Title: Effects of Carbohydrate and Branched Chain Amino Acid Beverage Ingestion during Acute Upper-Body Resistance Exercise on Performance and Post-Exercise Hormone Response

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The purpose of this investigation was to examine the individual and combined effects of ingesting carbohydrates (CHO) and branched chain amino acids (BCAA) during high volume upper-body resistance exercise (RE) on markers of catabolism and performance. Thirteen resistance trained males completed four experimental trials with supplementation ingesting beverages containing CHO, BCAA, CHO+BCAA, or placebo (PLA) in a randomized, double-blind design. The beverages were ingested in 118 mL servings six times during a ~60 min RE session consisting of bench press, bent-over row, incline press, and close-grip row. Each RE was performed with five sets of repetitions at 65% one-repetition max until volitional fatigue. Blood samples were collected at baseline, immediately and 60-min post-exercise to assess glucose and insulin. Cortisol was assessed immediately and 60-min post exercise. No significant performance benefits were observed for any RE. CHO+BCAA (152.4 ± 71.4 ng/mL) resulted in the lowest cortisol levels, which was lower than BCAA and PLA (193.7 ± 88.5, 182.8 ± 67.5 ng/mL, p<0.05), but not different from CHO (165 ± 76.5 ng/mL, p=0.342). Post-exercise insulin concentrations were significantly higher with CHO (4.79 ± 3.4 mU/L) compared to BCAA and PLA (3.7 ± 2.0, 3.5 ± 1.8 mU/L, p<0.05), but not different from CHO+BCAA (4.3 ± 2.5 mU/L, p=0.339). There was no treatment effect for glucose, but glucose significantly increased from baseline to immediately post-exercise and significantly decreased 60-min post-exercise.

Ingesting beverages containing CHO with or without BCAA during upper-body resistance exercise may promote a more favorable post-exercise catabolic environment.

**KEY WORDS:** ergogenic aids, resistance training, muscle hypertrophy, high-intensity exercise, glucose,
INTRODUCTION

Nutritional supplementation during exercise is carried out with the goal of supporting performance during and promoting positive adaptations after training. Two of the most common nutritional supplements are carbohydrates (CHO) and amino acids (AA). When ingested together before and during resistance exercise (RE), both have been shown to increase performance (Bird et al., 2013; Krings et al., 2016), decrease muscle damage and soreness (Baty et al., 2007), and promote a more favorable anabolic environment post-exercise (Bird et al., 2006a, 2006b).

CHO supplementation during RE has been shown to improve performance (Haff et al., 2001; Haff et al., 1999; Krings et al., 2016; Lambert et al., 1991; Wax et al., 2012; Wax et al., 2013). Improvements in performance may be due to the sparing of muscle glycogen via exogenous supplementation. RE has been shown to decrease muscle glycogen stores during lower body dynamic protocols (Pascoe et al., 1993; Robergs et al., 1991; Tesch et al., 1986; Tesch et al., 1998), lower body isokinetic protocols (Haff et al., 2000), and upper-body dynamic protocols (MacDougall et al., 1999). Although CHO supplementation is recommended to endurance athletes to support performance (Stellingwerff & Cox, 2014), efficacy with RE is not as consistent (Conley et al., 1995; Fairchild et al., 2016; Haff et al., 2000; Kulik et al., 2008).

Compared to receiving no nutritional supplementation during resistance exercise, CHO ingestion during exercise may promote a less catabolic environment post-exercise. Previous research examining CHO ingestion during RE, has reported significant increases in insulin post-exercise (de Oliveira Quirino et al., 2012). However, the addition of AA, specifically branched-chain amino acids (BCAA), to CHO containing beverages may provide a more favorable anabolic environment. In a large study examining the effects of CHO, AA, CHO+AA, and placebo on hormonal and skeletal muscle responses to RE, CHO+AA was found to have the
greatest effects in terms of attenuating myofibrillar protein breakdown (Bird et al., 2006b). Furthermore, there were no differences between insulin levels post-exercise with AA supplementation compared to CHO+AA and CHO (Bird et al., 2006a). These results make it difficult to conclude the efficacy of ingesting CHO+AA compared to AA. Due to the increasing popularity of intra-RE supplementation containing CHO, AA, and CHO+AA, more research is needed to establish the efficacy of beverage ingredients.

