Effects of an Amino Acid/Creatine Energy Supplement on the Acute Hormonal Response to Resistance Exercise

Nicholas A. Ratamess, Jay R. Hoffman, Ryan Ross, Miles Shanklin, Avery D. Faigenbaum, and Jie Kang

The authors aimed to examine the acute hormonal and performance responses to resistance exercise with and without prior consumption of an amino acid/creatine/energy supplement. Eight men performed a resistance-exercise protocol at baseline (BL), 20 min after consuming a supplement (S) consisting of essential amino acids, creatine, taurine, caffeine, and glucuronolactone or a maltodextrin placebo (P). Venous blood samples were obtained before and immediately after (IP), 15 min (15P), and 30 min (30P) after each protocol. Area under the curve of resistance-exercise volume revealed that BL was significantly less than S (10%) and P (8.6%). For fatigue rate, only S (18.4% ± 12.0%) was significantly lower than BL (32.9% ± 8.4%). Total testosterone (TT) and growth hormone (GH) were significantly elevated at IP and 15P in all conditions. The GH response was significantly lower, however, in S and P than in BL. The TT and GH responses did not differ between S and P. These results indicated that a supplement consisting of amino acids, creatine, taurine, caffeine, and glucuronolactone can modestly improve high-intensity endurance; however, the anabolic-hormonal response was not augmented.

Key Words: energy drink, branched-chain amino acids, testosterone, growth hormone

There are many sport supplements currently on the market that claim to enhance acute-exercise performance. Several of these have been touted as “energy drinks” because they contain nutrients that act as stimulants, as well as carbohydrates. Some supplement manufacturers have recently added other potential ergogenic nutrients to these energy drinks, such as essential amino acids and creatine. Elevations in plasma concentrations of essential amino acids have been shown to increase protein synthesis, and this increase in protein synthesis appears augmented when combined with resistance exercise (34, 47). Amino-acid supplementation provided...
immediately before or within 1 h of resistance exercise might result in a greater net muscle protein synthesis (8, 44). Branched-chain amino acids (BCAAs) account for 35–40% of essential amino acids in the diet (38) and are commonly found in sports supplements. BCAAs (leucine, isoleucine, and valine) are reported to reduce muscle soreness and fatigue after resistance training (41) and might attenuate exercise-induced protein catabolism and stimulate muscle protein synthesis to a greater extent than other mixtures of essential amino acids (21). Thus, the inclusion of essential amino acids in a sport-supplement drink might be more important for the immediate recovery period after resistance exercise.

Creatine is an amino-acid derivative synthesized from arginine, glycine, and methionine in the liver, kidney, and pancreas. It has been shown to be effective in increasing muscle strength, power, and lean body mass (6, 16, 46). Most studies examining creatine supplementation have generally employed a weeklong loading phase (20 g/d) to maximize muscle creatine content, and the loading phase has been shown to increase strength and power performance (15, 32, 33). In addition, a few studies have shown ergogenic benefits from low-dose creatine supplementation (10, 17). Thus, the inclusion of creatine in a sport-supplement drink might help increase muscle creatine content and thereby enhance the effects of the resistance-exercise workout.

Many energy drinks contain nutrients touted to act as stimulants in the human body. These nutrients include taurine, caffeine, and glucuronolactone and have been shown to enhance endurance, anaerobic performance, concentration, and alertness (1, 37, 40). Although the efficacy of these nutrients has been established, the combination of taurine, caffeine, glucuronolactone, creatine, and essential amino acids is not well understood. Thus, the primary purpose of the current investigation was to examine acute resistance-exercise performance within 20 min of initial consumption of an energy drink that contained this nutrient mixture in subjects who had not consumed this mixture previously.

