Uses and Application of β-Alanine in Sport Nutrition

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Disclosures: Receive industry sponsored research grants and serve as a scientific and legal consultant. Serve as scientific consultant to Nutrabolt (Bryan, TX)

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Overview

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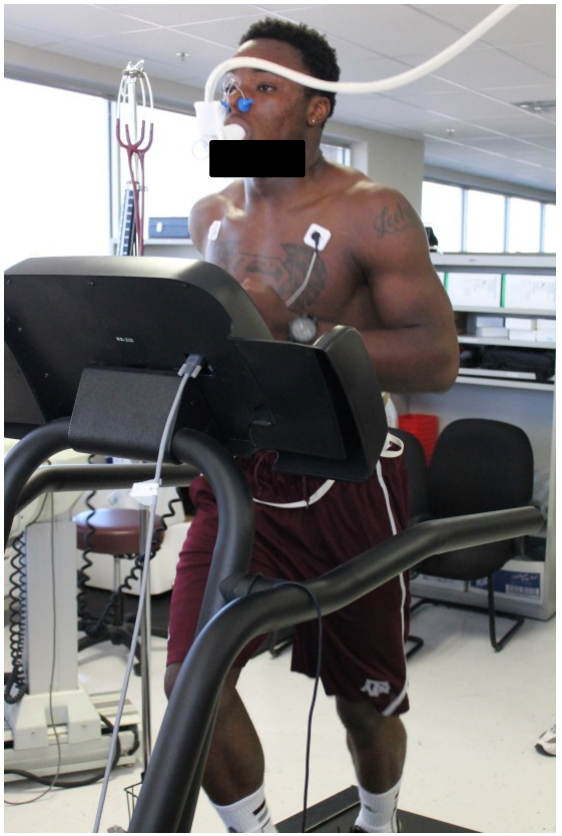
- Positioning of β-Alanine in the sport nutrition market
- Potential additive benefits of co-ingesting β-Alanine with other nutrients
- Summary and Future Directions



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β-Alanine

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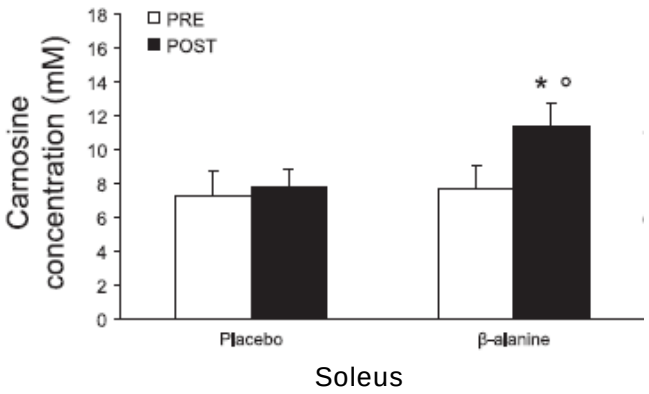
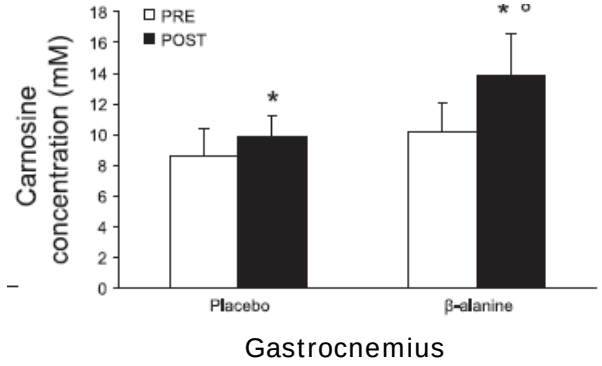
- Muscle carnosine has been reported to serve as a physiological buffer, possess antioxidant properties, influence enzyme regulation, and affect sarcoplasmic reticulum calcium regulation.
- Beta-alanine (β-ALA) is a non-essential amino acid. β-ALA supplementation (e.g., 2–6 grams/day) has been shown to increase carnosine concentrations in skeletal muscle by 20–80% (*Culbertson et al, Nutrients, 2010*).





Dareve et al. JAP, 2007

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Athletic Events that May Benefit from β-Alanine Supplementation

- **Increased Buffering**
  - Interval Sprint Training (e.g., 100 m – 400 m repeats)
  - Track sprints: 200, 400, 800 meters
  - Swimming: 50 – 400 meters
  - Pursuit cycling
- **Increased Recovery from Intermittent Intense Sprint Exercise**
  - Basketball
  - Field hockey
  - Football (American)
  - Ice hockey
  - Lacrosse
  - Soccer
  - Volleyball
- **Reduced Muscle Acidosis**
  - Downhill skiing
  - Rowing (1,000 meters)
  - Time trial performance (e.g., 1,600 m, 5-10 km running, 40-km cycling)

Nutrition Strategies

Strength / Power Athletes

- Nutritional Strategies
  - Water/GES
  - Post-Exercise CHO & PRO/EAA
- Ergogenic Aids
  - Creatine
  - β-HMB
  - β-alanine
  - Sodium Bicarbonate
  - Nitrates

International society of sports nutrition position stand: Beta-Alanine. *JISSN. 12:30, 2015*

1. Four weeks of beta-alanine supplementation (4–6 g daily) significantly augments muscle carnosine concentrations, thereby acting as an intracellular pH buffer.
2. Beta-alanine supplementation currently appears to be safe in healthy populations at recommended doses.
3. The only reported side effect is paraesthesia (tingling), but studies indicate this can be attenuated by using divided lower doses (1.6 g) or using a sustained-release formula.
4. Daily supplementation with 4 to 6 g of beta-alanine for at least 2 to 4 weeks has been shown to improve exercise performance, with more pronounced effects in open end-point tasks/time trials lasting 1 to 4 min in duration.

International society of sports nutrition position stand: Beta-Alanine. *JISSN. 12:30, 2015*

5. Beta-alanine attenuates neuromuscular fatigue, particularly in older subjects, and preliminary evidence indicates that beta-alanine may improve tactical performance.
6. Combining beta-alanine with other single or multi-ingredient supplements may be advantageous when supplementation of beta-alanine is high enough (4–6 g daily) and long enough (minimum 4 weeks).
7. More research is needed to determine the effects of beta-alanine on strength, endurance performance beyond 25 min in duration, and other health-related benefits associated with carnosine.

Market Positioning of β-Alanine

Non-Controlled Release of β-Alanine

- Most initial studies on β-alanine were performed on an immediate release version using oral doses of 10 - 40 mg/kg (800 mg to 3.2 g per dose for an 80 kg individual)
- Initial pharmacokinetic studies indicated that β-alanine typically peaks in the blood about 30-45-mins after ingestion.
- Ingestion of multiple doses of β-alanine promotes corresponding peaks in blood β-alanine levels.
- Most β-alanine supplements introduced on the market in the mid 2000's were immediate release formulations.

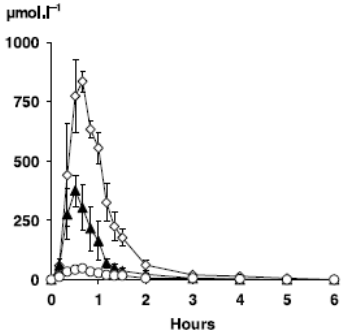


Fig. 2. Mean plasma β-alanine concentration with time following ingestion of 10 (○), 20 (▲) or 40 (◇) mg · kg^{-1} bwt β-alanine. For reasons of clarity the SE of the means is shown only for measurements following 20 and 40 mg · kg^{-1} bwt

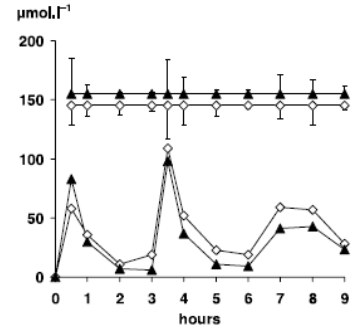


Fig. 6. Plasma β-alanine over 9 h following the oral ingestion of 10 mg · kg^{-1} bwt of β-alanine at 0, 3 and 6 h on days 1 (▲) and 15 (◇) whilst dosing at 3 × 10 mg · kg^{-1} bwt per day. For reasons of clarity the SE of the means are shown separately above the main trend line

