Effects of β-Alanine Supplementation on Performance and Body Composition in Collegiate Wrestlers and Football Players

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Abstract

Kern, BD and Robinson, TL. Effects of β-alanine supplementation on performance and body composition in collegiate wrestlers and football players. *J Strength Cond Res* 25(7): 1804–1815, 2011—The purpose of this study was to examine the effectiveness of β-alanine as an ergogenic aid in tests of anaerobic power output after 8 weeks of high-intensity interval, repeated sprint, and resistance training in previously trained collegiate wrestlers (WR) and football (FB) players. Twenty-two college WRs (19.9 ± 1.9 years, age ± *SD*) and 15 college FB players (18.6 ± 1.5 years) participated in this double-blind, placebo-controlled study. Each subject ingested either 4 $g \cdot d^{-1}$ β-alanine or placebo in powdered capsule form. Subjects were tested pre and posttreatment in timed 300-yd shuttle, 90° flexed-arm hang (FAH), body composition, and blood lactate after 300-yd shuttle. Although not statistically significant ($p > 0.05$) subjects taking β-alanine achieved more desirable results on all tests compared to those on placebo. Performance improvements were greatest in the FB supplement group, decreasing 300 shuttle time by 1.1 seconds (vs. 0.4-second placebo) and increasing FAH (3.0 vs. 0.39 seconds). The wrestlers, both placebo and supplement, lost weight (as was the goal, i.e., weight bracket allowance); however, the supplement group increased lean mass by 1.1 lb, whereas the placebo group lost lean mass (−0.98 lb). Both FB groups gained weight; however, the supplement group gained an average 2.1-lb lean mass compared to 1.1 lb for placebo. β-Alanine appears to have the ability to augment performance and stimulate lean mass accrual in a short amount of time (8 weeks) in previously trained athletes. Training regimen may have an effect on the degree of benefit from β-alanine supplementation.

Key Words ergogenic aid, high-intensity interval training, anaerobic power, lactate, lean mass

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Introduction

Athletes participating in the sports of collegiate wrestling (WR) and football (FB) rely primarily on anaerobic energy metabolism. These sports require frequent high-intensity (75–100% effort) bouts of activity, with short (5–45 second) rest periods (12). The work-to-rest ratios experienced by collegiate wrestlers and FB players could best be described as high-intensity interval training (HIIT). High-intensity interval training is an exercise strategy that uses brief burst of exercise (typically sprinting), followed by a short to moderate length rest period (walking or jogging) (2). For the purpose of this study, HIIT is defined as 75–100% of maximal effort for a period of 5–30 seconds followed by a rest period of 1–2 minutes.

Training for both collegiate WR and FB uses HIIT and is intended to promote muscle adaptation to accommodate the physical and metabolic demands of competition. Progressive overload of exercise intensity and manipulation of the duration of rest periods characterizes training, with FB being more reliant on the ATP-PC system and anaerobic glycolysis and WR relying predominantly on anaerobic glycolysis.

Early season training for collegiate WR includes daily practice sessions consisting of tactical drills, simulated matches, and physical conditioning. Additionally, collegiate wrestlers use frequent resistance training sessions separate from daily practice. Both practice sessions and resistance training follow the HIIT pattern defined previously. In-season resistance training for WR emphasizes multijoint movements with moderate weights and high repetitions. Rest periods for resistance training between sets are short or may simply be a transition to another exercise that uses an antagonistic muscle group (super-set). Rest periods during practice sessions may be a period of reduced intensity exercise rather than no activity. The training effect likely elicited by this aspect of WR training is increased muscle buffering capacity because of the prolonged reliance on anaerobic glycolysis (2,7,20,28).

In-season training for collegiate FB, likewise, implements HIIT not only for efficiency of practice and training sessions but also to mimic the metabolic demands of the sport (i.e., 5–10 seconds of near maximum effort followed by 30–60

TABLE 1. Participant characteristics (at pretest).*†

	Age (y)	Height (cm)	Weight (lbs.)	Body fat (%)
FB placebo ($n = 8$)	18.9 ± 2.1	177.8 ± 3.83	85.32 ± 15.12	9.45 ± 3.37
FB supplement ($n = 7$)	18.4 ± 0.59	182.9 ± 4.57	92.27 ± 15.89	9.89 ± 4.61
WR placebo ($n = 12$)	19.8 ± 1.83	174.8 ± 6.55	77.60 ± 13.84	8.05 ± 3.02
WR supplement ($n = 10$)	20.1 ± 2.06	174.0 ± 8.07	73.81 ± 15.64	7.54 ± 2.99

*FB = football; WR = wrestling.
†Values are given as mean ± *SD.*

seconds of rest). Daily practice sessions include maximum effort repeated short sprints, agility movements, and weighted pushing and pulling against animate and inanimate objects. In addition to the high-intensity movements, FB players are also weighted with approximately 30 lb of protective gear. Rest periods during this training consist of jogging a short distance (10–40 m) back to the huddle, then standing to receive the next play, and then starting the next play. In-season resistance training for collegiate FB includes multijoint movements with moderate to heavy loads (75–100% of 1RM), with strength and power being the emphasis. Rest periods during resistance training are typically short (1–2 minutes).

During short-term, high-intensity exercise, energy for muscle contraction comes primarily via the ATP-PC system and anaerobic glycolysis (2). When the duration of the exercise exceeds 10–15 seconds, anaerobic glycolysis becomes the predominant energy system, provided the intensity of the exercise remains high (2). As a result of this exercise, lactate accumulates in the blood because the rate of lactate production exceeds its rate of removal (3). Lactic acid production and, more specifically, the dissociation of a proton (H^+) decrease the overall pH of the intramyocellular environment, a condition known as metabolic acidosis (2). This condition is thought to be a major contributor to muscular fatigue, as the lowered pH may inhibit phosphofructokinase activity, thus slowing glycolysis (2). In addition, H^+ may displace Ca^{2+} from the troponin active site, thereby inhibiting contraction, and may prevent efficient release/return of Ca^{2+} to the sarcoplasmic reticulum (21). Blood lactate concentration is an indirect measurement of the ratio of lactate production to clearance and is an indicator of the body's ability to cope with metabolic demands (3). There is continuing debate about whether intracellular lactate + H^+ accumulation is responsible for fatigue (1). Generally, high blood lactate concentration is thought to be indicative of activity of the extracellular lactate shuttle while intracellular use of lactate as an energy substrate is at full capacity (21). Activities that require near maximal effort (75–100%) and are sustained for 15–60 seconds are fueled primarily by anaerobic glycolysis and are capable of producing extremely high postexercise blood lactate concentrations ($>10\ mmol\cdot L^{-1}$) (21).