It is well known that resistance exercise elicits a substantial acute elevation in anabolic-hormone concentrations (27). Numerous studies have shown acute elevations in testosterone and growth hormone (GH) during and through 15–30 min after resistance exercise (26, 25, 24). The quality of workout—interaction of intensity, volume, and other program variables—has been implicated as a major factor in determining the magnitude of the hormonal response (27). Some studies have shown potentiated acute testosterone and GH responses during resistance training when subjects were able to exert themselves to a higher degree or had a high level of training experience (13, 24). The greater total work completed during the workout appears to be an influential factor (27). Thus, the resistance-exercise stimulus might affect the overall magnitude of the hormonal response. If consumption of an energy drink (compared with placebo) before resistance exercise results in enhanced performance, it would be of interest to investigate whether or not the acute hormonal response would be augmented, as well. Therefore, a secondary purpose of the current study was to examine the acute anabolic-hormonal responses to resistance exercise after initial consumption of a supplement consisting of BCAAs, creatine, caffeine, taurine, and glucuronolactone touted to enhance exercise performance.
Materials and Methods

Experimental Design

To address the primary hypotheses of the present investigation, a randomized, double-blind crossover design was used. Eight resistance-trained men performed a resistance-exercise protocol consisting of 6 sets of 10 repetitions of the squat exercise with 75% of their 1-repetition maximum (1-RM), with 2-min rest intervals between sets, on 3 occasions: at baseline (fasted condition); 20 min after consuming a supplement consisting of essential amino acids, creatine, taurine, caffeine, and glucuronolactone; and 20 min after consuming a placebo. Venous blood samples were obtained before and after each protocol for measurement of serum GH, testosterone, and insulin. Resistance-exercise performance (volume, fatigue rate) was measured during each set and for the entire protocol. This study design (see Figure 1) enabled us to examine whether initial consumption of an energy drink could enhance acute-resistance-exercise performance more than a placebo and whether the acute anabolic-hormonal responses to resistance exercise are augmented if resistance-exercise performance is enhanced.

Subjects

Eight healthy, resistance-trained (minimum 3 y of experience) men were selected for the current investigation. The subject (N = 8) characteristics were age 20.5 ± 1.6 y, height 184.0 ± 5.3 cm, body mass 91.2 ± 5.6 kg, and 1-RM squat 181.0 ± 27.1 kg. All subjects were either current or former strength or power athletes who were following a periodized resistance-training program (including performance of the

---

Figure 1 — Schematic of the experimental design.
Hormonal Response and Supplementation

squat exercise 2 times per week). Each subject initiated the study in a trained state, and none were taking any medications, anabolic steroids, or nutritional supplements known to affect resistance-exercise performance. This study was approved by The College of New Jersey’s institutional review board, and each subject subsequently signed a written informed-consent document before participation. In addition, no subject had any physiological or orthopedic limitations that could have affected lifting performance as determined by completion of a health-history questionnaire before initiating the study.

Strength Testing

Maximal-strength testing took place at least 3 d before initiation of the resistance-exercise protocols. The 1-RM squat was used to assess maximal lower body strength and subsequently calculation of the loads used in the protocols (23). A warm-up set of 5–10 repetitions was performed using 40–60% of the perceived maximum 1-RM. After a 1-min rest period, a set of 2–3 repetitions was performed at 60–80% of the perceived 1-RM. Subsequently, 3–4 maximal trials (1-repetition sets) were performed to determine the 1-RM. Each subject descended to the “parallel” position in which the greater trochanter of the femur was aligned with the knee and ascended until full knee and hip extension. Rest periods between trials were 2–3 min. A complete range of motion and proper technique were required for each successful 1-RM trial.

Testing Protocol

Subjects arrived at the laboratory early in the morning (at the same time of day each visit) after an overnight fast (with a standard evening meal the night before) at least 3 d after strength testing. Each subject proceeded to perform the resistance-exercise protocol in a fasted state to provide baseline (BL) responses. Although subjects initiated the study in a trained state, this BL session assisted in familiarizing the subjects with the protocol without nutrient intervention before performing any supplementation sessions. Subjects returned to the laboratory 1 wk after the BL protocol. After preexercise venous blood samples were taken during the next 2 visits to the laboratory, subjects were randomly provided either a placebo (P) or an “energy” supplement (S) in a double-blind, crossover manner separated by 72 h. A 10-min rest period (based on company recommendation) was provided from the time the subjects consumed the drink until they began warming up for the exercise protocol. The warm-up consisted of 5 min of light stationary cycling at a self-selected cadence and an additional component of very light stretching and performance of 2–3 light to moderate sets of the squat. Thus, subjects initiated the resistance-exercise protocol 20 min after consuming the supplement or placebo. The supplement protocol marked the first time subjects consumed the energy supplement; therefore, acute performance and the subsequent hormonal-response results characterized the responses to initial consumption.

