



Original Research

A Low Dose Caffeine and Carbohydrate Supplement does not Improve Athletic Performance during Volleyball Competition

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ABSTRACT

International Journal of Exercise Science 10(3): 340-353, 2017. Dietary supplements are widely used to enhance sport performance and the combination of carbohydrate and caffeine (CHO+CAF) has yielded particularly high performance gains. Though the effects of a CHO+CAF supplement have been studied in a laboratory environment, little research exists on the effects of supplementation during competition. Therefore, the purpose of this study was to determine the effects of a CHO+CAF supplement on athletic performance in competition. Eight female collegiate volleyball players completed three testing sessions under three different conditions separated by approximately one week each: CHO+CAF supplement, placebo (PBO), and control (CTL) using a randomized, cross-over design. Blood glucose (BG) was assessed prior to supplementation and immediately after set three. The supplement and PBO were administered prior to play and between sets two and three. Following three sets of play, three performance tests were completed: vertical jump (VJ), agility (AGL), and repeated 30-m sprint ability (RSA). While CHO+CAF supplementation significantly increased BG, the performance tests were not different ($p > .05$) among the testing conditions. These findings suggest that the amount of the supplement used in this study is not beneficial to VJ, AGL, and RSA in female volleyball players. As these performance tests were largely anaerobic and non-glycolytic in nature, the ergogenicity of the supplement may have been underutilized. Additionally, coaches and athletes should not only be aware of what ingredients are in the supplements they choose, but the amount of those ingredients as they may modify the efficacy of the supplement to impact performance.

KEY WORDS: Supplementation, ergogenic, sport

INTRODUCTION

A dietary supplement is any product taken orally in addition to common foods that may have a performance-enhancing effect (6). Dietary supplementation is a multi-billion dollar industry with over 50% of US adults having used a supplement in one month's time (18). Supplements

are used to improve nutrient intake to support health and wellness and decrease the risk of certain diseases (36), but many people consume supplements to enhance sport performance. Supplement use has been reported to be as high as 85% in certain groups of athletes (33) with carbohydrates (CHO) and caffeine (CAF) being some of the most commonly used.

Research in the field of CHO supplementation on exercise performance can be traced back as far as Dill and colleagues in the '20s and '30s (19). Since then, sport supplement research has tremendously increased with many studies revealing a positive impact of CHO consumption on performance (4,6,7,9,16,21). Potential mechanisms of performance improvements from CHO supplementation include the provision of an exogenous fuel source, increased rates of CHO oxidation, and maintenance of blood glucose (BG) to meet energy demands. For a more detailed explanation of these mechanisms and others, see Coggan's and Coyle's reviews (12,15). Regarding performance enhancement with CHO supplementation, Campbell et al. (9) reported improvements in cycling time-trial performance after CHO ingestion in the form of a gel, drink, or sports beans when compared to the control. Coggan and Coyle (11) reported a 21% delay in the onset of fatigue with CHO supplementation during cycling as compared to the placebo group. Additionally, Dumke and colleagues (21) reported an attenuated decline in power output over time during prolonged cycling in the CHO group in comparison to the placebo.

CAF is the most commonly consumed drug in the world and is widely used as an ergogenic aid amongst athletes. In Perkin's and William's (39) brief review of CAF and exercise performance, they noted the ergogenic effect of CAF was documented as early as the late 19th century. Because of the popularity, availability, ease of administration, and rapid onset of effects (20), CAF is commonly used and studied in athletics (8,20,23,37). During aerobic performance, CAF may increase adrenaline circulation, enhance free fatty acid utilization and/or increase CHO metabolism (27) as well as decrease pain perception by acting as an adenosine receptor antagonist during anaerobic performance. Additionally, CAF has been shown to reduce perceived exertion and delay fatigue (17). For an in-depth review of the mechanisms of CAF action on aerobic and anaerobic performance, see Graham (27), Davis and Green (17), and Sökmen et al. (43). Related to performance, Pereira et al. (37) examined the effects of CAF on intermittent sprints, finding that the consumption of CAF increased performance by 12.5% compared to those who did not receive supplementation. Similarly, Foskett and colleagues (23) assessed the effects of CAF supplement on skill performance in soccer players. Improvement in skill performance, specifically passing accuracy and jumping performance, were observed when CAF was ingested.

