MEETING THE NUTRITIONAL DEMANDS OF HIGH-INTENSITY INTERVAL TRAINING

CEC Self-Test

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LEARNING OBJECTIVE

High-intensity interval training is being used by a growing number of clients to improve fitness levels and body composition as efficiently as possible. This article intends to provide health and fitness professionals with nutritional guidelines for maximizing the training effects and recovery of clients engaging in high-intensity interval training.

Key words:
Sports Nutrition, Glycogen, Carbohydrates, Sprints, Supplements

INTRODUCTION

High-intensity interval training (HIIT) is a cardiorespiratory workout that entails repeated bouts of high-intensity exercise intervals separated by periods of lower-intensity recovery intervals. HIIT may be preferred by certain clients for many reasons including (a) faster improvements in fitness, (b) less total time spent training, (c) perceived as more enjoyable, and (d) increased fat loss when compared with moderate-intensity continuous training (3,6,20). Intervals of high-intensity exercise and recovery can vary in length from 6 seconds to 4 minutes (6). Beginners might spend less time in higher-intensity zones and take longer recovery periods, whereas well-trained athletes may do the reverse. In some cases, HIIT also can involve bouts of cardiovascular exercises combined with resistance training exercises depending on the type of program being followed. The focus in this article will be on HIIT in cardiovascular-based activities.

It is well known that nutrition plays a critical role in general exercise performance and recovery and should therefore be a consideration for those engaging in HIIT to obtain the most out of these types of workouts. Proper nutrition could allow for higher-intensity intervals for the duration of the exercise session, as well as decrease the amount of time spent in recovery intervals, thereby enhancing the benefits from the investment of time in the workout. Nutrition also can enhance the recovery process, allowing for maximum benefits in subsequent training days. This article addresses more specific nutritional considerations for individuals who incorporate HIIT into their workout routine and want to maximize their results, with the assumption that these individuals already follow basic nutrition guidelines for healthy eating.

ENERGY USE IN HIIT

Exercise intensity and duration depend on the availability of glucose for energy and the maintenance of muscle glycogen stores during the exercise session. The intensity and duration of exercise also influence muscle glycogen use within the session, with higher intensity and longer duration depleting glucose and glycogen at a faster rate.

Most research and sports nutrition guidelines surrounding muscle glycogen focus on prolonged exercise sessions, defined here as more than 60 minutes. However, there is research to support that high-intensity exercise of less than 60 minutes can decrease glycogen levels and possibly impair exercise performance (1). Muscle glycogen is depleted faster from Type II (fast-twitch) fibers compared with Type I (slow-twitch) fibers during high-intensity training; research has shown that just 2 cycling sprints of 30 seconds each resulted

in a 47% drop in total muscle glycogen (13). As sprints are repeated, the rate of glycogen use decreases, but total glycogen use is still significant overall. For those clients engaging in HIIT at a more advanced level, there is a potential for reduced intensity or the necessity for longer recovery periods because of glycogen depletion in the muscle. The depletion of muscle glycogen not only impairs performance but also increases levels of muscle breakdown (22).

To obtain maximum results from HIIT, individuals should begin an exercise session with adequate muscle glycogen stores, ensure that they do not diminish muscle glycogen stores too extensively during the session, and finally understand how to replenish those stores adequately so that they are prepared for workout sessions on subsequent days without impeding results.

NUTRITIONAL CONSIDERATIONS BEFORE HIIT

The optimal amount of carbohydrate (CHO) and protein recommended before HIIT depends on the intensity and duration of the session. CHO intake during the days preceding intermittent-sprint exercise has been shown to maintain muscle glycogen and improve performance (1). This is important considering the popularity of many fad diets that emphasize low CHO consumption, resulting in less than optimal levels of glycogen stores entering a training session and impeding optimal performance.

During the consumption of a calorically reduced diet for weight loss, a higher CHO diet supports better exercise performance compared with a reduced CHO diet (15). Pre-exercise CHO ingestion and increased muscle glycogen stores improve intermittent-sprint exercise performance mainly because of increased distance during intense running bouts (28); low CHO intake can impair performance early in the exercise session (28). The general recommendation is to consume a higher carbohydrate diet of at least 60% of energy as CHO (32). A balanced meal containing moderate to high CHO and a serving of protein is recommended about 3 to 4 hours before the exercise session. The consumption of CHO within 1 hour before exercise also has been shown to improve exercise performance (22).