The protocol consisted of 6 sets of the squat exercise with a load equivalent to 75% of subjects’ predetermined 1-RM. A 2-min rest interval was provided between sets. Subjects were encouraged to perform 10 repetitions per set. If subjects could not perform 10 repetitions, resistance was modified based on performance of that
set similar to methods reported previously (35). Forced (spotter-assisted) repetitions were used to help subjects complete the required number of repetitions. Resistance was reduced, however, during subsequent sets because the goal was to allow subjects to perform as many unassisted repetitions as possible. A resistance reduction of 2.3–6.9 kg per assisted repetition was used as subjects became fatigued. Thus, the last 4–5 sets of the protocol were performed to muscle exhaustion. After each set, ratings of perceived exertion (RPE) were obtained using a 10-point (1–10) scale. Set volume was calculated as the number of unassisted repetitions completed × resistance used. Area under the curve (AUC) was also calculated using a trapezoidal technique for total volume. Fatigue rate, resistance/volume of Set 1 – Set 5/Set 1 (× 100), was calculated for each condition (35). Subjects returned 3 d later and were provided the other treatment and repeated the exercise protocol with identical procedures.

**Supplement Composition**

The supplement (Amino Shooter, Champion Nutrition, Concord, CA) consisted of 19 g of BCAAs (3000 mg L-leucine, 1100 mg L-isoleucine, and 1100 mg valine), other essential amino acids (1100 mg L-lysine, 300 mg L-methionine, 1100 mg L-phenylalanine, 700 mg L-histidine), 5 g of creatine monohydrate, 1500 mg of L-tyrosine, 350 mg of glucuronolactone, and 110 mg of caffeine and was mixed with 500 mL of water. The nutritional composition per serving of the supplement was 45 kcal, with 0 g of fat and carbohydrate. The placebo consisted of an equivalent amount of maltodextrin mixed with water. The nutritional composition per serving of the placebo was 60 kcal, with 14.9 g of carbohydrates and 0 g of both fat and protein. Both drinks were fruit-punch flavor and indistinguishable to the subjects in appearance and taste.

**Blood Measurements**

Subjects were required to arrive at the laboratory in the early morning after an overnight fast for blood draws. Venous blood samples were collected from subjects in a seated, semirecumbent position preexercise (PRE), immediately postexercise (IP), and 15 (15P) and 30 min (30P) postexercise. All blood samples were obtained using a 20-gauge Teflon cannula placed in a superficial forearm vein. The cannula was maintained patent via infusion of a heparin solution (1:9 dilution of heparin with saline), and blood was drawn with a plastic syringe connected to a 3-way stopcock with a male luer-lock adapter. PRE blood samples were drawn after a 15-min equilibration period before exercise. IP blood samples were taken within 30 s of exercise cessation.

Blood samples were collected into 2 Vacutainer tubes, one containing SST gel and clot activator and the other containing EDTA. A small aliquot of whole blood was removed and used to measure hematocrit and hemoglobin. Remaining whole-blood samples were processed and centrifuged at 1500 g for 15 min. The resulting serum was placed into separate 1.8-mL microcentrifuge tubes and frozen at −80 °C for later analysis.
Biochemical and Hormonal Analyses

Serum total testosterone, 22-kD GH, and insulin concentrations were determined using enzyme immunoassays (EIA) and enzyme-linked immunosorbent assays (ELISA; Diagnostic Systems Laboratories, Webster, TX). 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 thawed once and analyzed in the same assay run. All samples were run in duplicate, with a mean intra-assay variance of <10%.

Hemoglobin was analyzed in triplicate from whole blood using the cyanmethemoglobin method (Sigma Diagnostics, St. Louis, MO). Hematocrit was analyzed in triplicate from whole blood via microcentrifugation (IECmicro-MB centrifuge, Needham, MA) and microcapillary technique. Plasma-volume shifts after resistance exercise were calculated using the formula of Dill and Costill (14). Serum lactate and glucose concentrations were determined with an Analox GM7 enzymatic metabolite analyzer (Analox Instruments USA, Lunenburg, MA).