Harris et. al., Amino Acids. 30:279-89, 2006

Market Positioning of β-Alanine

Sustained-Release β-Alanine

- Décombaz et al. (2012) reported that using a sustained-release form of β-alanine resulted in a more prolonged elevation in plasma β-alanine, a greater area under the curve, less loss in urinary β-alanine (i.e., greater retention), and less side effects that were similar to placebo.
- The JISSN concluded that use of a sustained form of β-alanine may promote greater benefits with less side effects.
- More sustained release forms of β-alanine now found in dietary supplements

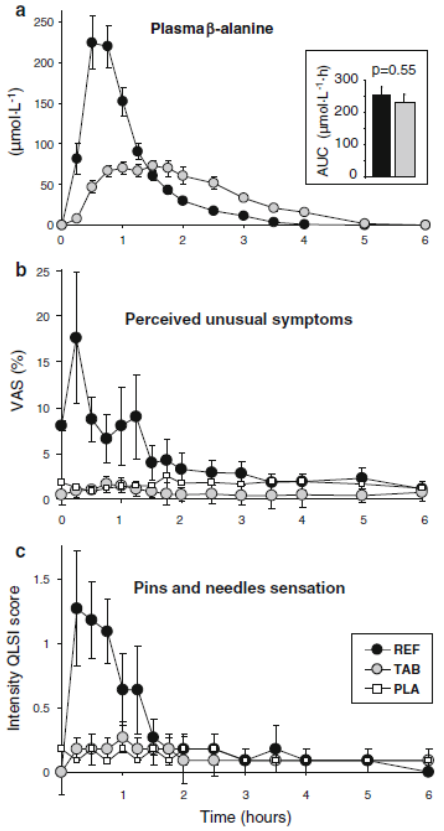
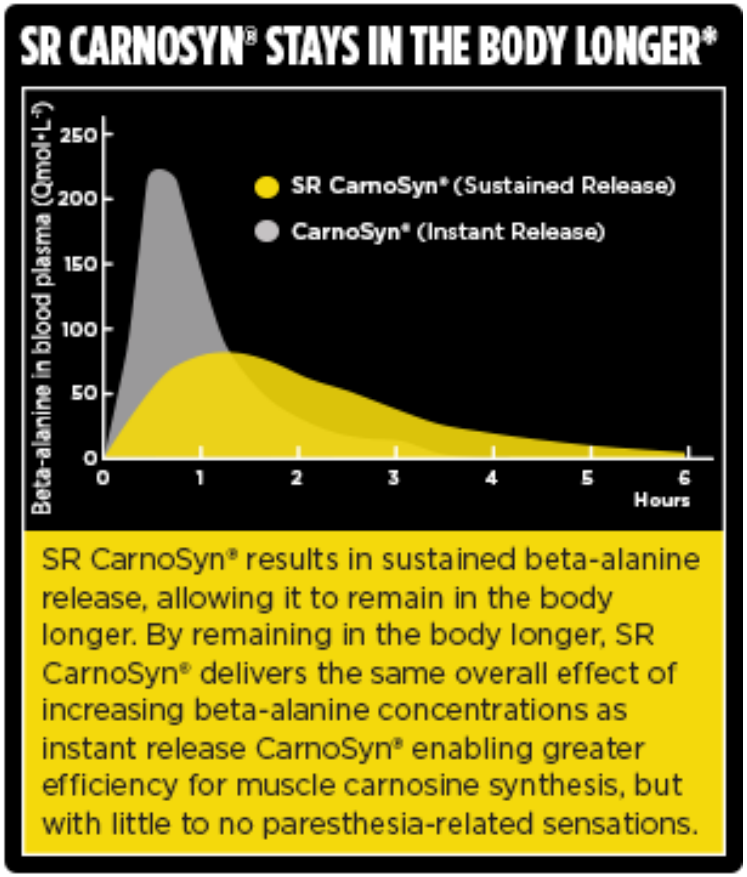


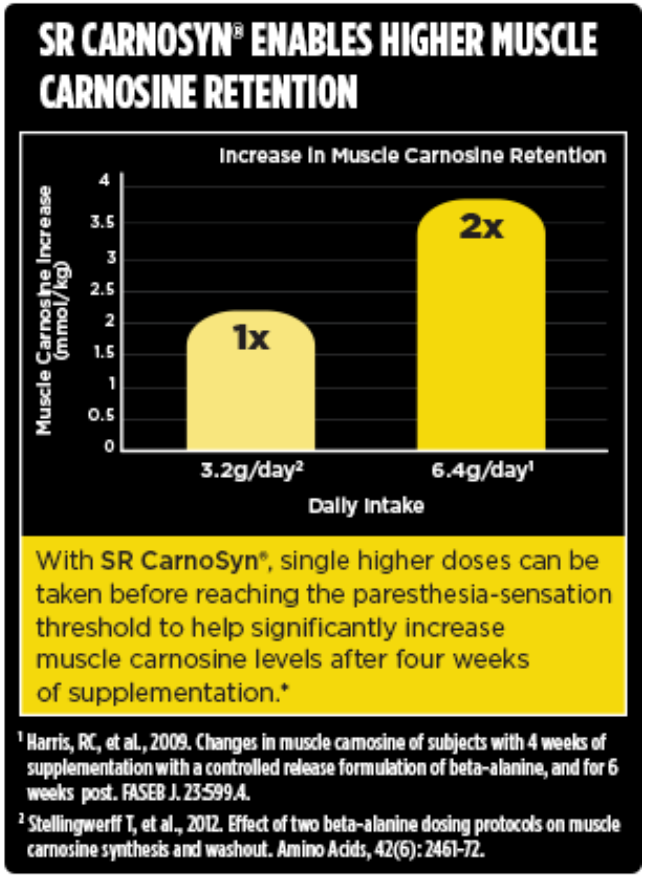
Fig. 1 a Plasma *β*-alanine concentration (μmol L^{-1}) for 6 h after the ingestion of 1.6 g *β*A in aqueous solution *REF* or in slow-release tablet form *TAB*. The area under the curve is depicted in the insert (μmol L h^{-1}). **b** Reported intensity of non-differentiated sensations of paresthesia using a Visual Analogue Scale (%), from 0 = "no unusual sensation" to 100 = "most intense sensation imaginable". **c** Intensity of "pins and needles" sensations using the Qualitative Light Symptom Inventory ($QLSI_{p\&n}$, scale from 0 = absent to 4 = extremely intense). Means ± SE(11)

Décombaz et. al., Amino Acids. 43:67-76, 2012

Market Positioning of β-Alanine

Comparison of Forms

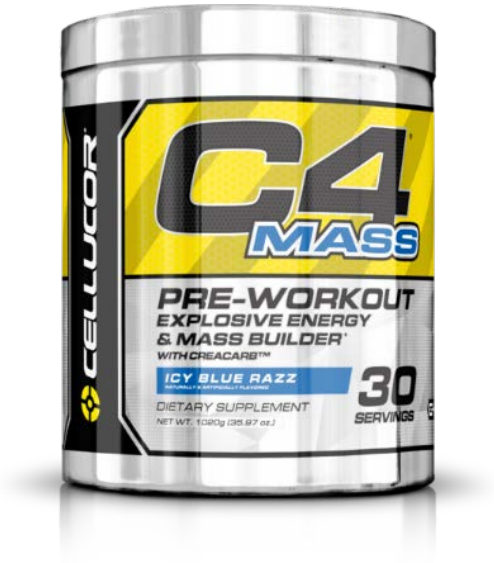




Market Positioning of β-Alanine

Multi-Ingredient Supplements

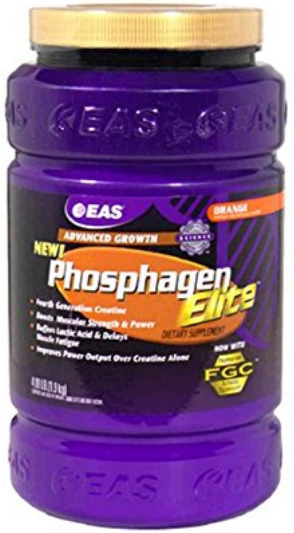
- While β-Alanine supplements continue to be sold separately, β-Alanine is also now included in many nutritional formulations with other potentially ergogenic nutrients such as:
  - Creatine
  - Sodium Bicarbonate
  - Nitrates / Vasodilators (e.g., L-Citrulline)
  - Thermogenics (e.g., Caffeine, Bioperine, Quercetin, Green Tea, Cinnulin, etc.)
  - Pre-Workout Supplements (Powder and RTD)



β-Alanine with Creatine

Theoretical Benefits

- Creatine has been reported to increase PC levels, enhance high-intensity exercise performance, and improve training adaptations.
- β-Alanine has been reported to enhance buffering capacity and intermittent high-intensity exercise typically lasting 30-s to 5-10 min.
- Theoretically, co-ingestion would enhance the phosphagen and glycolytic energy systems as well as promote recovering from high-intensity intermittent exercise.



