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GLYCEMIC AND INSULINEMIC RESPONSES TO COMMERCIALLY AVAILABLE BEVERAGES, CONSUMED DURING RECOVERY FROM SWIM TRAINING

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Abstract

Objective: To investigate the impact of consuming commercially available beverages on glycemic and insulinemic response during recovery from exercise.

Methods: Seven female and seven male adolescent competitive swimmers completed three trials in a randomized order. Commercially available beverages were consumed in volumes providing 1.2 g CHO·kg^{-1} body mass upon completion of a standardized swim training session, with a second feeding of the same beverage provided 60 min later. Blood samples were taken prior to, and 15, 30, 45, 60, 90 and 120 min after consumption of the first serving of the beverage for analysis of insulin and glucose.

Results: The carbohydrate sport beverage produced a significantly larger ($P < 0.001$) glucose incremental area under the curve than the sports specific meal replacement beverage and the meal replacement beverage. There were no differences between beverages in insulin incremental area under the curve. Consumption of the carbohydrate sports beverage resulted in higher ratings of gut fullness and lower ratings of hunger 30 min after consumption, compared to a sports specific meal replacement beverage and a standard meal replacement beverage. These differences were not evident 60 min after consumption of the beverages.

Conclusions: Commercially available beverages are convenient, and are frequently used by athletes during post-exercise recovery. The carbohydrate sports beverage elicited a larger glucose response compared to the other beverages used in this study. This higher glycemic response is favorable, especially when the time before the next training bout or competition is short and a quick and optimal recovery is paramount.

Key words: *recovery beverages, post-exercise nutrition, swimming*

Introduction

Recovery from exercise is greatly influenced by the food and beverages consumed in the hours after exercise [1]. Post exercise consumption of carbohydrate (CHO) has been shown to increase muscle glycogen synthesis and enhance subsequent performance [1]. Furthermore, consumption of foods that generate higher glycemic responses (i.e. high glycemic index foods) result in higher rates of muscle glycogen synthesis, possibly because glucose is presented to the muscle more quickly after consumption of high glycemic index foods [2]. Co-ingestion of protein (PRO) with CHO is of little benefit to muscle glycogen synthesis when supplements are balanced for energy [3-5]. However, the inclusion of PRO can promote muscle protein synthesis following endurance exercise [6].

Subjective observation indicates that athletes consume commercially available beverages due to accessibility and convenience. The athlete, therefore, has little control over the specific macronutrient composition of the beverage. Only three studies have investigated the effects of commercially available beverages consumed during recovery from exercise [7-9]. In two of these studies beverages were standardized based on volume, meaning that the CHO content of the beverages was not the same [7,9]. This means of standardization seems counterintuitive given the recommendation that athletes consume 1.2 g CHO·kg^{-1} body mass (BM)·h^{-1} post exercise to optimize recovery [1]. Only Macdonald et al [8] standardized the delivery of commercially available beverages by CHO content. The results of this study indicated that consumption of a meal replacement beverage in an amount that provided 1.2 g CHO·kg^{-1} BM, and 0.4 g PRO·kg^{-1} BM produced the most advantageous glycemic and insulinemic response [8]. However, participants were only provided with a single feeding over a 2 h period, contrary to current recommendations to consume 1.2 g CHO·kg^{-1} *per hour* [1]. To date, no study has investigated the response to commercially available beverages provided in such a way as to meet current sports nutrition recommendations for recovery [1].

The majority of work carried out investigating the effects of CHO and PRO ingestion during recovery has used cyclists as participants [5,7,10]. Competitive swimmers, also undertake high training volumes [11] which place enormous demands on muscle and liver glycogen stores [2]. Appropriate feeding after each session is important to ensure adequate recovery between sessions. Additionally, most studies have been performed in a laboratory setting, where environmental factors that would usually impact upon recovery from training are eliminated [5,7,10]. Furthermore, hunger and satiety will influence an athlete's desire to consume regular and appropriate quantities of CHO. To date, no study investigating the responses to commercially available beverages has reported subjective measures of satiety and hunger. The purpose of this study was to observe the glycemic, insulinemic and satiety responses to three commercially available beverages consumed immediately, and one hour after a standardized bout of swim training in a field environment. This study will be the first of its type carried out in competitive adolescent swimmers, it is hypothesized that, during recovery from exercise, the consumption of beverages containing both PRO and CHO will elicit higher glycemic and insulinemic responses, higher ratings of satiety and lower ratings of hunger than beverages containing CHO alone.