Statistical Analyses

Descriptive statistics (mean ± standard deviation) were performed for all dependent variables. A 3 (condition) × 6 (number of sets) analysis of variance (ANOVA) with repeated measures was used to analyze set performance data, and a 3 (condition) × 4 (time) ANOVA with repeated measures was used to analyze hormonal- and blood-variable data. A 1-way ANOVA was used to analyze total volume, AUC, and fatigue-rate data. Subsequent Tukey’s post hoc tests were used to determine pairwise differences when significant $F$ ratios were obtained. Significance in this study was set at $P \leq 0.05$.

Results

Performance Data

Figure 2 presents the lifting volume per set between the 3 conditions. A significant main effect over time was observed ($F = 20.4, P < 0.001$), but a significant interaction was not observed ($F = 0.73, P = 0.69$). No differences were observed between Sets 1 and 2. Lifting volume was significantly lower during Sets 3 and 4 (compared with Sets 1, 2, and 3) for BL and P only, whereas lifting volume for Set 4 in S was lower than in Sets 1 and 2. For Set 5, lifting volume was significantly lower than in Sets 1–3 in BL and Sets 1–4 in S and P. For Set 6, lifting volume was significantly lower than in Sets 1–4 in BL and Sets 1–5 in P and S.

Total volume per protocol was calculated as the summation of the lifting volume attained during each of the 6 sets. The results of the 1-way ANOVA revealed no statistically significant differences ($F = 0.97, P = 0.40$) between conditions: BL = 14,764 ± 2424 kg, S = 16,361 ± 2336 kg, and P = 16,073 ± 2557 kg. There were, however, statistically significant differences when AUC data for each protocol were analyzed. AUC for BL (12,460) was significantly less ($P = 0.03$) than AUC for S.
(13,846) and P (13,630). In addition, a trend \( (P = 0.06) \) was observed such that AUC for S approached a higher value than AUC for P.

Fatigue rate results are presented in Figure 3. The 1-way ANOVA showed a significant difference between conditions \( (F = 4.6, P = 0.02) \). Only the S condition differed significantly from BL.

**Figure 2** — Lifting volume obtained over 6 sets. \(^a\)Significant difference \( (P < 0.05) \) compared with Sets 1 and 2. \(^b\)Significant difference \( (P < 0.05) \) compared with set 3. \(^c\)Significant difference \( (P < 0.05) \) compared with Sets 1–4. \(^d\)Significant difference \( (P < 0.05) \) compared with Sets 1–5. BL indicates baseline; S, supplement; P, placebo. Data presented as mean ± standard deviation.

**Figure 3** — Fatigue rate. \(^*\)Significant difference \( (P < 0.05) \) compared with BL. \(^\#\)A trend \( (P = 0.08) \) compared with BL. BL indicates baseline; S, supplement; P, placebo. Data presented as mean ± standard deviation.
The RPE results are presented in Table 1. A significant main effect \((F = 20.6, P < 0.001)\) was observed. No interaction was observed \((F = 1.08, P = 0.40)\), however, indicating a similar response between conditions. RPE gradually increased with each set. Set 2 was higher than Set 1 for all conditions. Sets 3–5 were higher than Sets 1 and 2 for BL and S, whereas RPE remained elevated and similar from Set 2 through Set 6 in P. Set 6 was higher than Sets 1–3 in BL.

**Blood Variables and Hormonal Responses**

Total testosterone (TT) results are presented in Figure 4. A significant main effect was observed \((F = 10.4, P < 0.001)\), but not a significant interaction \((F = 1.3, P = 0.28)\). TT was significantly elevated at IP and 15P compared with PRE for all 3 conditions. Further analyses revealed that S and P AUC for TT tended to be lower compared with BL \((P = 0.08)\). Growth-hormone (GH) results are presented in Figure 5. A significant main effect \((F = 22.0, P < 0.001)\) and interaction \((F = 3.2, P = 0.01)\) were observed. GH was significantly elevated at IP, 15P, and 30P compared with PRE for all conditions. GH values at IP, 15P, and 30P were significantly higher in BL than in S and P. GH-AUC analyses showed similar results.