β-Alanine is a nonessential amino acid that in combination with the essential amino acid, histidine, results in the formation of carnosine within the muscle cell (2,10). Carnosine is recognized as an intramyocellular pH buffer because of its affinity for H^+ produced during anerobic glycolysis. Because of its H^+ buffering capability, increased carnosine concentration in skeletal muscle has been associated with improved performance in tests of anaerobic power (26). Supplementation with β-alanine has been shown in recent studies to increase carnosine content, therefore enhancing muscle buffering capacity and attenuating fatigue rates of working tissue (6,10,11,16). Although training improves muscle buffering capacity, supplementation with β-alanine has been shown to increase intramuscular carnosine concentration in highly trained athletes beyond already elevated levels because of training (6).

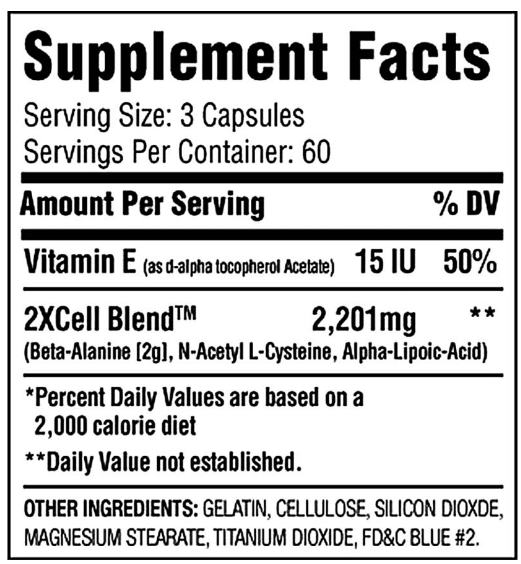

Figure 1. Beta-alanine supplement used in study (IntraXcell® by Athletic Edge Nutrition).

TABLE 2. Training programs for collegiate football players and wrestlers during 8-week study period.

	Football group	Wrestling group
Resistance training	4× per week Olympic and power assistance low rep, high weight 2-d combination routine 2-d split routine	3× per week Single and multijoint, upper and lower body pushing/pulling 3-d split routine
Practice sessions	Repeat sprints Skill acquisition drills Scrimmage sessions	Skill acquisition drills Simulated matches

Supplementation with creatine monohydrate has been one of few supplements to consistently show improvements in strength and power vs. placebo. Recent research examining the efficacy of β-alanine supplementation suggests a similar capability. Hoffman et al. (13) found similar strength improvements (50–73%) through resistance training when supplementing creatine alone and creatine plus β-alanine. Additionally, this study showed that subjects taking creatine plus β-alanine experienced significantly decreased body fat, increased lean mass, and reduced fatigue rates during exercise sessions, whereas creatine alone did not show this response. Smith et al. (23) found significant improvements in lean mass, total work done, and total time to exhaustion with HIIT and 6 $g \cdot d^{-1}$ β-alanine in previously untrained subjects compared to those on placebo.

In contrast to the 2 previously mentioned studies, Kendrick et al. (15) found no significant difference in whole body strength, lean mass, or body fat between β-alanine and placebo when training consisted of 10 weeks of heavy resistance training in previously untrained subjects. Kendrick et al. speculated that the training protocol they implemented (heavy resistance with low work-to-rest ratio) relied primarily on the ATP-PC system rather than on anaerobic glycolysis; therefore, muscle buffering capacity was not a factor in the outcome of the study. It appears that performance benefits experienced with β-alanine supplementation are dependent upon the degree to which the training stimulus elevates the acidity of the intramyocellular environment (i.e., reliance upon anaerobic glycolysis) (11,23,24,29). Hoffman et al. (12) speculated that β-alanine supplementation may not affect performance unless exercise intensity and duration induced high levels of blood lactate. Hoffman reported increases in training volume and significantly lower subjective feelings of fatigue during 60-second maximal exercise, thus supporting the notion that β-alanine supplementation may be most effective under high lactate producing conditions. Similarly, Van Thienen et al. (27) found significant improvements in 30-second sprint performance after a 110-minute simulated cycling road race for subjects taking β-alanine vs. placebo.

Numerous studies indicate that increased carnosine levels, because of β-alanine supplementation, are responsible for performance improvements, such as aerobic power, anaerobic endurance, and anaerobic power (9,11,13–16,23,24,27,29), yet only 3 studies report measurements of body composition. Success in collegiate WR and FB is highly dependent upon the individual's strength, speed, and power (12). In terms of maximizing these qualities, it is desirable for athletes to develop high levels of lean mass while keeping body fat minimal. Studies

TABLE 3. Changes in body composition and performance during 8-week study period.*†

Test	FB placebo ($n = 8$)	FB supplement ($n = 7$)	WR placebo ($n = 12$)	WR supplement ($n = 10$)
Δ Body weight	2.8 ± 1.2	2.6 ± 1.9	−3.2 ± 4.9	−0.43 ± 4.6
Δ Body fat %	0.88 ± 1.5	0.1 ± 1.1	−1.1 ± 1.4	−0.89 ± 0.66
Δ Lean mass	1.1 ± 2.3	2.1 ± 3.6	−0.98 ± 2.9	1.1 ± 4.3
Δ 300 shuttle	−0.4 ± 2.2	−1.1 ± 0.94	−1.3 ± 1.7	−1.6 ± 2.2
Δ 90° FAH	0.39 ± 6.5	3.0 ± 5.4	5.0 ± 3.9	6.5 ± 7.3
Δ Lactate	1.5 ± 3.3	0.03 ± 3.7	−2.3 ± 4.7	−2.6 ± 4.7

*FB = football; WR = wrestling.
†Values are given as mean ± *SD.*

TABLE 4. Mean values pre and post 8-week study period for body composition and performance measures.*

	Pre BW	Post BW	Pre BF%	Post BF%	Pre LM	Post LM	Pre 300	Post 300	Pre FAH	Post FAH	Pre LAC	Post LAC
FB placebo	188.1	190.9	9.5	10.3	169.5	170.6	59.5	59.1	50.1	50.5	8.66	10.19
FB supplement	203.4	206.0	10.5	10.6	180.6	182.6	61.1	60.0	42.4	45.4	8.43	8.46
WR placebo	171.1	166.4	8.1	7.2	154.8	153.8	61.5	60.1	59.9	65.3	11.09	8.2
WR supplement	162.7	162.3	7.5	6.6	149.8	150.9	60.2	58.7	56.8	63.3	9.99	7.37

*BW = body weight (lb); BF = body fat; LM = lean mass (lb); 300 = 300-yd shuttle (seconds); FAH = flexed-arm hang (seconds); LAC = blood lactate concentration ($mmol \cdot L^{-1}$).

conducted by Hoffman et al. (13) and Smith et al. (23) suggest that supplementation with β-alanine along with training may increase lean mass in collegiate strength and power athletes and recreationally active college-aged men.