NUTRITIONAL CONSIDERATIONS DURING HIIT

With shorter bouts of HIIT of less than 30 minutes total, it is unlikely for glycogen to become depleted and impair athletic performance. With sessions of greater than 30 minutes total, or when beginning a workout session glycogen depleted, exogenous consumption of CHO could enhance performance. CHO consumption during high-intensity sprinting sessions or in sports with prolonged intermittent sprinting has been shown to enhance performance and extend the duration of exercise (10,25). Using a mixture of CHO, such as glucose, sucrose, maltodextrin, and fructose, is suggested and has been shown to increase CHO oxidation levels and preserve glycogen use during longer sessions (22). The addition of protein to CHO in a ratio of 3:1 (CHO:protein) could enhance performance further (19). A 6% CHO and 2% whey protein beverage given every 15 minutes during multiple sprint running exercise resulted in better performance than CHO alone (14). Generally, liquid beverages or gel formulations are most convenient during exercise sessions.

NUTRITIONAL CONSIDERATIONS AFTER HIIT

Glycogen resynthesis is typically the goal when making nutrition choices after intense aerobic training, with CHO consumption as the main consideration. For those engaging in HIIT, enhanced muscle resynthesis after training sessions also is important for recovery and future performance. The intensity and duration of the HIIT session, as well as timing of the next training session, are important factors to consider with respect to CHO or other nutritional needs after training. In general, consuming CHO in adequate quantities as quickly as possible after training enhances glycogen synthesis because delaying CHO consumption can reduce the rate of glycogen resynthesis. CHO intake of 0.6 to 1 g/kg body weight in the first 30 minutes after glycogen-depleting exercise has been shown to enhance glycogen synthesis (21). In general, any form of CHO is acceptable, with the exception of fructose alone, which can cause gastrointestinal upset and may not replenish glycogen as effectively as other forms of CHO (5).

Several researchers support faster glycogen synthesis and enhanced muscle protein resynthesis with the addition of protein to the postexercise CHO (4,17,18). The consumption of CHO plus protein during recovery after repeated sprints may increase myofibrillar protein synthesis in muscle, and the absence of these nutrients could be detrimental to muscle maintenance (8). The CHO and protein combination was found to be most beneficial for those with limited recovery time or those on a CHO-restricted diet (17,18). The highest rates of glycogen synthesis occur when consumption of CHO is high (75 to 90 g) immediately after exercise; however, the same rate of glycogen synthesis can occur with moderate intakes of CHO (60 g) when combined with 10 to 20 g of protein (17,21). This more moderate amount of CHO ingestion is likely to be more realistic for most individuals engaging in HIIT. Overall, the regular ingestion of CHO and protein in a ratio of 3:1 (CHO:protein), whether at meals or snacks, promotes muscle glycogen synthesis (22). The Table provides examples of food that can be consumed that have a CHO-to-protein ratio of 3:1 based on CHO recommendations for different body weights.

SUPPLEMENTS AND HIIT

Although there are risks when taking supplements because of a lack of strict regulations for the industry, there are supplements that have the potential to improve performance or recovery in HIIT. The supplements to be reviewed in this article will be caffeine, creatine, sodium bicarbonate, and β-alanine.

Caffeine

Some research has shown that caffeine can be helpful in short-duration exercise, although the data are equivocal. High doses of caffeine (6 mg/kg) 1 hour before intermittent sprints significantly improved peak power, mean power, and total work when recovery intervals between sprints were 90 seconds long. Caffeine decreased performance when sprint recovery intervals were only 20 seconds long because of accumulation of blood lactate (23).

Caffeine may increase mobilization of free fatty acids, sparing muscle glycogen; however, more research is needed to determine if caffeine actually spares muscle glycogen (12). As mentioned earlier, glycogen sparing would allow for increased energy production during exercise at a moderate and high intensity. Some researchers did find some evidence of glycogen sparing but only during the first 15 minutes of exercise (12).

Most researchers have suggested that 1 to 3 mg caffeine per kilogram body weight is an effective dose for improving performance. To have benefit, caffeine should be ingested approximately 30 to 60 minutes before exercise.

