

國立體育學院九十四學年度研究所博士班入學考試試題

體育運動論文評論(生化營養組)

(本試題共七頁)

注意:答案一律寫在答案卷上,否則不予計分

請詳細閱讀所附之論文後,作答下列各問題。作答方式一律須橫書。

- 1、請說明本論文的主要目的。(10%)
- 2、請詳述本論文的實驗方法及步驟。(30%)
- 3、請詳述本論文所得結果及討論。(45%)
- 4、本論文的優缺點為何?(15%)

EFFECTS OF β -HYDROXY β -METHYLBUTYRATE ON POWER PERFORMANCE AND INDICES OF MUSCLE DAMAGE AND STRESS DURING HIGH-INTENSITY TRAINING

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ABSTRACT. Hoffman, J.R., J. Cooper, M. Wendell, J. Im, and J. Kang. Effects of β -hydroxy β -methylbutyrate on power performance and indices of muscle damage and stress during high intensity training. *J. Strength Cond. Res.* 18(4):000-000. 2004.—Twenty-six members of a collegiate football team were randomly assigned to either a supplement (S) (3 g of β -hydroxy β -methylbutyrate [HMB] per day) or placebo (P) group. Testing occurred before (PRE) and at the end of 10 days of preseason football training camp (POST). During each testing session, subjects performed an anaerobic power test, and blood samples were obtained for testosterone, cortisol, creatine kinase, and myoglobin analysis. No differences in anaerobic power were seen between PRE and POST in either group. Cortisol concentrations were significantly decreased from PRE (333 ± 81 nmol·L⁻¹) to POST (246 ± 79 nmol·L⁻¹), and a sixfold increase was seen in creatine kinase concentrations at POST. However, no significant differences between the groups were seen. No significant time or group effects were observed in testosterone or myoglobin concentrations. Results suggest that short duration HMB supplementation does not provide any ergogenic benefit in collegiate football players during preseason training camp.

KEY WORDS. nutritional supplementation, football, endocrine, training

INTRODUCTION

Beta-hydroxy β -methylbutyrate (HMB) is a relatively new ergogenic aid that is achieving some popularity. HMB is a derivative of the amino acid leucine and its metabolite α -ketoisocaproate. It is believed that HMB has both anabolic and lipolytic effects. However, there is limited research available to support such claims. In limited studies, significantly greater improvements in strength and lean body mass have been reported in previously untrained subjects after resistance-training programs of 4–8 weeks after supplementation compared with subjects consuming a placebo (4, 8, 16, 19). In addition, no adverse effects on hepatic enzyme function, lipid profile, renal function, or the immune system were noted after 8 weeks of HMB supplementation (5).

Studies that have examined HMB administration have also demonstrated possible anticatabolic properties of the supplement (21, 25). This has been attributed to reduced enzyme markers of muscle damage and an enhanced recovery during periods of high muscular stress after HMB administration (11, 15). Specifically, these studies have reported significantly lower creatine kinase and lactate dehydrogenase concentrations after a prolonged run (20 km) in endurance-trained athletes (11) or

in the initial weeks of a resistance-training program (15, 16). The subjects in these studies supplemented with 3 g per day of HMB for periods lasting 3–6 weeks. During supplementation schedules of shorter duration (<1 week), the ability to attenuate the catabolic effects of exercise or enhance strength seems to be limited (24). In addition, the ergogenic effects of HMB in a trained athletic population are less clear. Studies using resistance-trained or competitive athletes were unable to duplicate the results seen in a recreationally trained population using similar supplementation schedules (12, 17, 18, 20). Considering the growing popularity of this supplement, it seems that further research is warranted concerning its alleged ergogenic effect in highly trained competitive athletes.

During high-volume and high-intensity training, similar to what occurs during preseason training camp for football, the ability for an athlete to recover may become compromised, and as a result, the athlete may become susceptible to problems associated with overreaching and fatigue. Little information is known concerning the physiological changes occurring to these athletes during such training. However, anecdotal reports have been consistent in describing the highly stressful and intense nature of these types of training programs. A nutritional supplement that can enhance recovery and maintain or improve the quality of the workouts would be highly desirable. Thus, the purpose of this investigation was to examine the effectiveness of the nutritional supplement HMB on muscular performance and on the hormonal and biochemical parameters associated with stress, recovery, and muscle damage during preseason training camp in intercollegiate football players.