Effect of creatine and beta-alanine supplementation on performance and endocrine responses in strength/power athletes

Hoffman et al. IJSNEM. 16:430-46, 2006

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- 33 males were randomly assigned either:
  - ***Placebo***
  - ***Creatine (10.5 g/d)***
  - ***Creatine (10.5 g/d) and β-ALA (3.2 g/d)***
- Subjects completed a ***10-wk, 4-d/wk RT program***
- BP and squat 1RM's, Wingate sprints, 20-jump test, body composition, and fasting blood was obtained
- ***Changes in FFM and percent BF were greater (P < 0.05) in CA compared to C or P.***
- ***Significantly greater strength improvements were seen in CA and C compared to P.***
- Resting testosterone was elevated in C with no other significant endocrine changes noted.
- ***Creatine plus beta-alanine supplementation appeared to have the greatest effect on lean tissue accruement and body fat composition.***

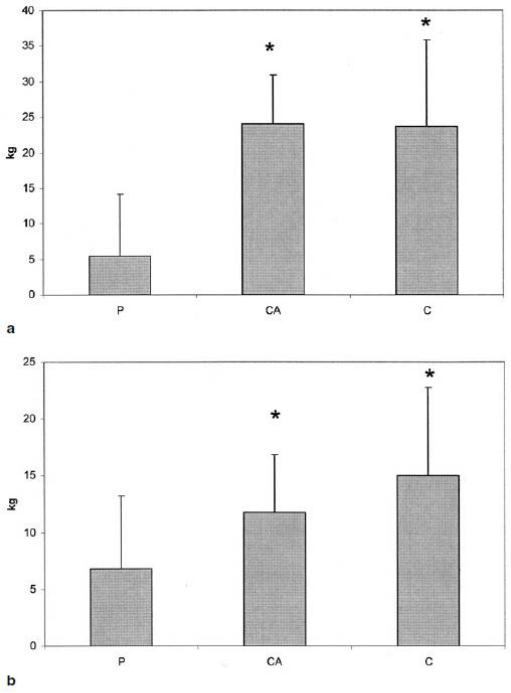

Figure 4 — (a) Δ 1-RM squat strength; (b) Δ 1-RM bench press strength; * $P < 0.05$ from P, ES > 0.89; data are presented as means ± standard deviation.

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Effects of twenty-eight days of beta-alanine and creatine monohydrate supplementation on the physical working capacity at neuromuscular fatigue threshold

Stout et al. JSCR. 20:928-31, 2006

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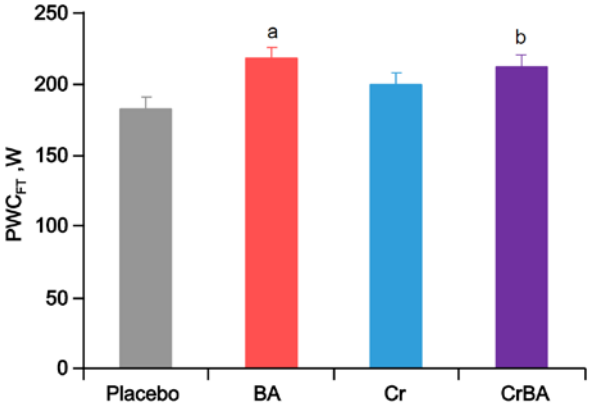
- 51 males were randomly assigned to ingest ***(4/d for 6-d):***
  - ***PLA (34 g dextrose; n = 13)***
  - ***CrM (5.25 g CrM plus 34 g dextrose; n = 12),***
  - ***BA (1.6 g BA plus 34 g of dextrose; n = 12), or***
  - CrBA (5.25 g CrM plus 1.6 g BA plus 34 g dextrose; n = 14).
- Subjects performed a cycle ergometry physical work capacity (PWC) test with surface EMG to assess neuromuscular fatigue threshold (FT)
- ***The adjusted mean posttest PWC(FT) values (covaried for pretest PWC(FT) values) for the BA and CrBA groups were greater than those for the PLA group (p < or = 0.05).***
- No differences were seen among groups.
- ***BA supplementation may delay the onset of neuromuscular fatigue but there was no apparent additive or unique effects of CrM vs. BA alone on PWC(FT).***



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Effects of 28 days of beta-alanine and creatine monohydrate supplementation on aerobic power, ventilatory and lactate thresholds, and time to exhaustion

Zoeller et al. Amino Acids. 33:505-10, 2007

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- 55 males were randomly assigned to ingest ***(4/d for 6-d):***
  - ***PLA (34 g dextrose; n = 13)***
  - ***CrM (5.25 g CrM plus 34 g dextrose; n = 12),***
  - ***BA (1.6 g BA plus 34 g of dextrose; n = 14), or***
  - ***CrBA (5.25 g CrM plus 1.6 g BA plus 34 g dext.; n = 16).***
- Subjects performed a cycle ergometry test determine VO_{2peak}, time to exhaustion (TTE), and power output, VO_2, and percent VO_{2peak} associated with VT and LT.
- No significant group effects were found. However, within groups, ***a significant time effect was observed for CrBA on LT VO_2, LT Watts, VT VO_2, VT Watts, VT % VO_2).***
- ***CrBA may potentially enhance endurance performance by increasing VT and/or LT.***

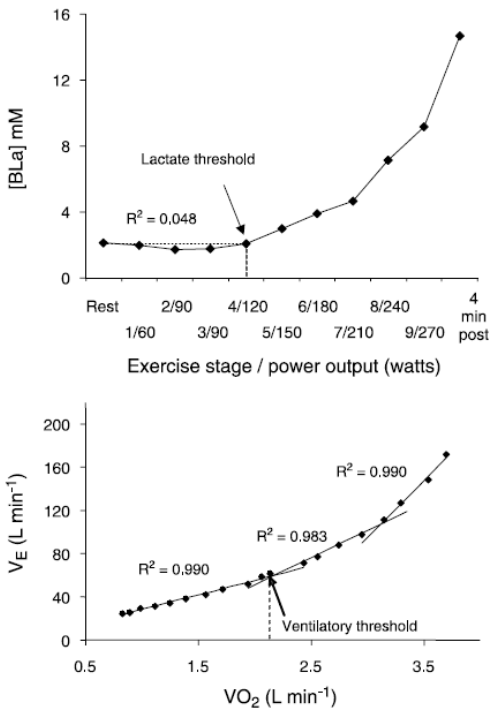

Fig. 1. Examples of lactate and ventilatory threshold determination

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Effects of 28 days of beta-alanine and creatine supplementation on muscle carnosine, body composition, and exercise performance in recreationally active females