Creatine

Creatine is one of the most widely studied supplements to date. Creatine can increase the amount of creatine phosphate stored in muscles and may improve performance in multiple sprints (9). During the first 0 to 15 seconds of explosive exercise, the body relies on what is known as "rephosphorylation" of adenosine diphosphate to adenosine triphosphate for energy. This process is dependent on the availability of phosphocreatine, but as phosphocreatine levels become depleted, the inability to continue to resynthesize adenosine triphosphate dictates the duration of the intensity.

Typical administration of creatine involves accumulating ("loading") supplemental creatine monohydrate in the system for 5 to 7 days at 0.3 g/kg body weight per day. However, Hultman et al. (16) reported that participants who ingested 3 g creatine daily for 28 days had similar muscle creatine stores at the end of 28 days without the loading protocol. Most researchers have reported that creatine supplementation is safe; however, long-term studies have not been conducted.

Sodium Bicarbonate

Sodium bicarbonate is an alkaline salt that works as a buffer to control excess acidity in the blood. Within the body, naturally produced sodium bicarbonate helps to buffer lactic acid produced via high-intensity, short-duration exercise. During high-intensity exercise, acid (hydrogen ions [H+]) and carbon dioxide (CO_2) are produced in greater quantities and accumulate in the muscle and blood. Because accumulation of lactic acid can lead to fatigue, it is theorized that supplemental sodium bicarbonate can further act as a buffer to create a more alkaline environment after natural sources have been depleted.

To date, researchers support that supplemental sodium bicarbonate is safe when taken in the proper dosages, which is typically 0.3 g/kg of body weight (24). Although some researchers have not observed significant improvements in performance,

TABLE: **Examples of Foods With a Ratio of 3:1 (CHO:protein) for Different Body Weights**

Body Weight	125 lbs (57 kg)	150 lbs (68 kg)	175 lbs (80 kg)	200 lbs (91 kg)
Carbohydrate (0.6 to 1.0 g/kg)	34 to 57 g	41 to 68 g	48 to 80 g	55 to 91 g
Protein*	11 to 19 g	14 to 23 g	16 to 27 g	18 to 30 g
Example of low end of range for CHO and protein	2 slices of wheat bread + 2 tablespoons of peanut butter	16 oz of low-fat latte + nutrition bar (approximately 22 g of CHO and 4 g of protein in bar)	1 cup of low-fat vanilla yogurt + ½ cup of berries + 100-calorie pack of almonds	1 large pita + ¾ cup of hummus
Example of high end of range for CHO and protein	10 wheat crackers + 2 cups of grapes + 2 low-fat cheese sticks	1 cup of trail mix of nuts and seeds that includes chocolate chips	2 cups of cereal + 1 cup of vanilla soymilk + 2 hard-boiled eggs	24 oz of a sports drink + sandwich (2 slices of wheat bread, 3 slices of lean ham, 1 slice of cheese)

**Carbohydrate-to-protein ratio should be 3:1.*
CHO indicates carbohydrate.

they have reported an increase in blood pH when sodium bicarbonate is given (27). This increase could theoretically help buffer the acids that accumulate during high-intensity activity. Nonetheless, research in this area has been equivocal.

In their review, McNaughton and colleagues (24) concluded that sodium bicarbonate is effective in both short- and long-term high-intensity exercise. However, because 10% of athletes may not tolerate it well, experimenting with tolerance before competition is strongly recommended (24).

Most researchers have used 0.3 g/kg body weight in their protocols (26). Intake is typically recommended 1 hour or more before exercise. Some regimens recommend a chronic intake regimen of 5 days or more. It is important to note, though, that doses above 0.3 g/kg can cause gastrointestinal symptoms including nausea and diarrhea. Excessive amounts also can lead to alkalosis, causing muscle spasms (7).

The combination of creatine with sodium bicarbonate for 2 days before a repeated sprint exercise session increased peak power and reduced decline in relative peak power over repeated sprints compared with placebo or creatine alone (2). In this study, Barber et al. (2) administered sodium bicarbonate in four smaller doses per day instead of as a bolus, which could be the reason that no gastrointestinal distress was reported.

β-Alanine

β-Alanine has garnered interest during the last several years, because several research groups have linked its use to increases in performance (30). β-Alanine is the "beta" form of the amino acid, alanine, which muscle cells use to form carnosine. Carnosine is one of the more effective buffering agents in skeletal muscle; β-alanine supplementation seems to increase intramuscular carnosine content.