While CHO and CAF yield performance benefits individually, additive benefits have been found when the two have been combined (CHO+CAF). Yeo et al. (44) showed that, compared to CHO only, a CHO+CAF yielded greater CHO oxidation resulting in enhanced endurance cycling performance. Acker-Hewitt and colleagues (1) found that a CHO+CAF supplement improved cycling time trials over a distance of 20-km, whereas no significant increase resulted from taking CHO or CAF independently. Gant et al. (25) observed increases in sprint

performance, countermovement jumping, and participative experiences (e.g., rate of perceived exertion, pleasure-displeasure rating, etc.) when CHO+CAF supplement was ingested compared to a CHO only supplement. Finally, a meta-analysis of 21 studies showed that CHO+CAF supplementation provides a small but significant effect of improvement on endurance performance over CHO only (13).

Previous literature on CHO+CAF supplementation is lacking in three areas. First, little research exists on the effect of supplementation on performance in team sports. The sparse research on CHO only supplementation in team sport athletes has yielded promising results. Patterson and colleagues (36) found that CHO supplementation improved endurance performance during intermittent high-intensity shuttle running in male soccer players. Furthermore, Phillips et al. (40) examined the effects of CHO gel on intermittent endurance capacity and sprint performance in soccer, field hockey, and rugby players with a resultant 21.1% increase in intermittent endurance capacity. Second, low doses of CAF (≤ 3 mg/kg body mass) have not been well-studied regarding their ability to improve sport performance. Some data have revealed promise for the impact of a 3 mg/kg body mass CAF supplement on volleyball players' athletic performance (17,38).

Finally, most supplement studies have been conducted in laboratory environments, limiting the generalizability to the natural sporting environment. As such, the question of how a low dose CHO+CAF supplement affects team sport athletes during competition remains largely unanswered. Therefore, the purpose of this study was to determine the effects of a low dose CHO+CAF supplement on athletic performance during competition.

METHODS

Participants

An NAIA women's volleyball team ($N=8$, ages 18-22) was selected from a small liberal arts university in the Midwest to participate in the experiment during the spring offseason (see Table 1 for participant characteristics). Prior to data collection, the Institutional Review Board approved the study and participants were informed of the benefits and risks of the investigation prior to signing the informed consent document to participate in the study. Exclusion criteria included injury that would have precluded athletes from safely consuming the supplements and completing the performance tests. Researchers also provided an explanation of the study, detailing study procedures and testing order. This explanation included an introduction to all testing instruments used throughout the study.

Table 1. Participant characteristics.

	Mean \pm SD
Height (cm)	174.8 \pm 4.69
Weight (kg)	72.1 \pm 9.94

Protocol

The experimental design employed (Figure 1) for this study was a within-subjects, single-blinded, placebo-controlled experiment. Participants were randomly assigned to three different conditions, supplement (SUPP), placebo (PBO), and no supplement/control (CTL), to prevent history and testing threats to internal validity. Participants were assessed on three different days (separated by approximately one week each to prevent any CAF carryover effect from previous sessions (27)) with each participant serving as her own control to enhance internal validity. The supplementation protocol utilized as well as the experimental environment were chosen specifically to replicate common practice in athletics thereby enhancing generalizability of findings. Consequently, the participants consumed a readily available commercial supplement as opposed to precisely measured, body mass-dependent supplements. Also, CAF consumption was not restricted as this restriction may be impractical for many athletes. The participants consumed the supplement prior to and during (in between sets two and three) their competitions.

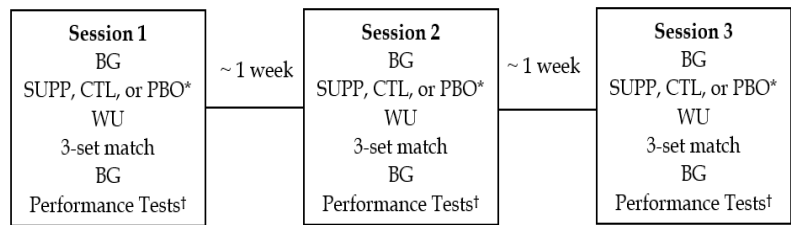


Figure 1. The within-subjects, blinded, placebo-controlled study lasted approximately 3 weeks. Blood glucose (BG) was measured at the beginning of each session. Participants were then randomly assigned (*) to either the supplement (SUPP), control (CTL), or placebo (PBO) groups. After supplementation, participants completed a warm-up (WU) followed by a 3-set intra-squad match. Post-match BG was measured immediately after the final point with randomly ordered (†) performance tests of vertical jump, agility, and repeat sprint ability completing each session.