Although supplementation of AA in combination with CHO during RE has been previously researched, there is still an inconsistency within the literature regarding CHO ingestion and its effects on RE performance (Conley et al., 1995; Fairchild et al., 2016; Haff et al., 1999; Haff et al., 2000; Haff et al., 2001; Krings et al., 2016; Kulik et al., 2008; Lambert et al., 1991; Wax et al., 2012; Wax et al., 2013). Furthermore, there is minimal research examining upper-body RE with CHO+BCAA supplementation. Therefore, the aim of the present investigation was to examine the individual and combined effects of CHO and BCAA supplementation during acute upper-body RE sessions on hormonal responses and exercise performance. It was hypothesized that CHO treatments would have positive effects on performance and CHO+BCAA supplementation would provide the most beneficial post-exercise anabolic environment.

**METHODS**

**Experimental Design**

Participants completed seven lab visits. Session one served as preliminary testing for collection of height, mass, and a baseline blood sample. During session two, participants performed one-repetition max (1RM) testing with each RE. Session three served as
familiarization of the RE protocol with assigned loads based upon 1RM results without supplementation. A second baseline blood sample was obtained during session three prior to commencing the RE protocol. Following a randomized, double-blinded, cross-over design, the last four sessions served as experimental trials with supplementation. Participants ingested a PLA or a solution containing either a CHO, BCAA, or CHO+BCAA. Blood samples were collected immediately post- and 60-min post-exercise (Figure 1). All seven sessions were completed between the hours of 0500 and 0900 with training sessions separated by at least seven days.

Participants

Thirteen healthy resistance trained males participated in the current investigation. Participant demographics and strength characteristics are presented in Table 1. Participants had to at minimum meet the intermediate resistance training experience classification of the National Strength and Conditioning Association. In order to meet the classification, participants had to be currently resistance training for at least 2-6 months and 2-3 days per week with a medium training stress level and have basic exercise technique (Haff & Triplett, 2015). Prior to beginning the study, participants completed a general health questionnaire, physical activity readiness questionnaire, and gave written informed consent in accordance with the University’s Institutional Review Board. Participants were required to maintain similar dietary habits in the 24 h prior to experimental trials. Food logs were distributed during initial baseline testing and participants were instructed to log food and fluid intake the day prior to their first experimental trial. Dietary food logs were recorded and given back to the participant with instruction to intake the same food and fluid for the final three experimental trials (Table 2).

Baseline Testing
Participants arrived at the exercise physiology lab following a 10-h fast. Mass and height were recorded using a digital scale (Defender 5000, Ohaus Corporation, Parsippany, NJ, USA) and digital stadiometer (235D; QuickMedical, Issaquah, WA, USA). Following these assessments, a baseline blood sample was collected from an antecubital vein using a butterfly needle and transfer device (BD Vacutainer, Franklin Lakes, NJ).

One-Repetition Max Testing

During the 1RM testing session, participants completed a 10-minute dynamic warm-up and commenced testing on barbell bench press, landmine bent-over row, barbell incline press, and landmine close-grip row. Participants were first instructed to perform 5-10 repetitions at 50% expected 1RM. After 2 min of rest, load increased to 65-80% perceived 1RM and 5-10 repetitions were completed. During the following 2-3 sets, participants were instructed to add a load they felt comfortable lifting 2-5 repetitions maximally. Each set was separated by 2 min of rest. Overall, the estimated 1RM testing was completed within 3-5 sets. Repetitions until failure and load during the last set were used to estimate 1RM (Brzycki, 1993).

Resistance Exercise Session

During sessions 4-7, participants completed a series of RE with randomized beverage interventions. Participants were instructed to arrive to each experimental session following a 10-h fast in which only water was allowed. Upon arrival to the exercise physiology lab, a 10-minute dynamic warm-up was completed. Immediately following the warm-up, the RE protocol began. The protocol consisted of barbell bench press, landmine bent-over row, barbell incline press, and landmine close-grip row. Five sets of repetitions until failure at 65% of 1RM were completed for each exercise separated by 2 min of rest. Participants were instructed to maintain proper form throughout each exercise. If proper form could not be maintained after being made aware it was
Total repetition count was summated and analyzed for performance. On average across trials 4-7, the protocol, including the warm-up, lasted 59.8 ± 2.3 min. After completion of trials 4-7, participants provided an immediate post-exercise and 60-min post-exercise blood draw.