METHODS

Experimental Approach to the Problem

The experimental design was single blind and involved 30 members of a NCAA Division III football team that were randomly assigned to either a supplemental or a placebo group. The supplement group consumed 1 g of HMB 3 times per day, whereas the control group was given a placebo similar in appearance. The study began 1 day before the onset of preseason training camp and concluded 10 days later at the end of 2-a-day training sessions. Performance, endocrine, biochemical variables, and subjective measures of fatigue and soreness were analyzed before and after the training camp to determine the efficacy of 10 days of HMB supplementation.

Subjects

Thirty members of a NCAA Division III football team volunteered as subjects for this investigation. After an explanation of all procedures, risks, and benefits, each subject gave his informed consent to participate in this study. The Institutional Review Board of the college approved the research protocol. All subjects were free of any musculoskeletal and neuroendocrine disorders. In addition, all subjects reported being free of any anabolic steroid supplementation during the previous year and agreed to refrain from any additional nutritional supplementation during the 2 weeks before this study and during the duration of this study. Four of the subjects were injured during practice sessions and were unable to complete the study. Analysis reflects the 26 subjects that were able to complete all phases of the study.

Experimental Design

Subjects were tested 1 day before the beginning of pre-season training camp (PRE) and 10 days later (POST) at the end of 2-a-day sessions. All testing sessions occurred at the same time of day. There were an equal number of linemen and skill-position (wide receiver, running backs, and defensive backs) players that volunteered as subjects. After the first testing session, subjects were randomly assigned per position to either a placebo (P) group ($n = 15$; 20.7 ± 1.2 years, 182.6 ± 6.5 cm, and 99.1 ± 19.2 kg) or a supplemental (S) group (1 g of HMB 3 times per day, for a daily total of 3 g; $n = 15$; 20.7 ± 1.3 years, 179.5 ± 6.2 cm, and 96.9 ± 12.8 kg). Because of the uneven number of subjects in each group, one group had 7 linemen and 8 skill-position players, whereas the other group had the opposite number. A single-blind procedure was used throughout the study.

All subjects were housed in the same dormitory during the duration of training camp. After evening meetings, each subject completed a muscle soreness and training questionnaire. Subjects also completed a 5-day dietary recall. Blood samples were obtained for determining testosterone, cortisol, creatine kinase, and myoglobin concentrations. After each blood draw, the subjects performed a 30-second Wingate anaerobic power test.

Blood Measures

Each subject reported to the Human Performance Laboratory on 2 different occasions for blood sampling: PRE and POST. All blood samples were obtained from an antecubital arm vein using a 20-gauge disposable needle equipped with a Vacutainer tube holder (Becton Dickinson, Franklin Lakes, NJ) with the subject in a seated position. Blood samples were collected into a Vacutainer tube containing SST Gel and Clot Activator. Serum was allowed to clot at room temperature and subsequently centrifuged at 1500g for 15 minutes. The resulting serum was placed into separate 1.8-ml microcentrifuge tubes and frozen at -86°C for later analyses of testosterone, cortisol, myoglobin, and creatine kinase.

Biochemical and Hormonal Analyses

Serum testosterone and cortisol concentrations were determined using enzyme immunoassays (EIA) (Diagnostic Systems Laboratories, Webster, TX). Myoglobin concentrations were determined using an enzyme-linked immunosorbent assays (ELISA) (American Laboratory

Products Company, Windham, NH). Determinations of serum immunoreactivity values were made using a SpectraMax340 Spectrophotometer (Molecular Devices, Sunnyvale, CA). To eliminate interassay variance, all samples for a particular assay were analyzed in the same assay run. All samples were run in duplicate with a mean intra-assay variance of $<10\%$. The detection limits of the testosterone, cortisol, and myoglobin assays were 0.14 nmol-L $^{-1}$, 2.76 nmol-L $^{-1}$, and 6.25 ng·ml $^{-1}$, respectively. The molar ratio of testosterone to cortisol was determined for each testing session. Serum creatine kinase concentrations were analyzed with the use of a spectrophotometer and a commercially available enzymatic kit (Diagnostic Chemicals Limited, Oxford, CT).