Kresta et al. JISSN. 11:55, 2014

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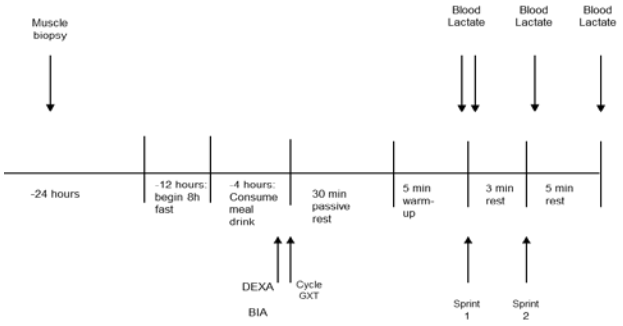
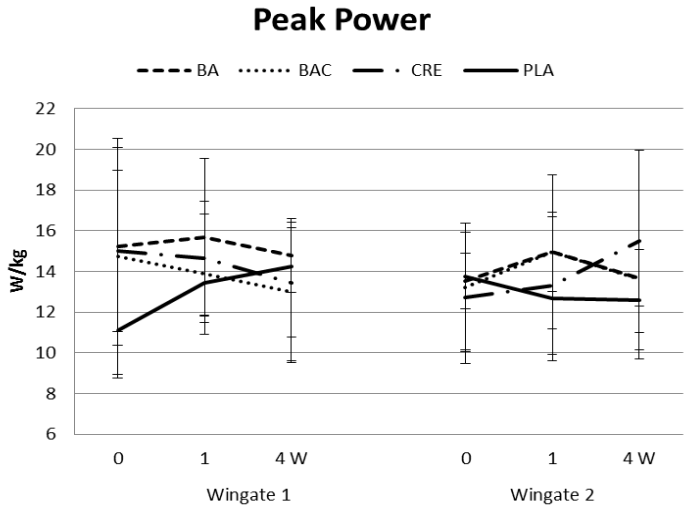
- 32 females were randomized in a double-blind, placebo-controlled manner into one of four supplementation groups:
  - ***β-ALA only (BA, n=8)***
  - ***Creatine only (CRE, n=8)***
  - ***β-ALA and Creatine combined (BAC, n=9)***
  - ***Placebo (PLA, n=7).***
- Participants supplemented for 4-wks and were assessed at 0, 7 and 28 days.
- Large but non-significant increases in muscle carnosine observed (BA 35.3±45; BAC 42.5±99; CRE 0.72±27; P 13.9±44 %)
- ***Participants in the BAC group showed a trend towards improvement during the second Wingate after one week.***





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The effects of beta alanine plus creatine administration on performance during repeated bouts of supramaximal exercise in sedentary men

Okudan et al. J Sports Med Phys Fitness 55(11):1322-8, 2015

- 44 untrained men were assigned to one of four treatment groups randomly:
  - ***P (10 g maltodextrose)***
  - ***Cr (5 g creatine plus 5 g maltodextrose);***
  - ***BA (1.6 g BA plus 8.4 g maltodextrose); or,***
  - ***BA + Cr (1.6 g BA + 5 g creatine + 3.4 g maltodextrose)***
- Supplements were taken twice a day for 22 days, then four times a day for the following 6 days.
- Prior to and following 28 days, peak power (PP), mean power (MP), and fatigue index (FI) was determined.
- PP increased in the Cr (from 642.7+/-148.6 to 825.1+/-205.2 in PP2 and from 522.9+/-117.5 to 683.0+/-148.0 in PP3, respectively).
- MP was increased in BA+Cr
- ***BA and BA+Cr have strong performance enhancing effect by increasing mean power and delaying fatigue Index during the repeated WAnT***.

Repeated supramaximal exercise-induced oxidative stress: effect of β-Alanine plus creatine supplementation

Belviranli et al. Asian J Sports Med. 1(7), 2016

- 44 untrained men were assigned to one of four treatment groups randomly:
  - ***P (10 g maltodextrose)***
  - ***Cr (5 g creatine plus 5 g maltodextrose);***
  - ***BA (1.6 g BA plus 8.4 g maltodextrose); or,***
  - ***BA + Cr (1.6 g BA + 5 g creatine + 3.4 g maltodextrose)***
- Supplements were taken twice a day for 22 days, then four times a day for the following 6 days.
- Participants performed 3 Wingate ACT's and had blood obtained prior to and following supplementation.
- Malondialdehyde levels and superoxide dismutase activities were not affected by supplementation.
- ***Oxidized glutathione (GSH and GSSG) levels increased in BA and BA+Cr immediately after the exercise compared to pre-exercise.***
- ***During the post-supplementation session, total antioxidant capacity increased in BA group immediately after the exercise.***
- ***BA supplementation has limited antioxidant effect during the repeated WTs.***

β-Alanine with Creatine

Summary

Dietary supplementation of creatine and β-alanine appears to have independent and synergistic effects

β-Alanine with Sodium Bicarbonate

Theoretical Benefits

- Sodium bicarbonate has been reported to promote buffering and improve exercise capacity generally in high-intensity glycolytic events lasting 1 to 4 min
- β-Alanine has been reported to enhance buffering capacity and intermittent high-intensity exercise typically lasting 30-s to 5-10 min.
- Theoretically, co-ingestion would enhance the glycolytic energy system capacity and/or recovery.

Effect of combined β-alanine and sodium bicarbonate supplementation on cycling performance

Bellinger et al. MSSE. 44(8): 1545-51, 2012

- 14 trained cyclists randomly ingested in a DBPC cross-over manner ***65 mg/kg of a PLA or BA for 28-days***
- Participants also ingested ***0.3 g/kg of SB or a PL prior to performance tests*** (PLA + PLA, PLA + BA, BA+ PL, BA + SB).
- In the acute SB loading trials, blood pH and HCO_3 were elevated from before loading to pretest, and the magnitude of the change in HCO_3 from pretest to posttest was significantly greater compared with the acute PLA loading trial ($P < 0.001$).
- Average power output in the 4-min cycling performance trial was increased in PLA + SB (+3.1% ± 1.8%) and β-alanine + SB(+3.3% ± 3.0%) compared with baseline ($P < 0.05$).
- BA + PLA did not significantly improve average power output compared with baseline (+1.6% ± 1.7%, $P = 0.20$); however, magnitude-based inferences demonstrated that BA + PLA was associated with a 37% likelihood of producing average power improvements.
- ***Acute SB improved performance and there may be a small meaningful improvement in performance***
- ***No additive effects of combined BA + SB supplementation.***

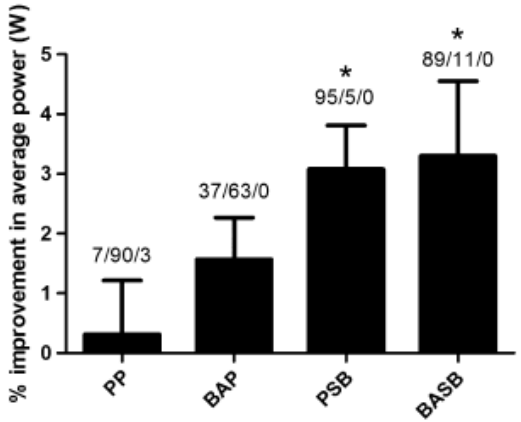


FIGURE 2—Improvement in average power output in the maximal 4-min cycling performance trial in each treatment group. The likelihood of a practically substantial difference of the supplementation condition relative to the baseline performance trial for each group (β-alanine or placebo) were provided as percent positive/percent trivial/percent negative above each *bar*. *Significantly different from baseline ($P < 0.05$).

Effect of beta-alanine, with and without sodium bicarbonate, on 2000-m rowing performance

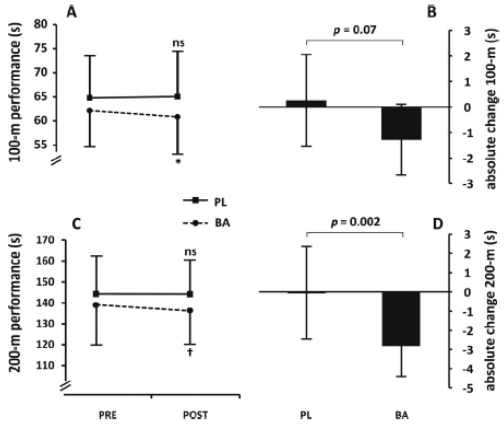
Hobson et al. IJSNEM. 23(45): 480-7, 2013

