participant jumped vertically landing on both feet at the same time. Participants performed four CMJs with 30 seconds between attempts; the highest CMJ was utilized for data analysis. The CMJ is commonly used as a measure of power (15) and to assess functional performance following exercise (8, 12, 34).

Bar velocity and power were measured via assessment of mean concentric velocity and peak power during 3 repetitions at 70% of 1RM bench press (19). During trial 1, participants completed a 1RM bench press protocol. Velocity and power were assessed via a linear position transducer (GymAware, Kinetic Performance Technology Pty Ltd., Mitchell ACT, Australia).

The seated medicine ball toss required participants to sit on the floor with legs extended and back against a wall to prevent movement at the hip. Participants held the medicine ball with their hands on either side of the ball and forearms positioned parallel to the ground, similar to the start of a chest pass. A 4.5 kg medicine ball was used. Participants were instructed to throw the medicine ball, using a chest pass technique, as far and straight as possible. The distance the ball first made contact with the floor was recorded to the nearest cm. A tape measure was secured to the floor starting from the end of the participants' heel of their shoe. Participants had 1-minute rest between attempts and completed 4 tosses. The highest and lowest medicine ball toss was removed and the average of the two remaining values was used for data analysis. This was done in an attempt to minimize variance. A similar protocol has been utilized to assess upper-body power in athletes (10).

The 1-minute push-up test was utilized to assess muscular endurance (33). This study used the push-up method described by Baumgartner et al. (2002) (3). The participants started in a prone position with hands shoulder-width apart. The "down" position of the push-up consisted of the participants' body (from chest to thighs) making contact with the ground. The "up" position consisted of the participants' arms in full extension and body in a straight line (from the shoulder to the ankle). Participants were placed on a metronome to maintain a rate of 45 push-ups per minute and continued until they either performed 45 push-ups, no more push-ups could be performed with correct form, or the pace could not be maintained. A push-up was counted when the participant successfully reached the "up" position.

To assess anaerobic performance this study employed a 250 m rowing ergometer test. The rowing ergometer test was performed on an air-braked rowing ergometer (Concept 2 Model D, Concept 2, Inc., Morrisville, VT). For the test, the rowing ergometer was set with a drag factor of 140 and was a maximal-time-to-completion effort for all participants. A similar protocol has been used in previous research that featured a short-duration rowing test as a performance test of recovery (12). Time to completion and mean power output of the 250 m rowing ergometer test were recorded from the display on the ergometer.

Values utilized for analysis from the CMJ, mean concentric bar velocity, peak bar power, seated medicine ball toss, 1-minute push-up, and 250 m rowing ergometer test were also combined into a single overall composite recovery score. This was done by converting the actual scores to z-scores and summing. The mean and standard deviation used for computing the z-scores were obtained from combined data of the current study and a separate unpublished study by Casey et al. (9). Two individuals' seated medicine ball toss scores, that were outliers from the other participants in the sample, were removed from the data set used for means and standard deviations.

Perceptual Measures. Three perceptual measures were utilized during this study to assess participants' RPE, skeletal muscle pain, and rating of perceived recovery (RPR). All perceptual measures utilized a continuous 0-100 mm horizontal line visual analog scale (VAS). For all VAS scales, participants marked a vertical line intersecting the 100 mm horizontal line indicating the perceptual response. The RPE VAS was anchored on the left with "No Exertion" and the right with "Maximal Exertion". Skeletal Muscle Pain VAS scale was anchored on the left with "No

Pain" and on the right with "Extreme Pain". The RPR VAS scale was anchored on the left with "Not Recovered at ALL" and right with "Completely Recovered". Participants' RPE was recorded for the rowing ergometer performance test and the ECP workout. Participants reported RPR and skeletal muscle pain 5-minutes after warm-up during each trial and two minutes after completing the recovery intervention.

Recovery Intervention

Electrical Muscle Stimulation. Commercial electrical muscle stimulation devices were utilized in this study (Marc Pro, Inc., Huntington Beach, CA). All procedures for the LFES intervention followed the manufacturer's instructions (26). Participants received the LFES recovery intervention placed directly on the anterior deltoid, posterior deltoid, anterior forearm, and medial triceps for 30-minutes utilizing the default pre-set low frequency setting. An electrode (Marc Pro, Inc., Huntington Beach, CA) (5.08 cm round) was placed on each anterior deltoid, posterior deltoid, anterior forearm (5-7 cm below the antecubital space), and medial triceps. A new electrode set was utilized for each trial. The stimulation frequency was 2 Hz. Participants were allowed to self-select the most comfortable intensity (as indicated on the Marc Pro Device). Participants remained in a seated position throughout the intervention.

Placebo. The placebo was comprised of thirteen sugar-free soft candies (Jelly Belly Gummi Bears, Fairfield, CA) administered over 2 doses. The first dose consisted of eight candies and was administered 1-hour prior to the ECP workout. The second does consisted of five candies administered 5-minutes following the ECP workout. Participants receiving placebo treatment remained in a passive seated position for 35 minutes after completion of the ECP workout (same duration as the LFES treatment).

Data Analysis

Data were analyzed using SPSS Statistics version 18.0 (Somers, NY). A repeated-measures two-way analysis of variance (ANOVA) (2x2) was utilized in order to compare skeletal muscle pain, RPR, seated medicine ball toss, CMJ, maximal push-ups, and 250-m rowing performance between the treatment conditions (LFES and placebo) and time (pre-ECP workout and post-ECP workout). When appropriate, a post hoc Fisher's LSD follow-up was performed to identify where significant differences occurred. A paired-samples t-test was used to detect differences in RPE and rounds completed during the ECP workout between R24 and R48.

In order to create a single metric capturing recovery status, we converted raw scores of the CMJ, mean concentric bar velocity, peak bar power, seated medicine ball toss, 1-minute push-up, and 250 m rowing ergometer test to z-scores using the mean and standard deviation used from combined data of the current study and a separate study by Casey et al. (9). Two individuals' seated medicine ball toss scores, that were outliers from the other participants in the sample, were removed from the data set used for means and standard deviations. The composite recovery score was then calculated for each individual as the sum of the six event z-scores (CMJ, average bar velocity, peak bar power, medicine ball toss, 1-minute push-up test, and 250 m rowing ergometer test). A repeated-measures two-way ANOVA (treatment x time) was utilized to compare the composite recovery scores.

In order to evaluate individual responses, data from each individual were compared to the least significant difference for the sample. Participants were classified as either positive-responders (performance increased greater than or equal to the least significant difference), negative-responders (performance decreased greater-than or equal to the least significant difference), or non-responders (smaller change in performance relative to the least significant difference). An alpha level of 0.05 was observed for statistical testing.

Results

All participants followed requested instructions concerning sleep and dietary intake required for this study. A paired-samples t-test revealed that there were no significant mean differences found between treatment conditions for time to completion of the ECP workout (LFES 11.68 ± 4.11 min vs placebo 12.10 ± 5.53 min; $p = 0.619$) or for RPE of the ECP workout (LFES 80.4 ± 7.4 vs placebo 81.0 ± 11.9; $p = 0.836$). Participants average heart rate during the ECP workout was 166.0 ± 10.1 bpm (84% age-predicted heart rate max) for LFES vs 169.0 ± 7.1 bpm (86% age-predicted heart rate max) for placebo.

Means and standard errors of the composite recovery score can be found in Table 2. We did not see a treatment x time interaction for the composite recovery scored. However, there was a significant effect of time for the composite recovery score indicating a diminution in performance post-ECP workout compared to pre-ECP workout ($p = 0.046$).

Mean values for PRI treatment x time interaction can be found in Table 3. Mean values for PRI main effects (treatment and time) can be found in Table 4. There were no treatment x time interactions for any PRI metric as shown by a two-way ANOVA. A main effect of time was shown for the seated medicine ball toss demonstrating a decrement in performance from pre-ECP workout to post-ECP workout ($p = 0.002$). Additionally, there was a main effect of time for the right arm shoulder reach test with post ECP workout values significantly worse than pre ECP workout values ($p = 0.015$). There was a main effect of time demonstrating an increased acute skeletal muscle pain after 35-minutes of passive rest following completion of the ECP workout compared to skeletal muscle pain at baseline ($p = 0.008$). A main effect of time revealed acute

RPR after 35-minutes of passive rest following the ECP workout to be lower than baseline ($p = 0.013$). Furthermore, through a main effect of time, it was shown that participants indicated a higher rating of skeletal muscle pain and RPR 24-hours after completing the ECP workout than at baseline ($p = 0.006$) and ($p = 0.048$), respectively. A two-way ANOVA revealed a main effect of treatment for the left arm shoulder reach test ($p = 0.011$), however, this appears to be an anomaly in analysis. Individual analysis via the least significant difference for the sample revealed one individual positive responder for the LFES treatment assessed via peak bar power in the bench press (least significant difference = 100 W).