Performance Measures

To quantify anaerobic power performance, all subjects performed the Wingate anaerobic power test (Lode Excilibur, Groningen, The Netherlands) after a warm-up period of 5-minutes pedaling at 60 rpm interspersed with 3 all-out sprints for 5 seconds. The subjects pedaled for 30 seconds at maximal speed against a constant force. The force setting was 1.0 N·m of body mass. Peak power, mean power, and rate of fatigue were measured. Peak power was defined as the highest mechanical power output elicited during the test. Mean power was defined as the average mechanical power during the 30-second test, and the rate of fatigue was determined by dividing the highest power output from the lowest power output.

Supplement Schedule

Subjects consumed either the supplement or placebo 3 times (at each meal) per day. A serving size of 4 tablets (1 g) at each meal (manufacturer's recommended use) was used. The placebo was indistinguishable in appearance and taste and was provided in the same form as the supplement.

Questionnaires

After each evening meeting on days 2–9, subjects were asked to complete a training questionnaire containing questions using a 7-point rating scale. Subjects were asked to rate their perception of practice intensity for that day using the following scale: 1 = very very easy; 2 = very easy; 3 = easy; 4 = average; 5 = hard; 6 = very hard; and 7 = very very hard. Subjects were asked to describe their feelings of soreness (both overall and specifically the legs) using the following verbal anchors: 1 = very very good; 2 = very good; 3 = good; 4 = tender but not sore; 5 = sore; 6 = very sore; and 7 = very very sore. Subjects were also asked to rate their feelings of fatigue using the following scale: 1 = very very fresh; 2 = very fresh; 3 = fresh; 4 = average; 5 = tired; 6 = very tired; and 7 = very very tired. The same researcher performed all test administrations in a quiet room.

Dietary Analysis

For the dietary analysis, 5-day dietary recalls were evaluated using FoodWorks Dietary Analysis software (McGraw Hill, New York, NY).

Statistical Analyses

Statistical evaluation of the data was accomplished by a 2×2 analysis of variance. In the event of a significant F ratio, Tukey post-hoc tests were used. Significance for all

TABLE 1. Average response to training questionnaire.*

	S	P
Muscle soreness, overall	3.79 \pm 0.70	4.17 \pm 0.55
Muscle soreness, legs	4.18 \pm 0.41	4.38 \pm 0.51
Feelings of fatigue	3.87 \pm 0.95	4.09 \pm 0.26
Perception of practice intensity	4.21 \pm 0.74	4.21 \pm 0.45

* Values are mean \pm SD; S = supplement; P = placebo.

TABLE 2. Wingate anaerobic power test performance.*

	PRE	POST
Peak power (w)		
P	2,131 \pm 510	2,062 \pm 539
S	1,968 \pm 375	1,921 \pm 453
Peak power (w \cdot kg $^{-1}$)		
P	23.1 \pm 7.6	22.9 \pm 8.3
S	20.9 \pm 4.2	20.6 \pm 4.9
Mean power (w)		
P	1,309 \pm 78	1,315 \pm 37
S	1,286 \pm 57	1,276 \pm 76
Mean power (w \cdot kg $^{-1}$)		
P	14.1 \pm 2.9	13.6 \pm 2.5
S	13.7 \pm 1.4	13.7 \pm 1.8
Rate of fatigue (w \cdot s $^{-1}$)		
P	31.3 \pm 12.0	37.0 \pm 13.1
S	32.3 \pm 7.6	35.2 \pm 9.4
Total work (J)		
P	38,748 \pm 1,969	39,226 \pm 870
S	38,564 \pm 1,697	38,175 \pm 2,163

* Values are mean \pm SD. S = supplement; P = placebo; PRE = 1 day before training camp; POST = after the 10-day training camp.

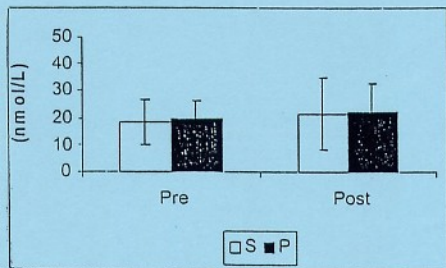


FIGURE 1. Comparison of serum testosterone concentrations (mean \pm SD) between the supplemental (S) and placebo (P) groups.

statistical analyses was set at $p \leq 0.05$. A sample size of 26 subjects provided >80% statistical power at an α level of 0.05 (two-tailed).