Collegiate wrestlers commonly implement extreme weight reduction methods (calorie restriction and dehydration) to compete at the lowest possible weight bracket (17,19). However, these extreme reductions (10–20 lb) in overall body weight can result in impaired strength because of indiscriminate weight loss (i.e., fat and lean mass) (4,22). Although several β-alanine studies have measured body composition, no research has examined the effect that β-alanine supplementation may have on athletes practicing extreme weight loss methods.

An objective of this study was to assess the feasibility of adding β-alanine to the in-season training of collegiate wrestlers and FB players and also to more accurately define the parameters of β-alanine efficacy. Research suggests that β-alanine supplementation may improve anaerobic performance and body composition provided the training stimulus is of sufficient volume and intensity to create a highly acidic intramyocellular environment (13,14,23). High-intensity interval sprinting and resistance training used in collegiate WR and FB training are capable of producing such an environment. Therefore, the purpose of this study was to examine the effectiveness of β-alanine as an ergogenic aid in tests of anaerobic power and its potential effect on body composition after 8 weeks of high-intensity interval, repeated sprint, and resistance training in previously trained collegiate wrestlers and FB players during the competitive season. We hypothesized that 4 $g \cdot d^{-1}$ β-alanine combined with normal in-season training would improve performance of collegiate wrestlers and FB players in tests of anaerobic power and would promote lean mass increase at a faster rate than placebo.

METHODS

Experimental Approach to the Problem

This study used a double-blind, placebo-controlled design. It involved 37 male collegiate athletes, 22 from the WR team and 15 from the FB team. Each team had a placebo and a supplement group of equal number of participants, who were randomly selected. Each group within each team ingested 6 colored capsules in 2 equal doses per day for a total of 8 weeks (60 days). Subjects in the 2 supplement groups ingested a product called IntraXcell® by Athletic Edge Nutrition, whereas the subjects in the 2 placebo groups ingested dextrose filled capsules. The capsules were exactly alike with the exception of their contents and were produced by the same laboratory. Anaerobic power performance measures, blood

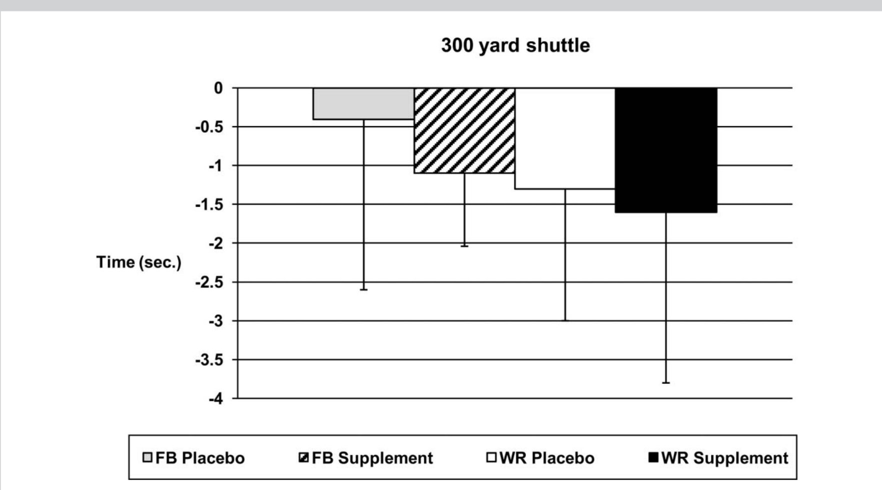

Figure 2. Changes in 300 yard shuttle time, pre to post 8-week study period.

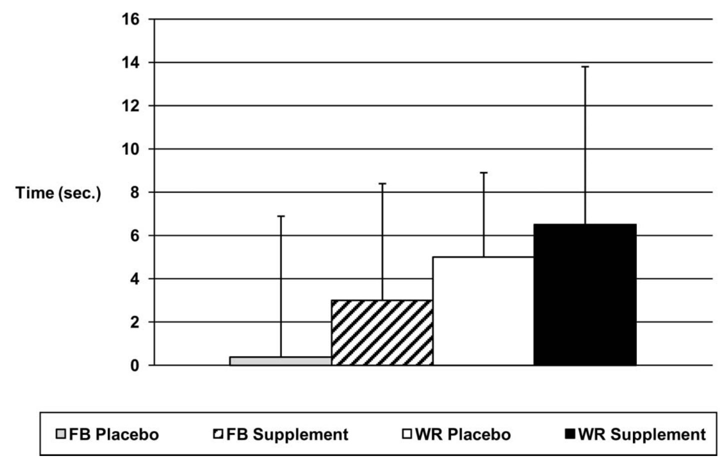

Figure 3. Changes in flexed arm hang time, pre to post 8-week study period.

lactate concentration after performance measures, body weight (BW) measurement, and 7-site skinfold measurement were conducted before the first day of supplementation and after the last day of supplementation. Three-day food records were required of all participants during the third week of supplementation. Food records were taken at week 3 of the study because the WR group had reached competition BW during the second week of the study, and both groups were instructed to maintain a consistent diet for the remainder of the study.

Subjects

Twenty-two NCAA Division II college wrestlers (19.9 ± 1.9 years, mean age ± *SD*) and 15 NCAA Division II college FB players (18.6 ± 1.5 years) completed this double-blind, placebo-controlled study. All procedures were approved by the Institutional Review Board (Adams State College, Alamosa, CO, USA) before initiation of the study. All subjects were informed of risks and benefits of both exercise testing and β-alanine ingestion, and all subjects gave informed consent for both treatments. All subjects completed a sports physical before the start of their respective competitive season (Table 1).