Discussion

It is well documented that inadequate training recovery can lead to decrements in subsequent performance (6). Additionally, it is known that high volume- and intensity-resistance-based exercise induces skeletal muscle damage which can result in subsequent performance decrement and increased muscle soreness following the activity. As a result, evaluation of various methods to enhance training recovery following a variety of high intensity training protocols is needed. The purpose of this study was to evaluate the effect of acute low frequency electrical stimulation (LFES) on recovery following an ECP workout in well-trained males. Recovery was assessed through analysis of a performance recovery indicator (PRI). This is the first study to evaluate a training recovery enhancement method following an ECP workout. Under the conditions of the current study, we saw no significant performance or perceptual improvements following LFES treatment compared to placebo.

There is limited research evaluating the effects of LFES on training recovery for the purposes of enhancing performance. In addition, of the published studies there is heterogeneity in the specific LFES device used for recovery, location of LFES treatment, recovery duration, methods to assess recovery, and fatiguing exercise protocol (5, 21, 23, 24, 27, 32, 35-37, 40, 41, 43). Additionally, only 3 of the 13 studies included in the 2014 review article by Malone et al. evaluated LFES treatment duration of 30 minutes or greater (23, 27, 43) and only 3 utilized LFES on a portion of the upper-body (17, 32, 42). Furthermore, only one of the published studies evaluated the effect of LFES following a primarily upper-body stimulus. However, that study by Warren et al. (42) evaluated LFES following pitching in baseball, which is a very different stimulus than that used in the present study. As a result, it is difficult to make direct comparisons to the previous research.

LFES has been shown to be an effective method of training recovery for some physiological components including anaerobic performance (5), muscular endurance (43), lowered creatine kinase levels (41), and blood lactate clearance (5, 32, 42). However, the primary performance variable impacted by the ECP workout in the present study was upper-body power assessed through a seated medicine ball toss. We did not see a significant difference in power output via the medicine ball toss distance between LFES and placebo treatment. Additionally, we did not see an improvement in the composite recovery score from LFES treatment.

Our results support those of Malone et al. (23) who provided 20 minutes of recovery treatment (LFES, active (cycling at 30% VO_{2max}), or passive) following three 30s. Wingate tests. Ten minutes after the recovery treatment, three additional Wingate tests were completed to assess peak power and mean power. There were no differences observed between treatments for peak or mean power. Tessitore et al. (36) demonstrated similar results with 20 minutes of LFES vs three other recovery strategies (passive, dry-land aerobic exercise, and water-aerobic exercise) on lower-body power (10 m sprint, CMJ, squat jump, and bouncing jump) following a standardized soccer training session. That study found no differences in performance of the lower-body power measures between the recovery strategies 5-hours after the soccer training.

Current study results, as well as the previously noted studies, do not support Taylor et al. (35). In a study of 28 professional rugby and football academy players, it was determined that 8 hours of LFES treatment to the calf muscle (vs passive recovery) resulted in higher CMJ values and increased peak lower-body power at 24-hours post fatiguing maximal sprint efforts. The differences seen by Taylor et al. (35) could be due to the significant duration of LFES stimulus. Our study, as well as Malone et al. and Tessitore et al., utilized an LFES duration of 30 minutes or less. The extended time period of LFES treatment (8 hours) may have provided additional benefits not shown with the shorter treatment durations, such as in the present study.

Another explanation for the power production improvement seen by Taylor et al. (35) is the location of LFES treatment. Taylor et al. (35) placed the electrodes on the peroneal nerve behind the knee to elicit visible contractions of the calf muscle. A 2014 study by Bieuzen et al. (5) showed benefits of 15 minutes of LFES treatment to the calf (vs active and passive recovery), indicating an improved shuttle run performance following a fatiguing effort. One of the primary methods in which LFES aids in recovery is through increased blood flow. Stimulation of the calves have been reported to be responsible for 80% of venous return (7, 28), thus, the LFES treatment seen in the studies by Taylor et al. (35) and Bieuzen et. al. (5) may have enhanced local and total blood flow and resulted in increased recovery benefits.

The present study also saw an increased rating of skeletal muscle pain and a decreased RPR immediately following the recovery treatment, as well as 24-hours after the ECP workout. However, we did not see any improvement to these perceptual responses from LFES treatment.

This is in contrast to several studies indicating beneficial results for perception of muscle pain, perception of recovery, and participative feelings of relative wellbeing (1, 11, 36, 37, 42, 43).

Due to individual variability, it is important to consider individual responses to recovery methods and not just group means. Out of the nine participants, we did find one individual positive responder to the LFES treatment compared to placebo as assessed through peak bar power in the bench press. The least significant difference for peak bar power in this study was 100 W. As noted in the study by Taylor et al. (35) LFES may provide some benefit for recovery of peak power output. Our results indicate that similar results may be seen for a small percentage of individuals following an upper-body, bodyweight ECP workout. Also, it should be noted that a 100 W improvement represented between a 10.7% to 17.5% increase in peak power for our sample. Thus, the practical application of this individual result should be considered. If some individuals increase peak upper-body power by 100 W following LFES treatment this may be considered a significant enhancement to performance, if the performance increase is stable. As a result, stability of performance following LFES treatment needs to be assessed individually.

A significant effect of time indicated that the metrics of our PRI most impacted by the ECP workout were upper-body power assessed through a medicine ball toss ($p = 0.002$), perception of pain (acute, $p = 0.008$; 24-hour, $p = 0.01$), perception of recovery (RPR) (acute, $p = 0.013$; 24-hour, $p = 0.048$), and right arm shoulder flexibility ($p = 0.015$). Additionally, when scores were combined into our composite recovery score there was an indication that the ECP workout resulted in a decrement in overall performance ($p = 0.046$). The diminishment of these scores indicates that the ECP workout was a fatiguing activity and adversely effected: 1) total recovery 24-hours post, 2) some performance parameters 24-hours post, and 3) perceptual responses acutely and 24-hours post. This is a novel finding in itself and could result in assisting practitioners with prescription of ECP workouts.

Conclusion

Due to short recovery periods and high volume and intensities of training, athletes often experience incomplete recovery between training sessions. As a result, methods to enhance training recovery may result in improved performance and maximize physiological adaptations to training. The results of this study indicated that acute LFES treatment following an upper-body, bodyweight ECP workout did not provide any benefits relative to placebo. It is of note that one participant did increase bar peak power during a bench press by over 100 W after LFES compared to placebo. This may be due to random variation and therefore it is recommended that stability of individual performance following LFES be assessed closely to determine benefits of the treatment. It appears that most individuals will likely not see enhancements to performance or perception via LFES as a recovery strategy following an upper-body, bodyweight ECP workout.