RESULTS

All subjects participated in each of the 19 football practices and 3 resistance-training sessions held during the 10-day training camp. Dietary analysis showed no significant differences between S and P in daily caloric intake

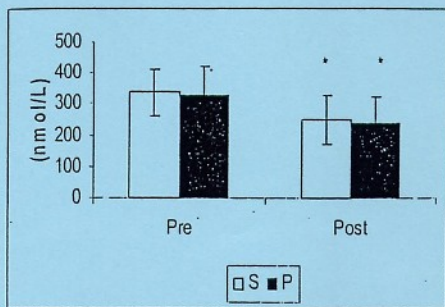


FIGURE 2. Comparison of serum cortisol concentrations (mean \pm SD) between the supplemental (S) and placebo (P) groups. * = significantly different from 1 day before training camp (PRE).

(3,543 \pm 908 and 3,254 \pm 1,241 Kcal, respectively), absolute protein intake (177 \pm 92 and 137 \pm 48 g, respectively), and relative protein intake (1.89 \pm 1.14 and 1.45 \pm 0.54 g \cdot kg $^{-1}$, respectively). Analysis of dietary composition showed that the daily diet for both groups was comprised of 52% carbohydrates, 31% fat, and 17% protein. No significant changes in body mass were seen from PRE to POST in either S (95.6 \pm 12.8 kg and 93.8 \pm 11.7 kg, respectively) or P (95.9 \pm 17.7 kg and 94.6 \pm 18.3 kg, respectively). In addition, no significant difference was seen between the groups in the Δ body mass (POST-PRE).

Subjective feelings of practice intensity, muscle soreness, and feelings of fatigue can be seen in Table 1. Results are expressed as the average daily response. No significant group differences were observed in any of these subjective questionnaires. No significant differences in practice intensity were observed during the 10-day training camp. Although increases in overall soreness, soreness in the legs, and feelings of fatigue were significantly increased from day 2 in both groups, no differences in the average ratings between the groups were seen.

The results of the anaerobic power measures can be seen in Table 2. No significant PRE to POST or group differences were observed. In addition, during the 3 resistance-training sessions, no differences were seen between S and P in exercise intensity for the bench press (77 \pm 4.0% and 77 \pm 2.0%, respectively) and squat (62 \pm 19.0% and 69 \pm 6.0%, respectively) exercises. In addition, no differences in the average training volume (average number of repetitions per workout session times load) was seen between S and P in the bench press (1,000 \pm 300 kg and 1,020 \pm 234 kg, respectively) and squat (1,120 \pm 776 kg and 1,290 \pm 586 kg, respectively) exercises as well.

The testosterone, cortisol, and testosterone-to-cortisol ratio (T:C ratio) responses can be seen in Figures 1-3, respectively. No significant between-group differences were seen in any of these variables at PRE or POST. When examined across time, no significant changes in testosterone concentrations were observed. However, cortisol concentrations significantly ($p < 0.05$) decreased from PRE to POST in both S and P (25.0% and 27.7%,

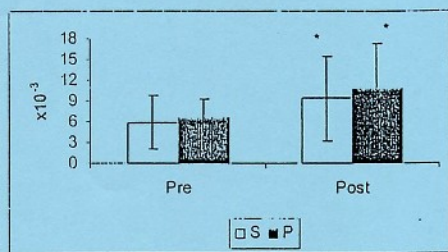


FIGURE 3. Comparison of molar ratio of testosterone to cortisol (mean \pm SD) between the supplemental (S) and placebo (P) groups. * = significantly different from 1 day before training camp (PRE).

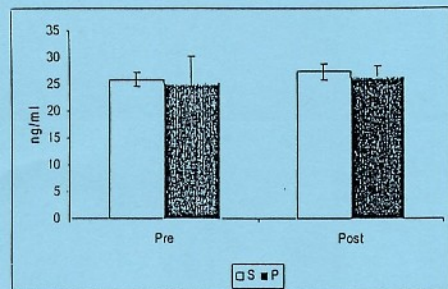


FIGURE 4. Comparison of serum myoglobin concentrations (mean \pm SD) between the supplemental (S) and placebo (P) groups.

respectively), whereas the T:C ratio was significantly increased from PRE to POST.

The myoglobin and creatine kinase responses can be seen in Figures 4 and 5, respectively. No significant between-group or within-group changes were seen in myoglobin concentration. Creatine kinase concentrations were significantly increased from PRE to POST in both S and P, but no significant group differences were observed.