- 20 trained rowers were assigned to either a ***PLA or BA (6.4 g/d) for 4 weeks)*** group.
- A 2,000-m rowing time trial (TT) was performed before supplementation (Baseline) and after 28 and 30 days of supplementation.
- The post supplementation trials involved supplementation with either ***maltodextrin or SB i***n a double-blind, crossover design, creating four study conditions (PL + M, PL + SB, BA + PL, BA + SB).
- BA was very likely to be beneficial to 2,000-m rowing performance (6.4±8.1 s effect compared to PL), with the effect of SB having a likely benefit (3.2±8.8 s).
- There was a small (1.1±5.6 s) but possibly beneficial additional effect when combining chronic BA with acute SB compared with chronic BA alone.
- SB ingestion led to increases in plasma pH, base excess, bicarbonate, and lactate concentrations.
- ***Both chronic BA and acute SB supplementation alone had positive effects on 2,000-m rowing performance.***
- ***The addition of acute SB to chronic BA supplementation may further enhance rowing performance.***

The ergogenic effect of beta-alanine combined with sodium bicarbonate on high-intensity swimming performance

Painelli et al. Appl. Physiol. Nutr. Metab. 38(5): 525-32, 2013

- In study A, 16 swimmers were assigned to either ***a PLA or BA (3.2 g/d for 1-wk and 6.4 g/d for 4-wks).*** In study B, 14 swimmers were assigned to either a PLA or BA (3.2 g/d for 1-wk and 6.4 g/d for 3-wks).
- 100m and 200m time trials were performed once before and twice after supplementation (with PL and SB) in a crossover fashion, providing 4 conditions: PL-PL, PL-SB, BA-PL, and BA-SB.
- In study A, BA supplementation improved 100- and 200-m time-trial performance by 2.1% ($p = 0.029$) and 2.0% ($p = 0.0008$), respectively.
- In study B, 200-m time-trial performance improved in all conditions, compared with pre-supplementation, except the PL-PL condition (PL-SB, +2.3%; BA-PL, +1.5%; BA-SB, +2.13% ($p < 0.05$)).
- BA-SB was not different from BA-PL ($p = 0.21$), but the probability of a positive effect was 78.5%.
- In the 100-m time-trial, only a within-group effect for SB was observed in the PL-SB ($p = 0.022$) and BA-SB ($p = 0.051$) conditions. However, 6 of 7 athletes swam faster after BA with a probability of BA having a positive effect was 65.2%; when SB was added to BA, the probability was 71.8%.
- ***BA and SB supplementation improved 100- and 200-m swimming performance.***
- ***Coingestion of BA and SB induced a further nonsignificant improvement in performance.***



Additive effects of beta-alanine and sodium bicarbonate on upper-body intermittent performance

Tobias et al. Amino Acids. 45(2): 309-17, 2013

- 37 athletes were assigned to ingest ***6.4 g/d of PL or BA for 4-wks and 500 mg/kg of SB for 7-d*** during the last week providing 4 groups: PL+PL; BA+PL; PL+SB or BA+SB.
- Prior to and following supplementation, athletes completed four 30-s upper-body Wingate tests, separated by 3 min.
- BA and SB alone increased the total work done in +7 and 8 %, respectively. The co-ingestion resulted in an additive effect (+14 %, $p < 0.05$ vs. BA and SB alone).
- BA alone significantly improved mean power in the 2nd and 3rd bouts and tended to improve the 4th bout.
- SB alone significantly improved mean power in the 4th bout and tended to improve in the 2nd and 3rd bouts.
- BA+SB enhanced mean power in all four bouts. PL+PL did not elicit any alteration on mean and peak power.
- Post-exercise blood lactate increased with all treatments except with PL+PL. Only BA+SB resulted in lower RPE ($p = 0.05$).
- ***Chronic BA and SB supplementation alone equally enhanced high-intensity intermittent upper-body performance in well-trained athletes.***
- ***Combined BA and SB promoted a clear additive ergogenic effect.***

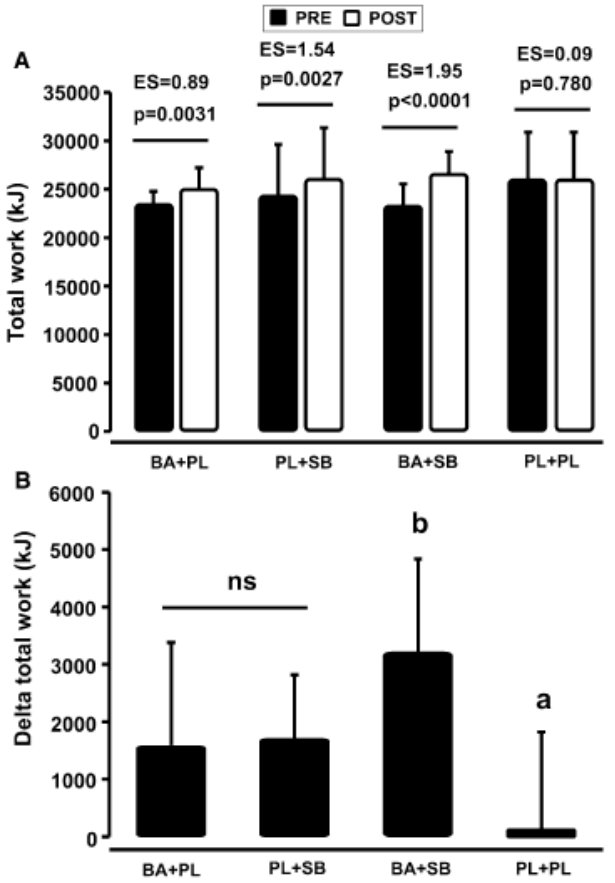


Fig. 2 Effects of supplementation on total work done (a) and absolute change (Δ POST–PRE) (b). *BA* beta-alanine, *SB* sodium bicarbonate, *PL* placebo, *EF* effect size, *NS* nonsignificant, *a* Different from all other groups ($p < 0.05$), *b* different from BA+PL to PL+SB ($p < 0.05$)

The effect of β-alanine and NaHCO3 co-ingestion on buffering capacity and exercise performance with high-intensity exercise in healthy males

Danaher et al. EJAP. 114(8): 1715-24, 2014

- 8 males ingested either ***BA (4.8 g/d) for 4 weeks, increased to 6.4 g/d for 2 weeks or PL for 6 weeks*** in a crossover manner.
- After each c supplementation period, participants performed two trials consisting a repeated sprint ability (RSA) test and cycling capacity test at 110 % Wmax (CCT110 %).
- PL or SB (300 mg/kg) was ingested prior to exercise in a crossover design creating 4 conditions (B-PL, BA-SB, PL-PL, and PL-SB).
- Carnosine increased in the gastrocnemius ($p = 0.03$) and soleus ($p = 0.02$) following BA supplementation, and PL-SB and BA-SB ingestion elevated blood HCO_3- concentrations ($p < 0.01$).
- Although buffering capacity was elevated following both BA and SB ingestion, performance improvement was only observed with BA-PL and BA-SB increasing time to exhaustion of the CCT110 % test 14 and 16 %, respectively, compared to PL-PL ($p < 0.01$).
- Supplementation of BA and SB elevated buffering potential by increasing muscle carnosine and bicarbonate levels, respectively.
- ***BA ingestion improved performance during the CCT110 %, with no aggregating effect of SB supplementation ($p > 0.05$).***
- ***Performance was not different between treatments during the RSA test.***

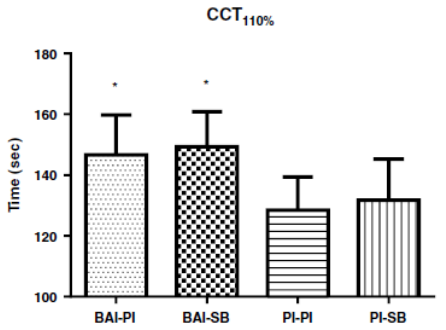


Fig. 5 Time to exhaustion (TTE) (s) results for the different supplement groups during the cycling capacity test ($CCT_{110\ \%}$). Values expressed as mean ± SEM. *$p < 0.05$ from PI–PI