Methods

Participants

Fourteen competitive adolescent male and female swimmers participated in this study (see Table 1 for participant characteristics). To be eligible to participate the swimmers had to swim ≥ 25 km per week in training, and have represented their province at a national swim meet. This study was approved by the University Ethics Committee. Written informed consent was obtained from all participants. When participants were under the age of 18 y, written consent was also obtained from a parent.

Preliminary testing

Prior to the intervention each participant attended two preliminary testing appointments. At the first appointment an International Society for the Advancement of Kinanthropometry (ISAK) level one accredited anthropometrist measured skin fold thickness from six sites (triceps, subscapular, supraspinale, abdominal, medial calf and thigh) to the nearest millimeter, according to ISAK protocols using calibrated skin calipers. These measures were then used to calculate body fat percentage [12]. Body mass was measured to the nearest 0.1 kg, using digital scales (BM-150; UWE Co Ltd, Taiwan).

At the second preliminary testing appointment each swimmer completed a 7 x 200 m swimming step test, according to the Swimming New Zealand physiological testing protocol [13]. Each swimmer completed the step test after a rest day from training as part of a usual afternoon training session, and was asked to consume a CHO rich meal 2-3 h prior to the test. The step test involved swimmers completing seven 200 m steady paced swims, five minutes apart. The first 200 m was swum at a pace corresponding to their personal best time plus 35 s. The pace of each subsequent swim was reduced by 5 s, and the final 200 m swim was swum at a pace 5 s slower then the individual's personal best. Swimmers were not permitted to drink or eat during the step test. Blood lactate concentration (Lactate Pro, Arkray Inc, Japan), and heart rate (A1 series, Polar Electro Oy, Kempele, Finland) were measured immediately after each 200 m swim was completed.

Study design

Each participant completed three randomized crossover trials, each separated by two weeks. The day prior to the first experimental trial, participants completed a 24-hour food and activity record. This record was photocopied and returned to participants prior to the two subsequent sessions and participants were asked to replicate their food intake and activity pattern from the record for the 24 h prior to each session. In addition, participants were required to avoid excessive training 24 h prior to each experimental trial, and to fast from 2200 h the night before each trial. All participants complied with these standardization measures.

Table 1. *Mean (± SD) baseline characteristics of competitive adolescent swimmers (n = 14)*

	Males (*n* = 7)	Females (*n* = 7)
Age (yr)	16 ± 2.0	16 ± 2.0
Body Mass (kg)	71.7 ± 6.1	64.3 ± 5.8
Height (cm)	181.3 ± 6.3	167.5 ± 5.1
Body fat (%)	8.6 ± 1.7	19.2 ± 3.9
Training per week (hours)	16 ± 1	18 ± 2
Final swim step test time (minutes)	2:15 ± 0:04	2:16 ± 0:08
Final swim step test Heart Rate (BPM)	187 ± 6	186 ± 5
Final swim step test Lactate concentration ($mmol \cdot L^{-1}$)	11.4 ± 3	7.6 ± 2

Table 2. *Standardised swim training protocol used in each intervention session*

Interval	Distance (m)	Stroke	Intensity(heart rate, BPM)	Rest time (s)
Warm up				
1	1 x 400	Freestyle	130	15
2	1 x 300	Freestyle	130	15
3	1 x 200	Individual Medley	140	15
4	1 x 100	Individual Medley	140	15
5	1 x 400	Individual Medley	150	15
6	1 x 300	Individual Medley	150	15
7	1 x 200	Freestyle	160	15
8	1 x 100	Freestyle	160	15
Main Session				
1	1 x 200	Preferred Stroke	130	
2	4 x 200 (each swim on 3:30 min intervals)	Butterfly	170	
3	2 x 800	Using pull buoy and paddles	170	15
4	4 x 100	Freestyle	140, 150, 160, 170	15
5	6 x 400 (each swim on 7.00 min intervals)	Freestyle	Max effort	
Warm down				
1	3 x 200	Kicking only	easy	30