DISCUSSION

The findings of this study suggest that short-term HMB supplementation does not attenuate biochemical markers of muscle damage, as reflected by the lack of significant differences observed between S and P in myoglobin and creatine kinase concentrations during 10 days of high-intensity football practice. Endocrine markers of stress (testosterone, cortisol, and T:C ratio) were also not significantly different between S and P, whereas anaerobic power and resistance-exercise performance was also similar between the groups. Interestingly, highly conditioned subjects participating in a 10-day preseason football training camp did not suffer any significant decrements in performance, recovery ability, or stress, as suggested by the endocrine responses observed.

Previous studies have suggested that supplementing

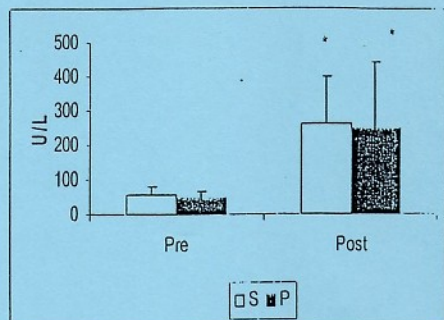


FIGURE 5. Comparison of serum creatine kinase concentrations (mean \pm SD) between the supplemental (S) and placebo (P) groups. * = significantly different from 1 day before training camp (PRE).

with HMB may have anticatabolic properties (4, 11, 15, 16). These studies have primarily used decreases in enzyme markers of muscle damage (creatine kinase and lactate dehydrogenase) after prolonged endurance runs or during initial periods of high-intensity exercise as the basis for these claims. This is appealing for those athletes that are participating in high-intensity training programs associated with muscle stress and damage. Practices during preseason football training camp are comprised of contact and non-contact drills, teaching periods, and conditioning. All drills are performed at a maximal effort, and practice sessions are generally 2 hours in duration and performed twice per day. Although no studies are known that has characterized the physiological stress or muscle damage in football players during such training, the highly intense and physical nature of these training sessions is well acknowledged by both players and coaches. Thus, in addition to the examination of the efficacy of HMB, this is the first study to characterize the physiological stress of football training camp.

During the 10 days of football training camp, no changes in myoglobin concentrations were observed, but a sixfold increase was seen in creatine kinase concentrations. The significant increase in creatine kinase is not surprising considering the highly physical nature of the game of football. However, these results were in contrast to that previously seen after a competitive football game (6). In that study, acute increases in myoglobin were observed with no significant increase in creatine kinase. It was suggested that myoglobin was a more sensitive measure of acute muscle damage than creatine kinase because of its smaller molecular weight and quicker transit time from the damaged muscle tissue through the various biocompartments into the peripheral circulation. In this study, the cumulative effect of 10 days of preseason training camp was examined. These results suggest that creatine kinase may be a better indicator for muscle damage than myoglobin when examining the cumulative effects of training compared with an acute bout of exercise. There are a couple of possible explanations for the different response patterns seen in these 2 biochemical markers of muscle damage. The low molecular weight of myo-

globin, which allows it to appear in the circulation before creatine kinase, is also rapidly cleared by the kidneys (10). As a result, plasma myoglobin concentrations begin to return to baseline levels within 24 hours of the muscle-damaging event (7, 28). In addition, creatine kinase seems to take an indirect route into the circulation. Because of the size of the creatine kinase molecule, it is not easy for it to enter the microvascular endothelium. Thus, instead of directly entering the systemic circulation, it is taken up by lymphatic vessels (14, 22). This causes a delay in the transport of creatine kinase into the bloodstream. In addition, the lymphatic system is slower moving than the circulatory system (14), and as a result, it would add to the delay of creatine kinase appearing in the systemic circulation.

The lack of a significant difference between S and P in myoglobin and creatine kinase concentrations suggests that supplementation with HMB does not provide any ergogenic benefit relating to reduced muscle protein breakdown. Although there are limitations to estimating muscle damage via changes in creatine kinase concentrations (27), previous studies have shown reduced creatine kinase, lactate dehydrogenase, and 3-methyl-histidine levels after HMB supplementation (4, 11, 15, 16). Based upon these results, it was assumed that HMB may partially attenuate muscle protein breakdown. However, these studies have primarily used a recreationally trained population with no resistance-training experience. In studies using either a competitive or resistance-trained subject population, HMB supplementation was also reported to have no significant effect on creatine kinase concentrations (12, 24). Thus, if HMB supplementation has any ergogenic benefit in attenuating muscle damage, it is likely to be most effective in the untrained population where the potential for muscle damage to occur during exercise is greatest.