As opposed to the highly-controlled laboratory setting, this experiment was conducted during an intra-squad competition in a gymnasium and closely reflected a “true competition”. The physiological measure was BG (prior to play and after 15 points in the third set of play) to assess glucose levels across testing conditions. Performance measures included vertical jump (VJ), agility (AGL), and repeated sprint ability (RSA), common sports performance measures that are relevant to volleyball. Performances measurements were taken after the third set to determine if supplementation provided benefits over the duration of a match, not just immediately after supplementation.

Height (HT) and mass were measured using a Seca (Chino, CA) model 700 and adhered to the measurement protocol outlined by the National Strength and Conditioning Association (NSCA) (3).

The OneTouch Ultra2 (LineScan, Inc., Wayne, PA) was used to measure BG. Convergent evidence of validity for the Ultra2 has been shown as the Ultra 2 provides similar BG readings to other monitors such as Accu-Chek Softclix (35). Blood samples were taken from participants’ index fingertip.

The supplement used was the PowerBar® PowerGel® manufactured by Nestle® (Vevey, Switzerland). Each PowerGel® pack contained 110 calories and included sodium (200 mg), potassium (20 mg), CHO (27 g) and CAF (50 mg). Given the two doses of this supplement during the experimental protocol, the average dose of CHO and CAF per unit of body mass was 1.34 g/kg and 1.39 mg/kg, respectively. Ingredients were listed in the following order: maltodextrin, fructose, water, sodium chloride, sodium citrate, potassium chloride, natural flavor, green tea extract and CAF from tea, citric acid, sodium benzoate, and potassium sorbate.

A PBO was administered to control for halo and PBO effects. The PBO, prepared by a university chemist, was a non-nutritive gel flavored with sugar alcohol to reflect the taste and consistency of the CHO+CAF supplement. The volume of the PBO matched that of the supplement. Both the supplement and PBO were given in a small plastic cup to blind participants to what they were consuming.

To assess each participants' VJ, the Vertec by Sports Imports® (Hilliard, OH) was used. Convergent validity evidence of the Vertec has been demonstrated by comparing Vertec data to jump platform data (10). Participants were allowed a two-step preparatory approach in phase three of the procedures as described by the NSCA (3). Results were recorded to the nearest 0.5 inch.

The three cone drill (34) was used to measure AGL. The drill consisted of participants moving between cones placed 4.6 meters apart in an L-shaped pattern. The participants' starting position was 0.9 meters behind the first cone. Timing was started with the first movement of each participant and was recorded to the nearest 1/100th of a second.

A Brower Speed II Timing Gate (Draper, UT) was used to measure participants' 30-meter repeated sprints. The measurement accuracy of the Brower Speed Trap II as described by the manufacturer is 1/100 of a second (42). The Running-based Anaerobic Sprint Test (RAST) test, which consisted of six repeated 30-meter sprints with approximately 30-sec of rest between each sprint (28), was utilized to measure sprint speed.

Prior to testing, a familiarization session was conducted. Demonstrations of proper technique were provided for each test. Time was allotted for the participants to ask any questions about the procedures. HT and mass were assessed following this session.

Participants were asked to consume a normal pregame diet prior to each session. Upon arrival to the gym on testing days, each participant's BG was measured. After pre-testing measurements, a 20-minute standardized volleyball warm-up was performed prior to the competition. There were three separate sessions in which the same procedures were completed. On each testing day, participants were randomly assigned to the CTL, PBO, or SUPP. Each participant completed one testing session under all conditions over a 3-week period. Supplementation for PBO and SUPP conditions was administered immediately prior to

the beginning of the three set volleyball match. There was also a 3-minute break between each set. Although only 8 participants of 11 were able to complete the testing due to sickness or injury, graduating seniors filled in for those participants thereby allowing for full 6 v. 6 matches.

After the second set was completed, the PBO or SUPP was re-administered to participants. Immediately after the third set was completed, participants were split into previously randomly assigned groups (two groups of three and one group of two) where researchers tested each participant's BG. The groups then cycled through the performance stations including VJ, AGL, and RSA. Prior to testing, the three groups were randomly assigned to a testing order and for every subsequent session the tests were completed in the same order. Each group started at their initial performance station and moved to the next station immediately after completing the previous station.