Table 3. *Nutritional composition of a single serving of the three commercially available beverages (as provided to a 65 kg swimmer)*

	CSB	MRB	SMRB
Beverage	Gatorade®	Up & Go Energize®	Sustagen® Sport
Flavour	Berry	Chocolate	Chocolate
Energy (kJ)	1362	2485	1870
CHO (g)	78.0	78.0	78.0
Protein (g)	nil	41	29
Total Fat (g)	nil	10	<1.0
Volume (ml)	1238	690	398
Glycemic Index	78* High	34† Low	43* Low

CSB: Carbohydrate Sports Beverage, MRB: Meal Replacement Beverage, SMRB: Sports Specific Meal Replacement Beverage
* Available from: [18]
† Available from the up and go website: http://www.upandgo.com.au/faq/upgoenergize/up--go-energize-faqs.aspx

Upon arrival at each experimental trial a finger prick blood sample was collected to ensure a normal fasting glucose concentration of less than 6.1 mmol·L^{-1} (Diabetes New Zealand cutoff for impaired fasting glycemia), and each participant was weighed in his or her swimsuit on digital scales. Participants were then provided with a standardized meal replacement beverage (Up & Go® Choc Ice, Sanitarium, New Zealand), which provided 850 kJ, 31.3 g of CHO, 9.3 g of protein and 3.8 g of fat and had a glycemic index of 46. Participants then completed a standardized swim training session (see Table 2). Immediately after training participants gave a rating of perceived exertion (RPE) on a 1 to 10 scale [14], and body mass, in swimsuits (having dried off excess water) was again recorded. Participants were then given 10 min to change out of their swimsuits and into their usual clothing. Fifteen minutes after the completion of training, two finger prick blood samples were collected and each participant rated their perceived hunger, gut fullness, satiety and recovery using a zero to seven point likert scale adapted from that described in Stevenson et al [15]. Anchor terms were

Table 4. *Mean (± SD) subjective rating scores for gut fullness, hunger, satiety and recovery for three commercially available beverages consumed post–exercise in competitive adolescent swimmers (n = 14)*

			Postprandial period beverage 1		Postprandial period beverage 2	
Variable	Trial	Immediately post exercise	30	60	90	120
Gut fullness	CSB	1.4 ± 0.8	3.0 ± 1.0*	2.6 ± 0.9	3.3 ± 1.4	2.8 ± 1.1
	MRB	1.4 ± 1.1	2.3 ± 0.6	2.4 ± 0.5	2.8 ± 1.0	2.9 ± 1.1
	SMRB	1.3 ± 0.6	2.0 ± 1.0	2.6 ± 1.2	3.1 ± 1.1	2.8 ± 1.1
Hunger	CSB	4.5 ± 1.3	3.1 ± 1.3†	3.6 ± 1.2	3.1 ± 1.3	3.4 ± 1.4
	MRB	4.5 ± 1.1	3.4 ± 0.9	3.5 ± 0.9	2.9 ± 0.7	3.1 ± 1.1
	SMRB	4.2 ± 1.7	3.9 ± 1.0	3.8 ± 1.1	3.1 ± 1.1	3.1 ±1.2
Satiety	CSB	2.1 ± 1.2	3.1 ± 1.2	2.9 ± 1.0	3.3 ± 1.0	3.5 ± 0.9
	MRB	2.1 ± 1.1	3.0 ± 0.9	2.7 ± 0.8	3.0 ± 1.1	3.1 ± 0.8
	SMRB	2.0 ± 1.4	2.4 ± 1.2	2.8 ± 1.3	2.8 ± 1.1	2.9 ± 1.0
Recovery	CSB	2.1 ± 1.0	2.7 ± 1.1	3.1 ± 1.4	3.2 ± 1.7	3.6 ± 1.5
	MRB	1.7 ± 1.0	2.6 ± 0.8	3.1 ± 1.1	3.3 ±1.3	3.5 ± 1.5
	SMRB	1.8 ± 1.2	2.6 ± 0.9	2.9 ± 1.0	3.4 ± 1.1	3.6 ± 1.6