Supplementation Schedule

Four experimental beverages were ingested in a randomized, cross-over manner during sessions 4-7. The beverages consisted of PLA, BCAA, CHO, and CHO+BCAA. Total fluid volume consumed was 708 mL, distributed across six ingestions in 118 mL volumes. Participants received beverages immediately before commencing the warm-up, immediately following the warm-up, and immediately following the last set of each exercise. The CHO beverage consisted of a 5% CHO solution (2:1, glucose: fructose ratio) delivering a total of 36 g. The BCAA beverage delivered a total of 7.5 g of leucine, isoleucine, and valine at a 2:1:1 ratio. CHO+BCAA delivered 36 g of CHO and 7.5 g of BCAA’s. The CHO solution has been shown to improve performance in endurance exercise (Smith et al., 2013) and resistance exercise (Krings et al., 2016) The PLA was an artificially flavored water. Each beverage was ingested in an opaque bottle and consisted of the same flavor (lemon-lime), color, and scent. This study used a double-blinded design, as the powder treatments were produced, packaged, tested, coded, and delivered by Dymatize (Dallas, TX). Beverages were mixed by a researcher who had no interaction with participants and attended no research sessions. The beverage mixer was provided a randomization table and participant schedule allowing the beverages to be made and placed into a refrigerator the evening prior to trials for researchers to access for trials the following morning blinded to the treatment.
Blood Collection

A total of 14 mL of blood was sampled at each draw and transferred into a sealed vacutainer (EDTA) containing an anticoagulant used for plasma collection. Samples were centrifuged at 4°C for 15 min at 2500 rpm. Plasma was aliquoted and stored at -80°C prior to subsequent analysis.

Blood Analysis

Plasma samples were analyzed, per assay instructions in duplicate for glucose (Pointe Scientific, Canton, MI, USA), cortisol (Abcam, Cambridge, MA, USA), and insulin (Eagle Bio, Nashua, NH, USA). Absorbance was read using an iMark Bio-Rad microplate absorbance reader (Life Science Research, Hercules, CA, USA). Insulin and glucose were analyzed at three time points, baseline, immediately post-exercise, and 60-min post-exercise. Cortisol was analyzed at two time points, immediately post-exercise and 60-min post-exercise. For analysis of the baseline timepoint, the blood samples collected and analyzed from the sessions one and two were averaged.

Statistical Analysis

All data were analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). An alpha of $p \leq 0.05$ was set a priori as statistically significant. Insulin, cortisol, and glucose were analyzed using a two-way repeated measure analysis of variance (ANOVA) (treatment × time point). If a significant main effects or interaction effects were observed, Fisher’s least significant different (LSD) post hoc was used to assess differences. Regarding performance data, total repetitions completed during each exercise between treatments were analyzed using ANCOVA with visit number included as the covariate. If no significant interaction effects between covariate and treatment were noted, Fisher’s LSD post hoc was used to compare treatment
means. In addition, to further investigate the order effect, a one way ANOVA was conducted to investigate the effects of changes in performance between trial numbers.

RESULTS

Cortisol

There was no significant treatment × time interaction (F=0.26, p=0.85) for cortisol levels, however, there was a significant main effect for both time (F=31.2, p<0.01, $\eta_p^2 = 0.17$) and treatment (F=3.76, p=0.01, $\eta_p^2 = 0.01$) (Figure 2). In terms of mean post-exercise cortisol levels, overall, CHO+BCAA resulted in the lowest cortisol levels, which was lower than BCAA (p<0.01) and PLA (p=0.02). CHO resulted in lower values compared to AA alone (p=0.04). There was no difference between CHO+BCAA and CHO alone (p=0.34). Finally, there was a significant decrease in cortisol from immediately post-exercise, to 60-min post-exercise with all treatments (p<0.05).

Glucose

There was no significant treatment × time interaction regarding plasma glucose (F=0.39, p=0.88) and no significant treatment effect (F=0.68, p=0.56) (Figure 3). However, there was a significant main effect for time (F=79.95, p<0.01, $\eta_p^2 = 0.54$). Immediately post-exercise, glucose levels were significantly higher than fasting glucose levels (p<0.01) and 60-min post-exercise (p<0.01). Further, glucose levels at 60-min post-exercise were significantly lower than fasting levels (p<0.01).