Statistical Analysis

With 8 participants completing the testing for every condition, non-parametric statistics were chosen for analyses. They do not assume normality of data and therefore allowed for a more robust and powerful analysis of the limited quantity of data (26). Friedman tests were used to assess the effects of each group on VJ, AGL, and RSA with an *a priori* alpha level of .05. Additionally, Wilcoxon Signed Ranks tests were used to analyze the differences between pre-supplement and post-supplement BG levels. Statistical analyses were conducted using SPSS Version 22.0 (IBM Corp., Armonk, NY).

RESULTS

No significant differences were found between conditions on the dependent variables of VJ, AGL, and RSA (Table 2). As seen in Figure 2, a significant difference was found between the pre-supplement and post-supplement BG levels for the SUPP condition ($Z = -2.668, p < 0.01, r = 0.889$), with the post-supplement BG level being higher than the pre-test BG level ($Mdn = 130\text{mg/dL}$ and 93mg/dL , respectively). Figure 3 shows the non-significant differences amongst the conditions for RSA ($p > 0.05$). As expected, speed tended to decrease with successive sprints.

Table 2. Comparisons of the dependent measures across the experimental conditions.

	Condition			p-value
	SUPP	PBO	CTL	
Vertical Jump (in)				0.64
Median				
MAD	19.50	19.00	20.50	
Agility				0.69
Median	8.81	8.84	8.87	
MAD	0.46	0.29	0.52	
Sprint 1				0.21
Median	5.11	5.13	5.20	
MAD	0.29	0.24	0.27	
Sprint 2				0.09
Median	5.37	5.55	5.48	
MAD	0.21	0.41	0.15	
Sprint 3				0.09
Median	5.54	5.64	5.69	
MAD	0.26	0.38	0.12	
Sprint 4				0.61
Median	5.89	5.73	5.59	
MAD	0.44	0.39	0.31	
Sprint 5				0.32
Median	5.65	5.77	5.66	
MAD	0.17	0.53	0.26	
Sprint 6				0.42
Median	5.55	5.44	5.45	
MAD	0.35	0.32	0.20	

MAD = Median Absolute Deviation. SUPP = supplement. PBO = placebo. CTL = control. Agility and Sprints measured in seconds.

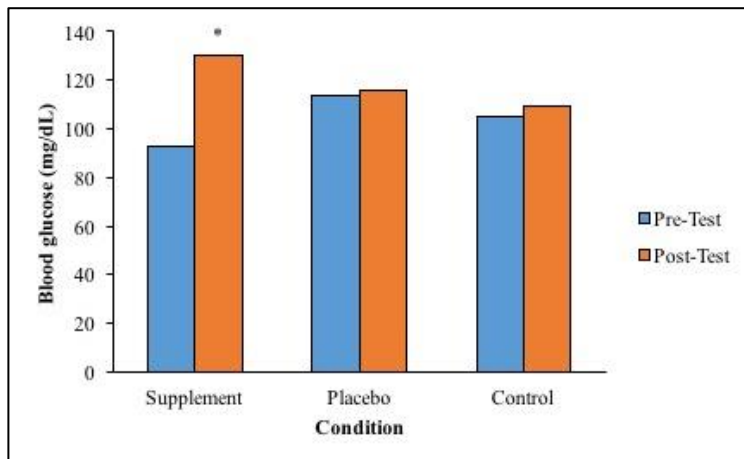


Figure 2. Blood glucose differences from pre-test to post-test by condition. * Denotes a significant increase, $p < 0.01$.

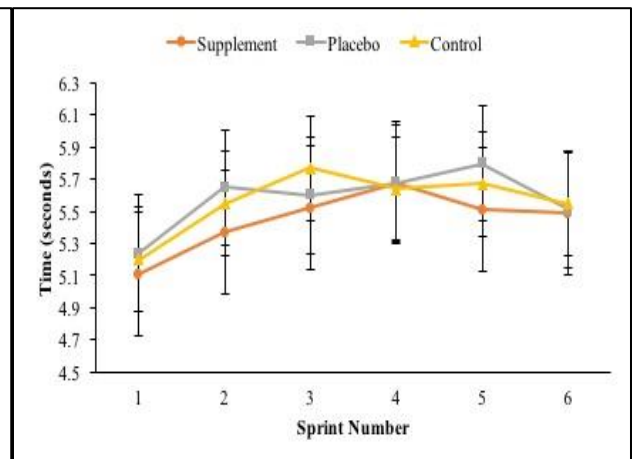


Figure 3. Sprint times by condition over repeated sprints.