CSB: High Carbohydrate Sports Beverage, MRB: Meal Replacement Beverage, SMRB: Sports Specific Meal Replacement Beverage
* significantly different from SMRB (*P* < 0.02)
† significantly different from SMRB (*P* < 0.002)
Note: Statistical method used was a Repeated ANOVA (Sidak's procedure) to calculate any significant differences between beverages

Key

Gut fullness	Not Full	0	1	2	3	4	5	6	Very Very Full
Hunger	Not Hungry	0	1	2	3	4	5	6	Very Very Hungry
Satiety	Not Satisfied	0	1	2	3	4	5	6	Very Very Satisfied
Recovery	Not at all	0	1	2	3	4	5	6	Fully Recovered

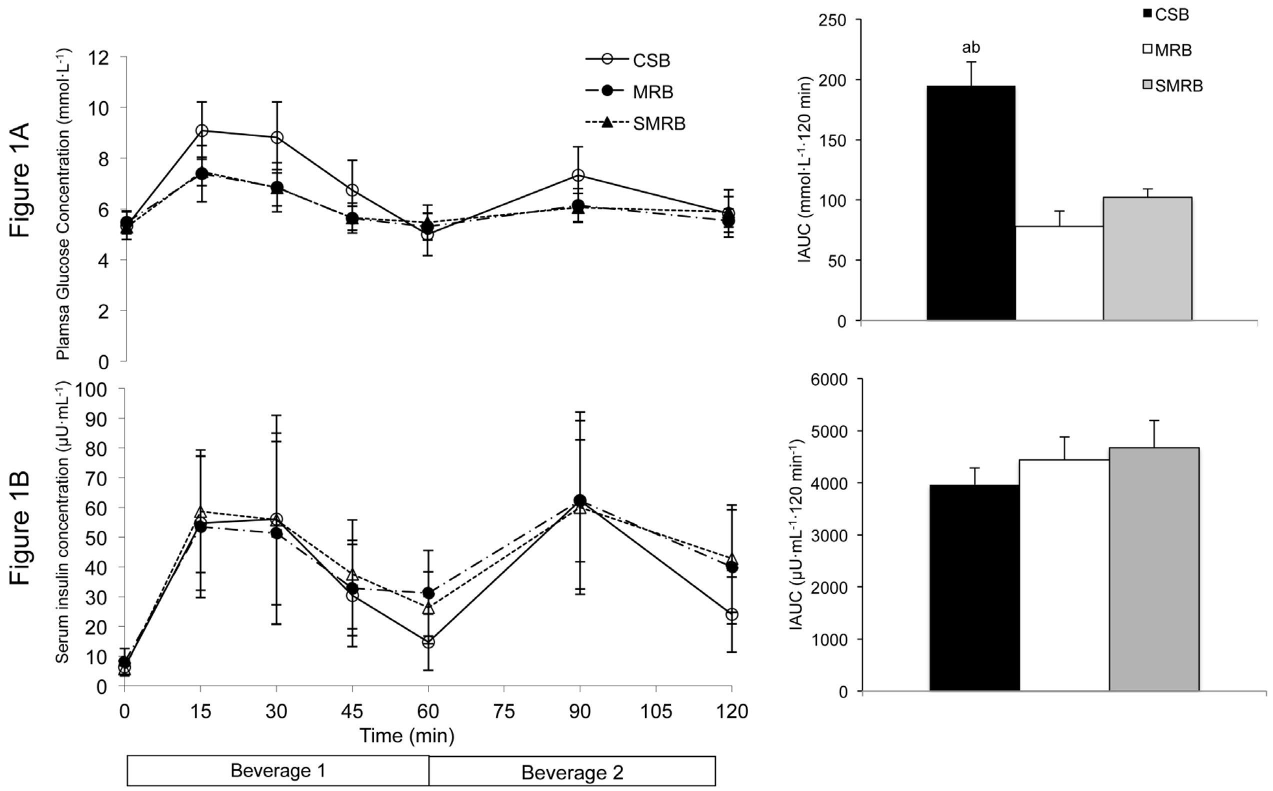

Fig. 1A and 1B. *Mean (SE) plasma glucose and serum insulin responses to the ingestion of three commercially available beverages by 14 comptitive adolescent swimmers post exercise*
HCSB: High Carbohydrate Sport Beverage, MRB: Meal Replacement Beverage, SMRB: Sport Specific Meal Replacement Beverage
a: significantly different from MRB *P* < 0.001
b: significantly different from SMRB *P* < 0.001