Procedures

Each subject ingested either 4 $g \cdot d^{-1}$ in 2 equal doses of a product containing β-alanine (IntraXCell® by Athletic Edge Nutrition; Figure 1) or placebo in powdered capsule form for a duration of 8 weeks. The subjects took the capsules with breakfast and with lunch and recorded the time of the dose in a journal that was provided by the researchers. Subjects were instructed to maintain their usual diet and refrain from using any performance enhancing substances. Subjects who had reported taking β-alanine 3 months before the study were not allowed to participate. All subjects completed a 3-day food record during the third week of the supplementation period. Diet records were then analyzed for mean kilocalories (kcal) per day, $kcal \cdot kg^{-1}$ BW per day, and grams protein per kilogram BW per day.

Exercise Testing. Subjects were tested before and after the 8-week treatment period in a timed 300-yd shuttle and 90° flexed-arm hang (FAH). Each subject performed the tests on the same day (FAH first, then 300-yd shuttle) with approximately 20 minutes of rest between tests. Pre and posttesting sessions occurred at the same time of the day, and subjects were instructed to eat their normal diet and refrain from any heavy physical exertion. The subjects were given verbal instruction and demonstration for each physical test, and they then participated in a general physical warm-up before testing.

The 300-yd shuttle test was conducted on a rubberized indoor track surface. Taped lines marked with cones were spaced exactly 25 yd apart to indicate where to run. Subjects were instructed to run as fast as

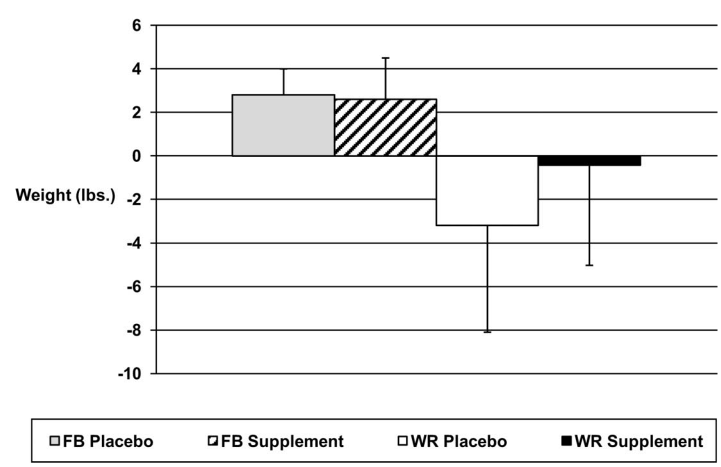

Figure 4. Changes in body weight, pre to post 8-week study period.

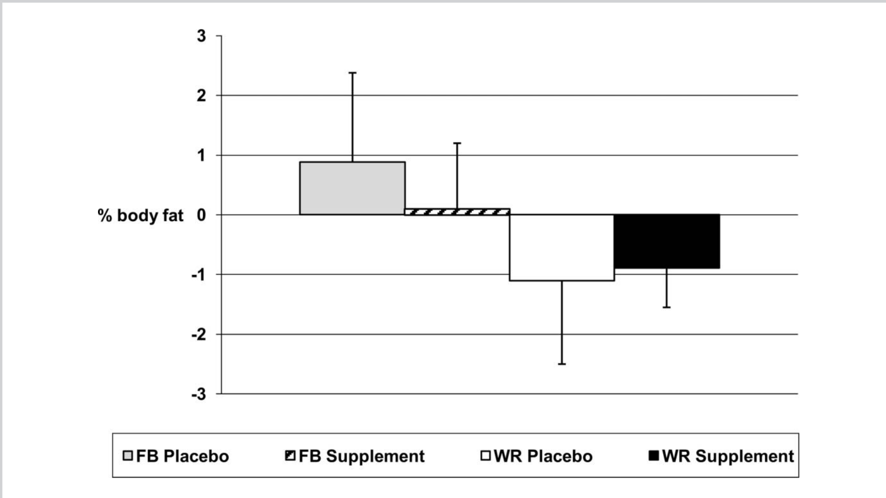

Figure 5. Changes in percent body fat, pre to post 8-week study period.

possible back and forth a total of 6 times (50 yd × 6 = 300 yd) and touch each line with 1 foot. All subjects had previous experience in the 300-yd shuttle test; therefore, a familiarization trial was not necessary. Two technicians kept track of the total repetitions and encouraged the subjects to run as fast as possible. Total elapsed time of each test (pre and posttesting) was kept by a skilled technician (assistant track and field coach) using a standard handheld stopwatch.

The 90° FAH was performed on a 1″ diameter straight pull-up bar. Subjects were instructed to grasp the bar with an underhand grip and hang with the elbows flexed at 90° for as long as possible. A small black line was drawn on the lateral aspect of each subject's mid–forearm to mid–upper arm so that the researcher could more accurately assess the 90° bend of the elbow required for the test. This method is consistent with the research conducted by Clemons et al. (5) indicating the undergrip 90° flexed-arm hang as a valid test of weight-relative strength, and "eyeballing the 90° angle" as a reliable test–retest practice. Timing of the test started when the subject fully upheld his entire BW with elbows in the proper position and stopped the instant the subject was unable to maintain 90° elbow flexion. Elapsed time of the test (pre and posttest) was kept by a skilled technician (head strength coach) using a handheld stopwatch.

Lactate. Blood lactate concentration was measured using a finger prick and Accusport lactate analyzer 3 minutes after the completion of the timed 300-yd shuttle to determine the amount of lactic acid built up during the test. The purpose for testing lactate was twofold: (a) to see if β-alanine supplementation would result in lowered lactate concentration during intense exercise and (b) to assess the overall intensity of the 300-yd shuttle and the effort given by subjects. Before the study, researchers ran pilot test subjects (separate from the subjects in the study) in the 300-yd shuttle and then took blood lactate measurements at 1, 2, 3, 4, and 5 minutes after the run to identify the amount of time needed to build up the highest lactate measures in the blood, because blood lactate is an indirect measurement of muscle anaerobic metabolism and time is needed for lactate clearance to fully take place in the body. This experimentation showed that 3 minutes after the 300-yd shuttle at maximum effort produced the highest lactate concentrations (10–20 mmol·L^{-1}).