DISCUSSION

The purpose of the current study was to determine the effects of a CHO+CAF supplement on athletic performance during competition. Little research has been conducted on the influence of supplementation during team sport competition. The main finding in this study was that no differences in performance occurred among CTL, PBO, and SUPP conditions, although BG increased significantly in the SUPP condition.

Changes in BG are determined in part by energy intake. The SUPP condition in the current study ingested a PowerGel® energy pack containing 27 g of CHO. Resultantly, BG increased in the SUPP condition from a pretest average of 93 mg/dL to a posttest average of 130 mg/dL. This increase in BG with a supplement in college athletes is similar to the finding of Ivy and colleagues (29) and Campbell and colleagues (9) who found increases in trained cyclists and triathletes, respectively.

Despite an increase in BG in the SUPP condition, no differences in performance on any measure were observed across conditions. The measures chosen to assess athletic performance in the current study were selected as they reflect the intermittent nature of the sport of volleyball. Given their very brief duration, the AGL test (< 10 seconds) and the VJ test (< 3 seconds) are metabolically anaerobic and non-glycolytic. Consequently, the source of ATP production that fuels muscular contraction in these measures of performance is mainly phosphocreatine degradation within the muscle fibers. For example, phosphocreatine degradation supplies the largest percentage of ATP production for a single 6-sec sprint (24). As phosphocreatine is the main supplier of ATP for these performance tests, a surplus of glucose may not have been advantageous.

Our finding of no significant change in AGL with supplementation is in agreement with some previous research. Lee and colleagues (30) studied the effects of CHO+CAF supplementation on RSA and AGL in 11, trained female athletes. Participants ingested 6 mg/kg body weight of CAF and .8 g/kg of CHO body weight prior to performing the T-agility test, five 4-sec cycle ergometer sprints, and a final T-agility test. There were no significant main or interaction effects for the CHO+CAF supplement on AGL performance. Similarly, Lorino and colleagues (32) examined how a CAF supplement impacted AGL in 17 young adult males. Participants performed two trials of pro-agility on separate days after ingesting a 6 mg/kg body weight CAF supplement or a PBO. No significant difference in pro-agility run times resulted between conditions.

However, when assessing reactive AGL, which requires decision-making, as opposed to preplanned movement, a significant difference has been found between SUPP and CTL groups (22). Duvnjak and colleagues (22) examined the effects of a 6 mg/kg CAF supplement on AGL performance and decision-making accuracy. Ten male collegiate athletes were randomized into a CAF group or CTL group and performed reactive AGL tests before, during, and after 80 minutes of intermittent running. The reactive AGL test required a change of direction in

response to a sport-specific video stimulus. A 3.9% increase in reactive AGL and a 3.8% increase in decision-making accuracy occurred in the CAF group as compared to the CTL group. Duvnjak et al. argued that their findings might have been due to the greater influence of CAF on perceptual and physical response as opposed to simple preplanned movement. It is reasonable then that the findings of the current study align more with those of Lee et al. (30) and Lorino et al. (32) given the similarities in AGL measurement.

Furthermore, the CAF dosage differences between previous studies and the current study were substantial. Duvnjak et al., Lorino et al., and Lee et al. utilized a 6 mg/kg body mass CAF supplement. AGL improvement in volleyball players with a low dose of CAF still required 3 mg/kg body mass (17,38). Given the average CAF supplement was equal to 1.39 mg/kg body mass in the current study, the two-to-four-fold difference in CAF amount may explain the differences in findings.

The current study resulted in no differences in VJ performance across conditions. The VJ test is an explosive, short duration (approximately 2 sec) measure of leg power. As such, VJ is metabolically anaerobic and non-glycolytic in nature. Thus, phosphocreatine degradation within the muscle fibers is the main source of ATP production supporting muscular contraction during the VJ. Consequently, increasing glucose levels through supplementation is likely not to enhance VJ performance, as glucose availability would not be a limiting factor. However, in 2009 Foskett et al. (23) found that CAF supplementation in soccer players improved VJ performance. Twelve young adult male soccer players ingested a 6 mg/kg body mass capsule of CAF before completing 90 minutes of intermittent running with VJ testing intermixed. A 2.7% higher VJ in the CAF group as compared to the PBO group was reported. Del Coso et al. and Pérez-López et al. (17,38) had similar results to Foskett et al. as a CAF drink significantly increased jumping performance in volleyball players by 1-2 cm when compared to a PBO. The conflict in findings between those of Foskett et al., Del Coso et al., and Pérez-López et al. (14,23) and the current study may be attributed again to dosage differences. The dosage Foskett et al. (23) used was a 6 mg/kg BM, which is four times the amount utilized in the current study. Even the lower dosage used by Del Coso et al. and Pérez-López et al. of 3 mg/kg BM was more than twice the amount of the current study. Given the lack of significant improvement in the current study in both AGL and VJ, a minimum dosage to realize these performance effects of CAF seems to be higher than 1.39 mg/kg BM.