### Table 1 Ratings of Perceived Exertion

<table>
<thead>
<tr>
<th></th>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
<th>Set 4</th>
<th>Set 5</th>
<th>Set 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>5.3 ± 2.2</td>
<td>7.1 ± 2.3</td>
<td>8.1 ± 2.3(^a)</td>
<td>8.3 ± 2.4(^{ab})</td>
<td>8.8 ± 1.3(^{ab})</td>
<td>9.5 ± 0.8(^{abc})</td>
</tr>
<tr>
<td>Supplement</td>
<td>5.5 ± 2.4</td>
<td>7.2 ± 2.2</td>
<td>8.3 ± 1.7(^{ab})</td>
<td>8.3 ± 1.4(^{ab})</td>
<td>8.6 ± 0.8(^{ab})</td>
<td>8.0 ± 1.5(^b)</td>
</tr>
<tr>
<td>Placebo</td>
<td>6.1 ± 2.3</td>
<td>7.3 ± 2.3(^a)</td>
<td>7.3 ± 2.4(^a)</td>
<td>7.4 ± 2.1(^a)</td>
<td>7.3 ± 1.6(^a)</td>
<td>7.4 ± 2.0(^a)</td>
</tr>
</tbody>
</table>

\(^aP < 0.05\) from Set 1. \(^bP < 0.05\) from Set 2. \(^cP < 0.05\) from Sets 3 and 4.

**Figure 4** — Total testosterone responses. \(^*\)Significant difference \((P < 0.05)\) compared with PRE. BL indicates baseline; S, supplement; P, placebo. Data presented as mean ± standard deviation.
Insulin, lactate, and glucose results are presented in Table 2. For serum insulin, a significant main effect was observed ($F = 4.9, P = 0.01$) but not an interaction ($F = 0.8, P = 0.61$). Insulin was elevated and remained elevated at IP, 15P, and 30P, with no significant differences observed between conditions. AUC analyses demonstrated no differences between conditions. For blood lactate, a significant main effect was observed ($F = 82.5, P < 0.001$) but not an interaction ($F = 0.5, P = 0.82$). Blood lactate was highest at IP and remained elevated at 15P and 30P, with no differences observed between conditions. For blood glucose, a significant main effect ($F = 17.3, P < 0.001$) and interaction ($F = 3.4, P = 0.01$) were observed. Blood glucose was elevated at IP, 15P, and 30P for all conditions. At IP, blood glucose was significantly higher in P than in BL and S. At 30P, blood glucose was significantly higher in BL than in S and P. Finally, similar significant reductions in plasma volume were observed for each condition at IP (−20% to −27%), 15P (−9% to −14%), and 30P (−4% to −11%). Hormonal data were not corrected for plasma-volume shifts because of molar exposure at the tissue level.

**Discussion**

The unique findings of the present investigation were as follows: 1) A supplement combining essential amino acids, creatine, caffeine, taurine, and glucuronolactone provided a modest ergogenic effect on high-intensity muscle endurance (i.e., total lifting volume AUC, fatigue rate) compared with exercising in a fasted state or after consuming a maltodextrin placebo during a resistance-exercise protocol consisting of 6 sets of 10 repetitions of the squat exercise with 2-min rest intervals; 2) the modest enhancement in resistance-exercise performance observed did not augment...
the acute anabolic-hormonal response compared with consumption of a maltodextrin placebo; and 3) the energy supplement and placebo resulted in reduced GH and TT ($P = 0.08$) responses to resistance exercise. To our knowledge, this was the first study to examine the efficacy of initial consumption of this type of supplement on acute-resistance-exercise performance.

High-intensity muscle endurance—as evidenced by a tendency for higher resistance-exercise volume AUC over 6 sets and a lower fatigue rate—was modestly enhanced in our subjects who consumed the energy supplement compared with placebo. Although mechanisms of enhanced performance were not elucidated in the current study, the individual or combined effects of several of the ingredients likely elicited the enhancement. This energy supplement contained essential amino acids, creatine, caffeine, taurine, and glucuronolactone.