Body Composition. Subjects' body fat was assessed via 7-site measure using a *Lange* skinfold caliper by the same highly experienced researcher pre and posttreatment (Standard Error <1.0%). The subject's BW was measured on a certified Detecto physicians scale. Body composition was then calculated by determining the overall

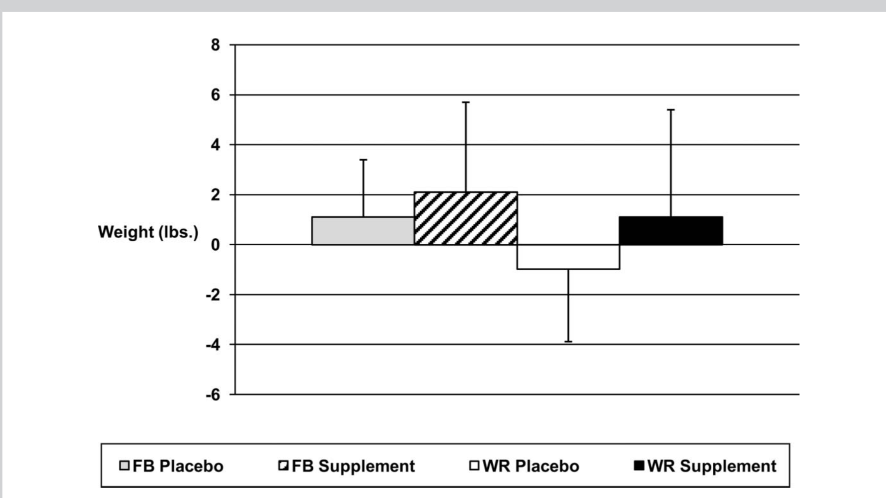

Figure 6. Changes in lean mass, pre to post 8-week study period.

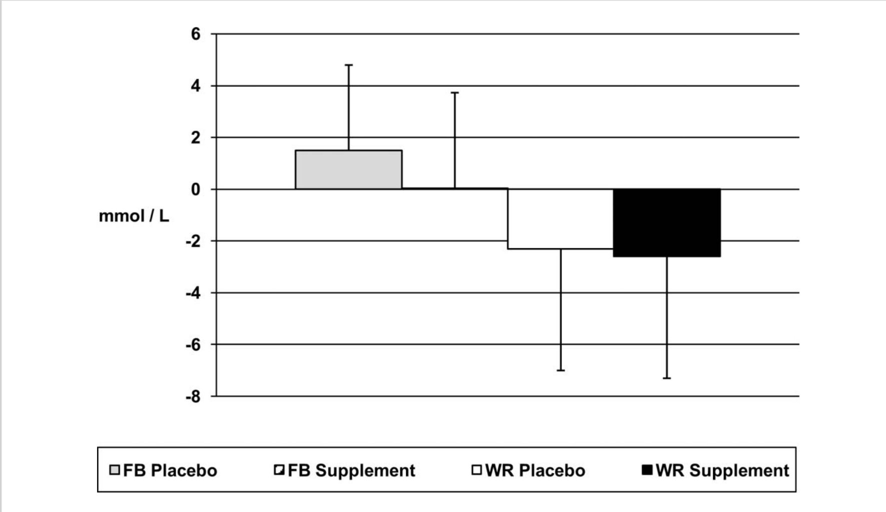

Figure 7. Changes in blood lactate concentration after 300-yard shuttle run, pre to post 8-week study period.

body fat % and fat-free mass. Body composition testing was performed before and after the 8-week treatment period.

Training Protocols. The 8-week treatment period took place during the early season for WR and in-season for FB subjects (September 15–November 7, 2008). The WR subjects had completed the first week of in-season practice before the testing, and most were cutting weight, while the FB subjects were in the middle of their competitive season.

The wrestlers participated in 4–5 d·wk^{-1} practice sessions that included skill acquisition and practice and physical conditioning (i.e., simulated matches and drills) that would best be described as HIIT (defined in the Introduction). They also participated in 3 d·wk^{-1} resistance training. Resistance training sessions could be described as 1 d·wk^{-1} upper body split routine that included pushing exercises (bench press, military press, tricep extension) and spinal flexion and rotation, 1 d·wk^{-1} lower body split routine that included various types of squats, leg extensions, leg curls, and spinal hyperextension, 1 d·wk^{-1} upper body split routine that included pulling exercises (pull-ups, lat pull, seated row, bicep curl, and grip strengthening) and abdominal flexion, extension, and rotation. All resistance training sessions for the WR subjects were performed in circuit fashion, allowing for approximately a 1:2 to 1:4 work-to-rest ratio. The resistance training program was designed to maintain strength gains made before season and enhance metabolic conditioning. The resistance training program and the practice sessions progressed in a linear fashion over 8 weeks beginning with higher volume and lower intensity to less volume and higher intensity.

The FB players were all first year players taking advantage of their "red-shirt" year. (Red-shirt players practice with the team and train, but gain a year of eligibility by not playing in games during that season.) Because of this, these players practiced 3 d·wk^{-1} and participated in resistance training sessions 4 d·wk^{-1}. Practice sessions comprised mostly skill acquisition drills, scrimmage sessions, and sprint conditioning (i.e., repeat 20-, 30-, 40-yd sprints, typically 6–8 sprints with 30- to 45-second rest). These sessions could best be described as HIIT but of a somewhat higher intensity and shorter duration and somewhat longer rest periods than for the subjects. Resistance training sessions could be described as 2 d·wk^{-1} upper and lower body combination routine that included upper body pushing exercises (bench press and incline press), lower body pushing exercises (squat and variations of), and Olympic lifts and assistance exercises (cleans, jerks, snatch, Romanian dead lift) and 2 d·wk^{-1} upper body split routine that included upper body pushing and pulling exercises designed work agonist and antagonist muscle groups (i.e., bench press, bent

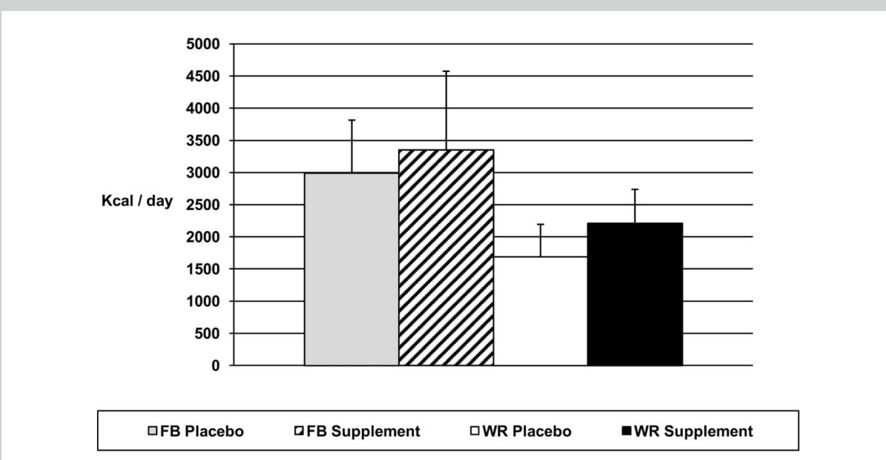

Figure 8. Average daily caloric intake (from 3-day diet record).