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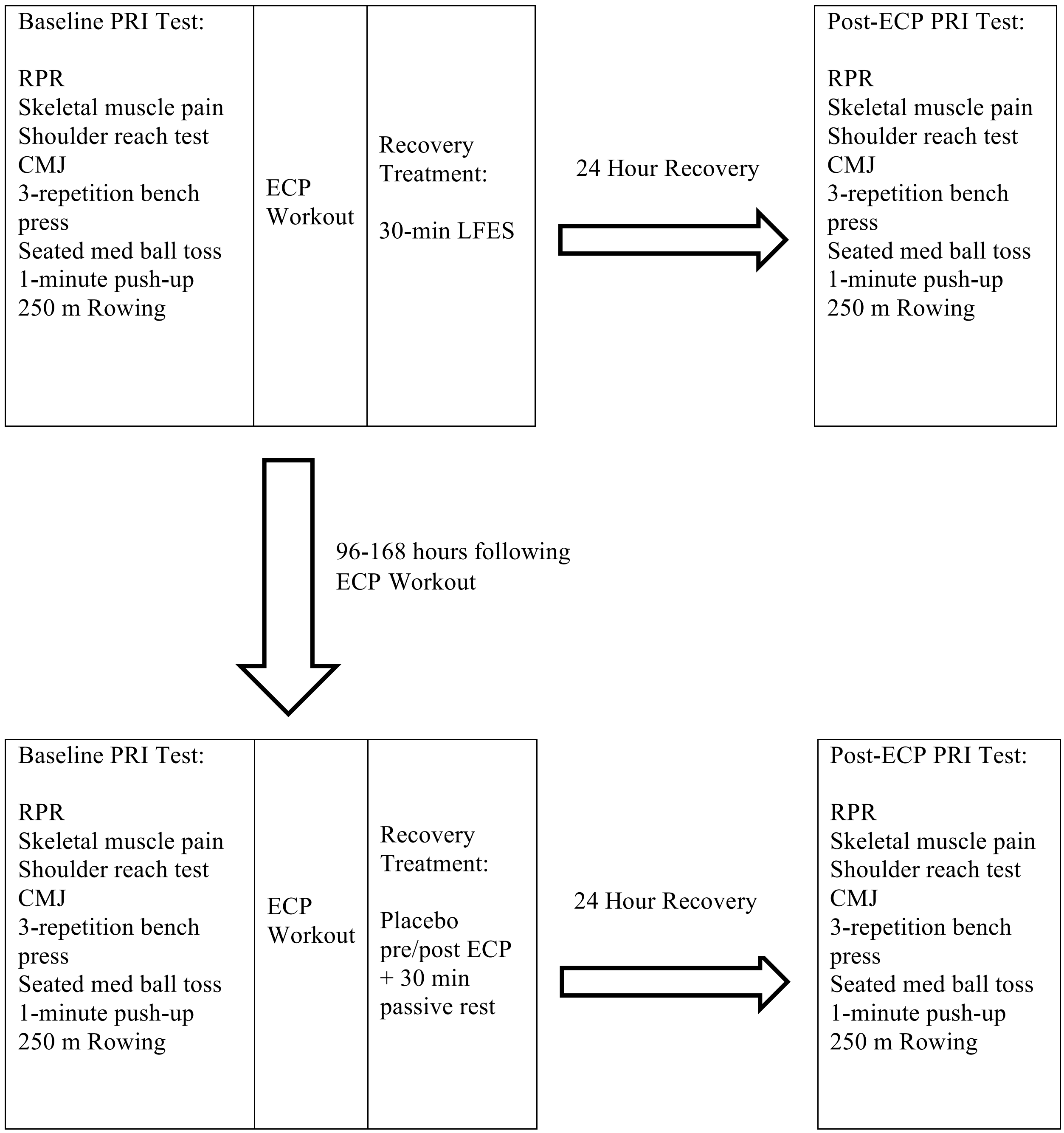

Figure 2.1. Study design (counterbalanced order)

Table 2.1. Descriptive characteristics of subjects (n = 9).

Variable	Mean ± SD	Min	Max
Age (y)	22.6 ± 4.5	18	30
Weight (kg)	85.4 ± 8.7	78.6	105.8
Height (cm)	177.2 ± 6.6	166.0	187.0
Body fat (%)	11.5 ± 4.4	4.6	20.2
ECP Experience (y)	3.3 ± 1.5	2.0	6.0

Table 2.2. Composite recovery score two-way ANOVA results (n = 9). Mean ± SE

Variable	Interaction					
	LFES Pre	LFES Post	Placebo Pre	Placebo Post	P-value	
Composite Recovery Score	1.93 ± 1.11	1.28 ± 1.06	1.97 ± 1.49	0.85 ± 1.21	0.435	
	Treatment			Time		
	LFES	Placebo	P-value	Pre	Post	P-value
	1.60 ± 1.08	1.41 ± 1.32	0.814	1.95 ± 1.23	1.06 ± 1.07*	0.046

LFES Pre = low frequency electrical stimulation trial pre-ECP workout, LFES Post = low frequency electrical stimulation trial 24-hours post-ECP workout, Placebo Pre = Placebo trial pre-ECP workout, Placebo Post = Placebo trial post-ECP workout, LFES = Low frequency electrical stimulation, Pre = pre-ECP workout, Post = post ECP workout;
*Significant main effect of time variable (p = 0.046).

Table 2.3. PRI measurement interaction (treatment x time) (n = 9). Mean ± SE

Variable	LFES Pre	LFES Post	Placebo Pre	Placebo Post	P-value
Shoulder Right (cm)	-2.9 ± 1.8	-4.3 ± 1.9	-4.5 ± 2.3	-5.3 ± 2.5	0.185
Shoulder Left (cm)	-7.2 ± 2.0	-7.5 ± 2.0	-8.5 ± 2.3	-9.6 ± 2.5	0.516
CMJ (cm)	74.4 ± 2.9	74.7 ± 3.5	73.3 ± 3.3	72.4 ± 3.3	0.574
Bar Velocity (m/s)	0.61 ± 0.02	0.60 ± 0.02	0.61 ± 0.02	0.60 ± 0.02	0.953
Bar Power (W)	728.0 ± 37.1	717.9 ± 28.4	750.4 ± 35.5	725.2 ± 39.6	0.593
Med. Ball Toss (cm)	272.4 ± 8.9	248.9 ± 12.0	267.2 ± 17.7	248.8 ± 14.9	0.614
1-minute Push Up	37.8 ± 2.5	39.0 ± 2.0	37.4 ± 2.0	37.2 ± 2.2	0.187
250m Row (s)	42.0 ± 0.8	41.9 ± 0.8	41.6 ± 0.7	41.7 ± 0.6	0.603
24-Hour Muscle Pain	7.4 ± 1.5	28.2 ± 7.0	10.9 ± 4.3	20.4 ± 6.7	0.179
24-Hour RPR	85.3 ± 4.2	73.6 ± 7.1	84.4 ± 4.0	72.3 ± 5.8	0.963
Acute Muscle Pain		22.7 ± 7.5		22.7 ± 4.8	0.672
Acute RPR		69.2 ± 6.3		63.0 ± 6.1	0.351

LFES Pre = low frequency electrical stimulation trial pre-ECP workout, LFES Post = low frequency electrical stimulation trial 24-hours post-ECP workout, Placebo Pre = Placebo trial pre-ECP workout, Placebo Post = Placebo trial post-ECP workout; There was no significant interaction for any variable (p > 0.05).

Table 2.4. PRI measurement main effects (n = 9). Mean ± SE

	Treatment			Time		
Variable	LFES	Placebo	P-value	Pre	Post	P-value
Shoulder Right (cm)	-3.6 ± 1.9	-4.9 ± 2.4	0.150	-3.7 ± 2.0	-4.8 ± 2.2**	0.015
Shoulder Left (cm)	-7.4 ± 2.0	-9.0 ± 2.4*	0.011	-7.9 ± 2.1	-8.5 ± 2.2	0.167
CMJ (cm)	74.6 ± 3.2	72.9 ± 3.2	0.140	73.9 ± 3.0	73.5 ± 3.4	0.172
Bar Velocity (m/s)	0.605 ± 0.02	0.607 ± 0.02	0.906	0.611 ± 0.02	0.601 ± 0.02	0.343
Bar Power (W)	722.9 ± 30.1	737.8 ± 36.7	0.647	739.2 ± 31.8	721.6 ± 30.2	0.326
Med. Ball Toss (cm)	260.7 ± 9.7	258.0 ± 16.2	0.828	269.8 ± 11.8	248.9 ± 12.6**	0.002
1-minute Push Up	38.4 ± 2.2	37.3 ± 2.0	0.351	37.6 ± 2.2	38.1 ± 2.0	0.563
250m Row (s)	41.9 ± 0.8	41.6 ± 0.6	0.265	41.8 ± 0.7	41.8 ± 0.7	0.836
24-Hour Muscle Pain	17.8 ± 4.0	15.7 ± 4.8	0.614	9.2 ± 2.4	24.3 ± 5.9**	0.010
24-Hour RPR	79.4 ± 4.6	78.4 ± 4.3	0.761	84.9 ± 3.2	72.9 ± 6.1**	0.048
Acute Muscle Pain	15.1 ± 4.3	16.8 ± 4.0	0.804	9.2 ± 2.4	22.7 ± 3.7**	0.008
Acute RPR	77.3 ± 3.7	73.7 ± 4.6	0.479	84.9 ± 3.2	66.1 ± 5.5**	0.013

LFES = Low frequency electrical stimulation, Pre = pre-ECP workout, Post = post ECP workout
*Significant effect of treatment ($p < 0.05$).
**Significant effect of time ($p < 0.05$).