In one double-blind, placebo-controlled study, participants performed a 30-second sprint, followed by a 110-minute simulated cycling race presupplementation and postsupplementation. The participants received 2.4 g of β-alanine per day for 8 weeks between testing periods. Researchers reported increased peak power and mean power output with β-alanine supplementation compared with the placebo (31).

However, researchers who used maximal strength performance as the outcome, or those who examined aerobic power, did not report benefits (29,33). Derave and colleagues (11) measured exercise performance and carnosine levels in 15 male athletes. Although they reported significant increases in muscle carnosine levels, this increase did not correlate to an improvement in exercise performance.

The ergogenic effects of buffering agents like β-alanine are more apparent when the high-intensity exercise activity lasts longer than 60 seconds or when multiple bouts of high-intensity, short-duration exercises are performed.

Most protocols suggest a total of 3 to 6.4 g/day for 4 to 6 weeks, divided throughout the day, to reduce any potential side effects. Short-term use (up to 10 weeks) of β-alanine supplements seems to be safe (29); however, there have been no studies conducted for longer than 10 weeks. Some have noted dose-dependent tingling in the scalp and extremities, which seems to be reduced by taking lower doses, evenly divided throughout the day.

References

1. Balsom PD, Gaitanos GC, Soderlund K, Ekblom B. High-intensity exercise and muscle glycogen availability in humans. *Acta Physiol Scand*. 1999;165(4):337–45.
2. Barber JJ, McDermott AY, McGaughey KJ, Olmstead JD, Hagobin TA. Effects of combined creatine and sodium bicarbonate supplementation on repeated sprint performance in trained men. *J Strength Cond Res*. 2013;27(1):252–8.
3. Bartlett JD, Close, GL, MacLaren DPM, Gregson W, Drust B, Morton JP. High-intensity interval running is perceived to be more enjoyable than moderate-intensity continuous exercise: implications for exercise adherence. *J Sports Sci*. 2011;29(6):547–53.
4. Berardi JM, Price TB, Noreen EE, Lemon PW. Postexercise muscle glycogen recovery enhanced with a carbohydrate-protein supplement. *Med Sci Sports Exerc*. 2006;38(6):1006–13.
5. Blom PCS, Hostmark AT, Vaage O, Kardel KR, Maehlum S. Effect of different post-exercise sugar diets on the rate of glycogen synthesis. *Med Sci Sports Exerc*. 1987;19(5):491–6.
6. Boutcher SH. High-intensity intermittent exercise and fat loss. *J Obes*. 2011;2011:868305.
7. Carr AJ, Slater GJ, Gore CJ, Dawson B, Burke LM. Effect of sodium bicarbonate on [HCO3-], pH, and gastrointestinal symptoms. *Int J Sport Nutr Exerc Metab*. 2011;21(3):189–94.
8. Coffey VG, Moore DR, Burd NA, *et al*. Nutrient provision increases signaling and protein synthesis in human skeletal muscle after repeated sprints. *Eur J Appl Physiol*. 2011;111(7):1473–83.

9. Cooper R, Naclerio F, Allgrove J, Jimenez A. Creatine supplementation with specific view to exercise/sports performance: an update. *J Int Soc Sports Nutr*. 2012;9(1):33.

10. Davis JM, Jackson DA, Broadwell MS, Queary JL, Lambert CL. Carbohydrate drinks delay fatigue during intermittent, high-intensity cycling in active men and women. *Int J Sport Nutr*. 1997;7(4):261–73.

11. Derave W, Ozdemir MS, Harris RC, *et al*. beta-Alanine supplementation augments muscle carnosine content and attenuates fatigue during repeated isokinetic contraction bouts in trained sprinters. *J Appl Physiol*. 2007;103(5):1736–43.

12. Graham TE, Helge JW, MacLean DA, Kiens B, Richter EA. Caffeine ingestion does not alter carbohydrate or fat metabolism in human skeletal muscle during exercise. *J Physiol*. 2000;529(3):837–47.

13. Hargreaves M, Finn JP, Withers RT, *et al*. Effect of muscle glycogen availability on maximal exercise performance. *Eur J Appl Physiol*. 1997;75(2):188–92.

14. Highton J, Twist C, Lamb K, Nicholas C. Carbohydrate-protein coingestion improves multiple sprint running performance. *J Sports Sci*. 2013;31(4):361–9.

15. Horswill CA, Hickner RC, Scott JR, Costill DL, Gould D. Weight loss, dietary carbohydrate modifications, and high intensity, physical performance. *Med Sci Sports Exerc*. 1990;22(4):470–6.