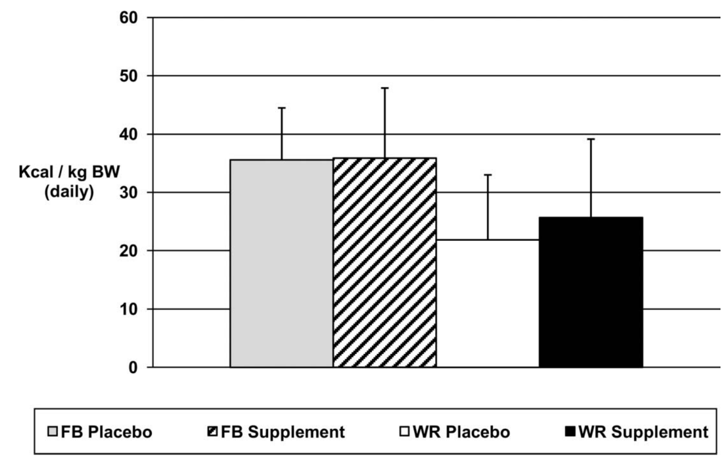

Figure 9. Average daily caloric intake in relation to body weight (from 3-day diet record).

over row, military press, pull-ups). Resistance training sessions were conducted as group training sessions, and rest time between sets was monitored by the head strength coach (CSCS), thus allowing for 1:3 to 1:5 work-to-rest ratio. Training sessions followed a linear progression from higher volume and lower intensity to lower volume and higher intensity throughout the 8-week treatment period (Table 2)

Two separate groups, each with a treatment and control, were used to help define the parameters of training relative to the use of β-alanine as an ergogenic aid. Training intensities and the metabolic demands of the sports or WR and FB are similar but differ slightly in that WR relies more predominantly on anaerobic glycolysis for energy production and FB primarily uses the ATP-PC system with some assistance from anaerobic glycolysis. Studies examining the effects of β-alanine supplementation have had some mixed results, along with a variety of training protocols; thus, this study attempts to add to the body of knowledge by examining β-alanine supplementation in combination with different magnitudes of training.

Statistical Analyses

Means and *SD*s were calculated for change in 300-yd shuttle time, 90° FAH time, total BW, fat-free mass, % body fat, and blood lactate after the 300 shuttle. Analysis of variance (ANOVA) was used to determine any differences in performance or body composition changes over the 8-week period either between or within groups. Then independent *t*-tests were used to determine any differences between supplement and placebo in each athletic group. The change in mean values from pre to posttest of each descriptive statistic was tested for significance using a dependent *t*-test, comparing treatment group vs. placebo for both wrestlers and FB players. All independent variables were measured using standardized methods, by the same researcher, thus minimizing potential measurement error; because of this diligence, the researchers believe that data analyzed comparing pre and posttreatment measures are meaningful and statistically significant when $p \leq 0.05$.

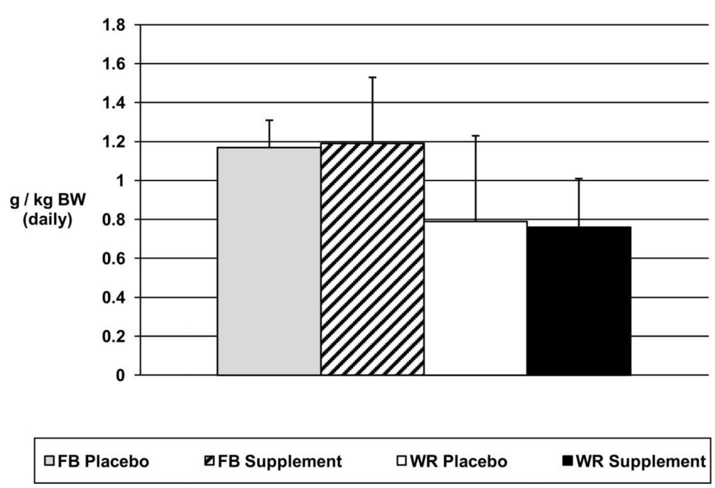

Figure 10. Average daily protein intake in relation to body weight (from 3-day diet record).

Results

The subjects taking β-alanine, FB supplement, and WR supplement, achieved more desirable results in all tests (mean values) compared to those on placebo, though no statistically significant difference was seen between mean change values (pre to posttreatment) on any tested variables. (NS, $p > 0.05$) (Tables 3 and 4).

Anaerobic Power

Performance improvements were greatest in the FB supplement group, with a mean decrease in 300 shuttle time of 1.1 ± 0.94 seconds vs. placebo

TABLE 5. Average daily caloric and protein intake (from 3-day diet record).*†

	FB placebo ($n = 8$)	FB supplement ($n = 7$)	WR placebo ($n = 12$)	WR supplement ($n = 10$)
kcal·d^{-1}	2,989 ± 825.8	3,351 ± 1224.3	1,688 ± 507	2,210 ± 528.8
kcal·kg^{-1} BW	35.6 ± 8.9	35.9 ± 12.01	21.9 ± 11.1	25.7 ± 13.45
Protein g·kg^{-1} BW	1.17 ± 0.14	1.19 ± 0.34	0.79 ± 0.44	0.76 ± 0.25

*FB = football; WR = wrestling; BW = body weight (lbs).
†Values are given as mean ± *SD.*

(0.4 ± 2.2 seconds) and increasing FAH time of 3.0 ± 5.4 vs. 0.39 ± 6.5 seconds, supplement and placebo groups, respectively. The WR supplement group showed a mean decrease in 300 shuttle time of 1.6 ± 2.2 seconds vs. placebo (1.3 ± 1.7 seconds) and a mean increase in FAH time of 6.5 ± 7.3 seconds vs. placebo (5.0 ± 3.9 seconds) (Figures 2 and 3).