STUDY III

EFFECT OF DIETRAY SUPPLEMENTATION ON TRAINING RECOVERY FOLLOWING AN EXTREME CONDITIONING PROGRAM WORKOUT

Abstract

Ensuring optimal training recovery is an integral component of any physical activity program. Branch chain amino acids (BCAA) and beta-hydroxy-beta-methylbutyrate (HMB) supplementation have shown to be promising aids in enhancing training recovery. The purpose of this study is to evaluate acute combined BCAA and HMB supplementation (SUP) as a strategy to enhance training recovery and perceptual response following an extreme conditioning program (ECP) workout. Ten well-trained experienced participants completed a baseline performance battery (PRI) consisting of a shoulder reach flexibility test, maximal countermovement jump, bench press assessing bar velocity and peak power, seated medicine ball toss, 1-minute push-up test, and 250 m rowing ergometer test, as well as perceptual markers, followed by an upper-body focused ECP workout. One-hour prior and immediately following the ECP workout participants were administered, single-blinded, a combination of BCAA and HMB or placebo. Participants returned 24-hours after completing the ECP workout to assess performance change via completion of the PRI. A composite recovery score (z-score of six PRI metrics) revealed a main effect of time indicating participant fatigue as a result of the ECP workout (pre 1.58 ± 1.16 vs post 0.57 ± 0.99, mean ± SE; $p = 0.043$). There was no main effect of treatment found for the composite recovery score or any metric of the PRI between SUP and

placebo conditions. Analysis of individual data did not reveal any positive responders to the SUP treatment compared to placebo. These findings suggest that acute combined BCAA and HMB supplementation, under the conditions of this study, did not attenuate the decrements in performance and alterations of perception associated with an upper-body focused ECP workout.

Key Words: supplements, extreme conditioning programs, training recovery, recovery enhancement, BCAA, HMB

Introduction

An integral component of training is to ensure optimal recovery from physical activity allowing an individual to return to baseline (restoring homeostasis) prior to subsequent sessions (6). Incomplete recovery may lead to a less than optimal physiological and psychological status, potentially resulting in deleterious effects on performance during subsequent activity (2, 6). The time required for appropriate training recovery is dependent on several factors, one of the main being training volume (22). Studies have demonstrated that in resistance-trained men and women a minimum of 48 hours is often required to achieve complete training recovery from an exhaustive resistance workout (16, 22, 24). However, many athletes complete additional training despite inadequate training recovery between sessions.

Continued training exposure while under-recovered may lead to early fatigue, less resistance to subsequent physical strain, increased muscle pain, and, in more severe cases, potential for increased risk of injury and overtraining syndrome (2, 6). As a result, developing and evaluating strategies to enhance training recovery can benefit performance by potentially reducing the time course required for recovery between training sessions, allowing for a more rapid adaptation to training. There are many different recovery strategies promoted to enhance training recovery, including various nutritional supplements (2, 6). Two supplements that have shown a degree of success in reducing muscle damage and accelerating recovery are branch chain amino acids (BCAA) and beta-hydroxy-beta-methylbutyrate (HMB).

BCAA include three essential amino acids (leucine, isoleucine, and valine) that are key substrates in protein synthesis (5). Additionally, effects ascribed to BCAA include enhancements in physiological and psychological responses to exercise, attenuation of muscle protein degradation, and accelerated training recovery following endurance and resistance exercise (11, 16, 29). HMB is a leucine derived metabolite that first showed promise in 1996 in reducing muscle proteolysis following resistance training (32). While studies have demonstrated a benefit of HMB supplementation for enhancing recovery (21, 33), there continue to be conflicting reports and under-researched applications (32).

The majority of the research with both BCAA and HMB supplementation have required participants to ingest the ergogenic aids for several days prior to a bout of fatiguing exercise (12, 16, 17, 27, 30, 32). Furthermore, many of these studies have only evaluated markers of skeletal muscle damage and have not assessed performance. Additionally, only one study (a dissertation from the University of Alabama) has evaluated the combined effects of BCAA and HMB supplementation (1). However, this study demonstrated an enhanced training recovery assessed through repetitions to failure of the leg extension and latissimus pull-down exercises. Thus, further evaluation of the acute effects of BCAA and HMB on training recovery in recreational and competitive athletes is warranted.

Extreme Conditioning Program (ECP) training and competition could benefit from a variety of training recovery strategies, including BCAA and HMB supplementation. ECPs often consist of intense workouts with high volume repetitions and short, or no, prescribed rest periods between sets and combine resistance training, Olympic lifting, bodyweight training, aerobic training, and interval training (4, 14). Thus, each workout is metabolically and physically highly demanding.

As ECPs have grown in popularity, extreme conditioning has emerged as a competitive amateur and professional sport. These events are highly intense and typically mimic ECP training. Consequently, it is crucial for these athletes to maximize training recovery to enhance subsequent performance. Currently, no research is available evaluating any method to enhance training recovery following an ECP workout. Thus, the purpose of this study was to evaluate the combination of acute BCAA and HMB supplementation (SUP) as a strategy to enhance training recovery and perceptual response following an extreme conditioning workout.

Methods

Participants

Ethical approval was obtained from the University's Institutional Review Board. Ten healthy males (between 18-30 years old) volunteered to completed this study. This study's sample was chosen in order to reduce cardiovascular risk, minimize any confounding effects associated with age-related differences in skeletal muscle recovery between younger and older individuals (24), and to minimize effects associated with training age. All participants were free of any cardiovascular or metabolic disease and classified as low or moderate risk according to guidelines established by the American College of Sports Medicine (ACSM) (28). All individuals interested in participating in the study completed an exercise history questionnaire to determine if they met the inclusion criteria for the study. All participants reported participating in an ECP at least 4 days per week for a minimum of 6 months. In addition, all participants were familiar with the experimental ECP workout prior to acceptance into the study. Individuals who reported the use of any exogenous steroids were excluded from participation in the study. Prior to participation, written informed consent was obtained from all participants. Descriptive characteristics are reported in Table 1.

Experimental Design

As a method to examine the effect of SUP on training recovery and perceptual response following a bout of ECP, this study examined performance alterations via a performance recovery indicator (PRI) test. The PRI consisted of seven performance metrics (shoulder reach flexibility test, maximal countermovement jump (CMJ), mean velocity and peak power of a 3 repetition bench press at 70% of 1RM, seated medicine ball toss, 1-minute push-up test, and 250 m rowing ergometer test) and three perceptual responses (rating of perceived exertion (RPE), skeletal muscle pain, and rating of perceived recovery (RPR)). All three perceptual ratings were assessed via a 0-100mm visual analog scale (VAS). The VAS was used instead of the traditional ordinal scales to analyze the results as continuous data.

This battery of tests was selected as a non-fatiguing metric that could be performed on consecutive days without affecting the recovery assessment. Additionally, the participants' familiarity with the PRI items was a factor in selection to optimize the sensitivity of the protocol, as well as the ease of assessment replication for practitioners in the field. A recovered participant in this study was defined as an individual who replicated or exceeded the baseline values of the PRI (6). A similar definition of a recovered participant has been established in previous work (13, 31).

In a repeated measures counterbalanced design, participants completed five separate trials within 14 days (Figure 1). Trial 1 consisted of familiarization with testing protocols and completion of a 1 repetition maximum (1RM) bench press. Trials 2 and 4 consisted of baseline PRI assessment prior to the ECP workout. Additionally, following each ECP workout, participants were randomly assigned to receive a counterbalanced recovery intervention (SUP or a placebo). SUP consisted of a combination of BCAA and HMB supplements. Participants consumed two 5-gram (5 capsules) doses of BCAA (Optimum Nutrition, Inc., Downers Grove, IL) (2.5 grams Leucine, 1.25 grams Isoleucine, 1.25 grams Valine) and one 3-gram (3 capsules) dose of HMB (MET-Rx Nutrition, Inc., Boca Raton, FL). One dose of BCAA and HMB supplement was consumed 1-hour prior to the ECP workout. The second dose of BCAA supplement was consumed 5-minutes following the ECP workout. Placebo was comprised of sugar-free soft candy (Jelly Belly Gummi Bears, Fairfield, CA) and administered in the same manner as SUP). Trials 3 and 5 consisted of repeating the PRI and occurred 24-hours following trials 2 and 4, respectively. A similar protocol to assess recovery after fatiguing exercise has been utilized in previous research (13, 31).