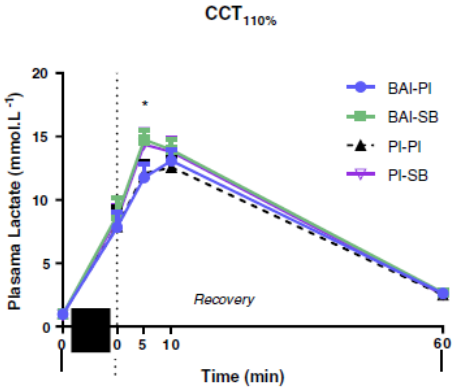
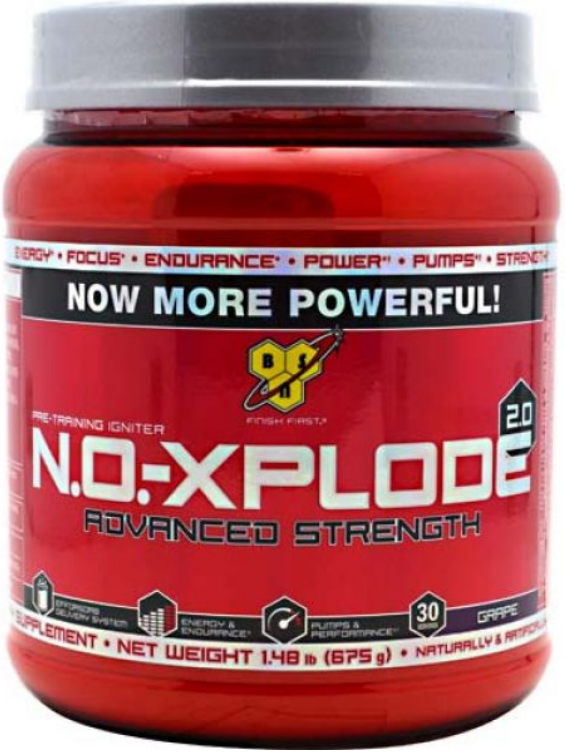


Fig. 6 Plasma lactate concentration (mmol L^{-1}) for the different supplemental groups during the cycling capacity test ($CCT_{110\ \%}$). Values expressed as mean ± SEM. *$p < 0.05$ BAI-SB from PI–PI. *Thick vertical bar* denotes exercise

β-Alanine with Sodium Bicarbonate

Summary

There is some evidence that co-ingesting BA with SB provides additional ergogenic benefit



β-Alanine in Multi-Ingredient Supplements

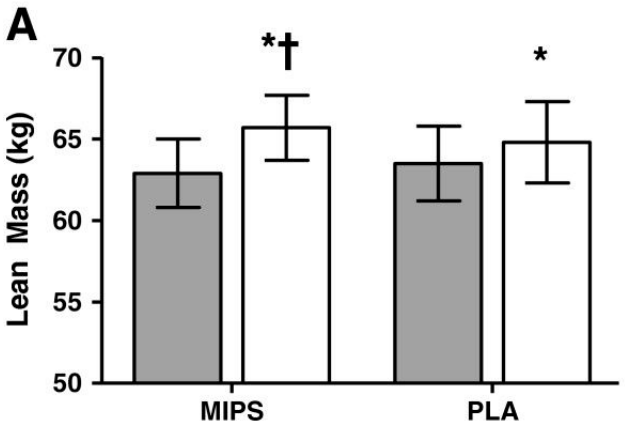
Theoretical Benefits

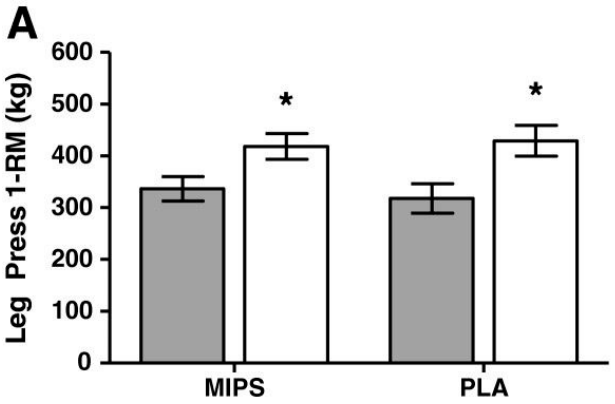
- β-Alanine has been reported to enhance buffering capacity and intermittent high-intensity exercise typically lasting 30-s to 5-10 min.
- Ingestion of daily maintenance doses in pre-workout supplements may provide a convenient way to improve acute and chronic training adaptations.
- Typically contain carbohydrate, caffeine, vasodilators (e.g., nitrates, L-citrulline, etc.), thermogenics, creatine, and/other purported ergogenic nutrients that can affect acute exercise, cognitive performance, and/or training adaptations.

The effects of six weeks of supplementation with multi-ingredient performance supplements and resistance training on anabolic hormones, body composition, strength, and power in resistance-trained men

Ormsbee et al. JISS. 15(9), 2012

- 24 RT males completed 6-wks of training while ingesting a PLA or supplement containing ***whey protein, casein protein, branched-chain amino acids, creatine, beta alanine, and caffeine before each workout and one serving of a supplement containing whey protein, casein protein, branched-chain amino acids, creatine, and beta alanine immediately after each workout and on non-RT days.***
- Group x time interactions were observed for LM (MIPS: PRE, 62.9 ± 2.1 to POST, 65.7 ± 2.0 vs. PLA: PRE, 63.5 ± 2.3 to POST, 64.8 ± 2.5 kg; p = 0.017).
- Both groups increased upper and lower body 1RM strength to a similar degree.
- MIPS significantly increased peak anaerobic power (PRE, 932.7 ± 172.5 W vs. POST, 1119.2 ± 183.8 W, p = 0.002) while PLA remained unchanged (PRE, 974.4 ± 44.1 W vs. POST, 1033.7 ± 48.6 W, p = 0.166).
- ***Consumption of MIPS during the course of a periodized RT program facilitated training-induced improvement in LM in trained males, whereas the consumption of PLA did not. MIPS improved measures of anaerobic power while PLA did not.***





Impact of Four Weeks of a Multi-Ingredient Performance Supplement on Muscular Strength, Body Composition, and Anabolic Hormones in Resistance-Trained Young Men

Kreipke et al. JCSR. 29(12), 2015

- 32 RT males completed 4-wks of training while ingesting a PLA or containing ***long jack root, beta-alanine, and branched-chain amino acids, and other proprietary blends***.
- Before and after the training protocol, mood state, body composition, blood hormones (also collected at midpoint), and maximal strength were measured.
- SUP had significantly greater increases in bench press (SUP, 102 ± 16 kg to 108 ± 16 kg vs. PL, 96 ± 22 kg to 101 ± 22 kg; $p < 0.001$) and total weight lifted (SUP, 379 ± 59 kg to 413 ± 60 kg vs. PL, 376 ± 70 kg to 400 ± 75 kg; $p < 0.001$) compared with PL.
- Additionally, deadlift strength relative to total body mass (calculated as weight lifted/body mass; kg:kg) (2.08 ± 0.18 to 2.23 ± 0.16; $p = 0.036$) and lean mass (2.55 ± 0.19 to 2.72 ± 0.16; $p = 0.021$) increased significantly in SUP but not PL (2.02 ± 0.30 to 2.15 ± 0.36 and 2.56 ± 0.31 to 2.70 ± 0.36, respectively).
- No other significant differences were detected between groups for the remaining variables.
- ***Supplementing with SUP enhanced resistance training adaptations independent of hormonal status, and thus SUP use may warrant inclusion into peri-workout nutrition regimens.***

Table 4. Body composition pre- and post-4 weeks of supplementation with SUP or PL in combination with resistance training.*

	SUP ($n = 14$)			PL ($n = 13$)			p	
Tissue	Pre	Post	% Δ	Pre	Post	% Δ	T	G × T
FM (kg)	14.3 ± 5.2	14.1 ± 5.0	−0.2 ± 5.9†	17.4 ± 7.2	16.7 ± 6.6‡	−3.8 ± 4.7	0.02	0.08
LM (kg)	61.6 ± 6.2	62.9 ± 6.7‡	2.1 ± 1.4	61.8 ± 4.8	62.9 ± 4.9‡	1.8 ± 1.5	0.0001	0.58
Total BM (kg)	75.9 ± 10.4	77.1 ± 10.8‡	1.5 ± 1.5	79.2 ± 9.7§	79.6 ± 9.4	0.5 ± 2.0	0.007	0.12
Total BF (%)	18.3 ± 4.7	17.9 ± 4.4	−1.8 ± 4.1	21.5 ± 6.1§	20.6 ± 5.7†§	−4.3 ± 4.0	0.0002	0.09

*SUP = supplement; PL = placebo; T = time effect; G × T = group by time effect; FM = fat mass; LM = lean mass; Total BM = total body mass; Total BF = total body fat.
†$p \leq 0.05$, between groups.
‡$p \leq 0.05$, within group.
§$p \leq 0.05$, between groups at the same time point.