Surprisingly, the highly intense and stressful nature of football preseason training camp was not reflected in the endocrine profile observed. Although no changes in testosterone concentrations were observed, a significant decrease in cortisol from PRE to POST was suggestive of a decreased training stress. This was also reflected by a more anabolic (significantly greater T:C ratio) stress hormone profile. Typically, the measurements of these steroid hormones and their molar ratio are performed to evaluate the stress levels of athletes during periods of high-intensity training and assess the risk of overtraining or overtraining (13). Although football preseason training camp is acknowledged to be highly stressful and physically demanding, it is also the time when the athletes are in peak physical condition and have physically prepared themselves to face the rigors of such training. Therefore, it is not surprising that the subjects seemed to maintain performance, both physically and physiologically, during the 10 days of high-intensity football practice. In addition, previous research has demonstrated that highly intense periods of training in the strength/power athlete may not lead to alterations in the hormonal profile (3) that are frequently seen in the endurance athlete (25).

Previous research has reported that cortisol levels are sensitive to changes in both intensity and volume of training (2, 9). In this study, subjects participated in 2-hour practices twice per day. No changes in training volume (time and number of daily practices) occurred during the

study duration, and measures of perceived practice intensity remained stable throughout the study period. Still, the decrease in cortisol concentrations from PRE to POST in both groups was difficult to understand. A possible explanation may be related to the subjects playing experience.

All subjects were veteran players with at least 1 year of college training camp experience. They were likely familiar and comfortable with the routine of training camp. Whereas speculative, this familiarity may have reduced anxiety levels, reflected by the smaller ($p < 0.05$) cortisol concentrations seen at POST. Previous research has shown that cortisol levels do respond to changes in anxiety (1). The larger cortisol concentrations seen at PRE may indicate some feelings of anxiousness that even veteran athletes experience before the onset of training camp (i.e., preseason testing and potential competition for playing time). Once the normal routine of training camp has begun, anxiety and stress levels in the veteran athlete may begin to subside.

The body mass in both groups tended to decline. However, the 1.9% loss in body mass in S and the 1.4% body mass loss in P were not significantly different. Interestingly, the caloric intakes observed in both of these groups were relatively small, compared with previous reports on collegiate football players (23), and perhaps accounted for the slight decreases seen in body mass. A possible explanation for the relatively small caloric intake seen in these subjects may relate to the timing between the third meal of the day and the second practice. This meal occurred approximately 2.5 hours after the second meal and 2 hours before the next practice. The subjects were likely not as hungry or were concerned about eating too close to practice. This is a situation that may be common in small college football programs that do not have complete autonomy over meal times and practice schedules.

Supplementation with HMB did not have any significant effect on anaerobic power performance or in the volume or intensity of the resistance-exercise sessions during training camp. Previous research has suggested that HMB supplementation can significantly improve strength performance (8, 16, 19). However, these studies examined recreationally trained subjects using a supplementation schedule of 3–7 weeks in duration. However, in other studies that used resistance-trained or competitive athletes, the ergogenic benefit during supplementation schedules of 4–6 weeks was unable to be duplicated (12, 20, 24). In addition, O'Connor and Crowe (17) reported no significant improvement in anaerobic power performance after 4 weeks of HMB supplementation in highly trained athletes. Thus, it seems that the effectiveness of HMB is observed primarily in a recreationally trained subject population. The ability of HMB to provide any ergogenic benefit in a highly trained or competitive group of subjects seems to be questionable.

PRACTICAL APPLICATIONS

The results of this study do not support previous research that have reported on the anticatabolic properties and improved strength performance of HMB supplementation. This seems to be a function of the training status of the subject and possibly the duration of supplementation. It was also surprising to see, regardless of supplementation, the ability of the subjects to maintain power and strength performance during the 10 days of preseason football

training camp. In addition, although subjective measures of muscle soreness and markers of muscle damage were significantly increased, the endocrine profile observed suggested that highly trained football players can withstand the rigors of 10 days of preseason training.

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