'not hungry' to 'very very hungry', 'not full' to very very full', 'not satisfied' to 'very very satisfied' and 'not at all recovered' to 'fully recovered' (see footnote of Table 4). Participants were then provided with one of three commercially available beverages in an amount that provided 1.2 g CHO·kg^{-1} BM as recommended by Burke et al [1]. Sixty minutes later participants consumed an identical, second serving of the beverage. Finger prick blood samples were collected at 15, 30, 45, 60, 90 and 120 min after consumption of the initial beverage for the analysis of blood glucose and insulin. Ratings of perceived hunger, gut fullness, satiety and recovery were collected at 30, 60 and 90 min after consumption of the initial beverage. No additional food or beverage was consumed during this time and participants were asked to remain as immobile as possible (see Figure 1 for protocol timeline).

Recovery beverages

Three beverages with known glycemic indices (GIs) that were similar in composition to beverages that were commonly consumed during recovery by the swimmers were selected for this study;

1. A CHO sports beverage (CSB): Gatorade® (Spring Valley Beverages Pty Ltd, Chelten, VIC, Australia);
2. A meal replacement beverage (MRB): Up & Go Energize® (Sanitarium, Auckland, New Zealand) and;
3. A sports specific meal replacement beverage (SMRB): Sustagen® Sport (Mead Johnson, Rydalmere, NSW, Australia).

Because we used commercially available beverages, in the form in which they are available for purchase, or made up to the volume specified on the packaging, it was not possible to standardize for every nutritional component (e.g. energy, protein and volume). We chose to standardize for CHO as CHO is considered the most important nutrient to consume during recovery. Beverages were provided in volumes that supplied 1.2 g CHO·kg^{-1} BM. Nutritional characteristics of the beverages, as consumed by a 65 kg swimmer, are presented in Table 3. All participants consumed the required amounts of beverage in the 10 min allowed.

Sample collection and analysis

Blood glucose concentration was determined from capillary blood collected from a finger prick blood sample. One droplet of whole blood was collected directly onto an Advantage Two Test Strip (Roche Diagnostics, Germany), and blood glucose measured by the Advantage Two Meter Pack: Glucose System (Roche Diagnostics, Germany).

Blood for insulin analysis was collected from a finger prick blood sample into a microcentrifuge tube. A minimum of 0.5 ml was collected for analysis at each time point. This blood was left to clot at room temperature for 30-60 min before being centrifuged at 2000 g for 10 min. Serum was then removed and stored at -20°C until analysis. Serum insulin was measured using an Electrochemiluminescent Immunoassay (1010 Immunoassay System, Roche Diagnostic Elecsys®, Mannheim, Germany).

Statistical analysis

The incremental area under the curve (IAUC) was calculated for both glucose and insulin, using the method described by Wolever and Jenkins [16] and used as a summary measure for each beverage [17].

Statistical analyses were performed using SPSS (version 13.0). IAUC data for insulin and glucose was analyzed using repeated measures ANOVA with Sidak's procedure to identify pair-wise differences between beverages. ANOVA was used to compare RPE, changes in body mass, and subjective ratings of gut fullness, hunger, satiety and recovery status between trials. Descriptive data and subjective ratings of gut fullness, hunger, satiety and recovery are presented as means±SD. Glucose and insulin concentrations as well as IAUC data are presented as mean ± SE.

Results

There were no differences in ratings of perceived exertion between trials (CSB 5.6 ±1.6, MRB 5.8 ± 2.1, SMRB 5.5 ± 1.5, $P = 0.64$). The mean changes in body mass from pre to post exercise were also not different between trials (CSB -0.2 ± 0.5 kg, MRB -0.1 ± 0.4 kg, SMRB -0.2 ± 0.4 kg, $P = 0.69$)

To allow each beverage to deliver 1.2 g CHO·kg^{-1} BM the volume, PRO and fat content of the beverages varied considerably. The mean±SD volume of the CSB, MRB and SMRB were 1295.1 ± 130 ml, 652.7 ± 66 ml and 415.6±42 ml, respectively. Two-hour blood glucose and insulin responses, and IAUC measures are reported in Fig. 2. The glucose IAUC for the CSB was significantly higher than the IAUC for the SMRB ($P < 0.001$) and the MRB ($P < 0.001$). There were no significant differences in insulin IAUC observed between beverages.