Body Composition

The wrestlers, both placebo and supplement groups, experienced a reduction in body fat % and BW (as was the goal of most of the WR subjects, that is, early season weight loss to weight bracket allowance); however, the supplement group increased lean mass by 1.1 ± 4.3 lb, whereas the placebo group lost lean mass (−0.98 ± 2.9 lb). Both FB groups gained weight; however, the supplement group gained an average 2.1 ± 3.6 lb lean mass compared to 1.1 ± 2.3 lb for placebo. The supplemented FB players' body fat % remained nearly unchanged (0.1 ± 1.1%), whereas the FB players taking the placebo gained 0.8 ± 1.5% (Figures 4–6).

Blood Lactate

Both FB groups (placebo vs. supplement) showed small increases in blood lactate concentration after the 300-yd shuttle from pre to posttest (1.5 ± 3.3 vs. 0.3 ± 3.7 mmol·L^{-1}), respectively. Both WR groups (placebo vs. supplement) demonstrated small decreases in blood lactate concentration after the 300-yd shuttle pre to posttest (−2.3 ± 4.7 vs. −2.6 ± 4.7 mmol·L^{-1}), respectively (Figure 7).

Diet Analysis

Table 5 shows comparisons of daily caloric intake (kcal·d^{-1}), mean daily caloric intake per kilogram of BW (kcal·kg^{-1} BW), and mean daily grams of protein per kilogram of BW (g·kg^{-1} BW) in the FB group and the WR group. Data for each of these categories are similar (placebo vs. supplement) within the FB group and the WR group (Figures 8–10, Table 5).

Discussion

At this time, the number of studies examining the efficacy of β-alanine is low (<20), and tested variables in these studies range from aerobic tests such as $\dot{V}O_2$max to anaerobic tests such as Wingate Anaerobic Power and 1RM bench press (6,9,11, 13–16,23–25,27,29). Roughly half of the studies used tests of an aerobic nature and half anaerobic. Most studies have used untrained or recreationally trained subjects. Performance testing procedures have primarily been performed on either treadmills or stationary cycle ergometers. Given the laboratory nature of the existing research, it was the aim of researchers in this study to examine the effectiveness of β-alanine in a practical setting. β-Alanine appears to be well tolerated by the subjects in recent studies, and in this study. A dosage of 4–6 g·d^{-1} has shown significant increase in carnosine levels, thus providing opportunity for performance increases (8–10). The remaining question of β-alanine efficacy is appropriate application in relation to training programs already in place. This study used subjects who had previously attained a high level of training, and the testing methods were more field based in nature. Additionally, this study was conducted on collegiate athletes during a time when performance is the most critical, during the competitive season.

The in-season training period presents unique challenges for coaches. In WR, the desire to compete in the lightest feasible weight bracket often creates a quandary for the athlete. Weight cutting practices often lead to lean mass losses along with fat and water loss. If the athlete loses lean mass, it is likely that some level of strength is lost as well (22). In FB, a larger body size is often an advantage in competition, but FB players also gain an advantage by being able to move faster than their opponent. Therefore, increases in lean mass that potentially lead to strength improvements are highly desirable.

The supplemented athletes in each group of subjects (wrestlers and FB players) achieved a more desirable result than those of placebo counterparts on tests of anaerobic power and body composition. The group of wrestlers who received β-alanine increased lean mass (+1.1 lb) despite losing overall BW (−0.43 lb). Both FB groups, supplement and placebo, gained nearly identical amounts of BW (about 2.5 lb), but the group taking β-alanine gained 1 lb more lean mass. Given the length of the study (8 weeks), the improvements of even the placebo groups would be satisfying to the coach and practitioner, but the added improvement of the supplemented groups is even more encouraging. Although not statistically significant, these improvements in lean mass are significant from a practical standpoint. Typical increases in lean mass among highly trained athletes can vary based on the initial size of the athlete and years spent training (2). To our knowledge, there are no normative data describing typical lean mass increases among collegiate wrestlers and FB players; however it has been the experience of the researchers in this study (collegiate strength coach) that an increase of 1–2 lb (0.45–0.9 kg) over an 8-week period is normal. Lehmkuhl et al. (18) reported 0.3-kg (0.66 lb) increase in lean mass among collegiate track and field athletes participating in 8 weeks of heavy multijoint resistance training and repeated sprints. The findings by Lehmkuhl et al. support the findings in our study, because the researchers used previously trained athletes participating in normal in-season training, and lean mass increases were quite similar over identical amounts of time (8 weeks). Additionally, the talent level of collegiate athletes and the degree to which they train is very high and fairly uniform among competing teams; therefore, seemingly small physical improvements can have a large impact on performance.

The supplemented wrestlers improved flexed-arm hang times by an average of 6.5 vs. 5.0 seconds for placebo (difference of 1.5 seconds). The FAH test requires a high-intensity static contraction to be held for 30–90 seconds, thus mimicking many holds performed in collegiate WR. Increasing the strength at which a wrestler may hold, or increasing the duration of the hold even a few seconds, may significantly improve the athlete's overall performance during competition. The supplemented wrestlers in the study improved 300-yd shuttle times by an average of 1.6 vs. 1.3 seconds for placebo. The fact that the supplemented wrestlers experienced greater improvements in both flexed-arm hang and 300-yd shuttle has added significance when considering that the supplemented wrestlers reduced overall BW by just 0.43 lb, whereas the placebo group reduced BW by 3.2 lb. A large reduction in BW would likely improve performance on tests like flexed-arm hang and 300-yd shuttle because the athlete must carry, or support his own BW for a relatively long period of time (≈60 seconds); however, this was not the case in this study, because the supplemented wrestlers performed better despite carrying a higher relative BW. This increase in performance, despite higher relative BW, is likely because of the increase in proportion of lean mass seen with the supplemented wrestlers, because of strength gains realized through lean mass increase.