16. Hultman E, Soderlund K, Timmons JA, Cederblad G, Greenhaff PL. Muscle creatine loading in men. *J Appl Physiol*. 1996;81(1):232–7.

17. Ivy JL, Ferguson-Stegall LM. Nutrient timing: the means to improved exercise performance, recovery, and training adaptation. *Am J Lifestyle Med*. 2014;8:246–59.

18. Ivy JL, Goforth HW Jr, Damon BM, McCauley TR, Parsons EC, Price TB. Early postexercise muscle glycogen recovery is enhanced with a carbohydrate-protein supplement. *J Appl Physiol*. 2002;93(4):1337–44.

19. Ivy JL, Res PT, Sprague RC, Widzer MO. Effect of carbohydrate-protein supplement on endurance performance during exercise of varying intensity. *Int J Sport Nutr Exerc Metab*. 2003;13(3):382–95.

20. Jacobs RA, Fluck D, Bonne TC, *et al*. Improvements in exercise performance with high-intensity interval training coincide with an increase in skeletal muscle mitochondrial content and function. *J Appl Physiol*. 2013;115(6):785–93.

21. Jentjens R, Jeukendrup AE. Determinants of post-exercise glycogen synthesis during short-term recovery. *Sports Med*. 2003;33(2):117–44.

22. Kerksick C, Harvey T, Stout J, *et al*. International Society of Sports Nutrition position stand: nutrient timing. *J Int Soc Sports Nutr*. 2008;5:18.

23. Lee CL, Lin JC, Cheng CF. Effect of creatine plus caffeine supplements on time to exhaustion during an incremental maximum exercise. *Eur J Sport Sci*. 2012;12(4):338–46.

24. McNaughton LR, Siegler J, Midgley A. Ergogenic effects of sodium bicarbonate. *Curr Sports Med Rep*. 2008;7(4):230–6.

25. Patterson SD, Gray SC. Carbohydrate-gel supplementation and endurance performance during intermittent high-intensity shuttle running. *Int J Sport Nutr Exerc Metab*. 2007;17(5):445–55.

26. Price M, Moss P, Rance S. Effects of sodium bicarbonate ingestion on prolonged intermittent exercise. *Med Sci Sports Exerc*. 2003;35(8):1303–8.

27. Price MJ, Singh M. Time course of blood bicarbonate and pH three hours after sodium bicarbonate ingestion. *Int J Sports Physiol Perform*. 2008;3(2):240–2.

28. Skein M, Duffield R, Kelly BT, Marino FE. The effects of carbohydrate intake and muscle glycogen content on self-paced intermittent-sprint exercise despite no knowledge of carbohydrate manipulation. *Eur J Appl Physiol*. 2012;112(8):2859–70.

29. Smith AE, Walter AA, Graef JL, *et al*. Effects of beta-alanine supplementation and high-intensity interval training on endurance performance and body composition in men; a double-blind trial. *J Int Soc Sports Nutr*. 2009;6:5.

30. Stout JR, Cramer JT, Mielke M, O'Kroy J, Torok DJ, Zoeller RF. Effects of twenty-eight days of beta-alanine and creatine monohydrate supplementation on the physical working capacity at neuromuscular fatigue threshold. *J Strength Cond Res*. 2006;20(4):928–31.

31. Van Thienen R, Van Proeyen K, Vanden Eynde B, Puype J, Lefere T, Hospel P. Beta-alanine improves sprint performance in endurance cycling. *Med Sci Sports Exerc*. 2009;41(4):898–903.

32. Walberg-Rankin J. Dietary carbohydrate and performance of brief, intense exercise. *Sports Sci Exchange 79*. 2000;13(4).

33. Zoeller RF, Stout JR, O'Kroy JA, Torok DJ, Mielke M. Effects of 28 days of beta-alanine and creatine monohydrate supplementation on aerobic power, ventilatory and lactate thresholds, and time to exhaustion. *Amino Acids*. 2007;33(3):505–10.

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BRIDGING THE GAP

Nutritional considerations should be made for individuals to obtain the greatest benefits from their HIIT sessions. Proper quantities and ratios of carbohydrate and protein can ensure higher intensity, duration, and recovery in HIIT and are important considerations before, during, and after training. Various supplements also can further enhance performance in HIIT if used properly; however, the results on these supplements and HIIT have been equivocal.