Consumption of the CSB resulted in significantly higher subjective ratings of gut fullness, and lower ratings of hunger compared to the SMRB at 30 min ($P < 0.02$). However, this difference was no longer apparent at 60 or 90 min. There were no significant differences in subjective ratings of satiety and recovery between the three beverages at any time point (Table 4).

Discussion

This study is the first to compare the glycemic, insulinemic and satiety responses to three commercially available beverages during acute recovery from swim training. It is also the first study to investigate the glycemic and insulinemic responses to commercially available beverages fed in a repeated dose, in accordance with current guidelines for recovery from exercise [1]. This study, therefore, adds to the very small body of knowledge that exists around the use of commercially available drinks during recovery from exercise.

In the current study the second feeding an hour after the first, resulted in a second peak in blood glucose when participants were fed the CSB. Macdonald et al [8] found that when similar beverages were fed in a single feed providing 1.2 g CHO·kg^{-1} BM blood glucose returned to baseline at 60 min and remained there for the remainder of the 2 h measurement period. Combining the results of the current study, and those of Macdonald et al. [8] provides support for the recommendation that athletes should consume additional CHO of 1.2 g CHO·kg^{-1} BM for up to five hours after exercise, or until normal meals resume [1].

One of the more interesting findings of this study is that the CSB produced the largest elevation in glucose levels (as expected due to its high GI) without a corresponding elevation in plasma insulin. A possible interpretation of this result is that the CHO contained in the CSB is more quickly absorbed and may provide the recovering muscle with a more rapid supply of CHO for muscle glycogen synthesis. However, it is also possible that the protein content of the MRB and SMRB enhanced insulin secretion, resulting in a more rapid disposal of the CHO contained in the beverage and observation of a lower glucose response. If this scenario is correct then it would suggest that the protein containing drinks may have resulted in a more rapid delivery and uptake of glucose to the recovering muscle, when compared to the CSB. Without a direct measure of glucose uptake neither mechanism can be completely discarded.

Adequate recovery between sessions is dependent on athletes consuming the appropriate amounts of CHO, fluid and energy. Therefore, beverages and food consumed during recovery that produce high ratings of gut fullness and satiety should be avoided to encourage adequate consumption of CHO, energy and fluid. In the present study, consumption of the CSB resulted in higher ratings of gut fullness and lower ratings of hunger compared to the SMRB at 30 min after the initial feeding. However, the results of the present study are likely due to the volume of the CSB, rather than the GI or protein content of the SMRB or MRB. Interestingly, differences in hunger and gut fullness were not maintained at 60 min. Therefore, the increase in gut fullness observed at 30 min in response to the CSB is unlikely to affect an athlete's desire to consume further CHO in the subsequent hour.

This study has highlighted differences in composition of commercially available beverages that are commonly consumed by adolescent swimmers. In the current study, standardization of beverage delivery by CHO content caused differences in volumes and macronutrient contents that made interpretation of metabolic responses challenging. However, athletes who do not have access to specifically formulated beverages face these challenges on a daily basis. Therefore, these athletes are forced to prioritize their nutritional goals based on the macronutrient makeup of the commercially produced beverages that are available to them.

Limitation of the study

Limitations of this study that should be considered include the small sample size. Without a sample size calculation it is difficult to determine whether lack of differences in ratings of perceived satiety and recovery were due to a true lack of effect or simply the study lacking power to detect a true difference. Strengths of this study include a retention rate of 100%; thorough standardization procedures, ensuring diet and exercise patterns were the same prior to each trial; the use of summary measures (IAUC) that clearly illustrate changes in glycemic and insulinemic response.