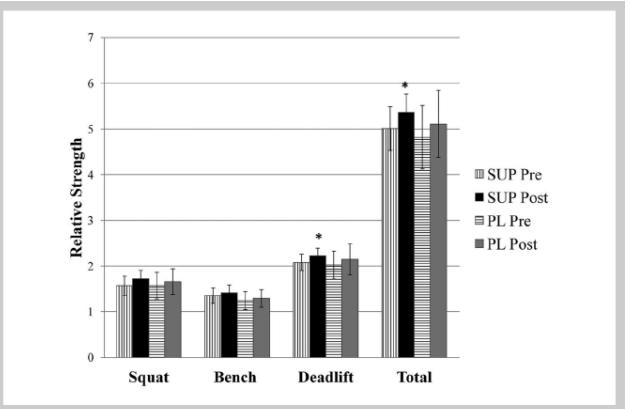


Figure 2. Relative strength after 4 weeks of resistance training and supplementation (measured in kilograms of weight lifted divided by kilograms of body weight). SUP = supplement; PL = placebo; total = total weight lifted. *Significantly different from pre, $p \leq 0.05$.

Effects of acute ingestion of a pre-workout dietary supplement with and without p-synephrine on resting energy expenditure, cognitive function and exercise performance

Jung et al. JISSN. 14:3: 2017

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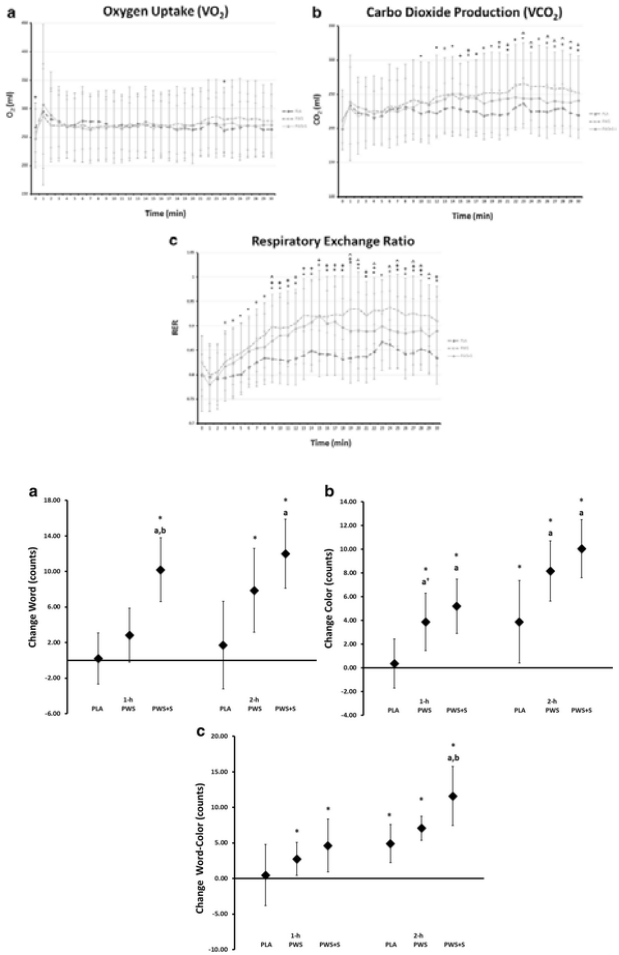
- In a DBCPC manner; 25 apparently men and women had resting BP, HR, 12-lead ECG, and REE measured for 10-min.
- Participants ingested a flavored placebo (P); a ***PWS containing 3.0 g beta alanine, 2 g creatine nitrate, 2 g arginine AKG, 300 mg of N-acetyl tyrosine, 270 mg caffeine, 15 mg of Mucuna pruriens; or, the PWS with 20 mg of synephrine (PWS+S).***
- Participants had HR, BP, REE, ECG's, perceptions about readiness to perform, cognitive function (Stroop Color-Word test), BP & LP performance (2 sets of 10 repetitions at 70% of 1RM and 1 set to failure), and Wingate anaerobic capacity (WAC) sprint performance determined prior to and following exercise.
- No clinically significant differences were observed among treatments in HR, BP, ECG, or general clinical blood panels.
- ***PWS and PWS + S ingestion promoted greater changes in REE responses***.
- ***Participants reported higher perception of optimism about performance and vigor and energy and there was evidence that PWS and PWS + S improved changes in cognitive function scores from baseline to a greater degree than PLA after 1 or 2 h.***
- No statistically significant differences were observed among treatments in total bench press lifting volume, leg press lifting volume or WAC sprint performance.



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Short-Term Effects of a Ready-to-Drink Pre-Workout Beverage on Exercise Performance and Recovery

Collins et al. Nutrients. 9(8), 823, 2017

EXERCISE & SPORT NUTRITION LABORATORY
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- In a DBCPC manner; 25 resistance-trained participants ingested a PLA beverage and a beverage (RTD) containing ***caffeine (200 mg), β-alanine (2.1 g), arginine nitrate (1.3 g), niacin (65 mg), folic acid (325 mcg), and Vitamin B12 (45 mcg) for 7-days,*** separated by a 7–10-day.
- On day 1 and 6, participants donated a fasting blood sample, completed an SEQ, hemodynamic challenge test, 1-RM and muscular endurance tests (3 × 10 reps @ 70% of 1-RM with the last set to failure) on the BP and LP followed by ingesting the assigned beverage.
- After 15 min, participants repeated the hemodynamic test, 1-RM tests, and performed a repetition to fatigue (RtF) test at 70% of 1-RM, followed by completing the SEQ.
- On day 2 and 7, participants donated a fasting blood sample, completed the SEQ, ingested the assigned beverage, rested 30 min, and performed a 4 km cycling time-trial (TT).

Protocol Overview					
Baseline				Follow-Up	
Familiarization	Day 1	Day 2	Day 3-5	Day 6	Day 7
Physical Exam	BIA	8-h fasting blood sample		BIA	8-h fasting blood sample
Body Weight	8-h fasting blood sample	Side Effects Questionnaire		8-h fasting blood sample	Side Effects Questionnaire
DXA Body Composition	Side Effects Questionnaire	Ingest Supplement		Side Effects Questionnaire	Ingest Supplement
BIA Body Water	Pre-Ingestion Hemodynamic Tilt Test	Wait 30-min		Pre-Ingestion Hemodynamic Tilt Test	Wait 30-min
Bench Press & Leg Press 1RM and 70% 1RM Test	Pre-Ingestion Initial Strength Testing	4-km Time Trial		Pre-Ingestion Initial Strength Testing	4-km Time Trial
Practice 4 km Cycling Time Trial	Ingest Supplement	Side Effects Questionnaire		Ingest Supplement	Side Effects Questionnaire
Schedule Baseline Testing	Wait 30-min			Wait 30-min	
Randomize to Treatment	Post Ingestion Hemodynamic Tilt Test			Post Ingestion Hemodynamic Tilt Test	
	Post Ingestion Recovery Strength Testing			Post Ingestion Recovery Strength Testing	
	Side Effects Questionnaire			Side Effects Questionnaire	