Insulin

In terms of post-exercise plasma insulin concentrations, there was no treatment × time interaction (F=1.52, p=0.17); however, there was a significant main effect for time (F=5.91,
post-exercise insulin concentrations were significantly higher with CHO when compared to BCAA alone ($p=0.03$) and PLA ($p=0.01$). No further treatment differences were noted.

**Resistance Exercise Performance**

Regarding RE performance, there were no significant trial × treatment interaction effects for bench press, bent-over row, incline press, or close-grip row ($p<0.05$). However, significant main effects for trial were observed for bent-over row ($F=18.16$, $p=0.01$), incline press ($F=8.51$, $p<0.01$), and close-grip row ($F=4.75$, $p=0.03$), indicating an order effect. There was a significant treatment effect for close-grip row ($F=10.02$, $p<0.01$). Post hoc analysis indicated significantly more repetitions performed with the CHO+BCAA treatment. There was no significant main effect for trials ($F=0.32$, $p=0.57$) or treatment ($F=1.05$, $p=0.38$), with respect to bench press. RE performance data are reported in Table 3. One way ANOVA across trial numbers showed no significant change among trials for bench press ($F = 0.26$, $p = 0.85$). There was a significant trial effect for bent row ($F = 6.73$, $p = 0.001$, $\eta_p^2 = 0.35$) with a significant increase in the number of repetitions performed during trials 3 and 4 compared to 1 and 2. There was also a significant trial effect for incline press ($F = 5.52$, $p = 0.003$, $\eta_p^2 = 0.315$) with no significant increase in the number of repetitions performed between trials 1-3 but a significant increase in trial 4 compared to 1-3. There was a significant trial effect for the close grip row ($F = 9.91$, $p < 0.01$, $\eta_p^2 = 0.45$) with a significant increase in repetitions performed during trials 3 and 4 compared to trials 1 and 2, with no significant increase from trial 1 to 2.

**DISCUSSION**
The main findings of this study are that CHO and CHO+BCAA ingestion during high volume RE lasting ~60 min did not improve performance but resulted in significantly lower post exercise cortisol levels and increased insulin levels 60-min after exercise. It is also important to recognize these changes occurred in the absence of a significant changes in plasma glucose between CHO and CHO+BCAA. It is likely the current ingestion rate of 36 g/hr CHO was not enough to elicit a significant increase in plasma glucose concentrations due to skeletal muscle oxidation given oxidation rates of this type of CHO solution can exceed ~60 g/hr (Jentjens et al., 2006; Pfeiffer et al., 2011).

Several previous investigations have shown that exogenous CHO ingestion during exercise can attenuate cortisol levels (de Oliveira Quirino et al., 2012; Green et al., 2003; Ihalainen et al., 2014; Nieman et al., 1998a, 1998b; Utter et al., 1999). However, most of these trials have been conducted in association with endurance/aerobic exercise (Green et al., 2003; Ihalainen et al., 2014; Nieman et al., 1998a, 1998b). Thus, the speculation based on previous reports suggest CHO ingestion during exercise attenuates cortisol levels assumes exogenous ingestion prevents hypoglycemia and therefore, reduces action of the hypothalamic pituitary axis (HPA) (Tabata et al., 1984; Tabata et al, 1991). Moreover, it is also interesting to note, our data does not support the suggestion from McAllister et al., (2016) that hyperglycemia due to exogenous CHO ingestion is inessential to attenuate action of the HPA.

Excessive cortisol secretion following an exercise bout may be detrimental for subsequent stimulation of protein synthesis (Goldberg & Goodman, 1969) and muscle accretion (Tarpenning et al., 2001). The reduced cortisol with CHO alone and CHO+BCAA post-exercise aligns with previous studies (Bird et al., 2006a, 2006b) suggesting a reduced catabolic environment after a resistance training bout. Additionally, insulin levels were significantly
elevated for CHO and CHO+BCAA 60-min post-exercise compared to BCAA and PLA. These
data support other findings reported in both studies by Bird and colleagues (Bird et al., 2006a,
2006b). However, these investigations used untrained males, in contrast to the present
investigation which used well-trained males, as it has been suggested that untrained males have
greater anabolic hormone response than trained males post-RE (Cadore et al., 2008). The present
study also differs from Bird and colleagues (Bird et al., 2006a, 2006b), in that our investigation
measured insulin at 60-min post-exercise compared to 30-min post-exercise. These time
differences show continual rise in insulin levels well after 30-min post-exercise found in the
previous two studies (Bird et al., 2006a, 2006b) until 60-min post-exercise suggesting an
enhanced anabolic window up to 1 h after exercise. Due to the anabolic role of insulin (i.e.,
increased muscle protein synthesis and decreased protein degradation) (Biolo et al., 1999), the
increases in insulin may be ideal for individuals training with muscular hypertrophy goals. While
recent evidence suggests acute hormone responses to resistance training may not fully correlate
with adaptations (Morton et al. 2016), these acute responses should not be totally overlooked due
to potential individual variances that may have chronic implications.