Procedures

For each trial, participants arrived to the testing facility at the same time of day at least 3-hours post-absorptive and were instructed to adequately hydrate as well as abstain from caffeine and alcohol 24-hours prior to each testing session. In addition, participants were instructed to refrain from any exercise (except the experimental trials) at least 48 hours preceding any trial. Participants were also instructed to get at least 8 hours sleep and to replicate dietary intake on the day of and immediately prior to testing. A questionnaire was utilized to evaluate participant adherence to the requested instructions before commencement of each trial.

On the first trial, participants provided initial informed consent, completed a 1-repetition maximum (1RM) bench press protocol, and were familiarized with all PRI measurements and the experimental ECP workout. Prior to the 1RM bench press participants were allowed a 5-10-minute dynamic warm-up of their choosing. The 1RM bench press protocol followed the suggested guidelines by the National Strength and Conditioning Association (25). Additionally, each participant's height and body mass were measured using a calibrated stadiometer and beam-balance scale (Detecto, Webb City, MO). Participants' body fat percentage was estimated during trial 1 utilizing a three-site skin-fold measurement (Lange Caliper, Beta Technology Inc., Deer Park, NY) and the equations developed by Jackson and Pollock (18).

Prior to data collection at all 5 trials, participants were familiarized with the RPE, skeletal muscle pain, and RPR scales. All three perceptual ratings were assessed via a 0-100mm visual analog scale (VAS). Additionally, 1-hour prior to the ECP workout during trials 2 and 4, participants consumed the first dose of either SUP or placebo. Participants were then fitted with a HR monitor (Polar Electro Inc., Lake Success, NY) and HR was recorded continuously throughout the trial.

Each participant was then allowed to perform a 5 to 10-minute dynamic warm-up of their choosing (the same warm-up was completed prior to each trial). Following the warm-up, participants were allowed a 5-min rest period. After the 5-min rest period, participants indicated skeletal muscle pain and RPR followed by one attempt per arm of the shoulder reach flexibility test. Next, participants completed four CMJ, interspersed with 30 seconds recovery between jumps. Participants then performed a standardized bench press warm-up leading to 70% of 1 RM, then completed 3 repetitions of the bench press at 70% of 1RM (1RM was determined in trial 1). Mean concentric velocity and peak concentric power of the 3 repetitions was assessed with a linear position transducer (GymAware, Kinetic Performance Technology Pty Ltd., Mitchell ACT, Australia) (19) and the highest value of the 3 repetitions was analyzed. Following the bench press, participants completed four attempts of a seated medicine ball toss using a 4.5kg medicine ball. Each toss was interspersed by a 1-minute rest period and a 5-minute rest period following the final toss. After the 5-minute rest period participants completed a 1-minute push-up test (3) using a metronome to maintain a pace of 45 push-ups per minute. An additional 5-minute rest period was allowed, and then participants completed the 250 m rowing ergometer test (13) followed by 10 minutes of recovery. Two-minutes after completion of the rowing ergometer test, participants indicated an RPE for the rowing ergometer test.

Following completion of the PRI participants performed the ECP workout. After completing the ECP workout, participants were seated for 35 minutes of passive rest. Two-minutes after completion of the ECP workout participants indicated an RPE for the ECP workout and 3-minutes later consumed the second dose of either SUP or placebo. Two minutes following the recovery period participants were asked to report skeletal muscle pain and RPR. Participants were instructed to abstain from all exercise and recovery strategies and return to the testing facility after 24-hours to replicate the warm-up protocol and PRI.

ECP Workout. The ECP workout utilized in this study was a popular standard workout. This ECP workout is a time-to-completion effort, consisting of 21 handstand push-ups, 21 ring dips, 21 push-ups, 15 handstand push-ups, 15 ring dips, 15 push-ups, 9 handstand push-ups, 9 ring dips, and 9 push-ups. Participants were asked to perform this workout at maximal intensity. Time to completion was recorded.

The ECP workout required that the individual complete all prescribed repetitions for the movement before moving on to the next exercise. Each movement was standardized for all participants. Handstand push-ups standards require participants to begin upside-down, against a wall with arms and legs extended. Participants then descended until the head touched the ground and returned to the starting position for the repetition to be successful. Ring dips consisted of the participant starting on the gymnastics rings, with arms extended along the sides of the body.

Participants then bent at the elbow and descend until the anterior portion of the shoulder broke the plane of the elbow. Push-ups followed the traditional method with a requirement of touching the chest on the ground at the lower portion of each repetition. For the purposes of this study, traditional or "kipping" technique was allowed for the handstand push-ups and ring dips. However, participants were required to utilize the same technique for all trials. Failure to achieve these standards required the participant to repeat the repetition of that movement until successfully performed.

Performance Recovery Indicators. A shoulder reach flexibility test was utilized to assess shoulder flexibility. Participants elevated the right arm overhead, bent the right elbow, and let the right palm rest on the back of the neck or between the shoulder blades. The participant then reached behind the back with the left hand attempting to touch the right hand. A measurement in centimeters was taken of the distance between the hands (resulting in a negative value) or the overlap of the fingers (resulting in a positive value). The procedure was replicated on the opposite arm.

A jump mat system (Just Jump, Probotics, Huntsville, AL) was utilized to perform the CMJs. During trial 1, each participant was educated on how to perform a CMJ. The CMJ required that the participant be in an upright posture with feet shoulder width apart. The participant then descended into a semi-squat position while simultaneously swinging the arms back. The arms then swung forward and overhead as the participant jumped vertically landing on both feet at the same time. Participants performed four CMJs with 30 seconds between attempts; the highest CMJ was utilized for data analysis. The CMJ has been shown to be a popular measure of power in the field (15) and has been used to assess functional performance following exercise (7, 9, 13, 31).

Three repetitions at 70% of 1RM bench press was used to assess mean concentric bar velocity and peak bar power (19). During trial 1, participants completed a 1RM bench press protocol. A linear position transducer (GymAware, Kinetic Performance Technology Pty Ltd., Mitchell ACT, Australia) was used to assess velocity and power.

The seated medicine ball toss consisted of participants sitting on the floor with legs extended and back against a wall to prevent movement at the hip. Participants began similar to the start of a chest pass, with their hands on either side of the ball and forearms positioned parallel to the ground. A 4.5 kg medicine ball was used. Participants were instructed to throw the medicine ball, using a chest pass technique, as far and straight as possible. A tape measure was secured to the floor from the end of the participants' heel of their shoe. The site the ball first made contact with the floor was recorded to the nearest cm. There was a 1-minute rest between attempts and participants completed 4 tosses. In an attempt to minimize variance, the highest and lowest medicine ball toss was removed and the average of the two remaining values was used for data analysis. A similar field assessment has been utilized to assess upper-body power in athletes (10).

Muscular endurance was assessed via a 1-minute push-up test (28). This study used the push-up method described by Baumgartner et al. (2002) (3). Participants started with hands shoulder-width apart in a prone position. The "down" position of the push-up consisted of the participants' body (from chest to thighs) making contact with the ground. The "up" position consisted of the participants' arms in full extension and body in a straight line (from the shoulder to the ankle). A metronome was utilized to maintain a rate of 45 push-ups per minute and participants continued until they either performed 45 push-ups, no more push-ups could be performed with correct form, or the pace could not be maintained. A push-up was counted when the participant successfully reached the “up” position.

Anaerobic performance was assessed this via a 250 m rowing ergometer test. The rowing ergometer test was performed on an air-braked rowing ergometer (Concept 2 Model D, Concept 2, Inc., Morrisville, VT) and was a maximal-time-to-completion effort for all participants. The rowing ergometer was set with a drag factor of 140 and the same ergometer was utilized each trial for all participants. A similar protocol has been used in previous research that featured a short-duration rowing test as a performance test of recovery (13). Time to completion and mean power output of the 250 m rowing ergometer test were recorded from the display on the ergometer.

A single overall composite recovery score was computed from values utilized for analysis from the CMJ, mean concentric bar velocity, peak bar power, seated medicine ball toss, 1-minute push-up, and 250 m rowing ergometer test. We did this by converting the actual scores to z-scores and summing. Combined data of the current study and a separate unpublished study by Casey et al. (8) were used to calculate the mean and standard deviation used for computing the z-scores.