Essential amino acids and creatine play critical roles during resistance training. Essential amino acids have been shown to increase protein synthesis (44). Amino-acid supplementation provided immediately before or within 1 h of resistance exercise has been shown to result in greater net muscle protein synthesis (8, 44). BCAAs have been shown to reduce muscle damage, soreness, and fatigue after resistance exercise (41). Creatine supplementation has been shown to increase muscle strength, power, and lean body mass (6, 16, 46). Although essential amino acids and creatine have shown to be ergogenic in anaerobic-exercise performance, their effects appear to rely on consistent use rather than acting acutely (within 20–30 min) during initial consumption of a supplement, as was the case in the present study. Thus, it is likely that other ingredients in this supplement potentially led to the enhanced high-intensity muscle endurance observed in the current study.

Caffeine is part of a group of stimulants, methylxanthines or xanthines, that have been shown to enhance exercise performance by stimulating the central nervous system, which changes the perception of effort or muscle-fiber activation, potentiating calcium release and sparing muscle glycogen and increasing fat breakdown via higher catecholamine response (43). Studies have shown that caffeine increases endurance-exercise performance by 20–50% with as little as 3 mg/kg body mass

### Table 2  Insulin, Lactate, and Glucose

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Immediately post</th>
<th>15 min post</th>
<th>30 min post</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insulin (U/L)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>baseline</td>
<td>9.2 ± 3.7</td>
<td>10.7 ± 3.4$^a$</td>
<td>12.8 ± 5.3$^a$</td>
<td>11.7 ± 4.1$^a$</td>
</tr>
<tr>
<td>supplement</td>
<td>9.9 ± 3.8</td>
<td>11.3 ± 3.2$^a$</td>
<td>14.5 ± 6.9$^a$</td>
<td>13.9 ± 6.4$^a$</td>
</tr>
<tr>
<td>placebo</td>
<td>9.1 ± 2.2</td>
<td>12.0 ± 2.9$^a$</td>
<td>12.3 ± 2.9$^a$</td>
<td>10.3 ± 4.2$^a$</td>
</tr>
<tr>
<td><strong>Lactate (mmol/L)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>baseline</td>
<td>2.9 ± 0.6</td>
<td>18.7 ± 4.6$^a$</td>
<td>14.1 ± 3.7$^a$</td>
<td>10.0 ± 2.7$^a$</td>
</tr>
<tr>
<td>supplement</td>
<td>2.1 ± 0.8</td>
<td>18.3 ± 5.1$^a$</td>
<td>12.5 ± 4.2$^a$</td>
<td>8.9 ± 3.0$^a$</td>
</tr>
<tr>
<td>placebo</td>
<td>2.2 ± 0.4</td>
<td>16.7 ± 4.7$^a$</td>
<td>12.5 ± 3.5$^a$</td>
<td>8.9 ± 2.7$^a$</td>
</tr>
<tr>
<td><strong>Glucose (mmol/L)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>baseline</td>
<td>5.0 ± 0.6</td>
<td>6.1 ± 1.0$^a$</td>
<td>6.8 ± 0.9$^a$</td>
<td>6.8 ± 1.3$^a$</td>
</tr>
<tr>
<td>supplement</td>
<td>4.7 ± 0.4</td>
<td>6.5 ± 1.6$^a$</td>
<td>6.4 ± 1.6$^a$</td>
<td>5.7 ± 1.3$^{ab}$</td>
</tr>
<tr>
<td>placebo</td>
<td>5.0 ± 0.5</td>
<td>7.0 ± 1.4$^{ab}$</td>
<td>6.5 ± 1.6$^a$</td>
<td>5.9 ± 1.5$^{ab}$</td>
</tr>
</tbody>
</table>

$^aP < 0.05$ from corresponding time point Pre. $^bP < 0.05$ compared with baseline.
Resistance-exercise performance has been shown to be enhanced after caffeine consumption in some (5, 20) but not all studies (19). Because of the rapid effects of caffeine on consumption, it is likely that caffeine, in part, contributed to the modest performance enhancement in S observed in the current study.