The supplemented FB players in this study improved 300-yd shuttle times by an average of 1.1 vs. 0.4 seconds for placebo. The 300-yd shuttle test requires 12 repeated 25-yd sprints and corresponding start and stops. The average time difference (0.7 seconds) divided by the number of repeated sprints is equal to 0.06 seconds per repeated sprint. Having a speed advantage of 0.06 second per 25-yd sprint in the game of FB is very significant, particularly for the players who sprint longer distances. In addition, the likelihood of each athlete being able to maintain this speed advantage through the duration of a game is high because of the ability of carnosine (induced by β-alanine) to improve muscle buffering capacity (10). This speed advantage multiplied over the course of an entire game could be very impactful for the athlete. The supplemented FB players increased flexed-arm hang time by 3 seconds compared to basically no gain for the placebo group (0.39 seconds). Notable in this data is the increase in strength to BW ratio demonstrated by the FB players' performance on the flexed-arm hang. Both groups increased overall BW by nearly the same amount (+2.6 lb for supplement group vs. +2.8 lb for placebo), but the supplement group increased hang time substantially, whereas the placebo group remained roughly the same. These data may have added significance considering that the FB supplement group maintained a higher overall BW throughout the study (206 vs. 191 lb). In both performance tests, the supplemented FB players experienced greater improvement, and did so while increasing lean mass at a faster rate.

Very little change was seen in lactate values after the 300-yd shuttle pre to posttreatment in any of the groups despite very high absolute values for all groups (≈10 $mmol\cdot L^{-1}$). Both WR groups showed a trend toward reduced lactate (≈2 $mmol\cdot L^{-1}$), whereas the FB placebo group increased slightly (1.5 $mmol\cdot L^{-1}$) and the FB supplement group stayed nearly the same (0.3 $mmol\cdot L^{-1}$). Although changes were minimal, and not statistically significant, the supplemented athletes had faster 300-yd shuttle times than the non-supplemented athletes had, while exercising at the same relative intensity (as indicated by similar lactate values). This may suggest that β-alanine improves the athlete's ability to clear lactic acid more efficiently or tolerate high lactic acid levels longer, therefore allowing the athlete to exercise at a higher relative intensity for a longer period of time (3). This is apparent even when considering the heterogeneity of the subjects.

The lack of statistical significance in change values between placebo and supplement groups can be explained in part by the high degree of variability among subjects. A WR team consists of athletes who compete in weight brackets from 125 to 197 lbs and heavyweight (183–285 lb), in 8-lb increments. The FB teams are comprised of very large players, smaller players, and nearly all sizes in between (150–350 lb). This heterogeneous makeup in both groups helps explain the highly variable test results and thus very high *SD*s. High *SD*s in relation to the mean can make achieving statistical significance very difficult. In addition, the large difference in body sizes makes interpretation of results more difficult. For example, an increase of 2 lbs of lean mass in 8 weeks for a 125-lb athlete is more impressive than the same increase for an athlete weighing 250 lb. However, because of high variability, the changes observed in this study appear even more meaningful, practically, when applied to a heterogeneous grouping of athletes with varying training programs, over a relatively short 8-week period.

Of particular interest in the results of this study was the similarity of performance and body composition improvements among the supplemented wrestlers and supplemented

FB players, despite the fact that they participated in different training programs throughout the study. Though in-season WR and FB training programs both emphasize strength and speed improvements, they are different from a metabolic standpoint. Wrestling tends to emphasize anaerobic glycolysis in both competition and training, whereas FB is nearly exclusively reliant upon the ATP-PC system for energy. Despite this difference, β-alanine supplementation was able to similarly influence performance and body composition variables when compared to placebo.

The most effective means of training and β-alanine supplementation are yet to be firmly established. Hoffman et al. (14) suggested that β-alanine supplementation is most effective when training stimulates a high amount of H^+, as the increased carnosine (result of β-alanine supplementation) effectively delays fatigue by buffering the high concentration of H^+. Smith et al. (23) suggested that β-alanine supplementation may reduce intramuscular acidosis, therefore reducing possible protein degradation and inhibited protein synthesis as a result of lowered pH levels. Considering the fact that the athletes in this study had relatively low to moderate protein and caloric intakes (2), this mechanism may at least, partially explain the similarity in lean mass gain between the supplemented FB players and supplemented wrestlers. Both WR groups, for example, had similar caloric intake (21.9 vs. 25.7 $kcal \cdot kg^{-1}$ BW) and protein intake (0.79 vs. 0.76 $g \cdot kg^{-1}$ BW), and participated in the same training program, yet WR subjects taking β-alanine increased muscle mass, whereas their placebo counterparts lost lean mass. Similarly, both FB groups consumed nearly identical calories (35.6 vs. 35.9 $kcal \cdot kg^{-1}$ BW), and nearly identical amounts of protein (1.17 vs. 1.19 $g \cdot kg^{-1}$ BW), gained nearly identical amounts of BW (+2.8 placebo vs. +2.6 supplement), and trained in the same program, yet the group taking β-alanine gained nearly double the lean mass (+2.1 vs. 1.1 lb). In addition, it is worth noting that both WR groups were severely calorie restricted (1,688 $kcal \cdot d^{-1}$ for placebo group, 2,210 $kcal \cdot d^{-1}$ for the supplement group). Under these conditions, the most likely outcome is indiscriminant weight loss (lean and fat mass) (2,3,19), as was the result for the WR placebo group. The low protein intake demonstrated by both WR groups (<1 $g \cdot kg^{-1}$ BW) combined with high-intensity training does not typically produce an optimal environment for lean mass gains (2); however, the supplemented wrestlers were able to increase lean mass while taking in only 0.76 g of protein per kilogram of BW. The degree to which carnosine and other intramyocellular buffers affect protein metabolism is an area where more research is needed.

Practical Applications

Supplementation with β-alanine appears to have the ability to augment performance and stimulate lean mass accrual in a short amount of time (8 weeks) in previously trained athletes. β-alanine may magnify the expected performance outcomes of training programs with different metabolic demands. Adding β-alanine to athletes' training programs may improve anaerobic endurance and may aid in lean mass accrual and preservation. Supplementation with β-alanine may assist wrestlers in maintaining lean mass while cutting weight. Supplemented FB players may experience faster improvements in strength, speed, and body composition. β-alanine seems to be well tolerated and side effects are absent or minimal. β-alanine is a worthwhile supplement relative to cost, as most products have a monthly cost of roughly 30–40 USD. Further research is needed to fully outline the most appropriate training methods, which will enhance the potential ergogenic effects of β-alanine supplementation. In addition, future research should include a wider variety of subjects, particularly female subjects.

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