Perceptual Measures. Three perceptual measures were utilized during this study to assess participants’ RPE, skeletal muscle pain, and rating of perceived recovery (RPR). All perceptual measures utilized a continuous 0-100 mm horizontal line visual analog scale (VAS). For all VAS scales, participants marked a vertical line intersecting the 100 mm horizontal line indicating the perceptual response. The RPE VAS was anchored on the left with “No Exertion” and the right with “Maximal Exertion”. Skeletal Muscle Pain VAS scale was anchored on the left with “No Pain” and on the right with “Extreme Pain”. The RPR VAS scale was anchored on the left with

"Not Recovered at ALL" and right with "Completely Recovered". Participants' RPE was recorded for the rowing ergometer performance test and the ECP workout. Participants reported RPR and skeletal muscle pain 5-minutes after warm-up during each trial and two minutes after completing the recovery intervention.

Recovery Intervention

Supplementation. SUP consisted of a combination of BCAA and HMB supplements and was administered single-blinded. Participants consumed two 5-gram (5 capsules) doses of BCAA (Optimum Nutrition, Inc., Downers Grove, IL) (2.5 grams Leucine, 1.25 grams Isoleucine, 1.25 grams Valine) and one 3-gram (3 capsules) dose of HMB (MET-Rx Nutrition, Inc., Boca Raton, FL). One dose of BCAA and HMB supplement was consumed 1-hour prior to the ECP workout. The second dose of BCAA supplement was consumed 5-minutes following the ECP workout. These doses and timing of doses are consistent with previous studies (16, 32, 33) and are not associated with negative side effects. Participants receiving SUP treatment remained in a passive seated position for 35 minutes after completion of the ECP workout.

Placebo. The placebo was comprised of thirteen sugar-free soft candies (Jelly Belly Gummi Bears, Fairfield, CA) administered over 2 doses. The first dose consisted of eight candies and was administered 1-hour prior to the ECP workout. The second does consisted of five candies administered 5-minutes following the ECP workout. Participants receiving placebo treatment remained in a passive seated position for 35 minutes after completion of the ECP workout.

Data Analysis

A 2x2 (treatment x time) repeated-measures two-way analysis of variance (ANOVA) was utilized in order to compare skeletal muscle pain, RPR, seated medicine ball toss, CMJ, maximal push-ups, and 250-m rowing performance between the treatment conditions (SUP and placebo) and time (pre-ECP workout and post-ECP workout). When appropriate, a post hoc Fisher's LSD follow-up was performed to identify where significant differences occurred. A paired-samples t-test was used to detect differences in RPE and time to completion of the ECP workout between SUP and placebo treatments.

All raw scores of the CMJ, mean concentric bar velocity, peak bar power, seated medicine ball toss, 1-minute push-up, and 250 m rowing ergometer test were converted to z-scores using the mean and standard deviation used from combined data of the current study and a separate study by Casey et al. (8). This was done in order to create a single metric capturing recovery status (composite recovery score). The composite recovery score was then calculated for each individual as the sum of the six z-scores. A repeated-measures two-way ANOVA (treatment x time) was utilized to compare the composite recovery scores.

In order to evaluate individual responses, data from each individual were compared to the least significant difference for the sample. Participants were classified as either positive-responders (performance increased greater than or equal to the least significant difference), negative-responders (performance decreased greater-than or equal to the least significant difference), or non-responders (smaller change in performance relative to the least significant difference). An alpha level of 0.05 was observed for statistical testing. Data were analyzed using SPSS Statistics version 18.0 (Somers, NY).

Results

All participants followed requested instructions concerning sleep and dietary intake required for this study. Mean values for the composite recovery score can be found in Table 2. Mean values for PRI treatment x time interaction can be found in Table 3. Mean values for PRI main effects (treatment and time) can be found in Table 4. A paired-samples t-test revealed that there was no significant mean difference found for time to completion of the ECP workout between SUP (10.88 ± 4.19 min) and placebo (11.90 ± 5.25 min) ($p = 0.103$). Additionally, there was no difference for RPE of the ECP workout between treatment conditions (SUP 81.1 ± 10.7, placebo 79.7 ± 11.9; $p = 0.574$). Participants average heart rate during the ECP workout was 169.1 ± 10.1 bpm (86% age-predicted heart rate max) for SUP and 169.1 ± 6.7 bpm (86% age-predicted heart rate max) for placebo.

A two-way ANOVA revealed there was a significant effect of time for the composite recovery score demonstrating a decrement in performance post-ECP workout compared to pre-ECP workout ($p = 0.043$). There was a main effect of time for the seated medicine ball toss indicating a decrement in performance from pre-ECP workout to post-ECP workout ($p = 0.006$). A main effect of time showed an increase in skeletal muscle pain after 35-minutes of passive rest following completion of the ECP workout compared to skeletal muscle pain at baseline ($p = 0.005$). Additionally, a main effect of time indicated RPR was lower after 35-minutes of passive rest following the ECP workout compared to baseline ($p = 0.008$). Furthermore, a main effect of time demonstrated that participants indicated a higher rating of skeletal muscle pain 24-hours after completing the ECP workout than at baseline ($p = 0.006$).

There was no significant main effect of treatment or treatment x time interaction for any single PRI metric. In addition, individual analysis did not reveal that any participant positively responded to the SUP treatment compared to placebo in any of the metrics in our PRI.

Discussion

The purpose of this study was to evaluate the effect of acute BCAA and HMB combined supplementation (SUP) on recovery following an ECP workout via analysis of the PRI in well-trained and experienced males. This is the first study assessing a recovery treatment following an ECP workout. We hypothesized that SUP would result in improvements relative to placebo. However, we observed no improvements in the PRI between SUP and placebo treatments, thus, the hypothesis was not supported in the conditions of the current study.

Although, there is currently little research evaluating the acute physiological effects of ECP workouts, it is well established that high volume- and intensity-resistance-based exercise induces skeletal muscle damage which can result in subsequent performance decrement and increased muscle soreness following the activity. The ECP workout employed in this study could be classified as high intensity as it consisted of 135 upper-body, bodyweight pressing repetitions completed in an average of 10.88 ± 4.19 min for the SUP condition and 11.90 ± 5.25 min for the placebo condition. The average participant heart rate for the workout was 169.1 ± 10.1 bpm (86% age-predicted heart rate max) for SUP and 169.1 ± 6.7 bpm (86% age-predicted heart rate max) for placebo. Similar values have been noted from other ECP workouts (20, 34).

Additionally, we did see that the ECP workout resulted in fatigue 24-hours after completion as indicated through a main effect of time for the composite recovery score (pre 1.58 ± 1.16 vs post 0.57 ± 0.99, mean ± SE; $p = 0.043$) and a main effect of time for the medicine ball toss (pre 260.3 ± 14.5 cm vs post 247.2 ± 12.4 cm, mean ± SE; $p = 0.006$). As noted in Table 4, the ECP workout also resulted in an increase of participant perception of acute muscle pain ($p = 0.005$) and decrement of RPR ($p = 0.008$), as well as an increase of 24-hour perception of muscle pain ($p = 0.006$).

One potential method to assist in performance recovery and attenuation of muscle soreness is supplementation of BCAA and HMB. The primary mechanisms of action for both supplements are enhanced muscle protein synthesis through stimulation of mTOR and attenuation of muscle protein degradation (12, 32). While it is of note that the current literature supports an ergogenic role of BCAA and HMB promoting enhanced skeletal muscle recovery and reduction in muscle soreness following strenuous training (11, 12, 32), much of the research has focused on chronic supplementation (16, 29, 32) or effects in untrained populations (12, 30, 32). Additionally, no research has currently been completed evaluating the efficacy of combined BCAA and HMB supplements following an ECP bout. Thus, it is difficult to compare the results of the current study to the previous literature.

Howatson et al. (16) suggested that chronic supplementation of BCAA (7 day loading phase followed by 5 day maintenance phase following damaging exercise) reduced markers of muscle damage and accelerated recovery in resistance-trained males. Twelve trained males (BCAA n = 6, placebo n = 6) supplemented BCAA or placebo for 7 days and then performed 100 consecutive drop-jumps. Markers of recovery (creatine kinase, perceived muscle soreness, maximal voluntary contraction (MVC) of knee extensors, and vertical jump) were assessed pre damaging exercise and 24, 48, 72, and 96 hours post damaging exercise. At 24 hours, all measures were improved relative to placebo except vertical jump, which saw no improvement at any time point relative to placebo. Potentially the most notable findings of that study were that reductions of MVC were blunted and recovery of MVC was enhanced in the BCAA condition. This is in contrast to a previous study by Jackman et al. (17) indicating that while BCAA did attenuate increases of perceived muscle soreness, there was no enhancement of force production in the BCAA condition relative to placebo in untrained men.