Glucuronolactone is a compound produced by the metabolism of glucose in the liver. It is thought to improve concentration, reduce fatigue, and act as a stimulant and is often found in energy drinks, often in combination with caffeine and taurine (1, 37, 40). Taurine is a derivative of the amino acid cysteine, which has been thought to play a role in many physiological functions including adipose-tissue regulation, calcium homeostasis, and neural transmission (9). In addition, taurine has been shown to reduce exercise-induced oxidative stress (49). Taurine supplementation alone has been shown to increase VO$_{2\text{max}}$ and exercise time to exhaustion in rats and humans (48, 49). The combination of glucuronolactone, taurine, and caffeine in other energy drinks has been shown to increase concentration, mental alertness, cardiac contractility, and aerobic and anaerobic performance 30–60 min after consumption (1, 4, 37, 40). Compared with other supplement drinks, the amount of caffeine was higher (110 vs. ~80 mg), glucuronolactone was lower (350 vs. ~600 mg), and taurine was higher (1500 mg vs. ~1000 mg) in the supplement used in the current study. It is likely that the combination of caffeine, glucuronolactone, and taurine contributed to the modest performance enhancement observed in the current study.

Because acute-resistance-exercise performance was modestly enhanced by this supplement (and to some extent by the maltodextrin placebo), we examined whether this enhancement augmented the acute anabolic-hormonal response to resistance exercise. A few resistance-training studies have shown that chronic training might enhance the acute GH and TT responses to an acute-resistance-exercise protocol in young, highly trained and elderly individuals (13, 24). This has been suggested to be the result of subjects’ increased ability to exert themselves with training experience (27). Because the acute TT and GH responses are based, in part, on total work and exertion during resistance exercise (27), the ability to enhance the quality of the resistance-exercise workout appears to play a role in potential hormonal augmentation and adaptations over time. Little is known, however, concerning the acute hormonal response to 1 short-term protocol enhanced modestly via supplementation. Although our data showed significant elevations in TT and GH at IP, 15P, and 30P (GH only), which supports previous studies (26, 25), we did not see any augmentation in the acute anabolic-hormonal response in S compared with P, at least in the measured time frame (i.e., through 30 min postexercise). In addition, McCall et al. (30) did not observe an augmented acute anabolic-hormonal response between the 10th and 20th workouts (out of 33 workouts over 12 wk). Thus, it is likely that long-term consistent progressive resistance training and supplementation are needed for augmentation to occur and not just a single resistance-exercise session or a few weeks.

An interesting finding in the current study was that, in comparison with the fasted BL condition, the TT ($P = 0.08$) and GH responses were reduced in S and P. Previous studies have shown similar findings when amino acids or carbohydrates were consumed before exercise (31, 45). Carli et al. (11) demonstrated a lower GH response to endurance exercise—a 1-h run—when BCAAs were consumed before exercise than with a placebo. Hulmi et al. (18) examined consumption of 25 g of protein (whey and caseinates) 30 min before resistance exercise and
reported that the elevation in GH and TT was significantly less than that observed after consumption of a placebo. Kraemer et al. (29) examined consumption of a carbohydrate–protein supplement 2 h before and immediately after resistance exercise and reported an augmented GH response; however, the acute elevation in TT was less than with a placebo. Chandler et al. (12) had subjects consume either a carbohydrate (1.5 g/kg body mass), protein (1.38 g/kg body mass), or carbohydrate–protein (1.06 g carbohydrate/kg body mass and 0.41 g protein/kg body mass) supplement immediately and 2 h after resistance exercise and reported no reduction in GH but a reduction in TT 6 h postexercise. In contrast, Bird et al. (7) compared consumption of a 6% carbohydrate solution, 6 g of essential amino acids, or a combined carbohydrate–essential-amino-acid supplement and reported no differences between the TT and GH responses to supplementation versus placebo despite an elevation in insulin. Thus, the findings in the current study in S (19 g of amino acids) and P (14.9 g of carbohydrates) were consistent with most studies showing reduced acute GH and TT responses.