Despite the negligible effects of BCAA treatment on cortisol and insulin, other studies
have reported decreased cortisol (Sharp & Pearson, 2010) and increased insulin (Bird et al.,
2006a, 2006b) with BCAA supplementation compared to a PLA at baseline measures. These
contradicting results may be the result of differences in the duration of supplementation and
discrepancies in beverage ingredients. Thus, in speculation, the acute BCAA supplementation in
the present study may have been inadequate for enhancing intracellular muscle BCAA
concentrations needed to deter the glucoregulatory effects of cortisol.
Regarding performance, our findings suggest improvements may be found in some exercises (close grip row) but most exercises demonstrated no beneficial effects from ingestion of four different treatments. Previously, our lab observed beneficial effects with CHO+AA supplementation compared to AA alone during a strength and conditioning protocol (Krings et al., 2016). Differences between the previous and present findings may be related to the overall duration and type of activity, as Krings et al. (2016) protocol lasted ~71 min compared to ~60 min in the present study. Likely more importantly, Krings et al. (2016) had subjects complete a more rigorous protocol requiring participants to completed a series of jumps, sprints, full body resistance exercises, and shuttle runs, compared to only upper-body RE. The results of this study align with previous literature suggesting that performance in various forms of resistance training are unaltered by the ingestion of CHO (Conley et al., 1995; Fairchild et al., 2016; Haff et al., 2000; Kulik et al., 2008) and AA (Smith et al. 2017). However, it is difficult to fully conclude from our performance data, due to the significant order effect with incline bench press, bent-over row, and close-grip row.

This study is not without limitations. University IRB allowed only two venipunctures per session. This resulted in the lack of a baseline cortisol sample and limited blood sampling during each session. While baseline samples were collected for insulin and glucose via venipuncture, cortisol was only collected and compared on a daily basis to account for day to day fluctuations.

Finally, this study only investigated young, active males. While this population is likely the most prevalent training in a manner corresponding with the study design, other populations or training styles could see differing responses.

In conclusion, ingesting low levels of CHO (~ 30g/hr) and BCAA (~ 7.5 g/h) do not appear to impact exercise performance. Even though studies have demonstrated the ingestion of
BCAAs can beneficial effects on cortisol and insulin in response to exercise (Bird et al., 2006a, 2006b; Sharp & Pearson, 2010), the findings of this study did not demonstrate beneficial responses with only the addition of BCAAs. However, acute CHO and CHO+BCAA supplementation during RE potentially promotes a less catabolic environment post-exercise compared to BCAA and PLA ingestion. Although it is well established that post-exercise nutrition (i.e. complete protein blends) provides an adequate anabolic stimulus, our results suggest a less catabolic environment can also be elicited with nutritional supplementation containing lower amounts of CHO and BCAA. While the ingestion of protein to promote an anabolic environment post exercise is common, individuals training to increase muscular hypertrophy may see beneficial effects with supplementing CHO or CHO+BCAA during high volume upper-body resistance exercise through reducing catabolism.

CONFLICTS OF INTEREST

JWS serves on the scientific advisory board for Dymatize® Nutrition. The other authors report no conflicts of interest.