Conclusions

This study adds to the very limited literature available focusing on the use of commercially available beverages during recovery from exercise (in this case swim training). The results support the current recovery guidelines that indicate additional CHO should be consumed hourly after exercise. The results of this study also highlight the challenges involved in using commercially available beverages in a research setting. Studies carried out in the future should look to replicate this study in a more highly controlled laboratory environment and include measures of muscle glycogen synthesis, or subsequent performance, as well as measures of protein synthesis. Additionally, thought should be given as to how commercially available beverages can be easily modified (through dilution, or the addition of simple ingredients) to make them more comparable in terms of energy and volume while still providing appropriate amounts of CHO. This would provide athletes of all levels with convenient, accessible and appropriate recovery beverages.

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Declaration of interest

The authors report no conflicts of interest.

References

1. Burke LM, Kiens B, Ivy JL. Carbohydrates and fat for training and recovery. *J Sports Sci* 2004; 22(1): 15-30.
2. Burke LM, Collier GR, Hargreaves M. Muscle glycogen storage after prolonged exercise: effect of the glycemic index of carbohydrate feedings. *J Appl Physiol* 1993; 75(2): 1019-23.
3. Berardi JM, Price TB, Noreen EE, Lemon PWR. Postexercise muscle glycogen recovery enhanced with a carbohydrate--protein supplement. *Med Sci Sports Exerc* 2006; 38(6): 1106.
4. Carrithers JA, Williamson DL, Gallagher PM, et al. Effects of postexercise carbohydrate-protein feedings on muscle glycogen restoration. *J Appl Physiol* 2000; 88(6): 1976-82.
5. van Loon LJC, Saris WHM, Kruijshoop M, Wagenmakers AJM. Maximizing postexercise muscle glycogen synthesis: carbohydrate supplementation and the application of amino acid or protein hydrolysate mixtures. *Am J Clin Nutr* 2000; 72(1): 106-11.
6. Howarth KR, Moreau NA, Phillips SM, Gibala MJ. Coingestion of protein with carbohydrate during recovery from endurance exercise stimulates skeletal muscle protein synthesis in humans. J *Appl Physiol* 2009; 106(4): 1394-402.
7. Williams MB, Raven PB, Fogt DL, Ivy JL. Effects of recovery beverages on glycogen restoration and endurance exercise performance. *J Strength Cond Res* 2003; 17(1): 12-9.
8. Macdonald S, Perry T, Rose M. Glycemic, Insulinemic and immune responses to commercially available beverages, consumed during recovery from rowing training. *Eur J Sport Sci* 2010; 10(5): 337-45.
9. Karp JR, Johnston JD, Tecklenburg S, et al. Chocolate milk as a post-exercise recovery aid. *Int J Sport Nutr Exerc Metabol* 2006; 16(1): 78-91.
10. Zawadzki KM, Yaspelkis BB, Ivy JL. Carbohydrate-protein complex increases the rate of muscle glycogen storage after exercise. *J Appl Physiol* 1992; 72(5): 1854-9.
11. Barbosa TM, Fernandes R, Keskinen KL, et al. Evaluation of the energy expenditure in competitive swimming strokes. *Int J Sports Med* 2006; 27(11): 894-9.
12. Yuhasz MS. *Physical fitness and sports appraisal laboratory manual.* London, Ontario: Univiersity of Western Ontario, 1974.
13. S*wimming New Zealand. Guidelines for Athlete Assessment in New Zealand Sport.* Wellington: Swimming New Zealand High Performance Programme, 2000.
14. Borg G. *Borg's Perceived Exertion and Pain Scales*. Human Kinetics, 1998.
15. Stevenson E, Williams C, Nute M, et al. Influence of the glycaemic index of an evening meal on substrate oxidation following breakfast and during exercise the next day in healthy women. *Eur J Clin Nutr* 2008; 62: 608-16.
16. Wolever TM, Jenkins DJ. The use of the glycemic index in predicting the blood glucose response to mixed meals. *Am J Clin Nutr* 1986; 43(1): 167-72.
17. Matthews JNS, Altman DG, Campbell MJ, Royston P. Analysis of serial measurements in medical research. *Brit Med J* 1990; 300(6719): 230-5.
18. Atkinson FS, Foster-Powell K, Brand-Miller JC. International tables of glycemic index and glycemic load values: 2008. *Diabetes Care* 2008; 31(12): 2281-3.

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