Consuming a carbohydrate, protein, or combination carbohydrate–protein supplement before resistance exercise has been shown to augment the acute elevation in insulin (18). The results of the current study support those of previous research in which we observed an elevation in insulin after resistance exercise in S and P. It is interesting that a reduced TT response has been suggested to be linked with an elevation in insulin concentrations (29). The acute elevation in insulin has been shown to occur at a time corresponding to reduced TT response (12, 29). Other studies have shown a significant negative correlation between insulin and TT concentrations (39). The elevation in insulin after resistance exercise has been shown to reduce protein degradation and increase amino-acid transport into skeletal muscle (44). Thus, it might be speculated that the favorable protein balance in the hyperinsulemic environment might lessen the need for other anabolic-hormonal stimulation of protein synthesis from GH and TT. Further research is warranted, however, examining the relationship between insulin, TT, and GH.

The mechanisms for the reduced acute TT response were not elucidated in the current study but could be related to several factors. Reduced TT synthesis and secretion is one potential mechanism. Chandler et al. (12), however, reported that the reduced TT response was not associated with the luteinizing hormone response. In addition, much of the acute TT elevation might be accounted for by plasma-volume reductions (30), thereby not supporting reduced secretion as a likely contributing mechanism. An increase in metabolic clearance and greater free-testosterone uptake into skeletal muscle are other potential mechanisms (18, 29). Androgen receptor (AR) content has been shown to be up-regulated in subsequent days after resistance exercise (2). We have recently shown that, in a fasted state, AR protein content is initially down-regulated within 1 h after resistance exercise, provided that the volume is sufficient (36). The down-regulation of AR content 1 h after resistance exercise is attenuated, however, when a carbohydrate–protein supplement is consumed after exercise (28). Higher AR content creates greater opportunity for AR binding with testosterone and subsequent translocation to the nucleus, thereby enhancing the diffusion gradient for free-testosterone uptake into skeletal muscle. Therefore, it is possible that greater skeletal-muscle uptake could have occurred, although further research is needed to examine the relationship between nutrient consumption and the reduced TT response to resistance exercise.
The mechanism(s) for reduced 22-kD GH response also remain unclear. Because the 22-kD GH molecule is part of a superfamily of GH molecules (27), the response of other variants was not elucidated. In addition, the acute GH elevation during resistance exercise occurs despite correction for reduced plasma volume (30). Because plasma-volume reductions were similar between conditions in the current study, this does not appear to be a plausible mechanism for the GH response. It could be speculated that nutrient consumption elicits metabolic and hormonal responses that feed back to the hypothalamus- or anterior-pituitary-regulating secretion of GH-releasing hormone and somatostatin. In pigs, glucose administration has been shown to suppress the GH response to GH-releasing hormone, and insulin was shown to regulate GH secretion from the anterior pituitary (3). Thus, carbohydrate and protein intake (that result in an elevation in insulin) before resistance exercise might lead to a milieu of metabolic and hormonal signals that can potentially regulate GH secretion, but further research is needed to identify the role of nutrient consumption in the regulation of 22-kD GH secretion. It is interesting that these signals appeared to override the stimulatory acidic effect that reduced pH has on GH secretion. Studies show significant correlations between pH reductions, blood lactate concentrations, and the acute GH response to exercise (22). Because the acute blood lactate increases were substantial and similar between conditions (i.e., 16.7–18.7 mmol/L at IP) in the current study, one would expect a similar GH response. It appeared, however, that the metabolic and hormonal stimuli might have offset the potent acidic stimulus of the resistance-exercise protocol.

In conclusion, the results of the current study indicated that initial consumption of an “energy” drink combined with essential amino acids and creatine produces a modest ergogenic effect on high-intensity muscle endurance during resistance exercise compared with consumption of a maltodextrin placebo. The enhanced training stimuli did not, however, augment the acute anabolic-hormone response. It appears that long-term progressive resistance training is needed to augment the acute TT and GH responses to resistance exercise. Rather, the nutrient composition of both the energy supplement and placebo led to reduced acute GH and TT responses compared with a fasted condition. These data support previous investigations (18) demonstrating carbohydrates’ and amino acids’ role in regulating the acute hormonal response to resistance exercise.

Acknowledgments

We would like to thank a dedicated group of subjects for their participation. In addition, we would like to thank the National Strength and Conditioning Association for funding this study.

References