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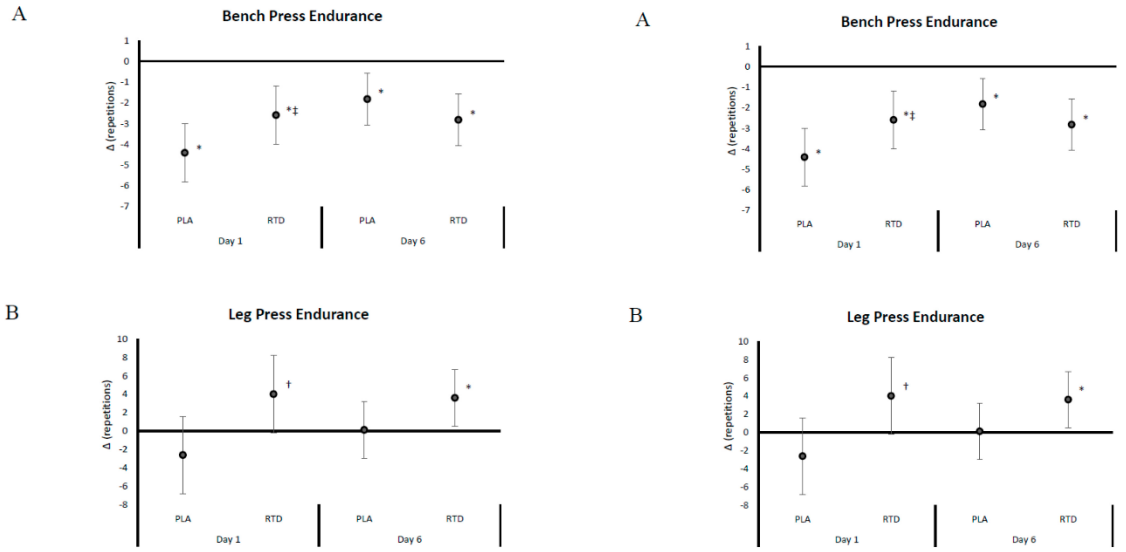
Collins et al. Nutrients. 9(8), 823, 2017

- An overall multivariate interaction was observed on strength performance variables (p = 0.01).
- Acute RTD ingestion better maintained LP 1-RM; increased LP RtF; increased BP lifting volume; and, increased total lifting volume.
- Short-term RTD ingestion maintained baseline LP 1-RM; LP RtF; and, LP lifting volume to a greater degree than PLA.
- No significant differences were observed between treatments in cycling TT performance, hemodynamic assessment, fasting blood panels, or self-reported side effects. View Full-Text



A
Bench Press Endurance
Δ (repetitions)
PLA
RTD
PLA
RTD
Day 1
Day 6
B
Leg Press Endurance
Δ (repetitions)
PLA
RTD
PLA
RTD
Day 1
Day 6

Short-Term Effects of a Ready-to-Drink Pre-Workout Beverage on Exercise Performance and Recovery

Collins et al. Nutrients. 9(8), 823, 2017

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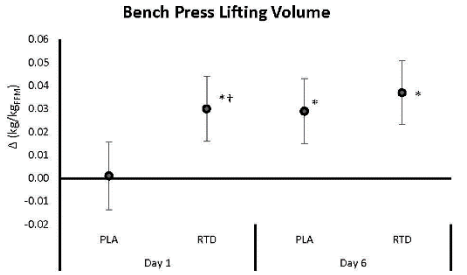
A



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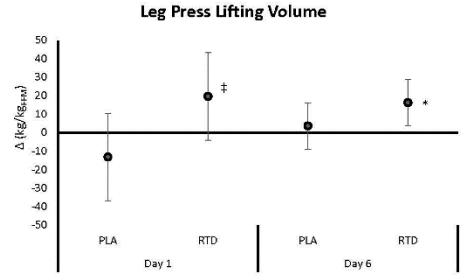

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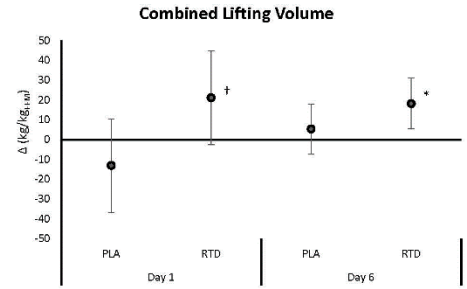

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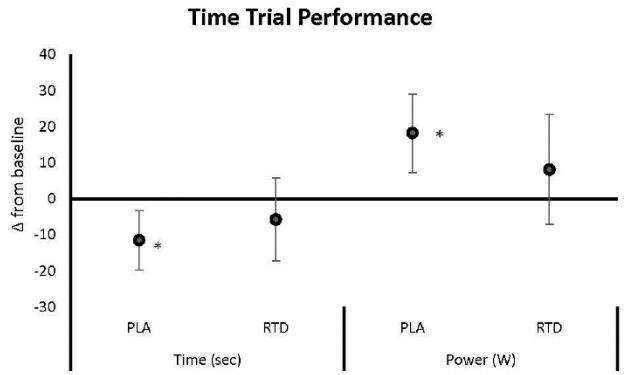

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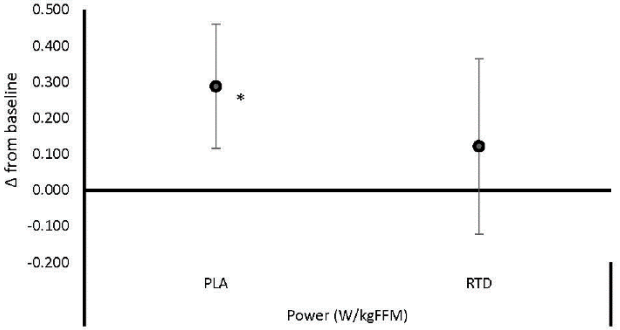

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Effects of ingesting a pre-workout dietary supplement with and without synephrine for 8- weeks on training adaptations in resistance-trained males.

Jung et al. JISSN. 14:1, 2017

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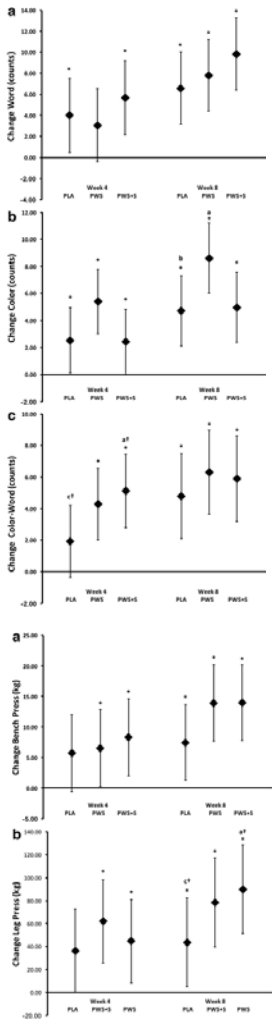
- RT males (N=80) were randomly assigned to supplement their diet in a DBPC manner with a PLA; a ***PWS containing beta alanine (3 g), creatine nitrate (2 g), arginine alpha-ketoglutarate (2 g), N-Acetyl-L-Tyrosine (300 mg), caffeine (284 mg), Mucuna pruiriens extract standardized for 15% L-Dopa (15 mg); or, the PWS with Citrus aurantium (PWS+S) extract standardized for 30% synephrine (20 mg) once per day for 8-weeks during training.***
- Dietary supplementation of PWS and PWS + S did not increase the incidence of reported side effects or significantly affect the number of blood values above clinical norms compared to PLA.
- No statistically significant overall Wilks' Lambda interactions were observed among groups for body composition, resting heart and blood pressure, readiness to perform questions, 1RM strength, anaerobic sprint capacity, or blood chemistry panels.
- Univariate analysis and analysis of changes from baseline with 95% CI revealed some evidence that cognitive function and 1RM strength were increased to a greater degree in the PWS and/or PWS + S groups after 4- and/or 8-weeks compared to PLA responses.
- ***Results provide some evidence that 4-weeks of PWS and/or PWS + S supplementation can improve some indices of cognitive function and exercise performance during resistance-training without significant side effects in apparently health males. However, these effects were similar to PLA responses after 8-weeks of supplementation and inclusion of synephrine did not promote additive benefits.***



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Summary & Future Directions

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- β-Alanine has become a staple in the sport nutrition dietary supplement arena.
- Continue to see stand alone performance enhancement supplements with β-Alanine
- Interest in determining if there benefit to adding β-Alanine to other ergogenic nutrients and/or formulations.
- Given known metabolic and performance effects, there is a need to examine the potential health and/or therapeutic benefits of ingesting β-Alanine alone and/or in combination with other potentially beneficial nutrients.

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