Wilson et al. (33) demonstrated that there was no difference in MVC of the knee extensors or flexors following fatiguing lower-body exercise in untrained participants between acute supplementation of 3-grams of HMB and placebo. Additionally, there were no improvements in perceived muscle soreness between conditions. In a similar study of chronic supplementation of 3-grams of HMB per day, Paddon-Jones et al. (27) found similar results with no enhancements in muscle soreness or muscle torque of the elbow flexors between HMB and placebo groups following a damaging eccentric upper-body exercise protocol.

The lone study evaluating a combination of BCAA and HMB supplementation, along with glutamine supplementation, on resistance training is a dissertation from the University of Alabama by Baggett et al. (1). Participants were administered a combination of the three supplements or placebo followed by fatiguing resistance exercise (3 x 8-12 repetitions of six exercises). The study showed that in resistance-trained men and women acute supplementation resulted in enhanced performance based recovery in the repetitions-to-failure of the leg extension and latissimus pull-down, 24-hours following the fatiguing exercise. Additionally, participants indicated a significantly lower rating of perceptual muscle pain 24-hours following the fatiguing resistance training protocol.

The current study is in agreement with the limited previous research that indicated no significant alterations to performance following acute supplementation of BCAA or HMB, specifically with measurements of force and power. Whereas we did not assess lower-body force, we did see similar results to Jackman et al. (17), Wilson et al. (33), and Paddon-Jones et al. (27) in that power production was not altered through BCAA and HMB combined supplementation relative to placebo when assessed via a seated medicine ball toss. Furthermore, there was no effect of treatment for the composite recovery score, indicating that there was no recovery enhancement for total fatigue. In addition, our study doesn't support attenuation of muscle soreness via acute dosing of BCAA and HMB combined supplementation when assessed following an upper-body pressing ECP workout. The current literature is quite mixed on the benefits of BCAA and HMB supplementation. It appears that the most significant benefits would come as a result of chronic supplementation (12, 16, 32), be expressed through biochemical markers of muscle damage (12, 32), enhanced muscular endurance (1), and reductions in pain (1, 12, 16, 32), as opposed to maximal force or power efforts (17, 27). Additionally, it seems that HMB supplementation may be more effective in an untrained population unless the exercise stimulus is of a very high volume and intensity (23, 26, 32).

The present study is different from the existing literature in that our fatiguing workout was a time to completion, upper-body focused, body-weight ECP workout. Additionally, our sample consisted of well-trained individuals who regularly partake in fatiguing ECP training. We theorize that differing results between the current study and the previous literature could simply be a result of a different stimulus and study sample. It is of note that our ECP workout allowed the “kipping” style movement of handstand push-ups and ring dips. This style promotes a full-body effort to enhance the speed of movement. This could result in a reduction of muscular tension placed on the primary movers of the specific movements. As a result, there may be less fatigue in an ECP workout that incorporates “kipping” style movements. Future research should focus on recovery strategies following higher volume ECP workouts.

Conclusion

In summary, adequate training recovery is necessary for competitive and recreational athletes. Thus, interventions to enhance training recovery may assist individuals in maximizing adaptations to training and minimizing deleterious effects of higher training volume and intensities. Our study did not find that an acute combined BCAA and HMB supplement enhanced any of our PRI metrics or composite recovery score following an upper-body focused ECP workout. These results are in agreement with a limited body of literature indicating that acute supplementation of BCAA or HMB may not result in vast enhancements in recovery following fatiguing exercise.

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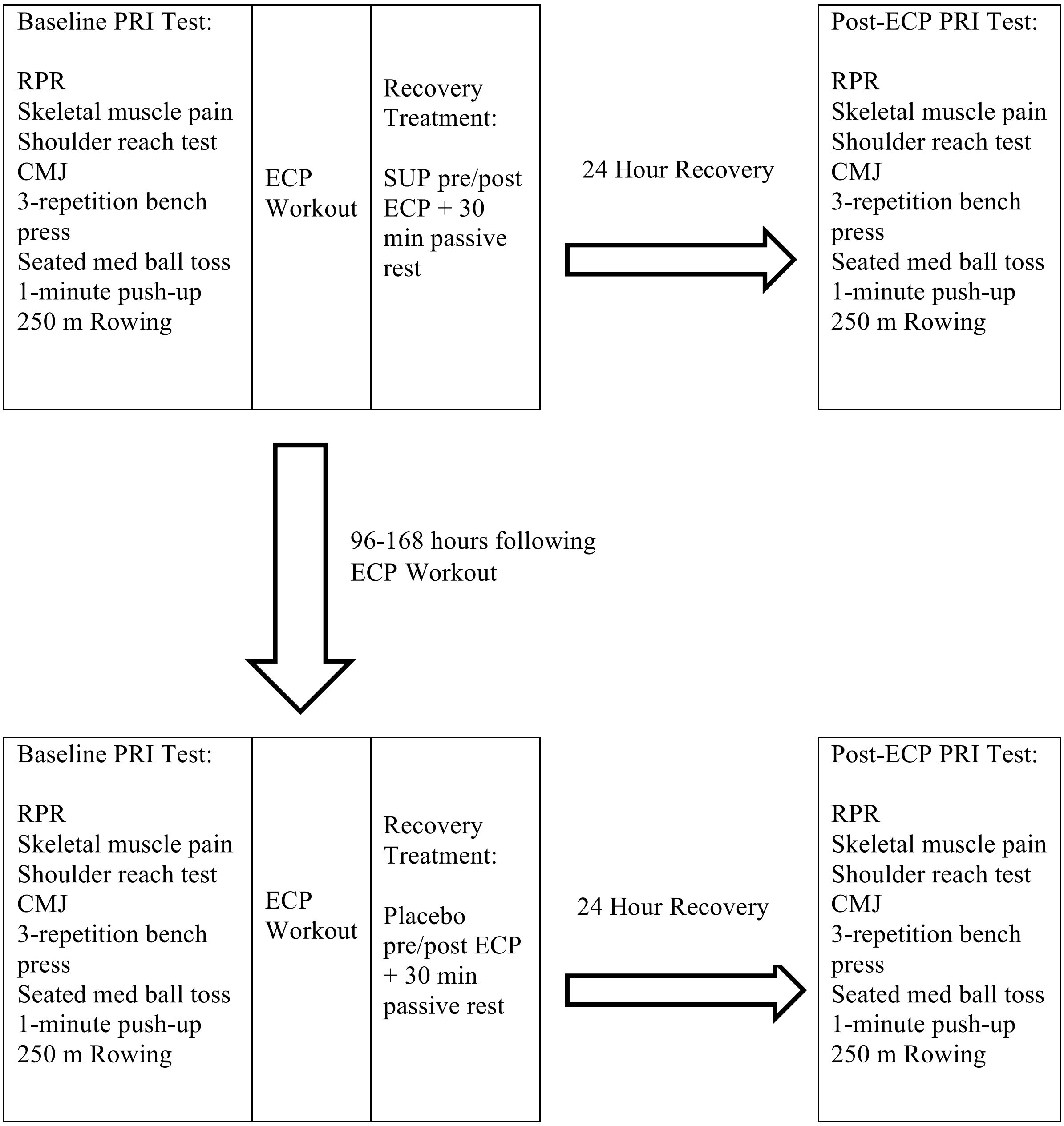

Figure 3.1. Study design (counterbalanced order)

Table 3.1. Descriptive characteristics of participants (n = 10).