ACKNOWLEDGEMENTS

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REFERENCES


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<tr>
<th>Characteristic</th>
<th>Mean ± Standard Deviation</th>
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<tr>
<td>Age (years)</td>
<td>23.0 ± 3.8</td>
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<tr>
<td>Height (cm)</td>
<td>175.8 ± 8.9</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>82.1 ± 11.0</td>
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<td>1RM Bench Press (kg)</td>
<td>115.4 ± 13.5</td>
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<td>Bench press to Body Mass Ratio</td>
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<td>Dietary Category</td>
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<tr>
<td>Total Kilocalories</td>
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<td>% Protein</td>
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Table 3. Resistance Exercise Performance

<table>
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<th>BCAA</th>
<th>CHO</th>
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<td>Bench Press</td>
<td>49.3 ± 8.0</td>
<td>49.6 ± 9.2</td>
<td>47.9 ± 6.6</td>
<td>49.5 ± 8.6</td>
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<td>Trial 1</td>
<td>Trial 2</td>
<td>Trial 3</td>
<td>Trial 4</td>
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<td>Bent-over Row</td>
<td>56.6 ± 10.6</td>
<td>57.0 ± 11.7</td>
<td>63.2 ± 13.0*</td>
<td>66.8 ± 18.1*</td>
</tr>
<tr>
<td>Incline Press</td>
<td>37.1 ± 6.3</td>
<td>38.8 ± 6.0</td>
<td>38.7 ± 4.9</td>
<td>41.0 ± 6.8#</td>
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<tr>
<td>Close-grip Row</td>
<td>53.9 ± 8.5</td>
<td>58.4 ± 12.4</td>
<td>62.4 ± 15.4^</td>
<td>69.2 ± 15.0#</td>
</tr>
</tbody>
</table>

Repetitions completed during each exercise is presented as mean ± standard deviation.

*Significant difference from trials 1 and 2. ^Significantly different from trial 1. #Significant difference from trials 1-3. (p ≤ 0.05)
Figure Captions:

**Figure 1.** Protocol design.

**Figure 2.** Cortisol concentrations immediately post-exercise and 60-min post-exercise.
*Significant cortisol reduction from immediately post-exercise to 60-min post-exercise.
#CHO+BCAA significantly lower than BCAA. CHO, carbohydrate solution; BCAA, branched chain amino acid solution; CHO+BCAA, carbohydrate and branched chain amino acid solution; PLA, placebo solution. Data is presented as mean ± standard error of the mean.

**Figure 3.** Glucose concentrations at baseline, immediately post-exercise, and 60-min post-exercise. *Significantly greater glucose concentrations from baseline and 60-min post-exercise.
#Significantly lower glucose concentrations from baseline and immediately post-exercise. CHO, carbohydrate solution; BCAA, branched chain amino acid solution; CHO+BCAA, carbohydrate and branched chain amino acid solution; PLA, placebo solution. Data is presented as mean ± standard error of the mean.

**Figure 4.** Insulin concentrations at baseline, immediately post-exercise, and 60-min post-exercise.
*Significantly greater insulin concentrations immediately post-exercise and 60-min post-exercise compared to baseline.
#CHO and CHO+BCAA significantly greater than BCAA and PLA. CHO, carbohydrate solution; BCAA, branched chain amino acid solution; CHO+BCAA, carbohydrate and branched chain amino acid solution; PLA, placebo solution. Data is presented as mean ± standard error of the mean.
Figure 2. Cortisol concentrations immediately post-exercise and 60-min post-exercise. *Significant cortisol reduction from immediately post-exercise to 60-min post-exercise. #CHO+BCAA significantly lower than BCAA. CHO, carbohydrate solution; BCAA, branched chain amino acid solution; CHO+BCAA, carbohydrate and branched chain amino acid solution; PLA, placebo solution. Data is presented as mean ± standard error of the mean.
Figure 3. Glucose concentrations at baseline, immediately post-exercise, and 60-min post-exercise. *Significantly greater glucose concentrations from baseline and 60-min post-exercise. #Significantly lower glucose concentrations from baseline and immediately post-exercise. CHO, carbohydrate solution; BCAA, branched chain amino acid solution; CHO+BCAA, carbohydrate and branched chain amino acid solution; PLA, placebo solution. Data is presented as mean ± standard error of the mean.
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*Significantly greater insulin concentrations immediately post-exercise and 60-min post-exercise compared to baseline. #CHO and CHO+BCAA significantly greater than BCAA and PLA. CHO, carbohydrate solution; BCAA, branched chain amino acid solution; CHO+BCAA, carbohydrate and branched chain amino acid solution; PLA, placebo solution. Data is presented as mean ± standard error of the mean.