Finally, no significant differences occurred across conditions for RSA in our study. Our findings agree with those of Lee et al. (30) who measured repeat sprint performance after supplementation of CHO, CAF, CHO+CAF, or a PBO in recreational team sport athletes. Lee et al. found no improvements in RSA across conditions when testing a cycle ergometer protocol for RSA with 10 sets of five 4-second sprints. This differs from the running protocol of six repeated 30-meter sprints utilized in our study. However, both studies resulted in no RSA improvement following CHO and CAF supplementation.

The lack of improvement in RSA performance after glucose supplementation may have been due to the participants' prandial state. In the current study, participants were instructed to intake a normal pregame meal prior to game play. Similarly, Lee et al. (30) obtained dietary logs from participants who ingested similar meals prior to each exercise bout. Both studies included measures of BG and found participants to be euglycemic (70-140 mg/mL) prior to supplementation. The current participants had BG medians of 93 mg/dL pre-supplementation increasing to 130 mg/dL post-supplementation. Lee et al. reported BG ranging from approximately 90 to 110 mg/dL. Prior studies support this line of reasoning as performance improvements have occurred when individuals were in glycogen-depleted states (2,5,30) prior to supplementation versus those who had adequate glucose levels (41).

Furthermore, CAF was ineffective in improving performance of RSA in the study by Lee et al. (30), corroborating the findings in the current study. However, CAF has been shown to improve RSA through an ergogenic effect (37). The current findings may be yet again explained in part by the CAF dosage differences. In line with Foskett et al. (23) and Duvnjak et al. (22), Lee et al. (30) utilized a 6 mg/kg body mass supplement of CAF.

Finally, lack of RSA improvements with supplementation may also be explained in part by rest bout length differences. In 2011, Lee and colleagues (31) studied the effects of recovery time on cycling RSA after supplementation. They reported significant RSA improvement with 90 seconds of recovery, but a lack of improvement with 20 seconds of recovery. The current study utilized a 30-second recovery bout, potentially too short in duration for RSA improvement to have occurred. Similarly, Lee et al. (30) in 2014 found no improvements after supplementation utilizing a 20-second recovery bout.

While the current study procedures and protocols were carefully chosen, inherent limitation in attempting to address questions related to sport supplementation exist. As a main focus of the current study was to provide results with high external validity (i.e., generalizability), some internal validity was sacrificed. CAF habituation, current CAF consumption, stage of menstrual cycle, diet, sleep, etc. are possible confounding variables for the study. However, as these variables are impractical to control for athletes, the understanding of the effect of a supplement in a commonly-consumed form and quantity while testing performance in a natural sporting environment of a competition is most pertinent to coaches and practitioners. The procedural timing was also chosen carefully to reflect what is relevant to the coach/practitioner, but has limitations. While the current participants did not improve performance after three sets of intra-squad competition, how supplementation affects performance earlier and later in a match remains unclear.

Our findings do not support the use of this specific CHO and low dose CAF supplement to enhance athletic performance during competition for female volleyball players. Although previous literature has shown beneficial effects of CHO+CAF supplements, the amount of the supplement that was used in the current study was meant to reflect a common mode of supplementations (i.e., one package consumed twice, once prior to the match and once at

approximately the middle of the match) and may not have been sufficient to improve the performance tasks chosen, especially if athletes are in a properly-fed, euglycemic state. Furthermore, given the anaerobic, non-glycolytic nature of both the sport of volleyball and the performance tasks, the ergogenicity of the supplement may have been underutilized. Ultimately, when evaluating supplement options, coaches and athletes should not only consider the type and quantity of ingredients, but performance, task, or sport for which one is supplementing.

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