Variable	Mean ± SD	Min	Max
Age (y)	22.8 ± 4.3	18	30
Weight (kg)	85.6 ± 8.2	78.6	105.8
Height (cm)	177.6 ± 6.3	166.0	187.0
Body fat (%)	11.6 ± 4.1	4.6	20.2
ECP Experience (y)	3.3 ± 1.4	2.0	6.0

Table 3.2. Composite recovery score two-way ANOVA results (n = 10). Mean ± SE

	Interaction					
Variable	SUP Pre	SUP Post	Placebo Pre	Placebo Post	P-value	
Composite Recovery Score	1.34 ± 1.17	0.28 ± 1.15	1.82 ± 1.26	0.86 ± 1.07	0.876	
	Treatment			Time		
	SUP	Placebo	P-value	Pre	Post	P-value
	0.81 ± 1.13	1.34 ± 1.14	0.524	1.58 ± 1.16	0.57 ± 0.99*	0.043

SUP Pre = Supplement trial pre-ECP workout, SUP Post = Supplement trial 24-hours post-ECP workout, Placebo Pre = Placebo trial pre-ECP workout, Placebo Post = Placebo trial post-ECP workout, SUP = Supplement, Pre = pre-ECP workout, Post = post ECP workout; *Significant main effect of time variable (p = 0.043).

Table 3.3. PRI measurement interaction (treatment x time) (n = 10). Mean ± SE

Variable	SUP Pre	SUP Post	Placebo Pre	Placebo Post	P-value
Shoulder Right (cm)	-2.6 ± 1.6	-3.1 ± 1.7	-4.0 ± 2.1	-4.6 ± 2.3	0.861
Shoulder Left (cm)	-7.2 ± 1.8	-8.3 ± 2.1	-8.4 ± 2.1	-9.3 ± 2.2	0.830
CMJ (cm)	74.5 ± 2.3	72.3 ± 2.6	73.6 ± 2.9	72.9 ± 3.0	0.314
Bar Velocity (m/s)	0.61 ± 0.02	0.60 ± 0.02	0.61 ± 0.02	0.60 ± 0.02	0.953
Bar Power (W)	706.2 ± 32.7	690.9 ± 29.8	763.5 ± 34.4	741.9 ± 39.1	0.814
Med. Ball Toss (cm)	256.1 ± 15.0	244.6 ± 14.0	264.5 ± 16.0	249.7 ± 13.4	0.645
1-minute Push Up	38.7 ± 2.0	37.2 ± 2.2	37.7 ± 1.7	36.8 ± 2.0	0.720
250m Row (s)	41.6 ± 0.8	41.6 ± 0.7	41.5 ± 0.6	41.6 ± 0.5	0.770
24-Hour Muscle Pain	16.0 ± 6.3	23.4 ± 4.4	12.2 ± 4.4	24.4 ± 7.1	0.601
24-Hour RPR	77.3 ± 7.4	73.0 ± 4.0	81.1 ± 4.9	72.2 ± 5.2	0.580
Acute Muscle Pain		26.6 ± 6.3		23.7 ± 4.4	0.762
Acute RPR		64.4 ± 5.2		61.0 ± 5.8	0.138

SUP Pre = Supplement trial pre-ECP workout, SUP Post = Supplement trial 24-hours post-ECP workout, Placebo Pre = Placebo trial pre-ECP workout, Placebo Post = Placebo trial post-ECP workout; There was no significant interaction for any variable ($p > 0.05$).

Table 3.4. PRI measurement main effects (n = 10). Mean ± SE

	Treatment			Time		
Variable	SUP	Placebo	P-value	Pre	Post	P-value
Shoulder Right (cm)	-2.8 ± 1.7	-4.3 ± 2.2	0.075	-3.3 ± 1.8	-3.8 ± 2.0	0.170
Shoulder Left (cm)	-7.7 ± 1.9	-8.9 ± 2.1	0.269	-7.8 ± 1.9	-8.8 ± 2.1	0.098
CMJ (cm)	73.4 ± 2.4	73.2 ± 2.9	0.791	74.1 ± 2.6	72.6 ± 2.7	0.107
Bar Velocity (m/s)	0.61 ± 0.02	0.61 ± 0.02	0.906	0.61 ± 0.02	0.60 ± 0.02	0.343
Bar Power (W)	698.5 ± 29.9	757.7 ± 36.0	0.067	734.8 ± 32.1	716.4 ± 29.7	0.128
Med. Ball Toss (cm)	250.3 ± 14.3	257.1 ± 14.5	0.543	260.3 ± 14.5	247.2 ± 12.4*	0.006
1-minute Push Up	38.0 ± 2.0	37.3 ± 1.8	0.490	38.2 ± 1.8	37.0 ± 2.0	0.295
250m Row (s)	41.6 ± 0.7	41.5 ± 0.6	0.797	41.5 ± 0.7	41.6 ± 0.6	0.869
24-Hour Muscle Pain	19.7 ± 4.9	18.3 ± 5.1	0.697	14.1 ± 4.7	23.9 ± 5.0*	0.006
24-Hour RPR	75.2 ± 5.2	76.7 ± 4.2	0.788	79.2 ± 5.1	72.6 ± 3.5	0.131
Acute Muscle Pain	21.3 ± 6.2	18.0 ± 3.8	0.495	14.1 ± 4.7	25.2 ± 4.9*	0.005
Acute RPR	70.9 ± 5.6	71.1 ± 4.9	0.977	79.2 ± 5.1	62.7 ± 4.4*	0.008

SUP = Supplement, Pre = pre-ECP workout, Post = post ECP workout
*Significant effect of time ($p < 0.05$).

APPENDIX

THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Institutional Review Board for the Protection of Human Subjects

April 21, 2016

Jason Casey
Department of Kinesiology
College of Education
The University of Alabama
Box 870314

Re: IRB Protocol # 15-023-ME
"Time Course of Recovery in Trained Individuals Following an Extreme Conditioning Workout"

Mr. Casey:

The University of Alabama Medical Institutional Review Board has reviewed the revision to your previously approved full board protocol. The board has approved the change in your protocol.

Please remember that your approval period expires one year from the date of your original approval, December 10, 2015, not the date of this revision approval.

Should you need to submit any further correspondence regarding this proposal, please include the assigned IRB application number. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants.

Good luck with your research.

Sincerely,

J. Grier Stewart, MD, FACP
Medical IRB Chair

IRB Project #: 15-023-ME

UNIVERSITY OF ALABAMA
INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS
REQUEST FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS

I. Identifying information

	Principal Investigator	Second Investigator	Third Investigator
Names:	Jason Casey	Phil Bishop	
Department:	University Recreation	Kinesiology	
College:		Education	
University:	The Univeristy of Alabama	The Univeristy of Alabama	
Address:			
Telephone:			
FAX:			
E-mail:	jccasey@sa.ua.edu	pbishop@bamaed.ua.edu	

Title of Research Project: Time course of recovery in trained individuals following an extreme conditioning workout

Date Submitted: 3/24/2016
Funding Source: N/A

Type of Proposal	☐ New	☒ Revision	☐ Renewal Please attach a renewal application	☐ Completed	☐ Exempt
			Please attach a continuing review of studies form		
		Please enter the original IRB # at the top of the page			

UA faculty or staff member signature: ______________________

II. NOTIFICATION OF IRB ACTION (to be completed by IRB):
Type of Review: __✓__ Full board _____ Expedited

IRB Action:
___ Rejected Date: _________
___ Tabled Pending Revisions Date: _________
___ Approved Pending Revisions Date: _________
✓ Approved-this proposal complies with University and federal regulations for the protection of human subjects.
Approval is effective until the following date: 12-10-16
Items approved: ___ Research protocol (dated_________)
___ Informed consent (dated_________)
___ Recruitment materials (dated_________)
___ O (dated_________)

Approval signature ______ Date 4/21/16

THE UNIVERSITY OF
ALABAMA | Office of the Vice President for Research & Economic Development
Institutional Review Board for the Protection of Human Subjects

April 14, 2016

Jason Casey
Department of Kinesiology
College of Education
The University of Alabama
Box 870314

Re: IRB Protocol # 16-007-ME
"Effect of Low Frequency Electrical Stimulation and Dietary Supplementation on Training Recovery Following an Extreme Conditioning Workout"

Mr. Casey:

The University of Alabama IRB has received the revisions requested by the full board on 3/31/16. The board has reviewed the revisions and your protocol is now approved for a one-year period. Please be advised that your protocol will expire one year from the date of approval, 3/24/16.

If your research will continue beyond this date, complete the Renewal Application Form. If you need to modify the study, please submit the Modification of An Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, please complete the Request for Study Closure Form.

Should you need to submit any further correspondence regarding this proposal, please include the assigned IRB application number. Please use reproductions of the IRB approved stamped consent/assent forms to obtain consent from your participants.

Good luck with your research.

Sincerely,

J. Grier Stewart, MD, FACP
Medical IRB Chair